Minnesota Climate Strategies and Economic Opportunities

The Center for Climate Strategies
In Collaboration with Minnesota State Agencies

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- Agriculture Department
- Board of Water and Soil Resources
- Environmental Quality Board
- Department of Commerce
- Department of Employment and Economic Development
- Forest Resources Council
- Department of Health
- Metropolitan Council
- Natural Resources Department
- Office of Energy Security
- Pollution Control Agency
- Public Utilities Commission
- Transportation Department

The CCS project team included Tom Peterson, Project Director; Steve Roe, Technical Manager and lead for Baselines and for Agriculture, Forestry, and Waste Policy Design and Impact Analysis; Holly Lindquist, Baselines and Policy Design and Impact Analysis; Scott Williamson, Macroeconomic Policy Design and Impact Analysis; Loretta Bauer, Waste Management Policy Design and Impact Analysis; Fan Zhang, Research and Communications Assistance; Nikola Pilipovic, Research and Communications Assistance; Bill Dougherty, Energy Supply Policy Design and Impact Analysis; Evelyn Wright, Energy Systems Impact Analysis; David Von Hippel, Residential, Commercial, Industrial, and Institutional Policy Design and Impact Analysis; Jackson Schreiber and Jim Wilson, Transportation and Land Use Policy Design and Impact Analysis; Robert McKinstry, Legal Review; Katie Pasko, Communications Support; and Cecilia Sutter, Communications and Administrative Support.

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Acronyms and Abbreviations

A	Agriculture Policy
AEO 2014	*Annual Energy Outlook 2014* [US DOE Energy Information Administration]
BAU	Business as Usual
BMPs	Best management practices
Btu	British thermal unit
CCS	Center for Climate Strategies
cf	cubic feet
CH_4	methane
CHP	combined heat and power
CIP	Conservation Improvement Program
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DSM	demand-side management
DNR	[Minnesota] Department of Natural Resources
DOE	[United States] Department of Energy
EIA	Energy Information Administration [US DOE]
EE	energy efficiency
EPA	[United States] Environmental Protection Agency
ES	Energy Supply
eGRID	Emissions & Generation Resource Integrated Database [US EPA]
EF	emissions factor
FOLU	Forestry and Other Land Uses
FIA	Forest Inventory and Analysis [USFS/Minnesota DNR]
FRC	[Minnesota] Forest Resources Council
FSA	Farm Service Agency [USDA]
FSC	[Minnesota] Forest Stewardship Council
ft	foot
gal	gallon
GHG	greenhouse gas
GIS	geographic information system
GMAC	General Motors Acceptance Corporation
GJ	gigajoule
GSP	gross state product
GWh	gigawatt-hour [one million kilowatt-hours]
GWP	global warming potential
HFC	hydrofluorocarbon
IECC	International Energy Conservation Code
IPCC	Intergovernmental Panel on Climate Change
IRP	integrated resource planning
I&F	Inventory and Forecast
kW	kilowatt
kWh	kilowatt-hour
LandGEM	Landfill Gas Emissions Model [US EPA]
LDV	light-duty vehicle

LCOE	levelized cost of energy or electricity
LEED	Leadership in Energy and Environmental Design [Green Building Rating System™
LFG	landfill gas
LPG	liquefied petroleum gas
MJ	megajoule
MM	million
MMBtu	millions of British thermal units
MPG	miles per gallon
MSW	municipal solid waste
MW	megawatt [one thousand kilowatts]
MWh	megawatt-hour [one thousand kilowatt-hours]
N	nitrogen
N_2O	nitrous oxide
N/A	not applicable
NG	natural gas
NGCC	natural gas combined cycle
NGCT	natural gas combustion turbine
NGO	nongovernmental organization
NOx	oxides of nitrogen
NPV	net present value
O&M	operation and maintenance
PFC	perfluororocarbon
PHEV	plug-in hybrid electric vehicle
POD	policy option document
PV	photovoltaic
R&D	research and development
RCII	Residential, Commercial, Institutional and Industrial
RES	Renewable Electricity Standard
SF_6	sulfur hexafluoride
SO_2	sulfur dioxide
SOx	oxides of sulfur
t	metric ton (1,000 kilograms – approximately 2,200 pounds)
Tg	teragram [equal to a million metric tons]
$TgCO_2e$	teragrams of carbon dioxide equivalent
T&D	transmission and distribution
tCO_2	metric tons of carbon dioxide
tCO_2e	metric tons of carbon dioxide equivalent
tCO_2e/MWh	metric tons of carbon dioxide equivalent per megawatt-hour
TLU	Transportation and Land Use
TOD	transit-oriented development
VMT	vehicle miles traveled
WM	Waste Management
WTE	waste to energy
yr	year

Chapter I. Introduction & Executive Summary

The Minnesota Climate Strategies and Economic Opportunities (CSEO) project was convened February 4, 2014 through a Memorandum of Understanding between the Center for Climate Strategies (CCS) and the Minnesota Department of Commerce (COMM) and Minnesota Pollution Control Agency (MPCA). The Minnesota Environmental Quality Board (EQB) provided agency coordination.

The project was designed to improve the state's economic, energy, and environmental conditions and awareness in all sectors; expand the knowledge, planning, and implementing capacities of its agencies; and contribute to attainment and enhancement of state and federal goals across all sectors and agencies. It updates and improves upon Minnesota's 2008 comprehensive climate action plan.[1]

Recommended actions show a high level of potential in all sectors to deliver multiple benefits at competitive cost. If implemented fully, CSEO policies would:

1. Reduce greenhouse gas emissions (GHGs) in line with state goals and federal guidelines. Statewide greenhouse gas emissions experience a 34 percent reduction below the business as usual forecast of emissions in 2030, and a 33 percent reduction in comparison to 2015 base year emissions by 2030. This level parallels state legislative targets of 2008. The scale of reductions associated with the state's electricity system exceeds the US EPA requirements anticipated from the Federal Clean Power Plan (under Clean Air Act Section 111(d)) for Minnesota.
2. Expand macroeconomic output of jobs, income, and growth. Net gains for Minnesota include an average of 24,630 newly created jobs per year, or a total of 369,440 additional years of employment through 2030. Gross State Product (GSP) grows an additional $35.7 billion as a result of the CSEO policies over the 2016-2030 period – an average of $2.38 billion in additional economic activity per year (a 0.5 percent annual increase). Personal income expands by an annual average of $2.3 billion, or 0.6 percent per year.
3. Improve energy and resource efficiency and sustainability. Key improvements through 2030 include reduced energy intensity, greater efficiency, reduction of imported electricity, and shifts to new sources of domestically-generated renewable energy.

Returns on investment (benefits from direct outlays and net social investment) are strong, supported by well-defined financial flows and implementing mechanisms, and create a platform for expanded investment from sources inside and outside the state.

During the course of two years, CCS and over 60 representatives from ten Minnesota agencies worked jointly to identify, design, and evaluate a set of 20 highly-specific, customized policy actions and implementing mechanisms. CCS and the agencies utilized an iterative, stepwise

[1] http://www.climatestrategies.us/library/library/view/1149

process to achieve the combined project goals of economic development and greenhouse gas (GHG) reductions. This process encompassed:

- Goal setting
- Development of baselines (energy, emissions, land use, other emissions drivers)
- Identification of potential new or enhanced options
- Multi-criteria screening for selection of draft priority options
- Design of individual policy options to enable analysis of baseline shifts
- Direct (or microeconomic) impact analysis of individual and aggregate actions
- Indirect (or macroeconomic) impacts of policy options and mechanisms
- Final documentation and transition to implementation planning

The project culminated with a stakeholder exchange program supported by Minnesota agencies and the Minnesota Environmental Initiative (MEI).

Key policy options were developed in the areas of:

- Energy Supply (ES): renewable energy (RE) or lower-emitting heat and power production;
- Residential, Commercial, Institutional and Industrial (RCII): energy efficiency (EE), process improvements, and renewable fuels;
- Transportation and Land Use (TLU): low emissions vehicles, transportation price mechanisms, and improved transit and urban land use;
- Waste Management (WM): energy efficiency, source reduction, re-use, recycling, and composting;
- Agriculture (A): nutrient and soil conservation practices, biofuels production and utilization;
- Forestry, and Land Use (FOLU): urban and rural forest conservation and restoration, and bio-energy generation.

Table EX-1 provides a brief summary of each of the CSEO policy recommendations.

Table EX-1. CSEO Policy Recommendations

Policy ID	Policy Title	Description
ES-1	Increase the Minnesota Renewable Energy Standard	Expands Minnesota's Renewable Portfolio Standard to either 40% or 50% of renewable electricity generation as a share of retail sales by 2030
ES-2	Efficiency Improvements, Repowering, Retirement, and	Repowers or retires two of the largest coal-fired boilers in Minnesota (Sherburne Co plants 1 and 2)

	Upgrades to Existing Plants	
RCII-1	Incentives and Resources for Combined Heat & Power for Biomass and Natural Gas	Implements 800 MW of gas-fired CHP and 300 MW of biomass-fired CHP by 2030
RCII-2	Zero Energy Transition/Codes (SB2030)	Provide incentives for or mandates construction of highly energy efficient buildings and phasing in the use of renewable energy sources
RCII-4	Increase Energy Efficiency Requirements	Increase the requirements of the existing EERS for electric and gas utilities while allowing them to count energy savings from infrastructure improvements, end-use efficiency and CHP
RCII-5	Incentives and Resources to Promote Thermal Renewables	Establish new thermal goal of switching 5% of the future heat load that is fueled with non-electric sources by 2020 and 20% by 2030
TLU-1	Transportation Pricing	Use transportation pricing method to reduce GHG and provide more reliable funding for roads and bridges, including Pay-as-you-go insurance pricing, a carbon tax on fuels with rebates, and a 6.5% state wholesale fuel tax
TLU-2	Improve Land Development and Urban Form	Implement urban planning and development practices in the seven-county metropolitan area that result in greater concentration of development, more compact urban form, more locally diverse uses, and shorter trip distances, thus mitigating VMT and GHG from transportation
TLU-3	Metropolitan Council Draft 2040 Plan	Expansion and operation of the MnPASS System, the Transit System and the Bicycle/Pedestrian System
TLU-4	Zero Emission Vehicle Standard	Require automobile manufacturers, through their dealerships, to have a percentage of the total light and medium duty vehicle sales in Minnesota, designated as electric vehicle sales
AG-1	Nutrient Management	Achieve gains in nitrogen use efficiency with precision agricultural techniques and nitrification inhibitors
AG-2	Soil Carbon Management: Cover Crops	Improve soil carbon management through cover crop adoption for cropping systems
AG-3	Soil Carbon Management: Row to Perennial Crops Conversion	Sequester carbon and reduced fuel and fertilizer consumption
AG-4	Advanced Biofuels Production	Expand ethanol production through cellulosic and energy-beet production methods
AG-5	Biofuels Consumption (Existing Biofuels Statute)	Replace gasoline consumption with 14% biofuels by 2015, 18% by 2017, 25% by 2020, and 30% by 2025

FOLU-3	Community Forests	Strengthen community forests across the state by increasing and maintaining the overall tree canopy cover of community forests to 40% by 2050
FOLU-4	Tree Planting: Forest Ecosystems	Ensure timely restoration of carbon sequestration following large disturbances on state, county, and private lands
FOLU-5	Conservation on Private Lands	Protect forests and their ability to annually sequester carbon while preventing large one-time emissions associated with forest loss
WM-1	Wastewater Treatment: Energy Efficiency	Statewide reduction in energy usage by wastewater treatment plants of 25% by 2025
WM-2	Front-End Waste Management: Source Reduction	Avoid disposal emissions, reduce upstream product energy-cycle emissions from the manufacture and transport of new products and packaging
WM-3	Front-End Waste Management: Re-Use, Recycling & Composting	Improve front-end waste management to achieve a total recycling rate (including composting) of 75% by 2025
CPP	Comprehensive Effects of Sector Based CSEO Policy Recommendations on Electricity Supply and Demand Related to the EPA Section 111(d) Rule	CSEO policy recommendations affecting CPP 111d implementation goals for Minnesota include ES-1, ES-2, RCII-1, RCII-2, RCII-4, TLU-2, FOLU-3, WM-1, WM-2, WM-3 and AG-4/AG-5

For each CSEO policy recommendation, a series of customized policy design specifics were developed and documented through iterative conferrals between CCS and agencies, including: concept and description, design parameters and performance metrics (timing, level of effort, coverage of parties, eligibility), related actions already in place (both current and planned actions), policy impact analysis approaches and methodologies (data sources, methods, key assumptions, key uncertainties), implementation mechanisms (standards, pricing, incentives, education, funding, etc.), results of analysis (direct, integrative, and indirect impacts), key uncertainties, and critical implementation needs.

Analysis of the direct, integrative, and indirect effects of individual and aggregate CSEO policy options was conducted through the use of standard, systematic principles and guidelines for quantification of climate mitigation actions, regulatory impacts, and economic impacts. These were applied on a customized basis for each Minnesota sector and specific policy option through collaboration between CCS and agency experts using a modeling framework that linked baselines, direct, and indirect impacts. Additional details on the CSEO project, procedures, and results are summarized in the chapters that follow and in a series of technical appendices.

Table EX-2. Summary of Direct Impacts of Policy Recommendations

Direct Impacts of CSEO Policy Recommendations						
Policy Option	2030 Annual In-State	Cumulative In-State 2015-2030	2030 Annual Total	Cumulative Total 2015-2030	NPV Costs/Savings 2015-2030	Cost Effectiveness
	GHG Reductions ($TgCO_2e$)				($2014MM)	($2014/$tCO_2e$)
ES-1	5.3	53	6.3	62	($360)	($5.8)
ES-2	5.8	41	5.5	38	$854	$22
ES Sector Totals	**11**	**94**	**12**	**100**	**$494**	**$4.9**
RCII-1	4.9	46	5.2	49	($1,117)	($23)
RCII-2	9.3	54	11	60	($2,050)	($34)
RCII-4	4.9	34	5.2	40	($1,814)	($45)
RCII-5	2.9	22	4.1	30	$842	$28
RCII Sector Totals	**22**	**156**	**25**	**180**	**($4,140)**	**($23)**
TLU-1	2.0	21	2.6	28	$2,718	$98
TLU-2	0.82	7.0	0.97	8.2	($425)	($52)
TLU-3	0.25	2.0	0.32	2.6	($330)	($127)
TLU-4	1.0	5.5	1.3	6.7	$3,278	$489
TLU Sector Totals	**4.1**	**36**	**5.1**	**45**	**5,241**	**$116**
AG-1	0.13	1.0	0.34	2.7	($127)	($47)
AG-2	0.49	3.1	0.57	3.6	($1,346)	($377)
AG-3	1.6	14	1.6	14	($2,104)	($153)
AG-4+AG-5	0.17	1.76	0.32	3.5	$462	$133
Agriculture Totals	**2.4**	**19**	**2.8**	**23**	**($3,115)**	**($133)**
FOLU-3	0.49	3.2	0.53	3.4	$1,806	$525
FOLU-4	1.9	30	2.0	34	$187	$5.59
FOLU-5	0.34	3.0	0.34	3.0	$1,261	$421
FOLU Sector Totals	**2.7**	**36**	**2.8**	**40**	**$3,254**	**$81**
WM-1	0.068	0.89	0.076	0.99	($56)	($56)
WM-2	0.057	0.073	1.6	9.4	($228)	($24)
WM-3	0.15	(0.45)	2.7	27	($817)	($30)
WM Sector Totals	**0.28**	**0.52**	**4.4**	**37**	**($1,101)**	**($29)**
CPP	**17.0**	**199.2**	**N/A**	**N/A**	**($398)**	**($2.0)**
Total Integrated Plan Results	**42**	**342**	**52**	**426**	**$634**	**$1.5**

Note: CPP results estimate the comprehensive effects of CSEO policy recommendations on the electricity sector.

Figure EX-1. Minnesota Greenhouse Gas Baselines and CSEO Reductions

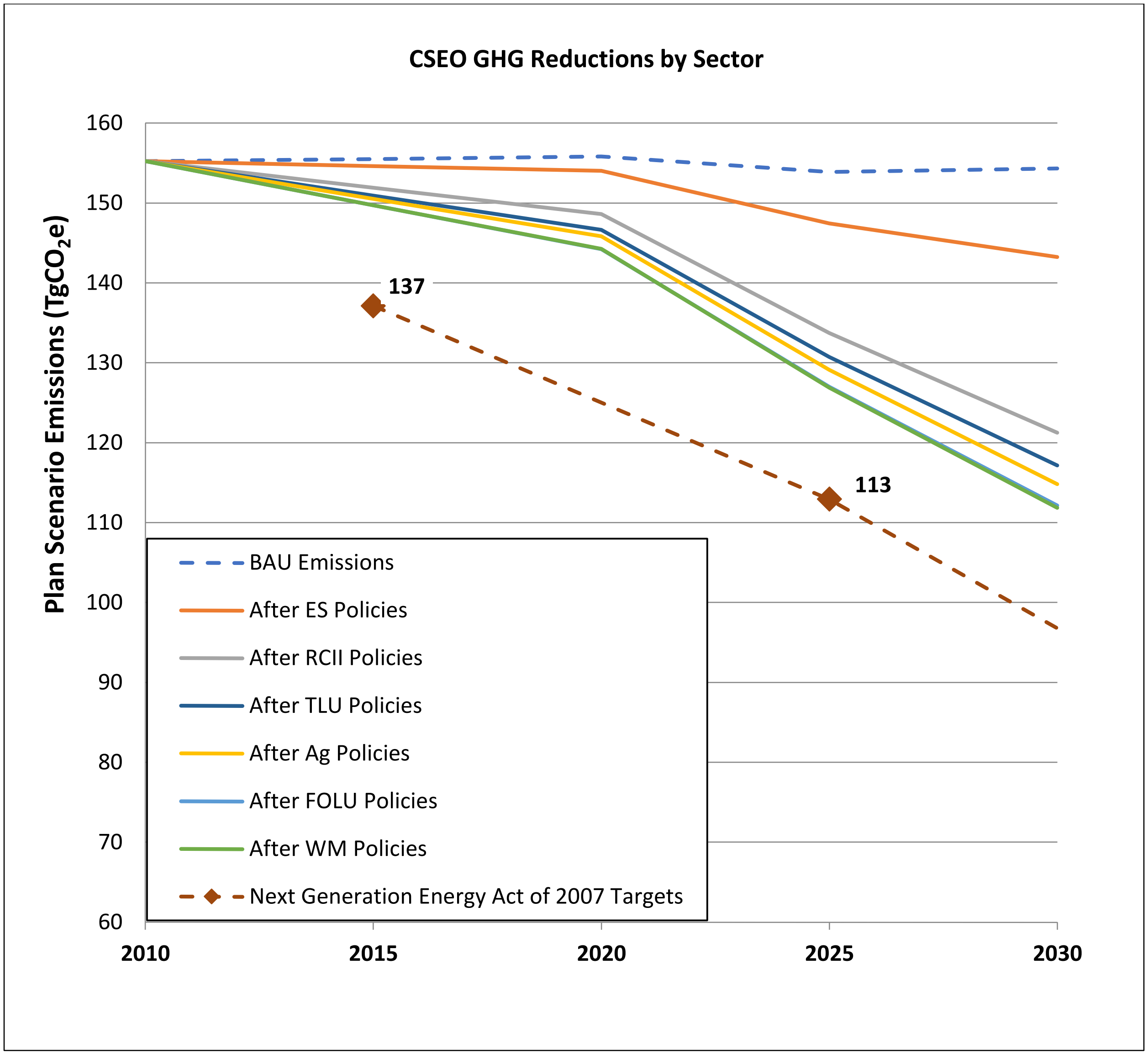


Figure EX-2. GHG Reductions for Policy Recommendations, Year 2030

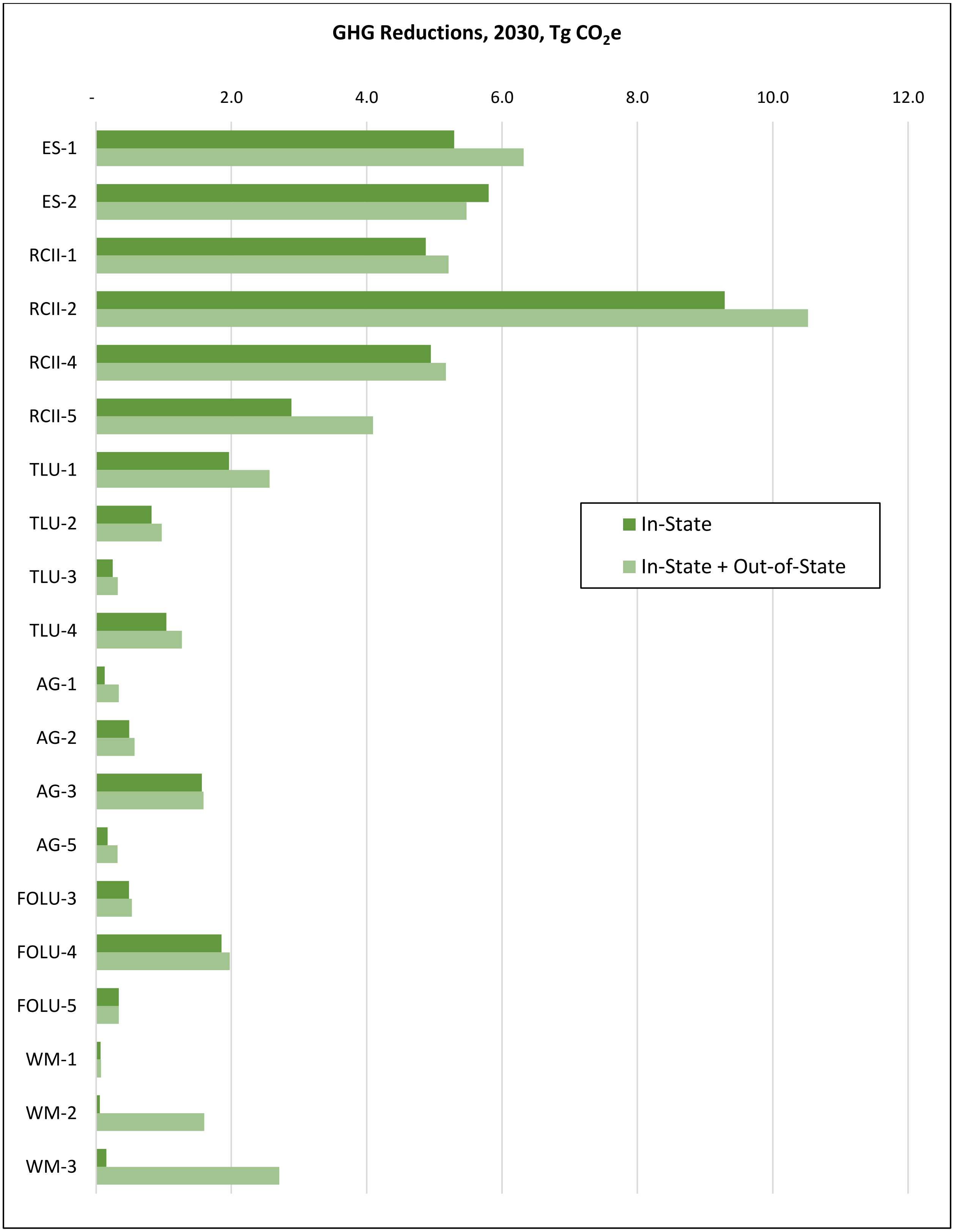
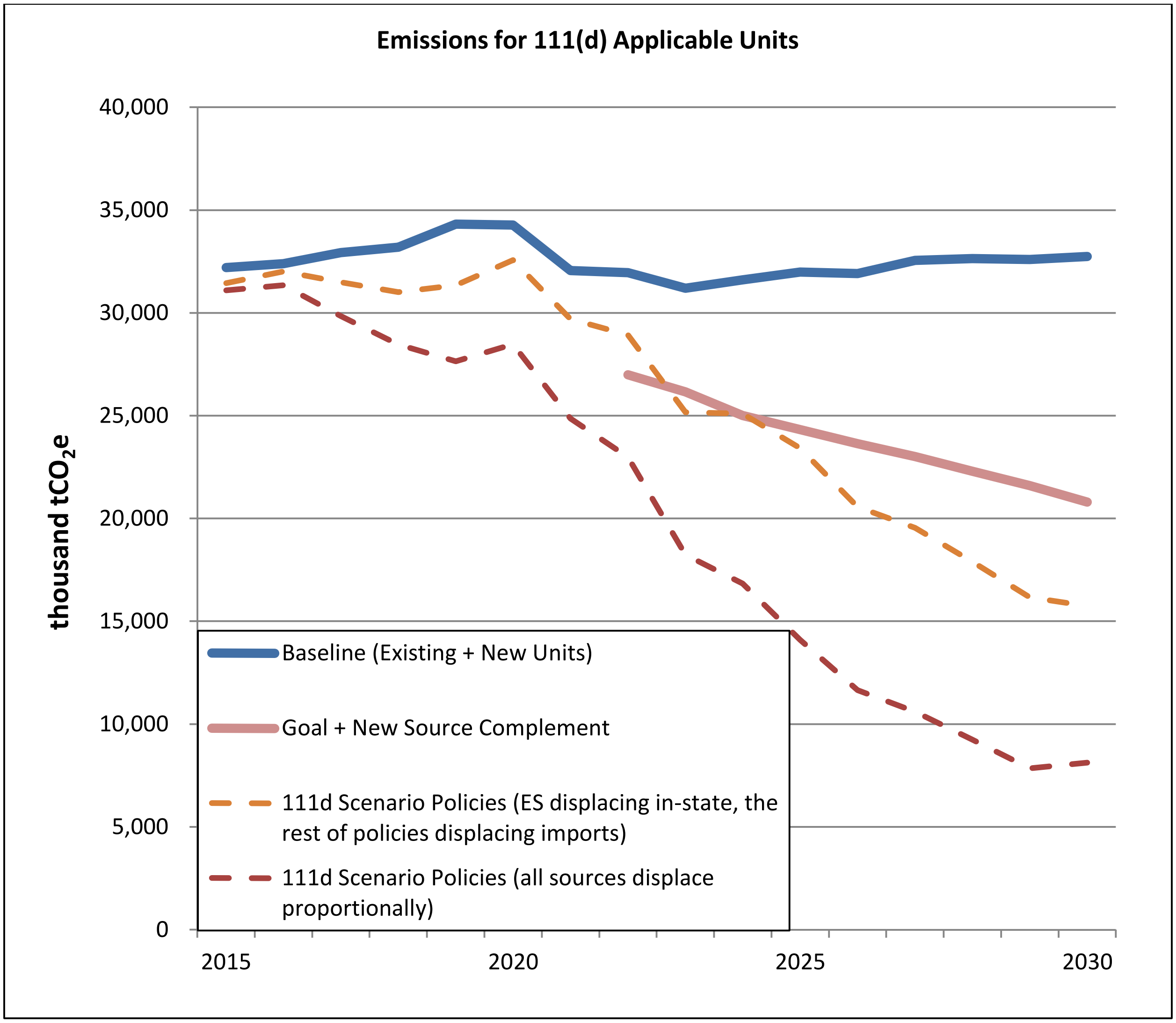


Figure EX-3. Achievement of Clean Power Plan Goals by Policy Recommendations, 2030



Notes:

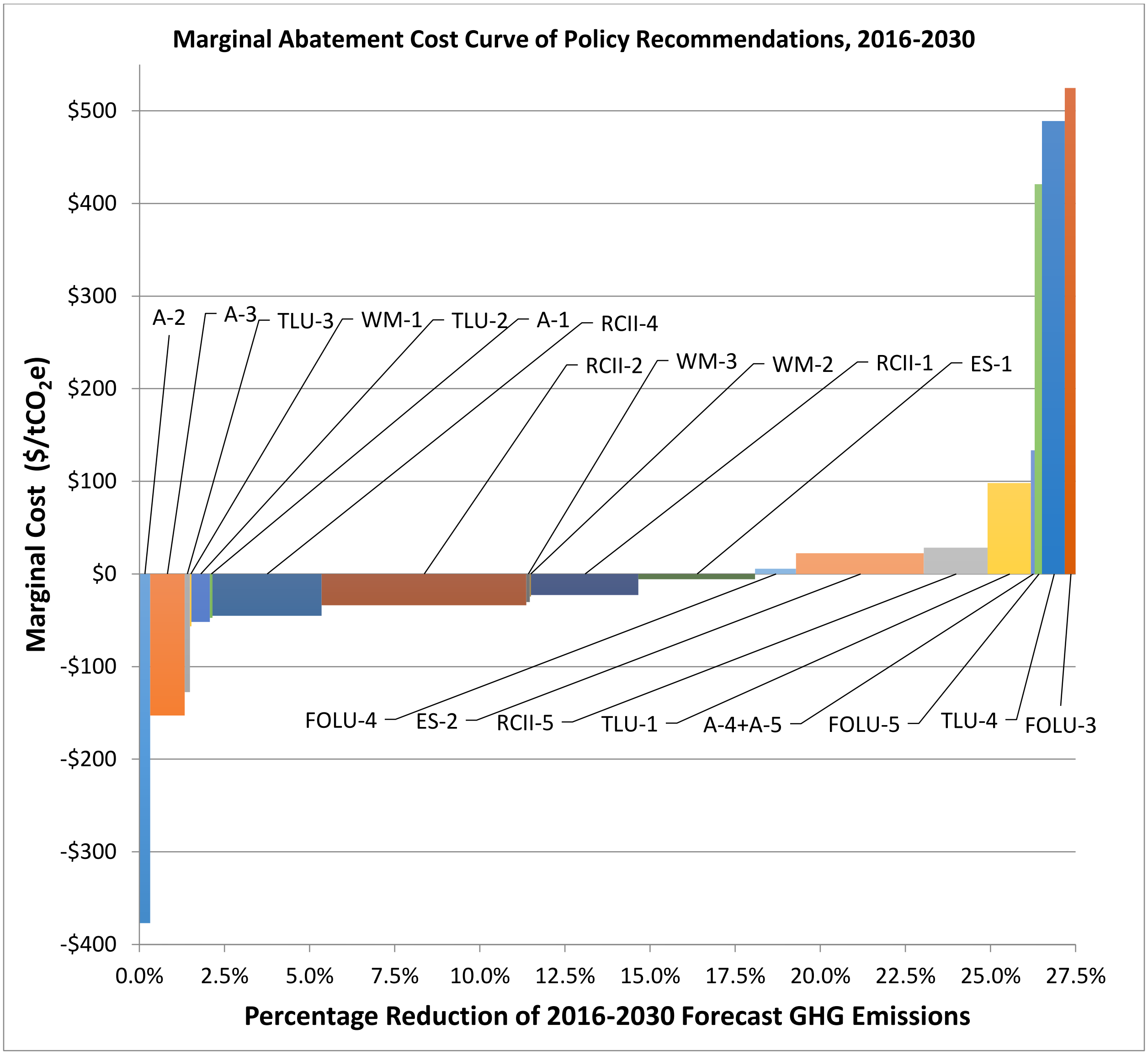
Clean Power Plan (referred to as 111d in graph) Scenarios include comprehensive effects of CSEO policy options that affect electricity supply and demand, adjusted as necessary, including: ES-1, ES-2, RCII-1, RCII-2, RCII-4, TLU-2, FOLU-3, WM-1, WM-2, WM-3 and AG-4/AG-5.

The dashed lines present CSEO policy impacts under two geographic displacement scenarios on a mass-basis for the overall MN electricity sector CO_2 emissions. Rate based evaluations are available in the report and appendices.

The blue solid line presents an estimated MN CO_2 and energy baseline, using marginal resource mix assumptions provided by MPCA.

The red solid line presents Clean Power Plan goal calculated for Minnesota, expressed as mass-based CO_2 emissions pathway.

Figure EX-4. Marginal Costs/Savings of Policy Recommendations, 2016-2030

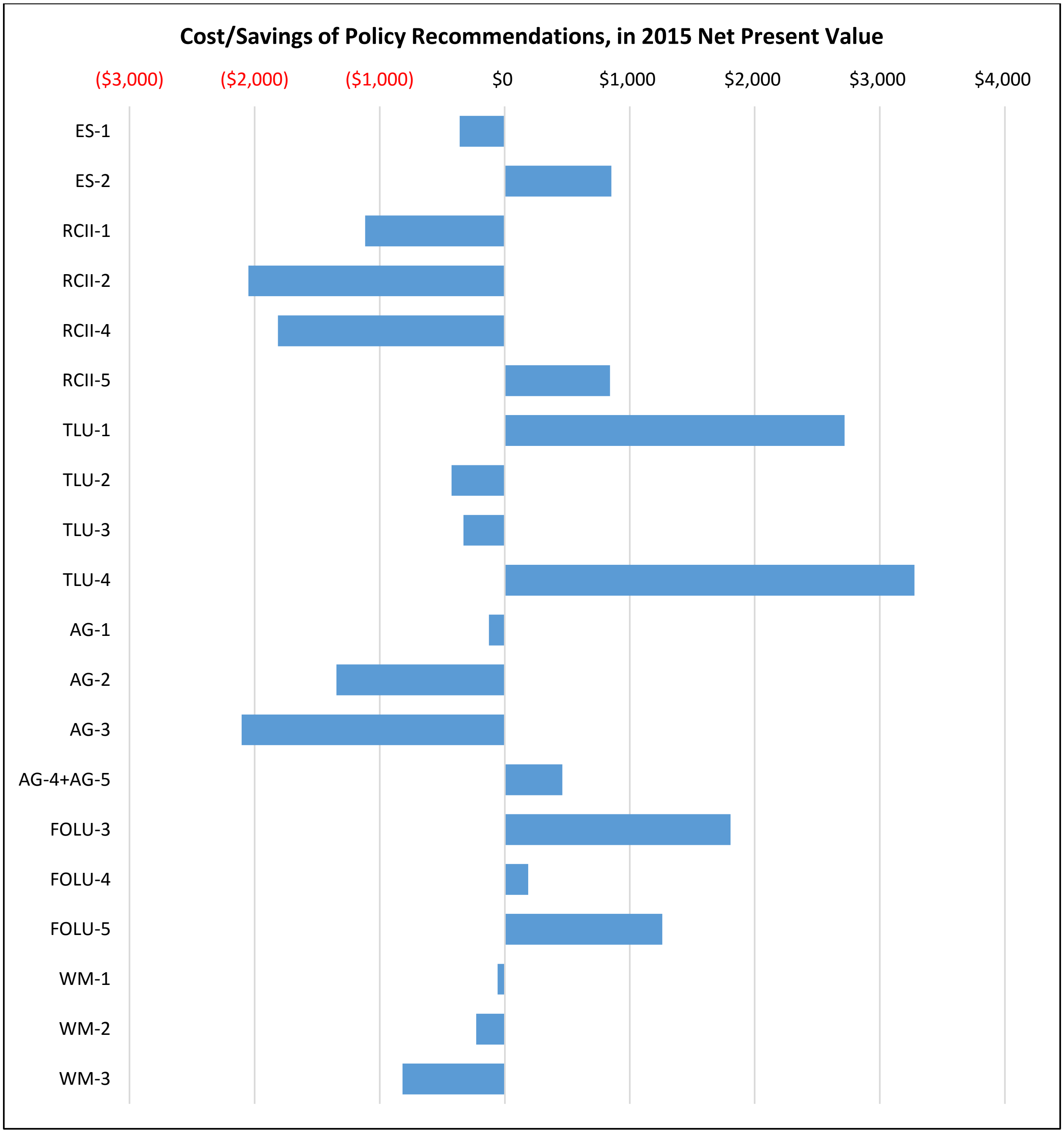


Notes: This curve displays policies from most cost-effective (those which produce net savings) to least (those which produce net costs. The height of each bar indicates the cost-effectiveness, or net cost per ton of emissions reduced, and the width represents the volume of emissions reduced as a percentage of baseline.

Table EX-3. Summary of Macroeconomic Impacts of Policy Recommendations

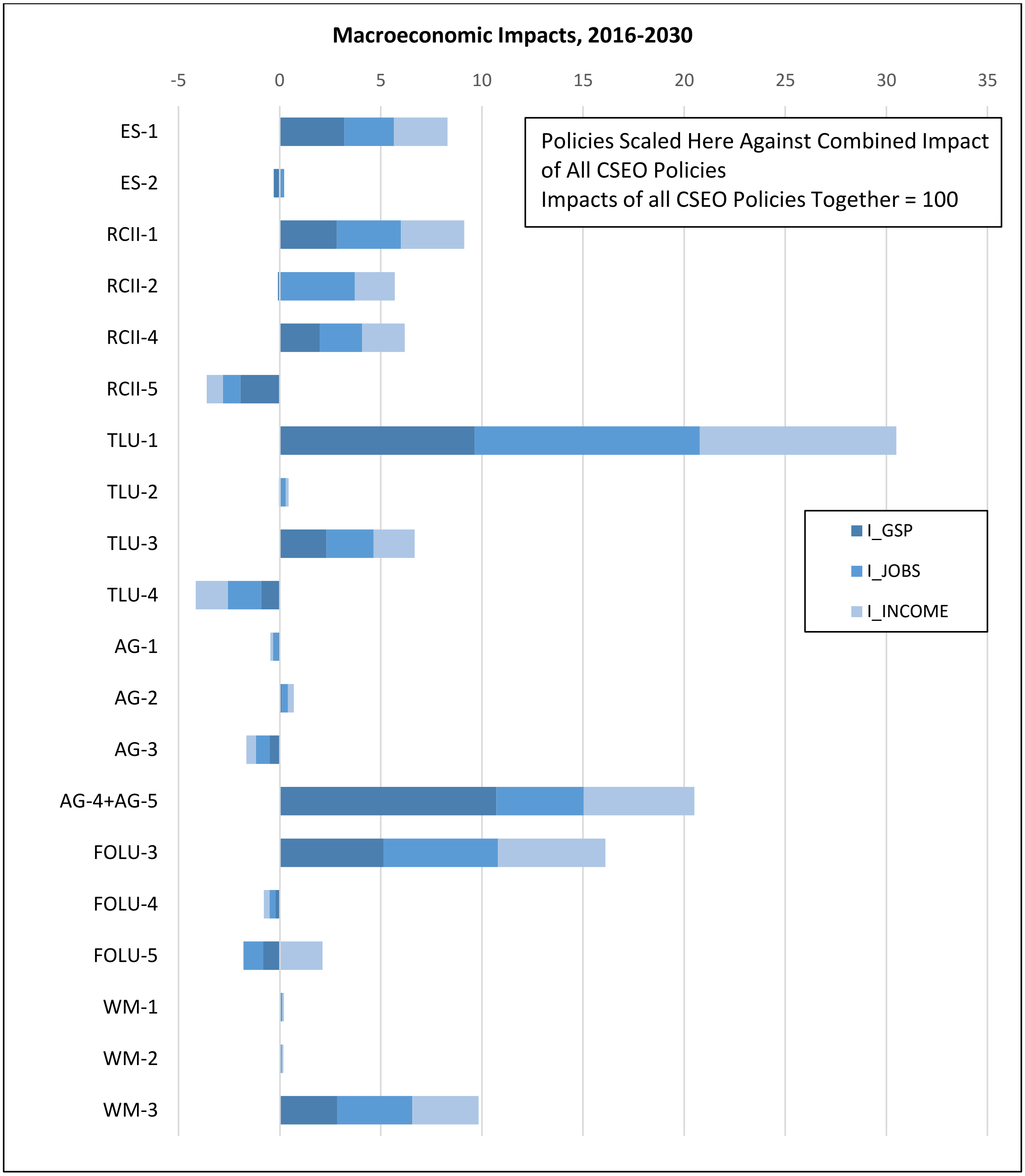
Macroeconomic Impacts of Policy Recommendations									
Policy	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average	Cumulative (2015-2030)	Year 2030	Average	Cumulative (2015-2030)	Year 2030	Average	Cumulative (2015-2030)
ES-1	$538	$228	$3,416	3,690	1,820	27,290	$434	$180	$2,695
ES-2	-$73	-$39	-$309	170	310	2,470	-$16	-$3	-$22
ES Sector Total	**$542**	**$239**	**$3,579**	**4,720**	**2,380**	**35,650**	**$485**	**$204**	**$3,058**
RCII-1	$508	$202	$3,026	3,840	2,330	35,020	$434	$213	$3,191
RCII-2	-$69	-$6	-$91	6,020	2,750	41,190	$336	$134	$2,011
RCII-4	$137	$141	$2,111	1,430	1,560	23,340	$163	$143	$2,140
RCII-5	-$345	-$149	-$2,081	-1,680	-690	-9,610	-$154	-$58	-$809
RCII Sector Total	**$262**	**$210**	**$3,149**	**9,820**	**6,080**	**91,270**	**$801**	**$444**	**$6,658**
TLU-1	$711	$688	$10,319	8,140	8,230	123,400	$781	$659	$9,885
TLU-2	$4	-$2	-$31	500	220	3,290	$29	$10	$151
TLU-3	$125	$165	$2,477	1,330	1,720	25,860	$78	$138	$2,068
TLU-4	$140	-$65	-$969	-810	-1,220	-18,300	-$56	-$108	-$1,622
TLU Sector Total	**$981**	**$787**	**$11,799**	**9,170**	**8,950**	**134,270**	**$833**	**$699**	**$10,485**
AG-1	-$9	-$5	-$73	-360	-200	-2,960	-$22	-$8	-$125
AG-2	-$2	$8	$113	70	230	3,380	$21	$20	$299
AG-3	$23	-$35	-$529	1,170	-490	-7,420	$56	-$32	-$486
AG-4+AG-5	$1,132	$819	$11,469	3,610	3,420	47,820	$539	$398	$5,576
AG Sector Total	**$980**	**$680**	**$10,203**	**810**	**1,490**	**22,300**	**$349**	**$277**	**$4,148**
FOLU-3	$382	$366	$5,495	4,420	4,180	62,670	$463	$361	$5,409
FOLU-4	-$10	-$15	-$232	-130	-210	-3,160	-$14	-$19	-$283
FOLU-5	-$75	-$59	-$883	-920	-720	-10,750	$117	$144	$2,157
FOLU Sector Total	**$294**	**$290**	**$4,345**	**3,340**	**3,220**	**48,340**	**$567**	**$486**	**$7,292**
WM-1	$2	$2	$31	90	80	1,130	$8	$6	$86
WM-2	$6	$2	$31	150	60	930	$13	$5	$72
WM-3	$240	$203	$3,039	3,290	2,750	41,210	$319	$223	$3,338
WM Sector Total	**$248**	**$207**	**$3,101**	**3,530**	**2,890**	**43,280**	**$340**	**$233**	**$3,496**
CPP	**$2,894**	**$1,914**	**$28,716**	**28,140**	**19,507**	**292,610**	**$2,797**	**$1,672**	**$25,078**
Overall Economy	**$3,246**	**$2,378**	**$35,677**	**30,820**	**24,630**	**369,440**	**$3,235**	**$2,261**	**$33,908**

Figure EX-5. Net Total Direct Costs/Savings of Policy Recommendations, 2016-2030



Notes: This chart shows the net cost of each policy to society in net present value. Positive NPVs indicate a net cost to implement a policy, while negative NPVs indicate a net savings to implement that policy.

Figure EX-6. Macroeconomic Indicators (Jobs, Income, and Economic Growth) of Policy Recommendations, 2016-2030



Notes: I_GSP, I_JOB, I_INCOME represent policy recommendation impacts on GSP, Employment and Income, respectively.

Figure EX-7. Jobs Impacts of CSEO Recommendations by Sectors and Clean Power Plan Goals

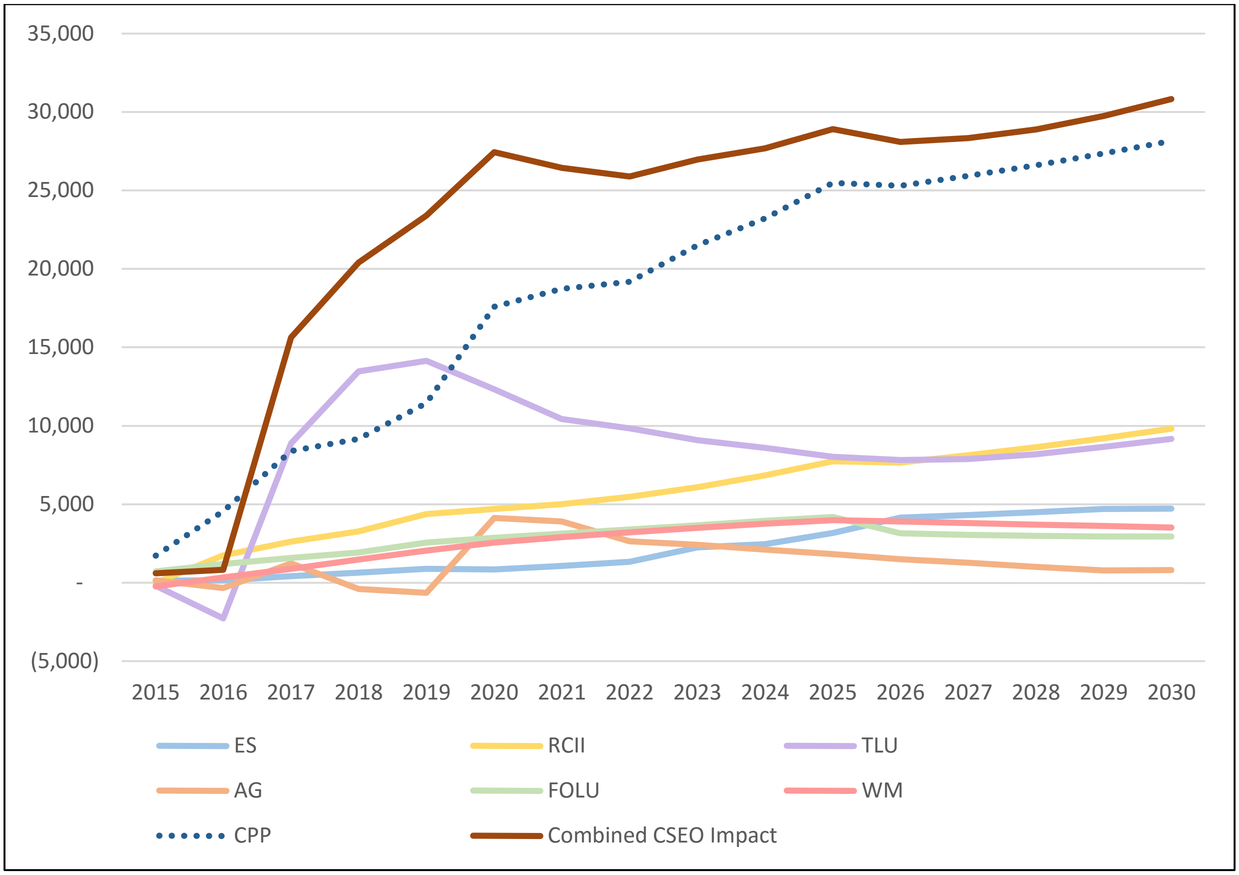


Figure EX-8. Job Gains and GHG Reduction by Policy Recommendations, 2016-2030

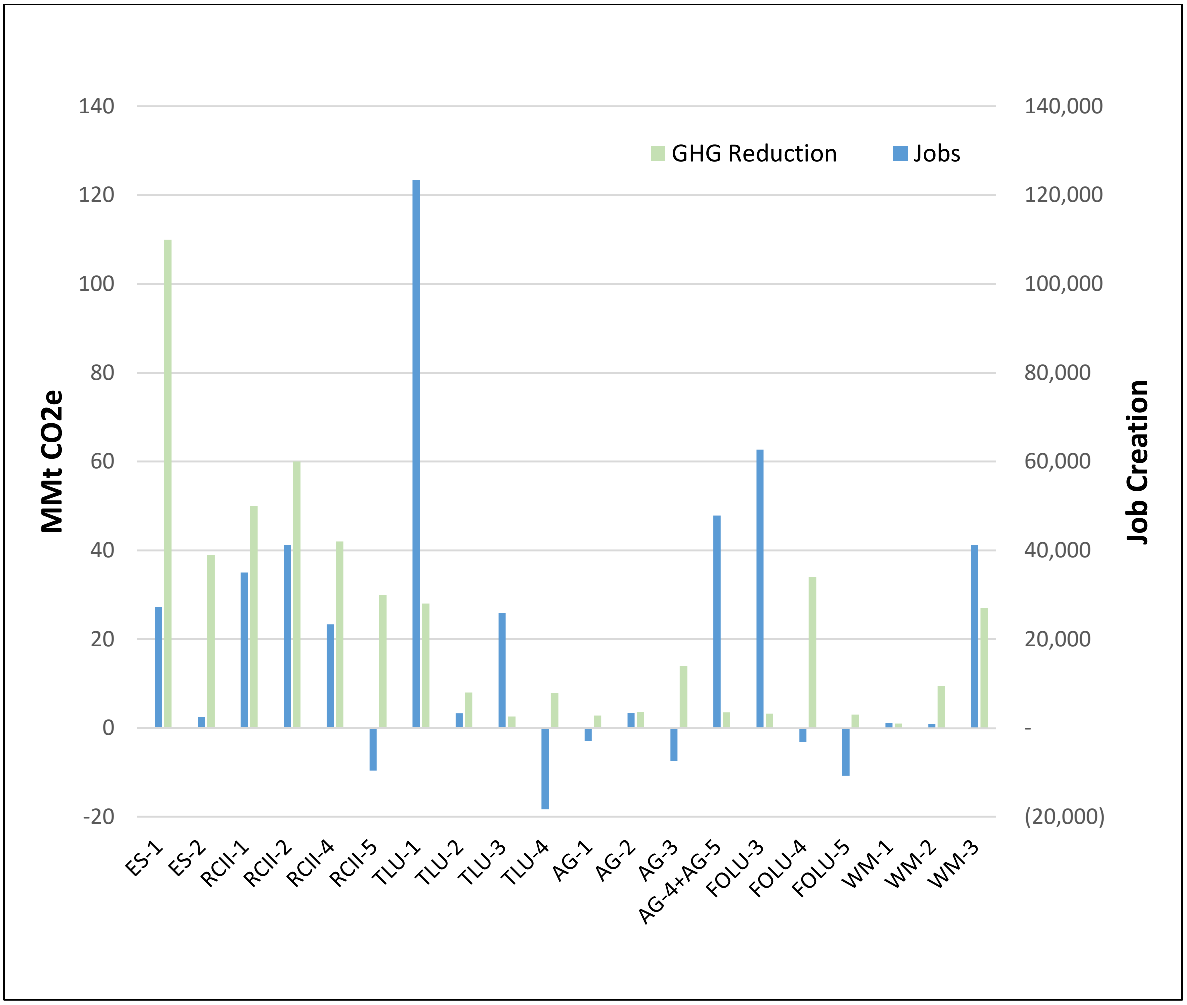


Figure EX-9. Job Gains and GHG Reduction by Sector, 2016-2030

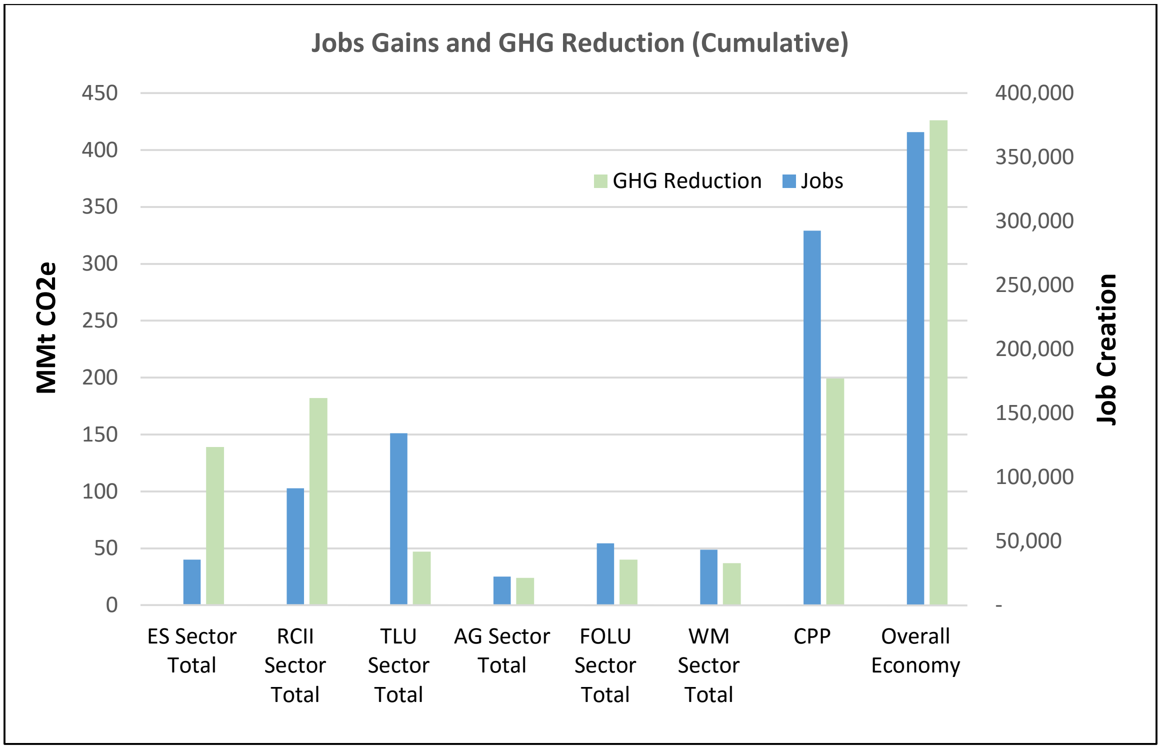


Figure EX-10. Net Job Creation by Policy Recommendations, Average Annual (Jobs)

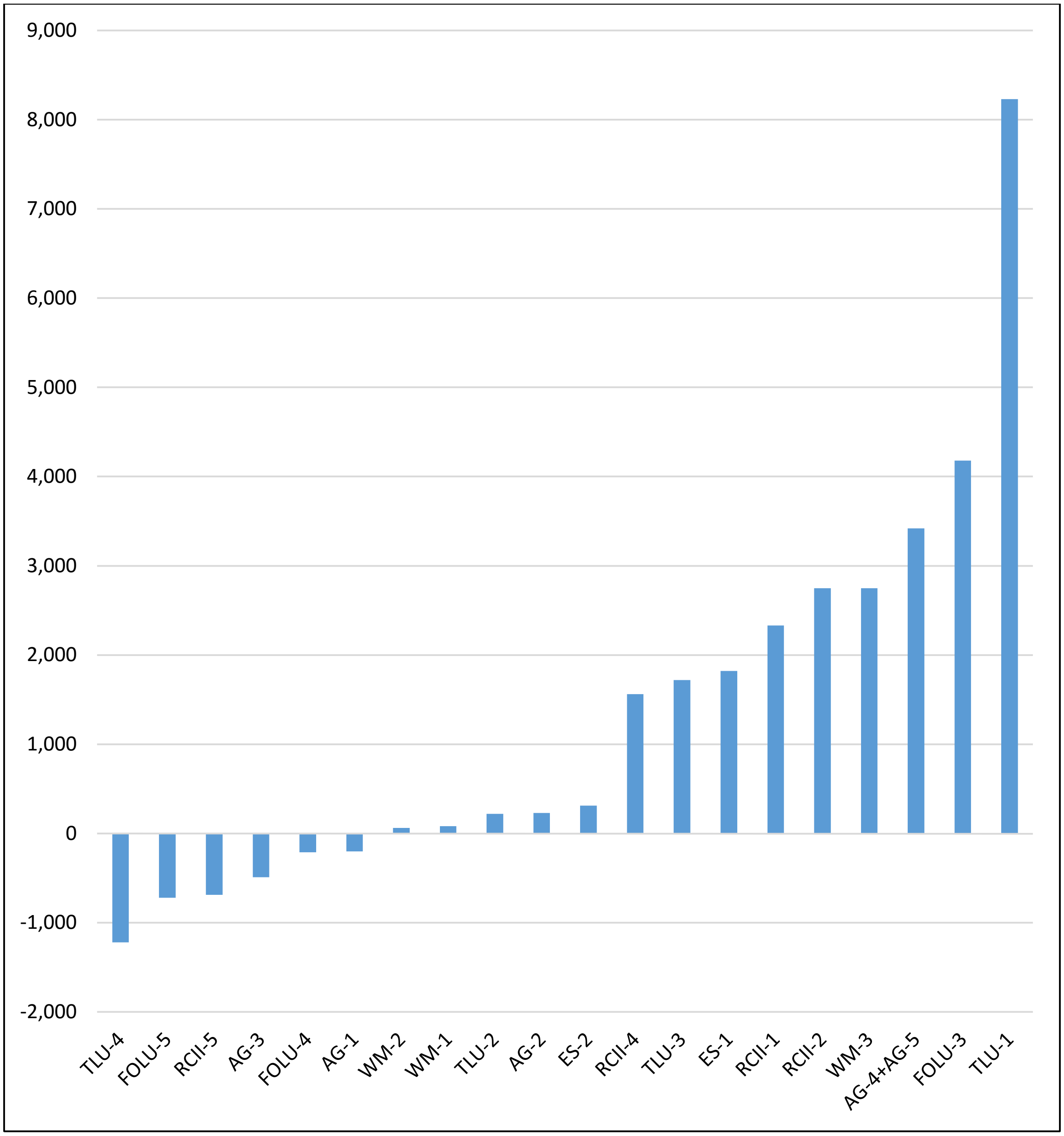
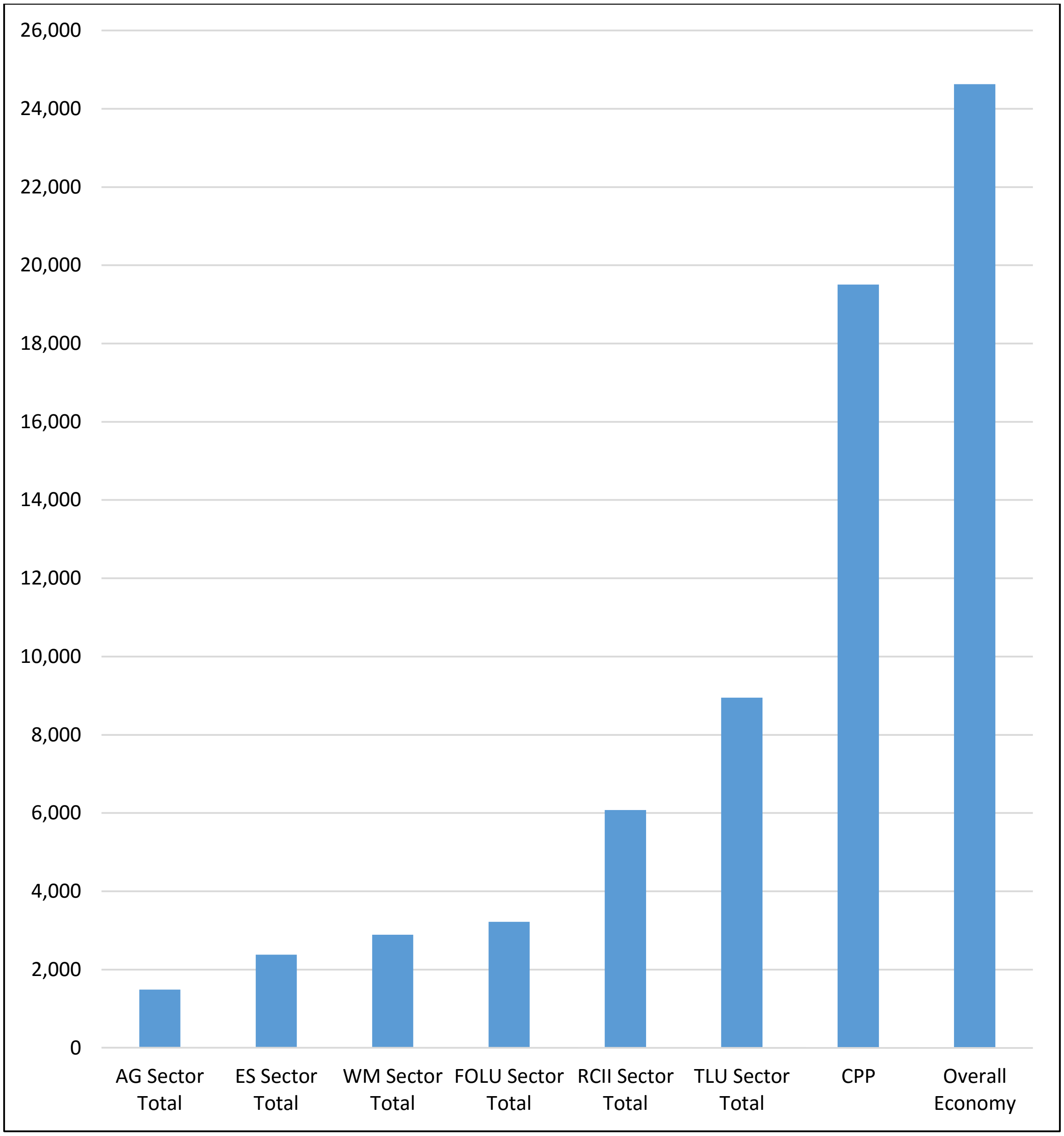


Figure EX-11. Net Job Creation by Sector, Average Annual (Jobs)



Chapter II. Minnesota Greenhouse Gas Baseline Emissions

This chapter provides an overview of the state's greenhouse gas (GHG) emissions inventory and business-as-usual (BAU) forecast (or "baseline"). Most of this information was drawn from the Minnesota Pollution Control Agency's (MPCA's) GHG inventory & forecast (see Appendix B). Some targeted additional work was done as part of this project to fill some gaps in the emissions forecast so that an impact analysis of Climate Solutions & Economic Opportunities (CSEO) policy options could be undertaken. This includes the development of an emissions baseline for the Forestry & Other Land Use (FOLU) sector (see Appendix C) and a BAU forecast for the Agriculture sector, crop production subsector (see Appendix D).

Concepts and Methods

In developing the CSEO baseline, MPCA and the Center for Climate Strategies (CCS) have followed the guidelines for GHG emissions reporting developed by the Intergovernmental Panel on Climate Change (IPCC) and used by the US Environmental Protection Agency (EPA) to report national emissions. All sectors of Minnesota's economy were addressed in the baseline. These follow the common categorization used in national GHG reporting:

- Energy Supply (ES): for Minnesota, this mainly addresses the Power Supply (PS) subsector.
- Residential, Commercial & Institutional (RCI): this covers emissions from fuel combustion in buildings.
- Industry (I): this sector includes emissions from fuel combustion for industrial processes and buildings, as well as non-combustion emissions that occur from industrial processes.
- Transportation: most importantly fuel combustion in onroad vehicles, but also including air, rail and marine vessels.
- Agriculture: covers emissions from crop production and livestock management, including both fuel combustion and non-combustion sources.
- Forestry & Other Land Use (FOLU): the FOLU sector primarily covers carbon sequestration in forests, rangeland, and urban forests. However, other GHG sources are also addressed (importantly, methane emissions from wetlands). See Appendix C for details on the FOLU baseline.
- Waste Management (WM): this includes the solid waste management and wastewater treatment subsectors; these include mostly non-combustion emissions, since, energy consumption for these sectors is difficult to break out of the Transportation and RCI sector supporting data.

The baseline estimates are presented in units of teragrams (Tg) of carbon dioxide equivalent (CO_2e) emissions (1 Tg is equal to 1 million metric tons). These estimates include all GHG emissions within each sector and put them in common units based on their global warming potential (GWP). For this study, GWPs from the IPCC's Fourth Assessment Report (AR4) were used to retain consistency with values that had been used by MPCA. As noted below, emissions for all GHGs required for reporting by the Intergovernmental Panel on Climate Change (IPCC) were addressed in the work done by MPCA and CCS:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFC)
- Sulfur hexafluoride (SF_6)
- Perfluorocarbons (PFC); and
- Nitrogen trifluoride (NF_3)

The CSEO planning period runs through the year 2030. Therefore the baseline addresses emissions from 1990 through 2030. Presentation of the results for Power Supply is provided on a "consumption-based" approach to emissions accounting. This means that emissions from Minnesota's net imports of power have been added to those from in-state generation sources, so that a complete accounting of the emissions associated with electricity consumption results. For the other sectors, only the emissions that occur within the state have been included in the baseline. In this study, reference to a "base year" will be to the year 2010; since this was the latest year across all sectors for which historical data were available to estimate emissions (although in some cases, more recent historical data are used).

This treatment of emissions varies somewhat from the way in which GHG reductions are credited for the CSEO policies. As detailed in Chapter III.1, a full energy-cycle approach to estimation of emissions impacts is taken to assess policy option implementation benefits. These would capture additional upstream reductions from sourcing fuels and materials. In doing that, CCS analysts have constructed two sets of GHG reduction estimates: those known to occur within the state; and those that may or may not occur within the state (i.e. the upstream component).

A more detailed discussion of the principles and guidelines used for quantification of baselines is provided in Chapter II and Appendix E. Policy specific baseline assumptions are provided in the policy option document for each individual CSEO Policy Option in the appendices to the report. Policy baselines are defined as a combination of existing and planned actions, and all analysis of policy options impacts is designed to document effects that are additional to these baseline actions. Emissions baselines are derived from related energy, resource, and economic activities and flows. As a result, GHG baselines provide important baseline data in these areas. Macroeconomic baselines are calculated separately through the REMI PI+ model for a wide range of subsectors, and discussed in Appendix G.

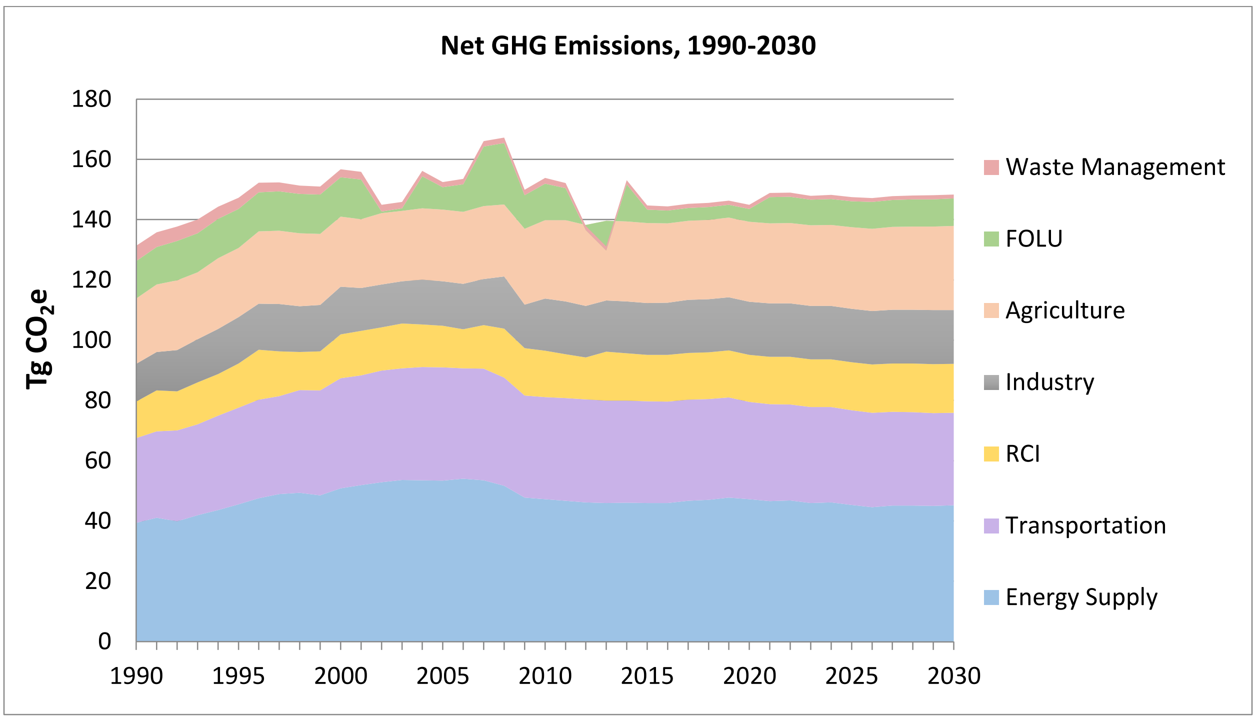
Results of GHG Baseline Assessments

A summary of both the economy-wide baseline and the emissions baseline for key sectors is provided below. Emissions are provided on a "net" emissions basis, meaning that both sources and sinks of GHGs are included (any summarized results indicating "gross" emissions indicate that only emissions sources are included).

All Sectors

Figure II-1 provides an overview of Minnesota's economy-wide baseline. These are shown on a net basis (sinks included). A big change has occurred from previous reported baselines, such as the one constructed for the 2008 CCAG report, in the portrayal of FOLU sector emissions. In the assessment from March 2015 (see Appendix B), CH_4 emissions from both woody and herbaceous wetlands have been included. While there is still a fairly high level of uncertainty around these emissions data, their inclusion shifted the overall net emissions for the sector to be positive in most years (i.e. more than offsetting the carbon sequestered in the state's forests).

Figure II-1. BAU Net GHG Emissions by Sector



The economy-wide baseline summary shown in Figure II-2 is provided on a gross basis, meaning that only GHG emissions sources are included. This includes the significant contributions of methane emissions in the FOLU sector. Unlike many states, where emissions contributions are concentrated mainly in the ES, TLU, and RCI sectors, Minnesota's emissions are more uniform across sectors. In the forecast period (after 2010 in most sectors), emissions overall are expected to remain fairly static. However, modest reductions in some sectors (e.g. Transportation) are offset by slight gains in others (Agriculture).

Figure II-2 BAU Gross GHG Emissions by Sector

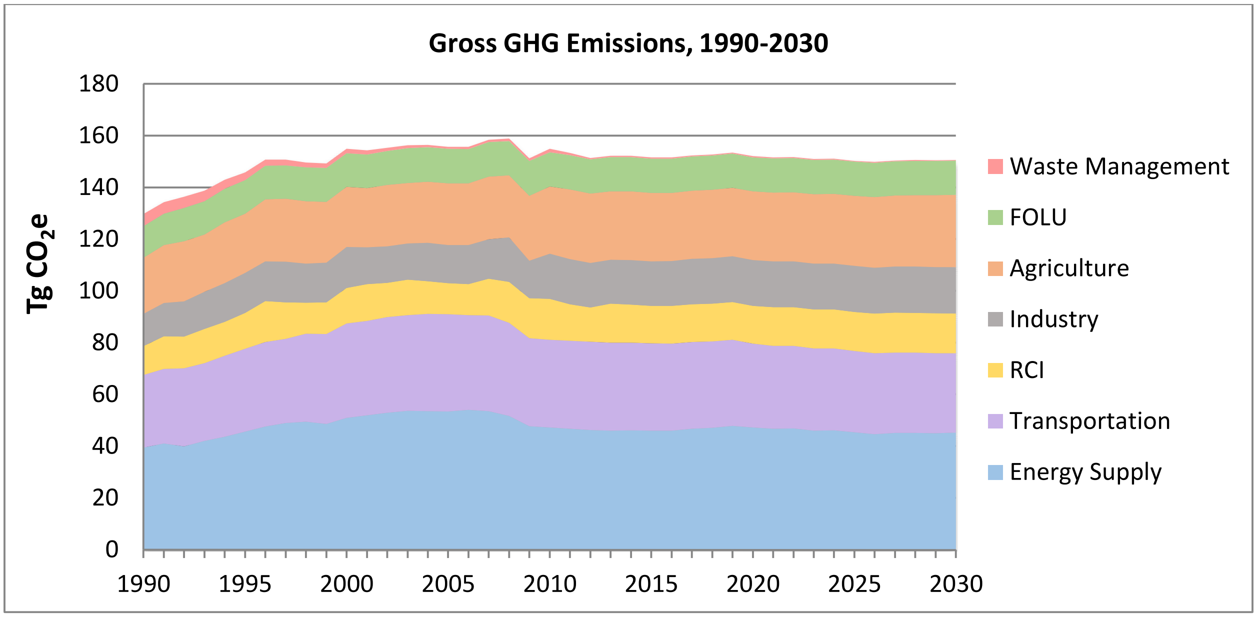
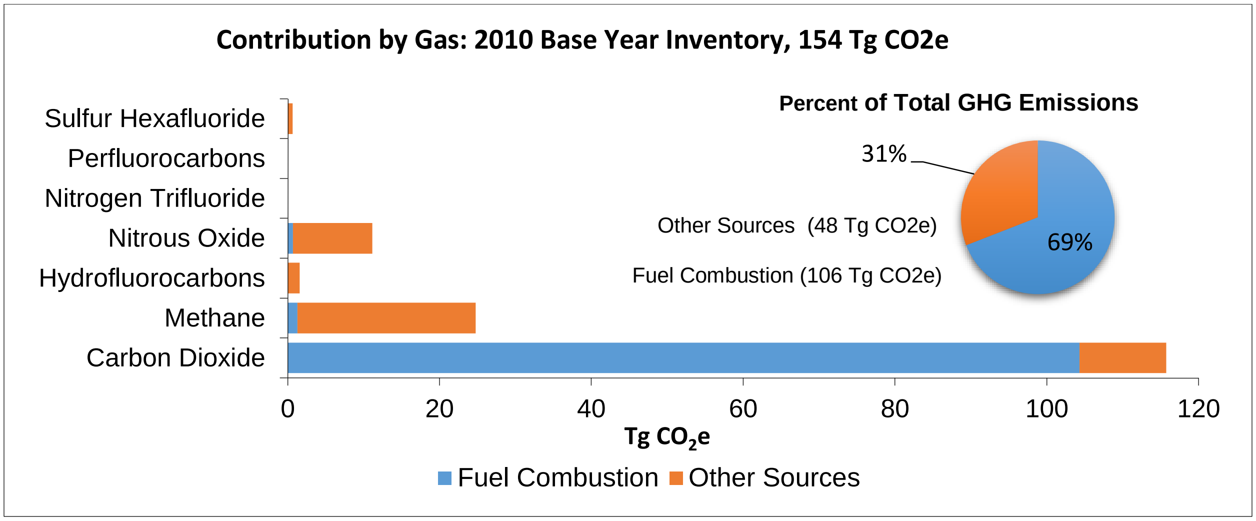


Figure II-3 provides a summary of emissions contribution by each GHG to the 2010 base year emissions. As shown, CO_2 is the dominant contributor (>75% of 2010 emissions), even when emissions are shown on a carbon dioxide equivalent basis (using AR4 GWPs). Methane and nitrous oxide are the next most important contributors to total CO_2e emissions. Also, as indicated in this figure, combustion of fuels produces 70% of the emissions estimated for the 2010 base year. Emissions for the "high global warming potential" (HGWP) gases (SF_6, PFC, HFC) are all very small contributors to base year emissions, as well as the forecasted BAU emissions. Nitrogen trifluoride (NF_3) emissions, most commonly used in the electronics industry, were not identified in Minnesota's baseline.

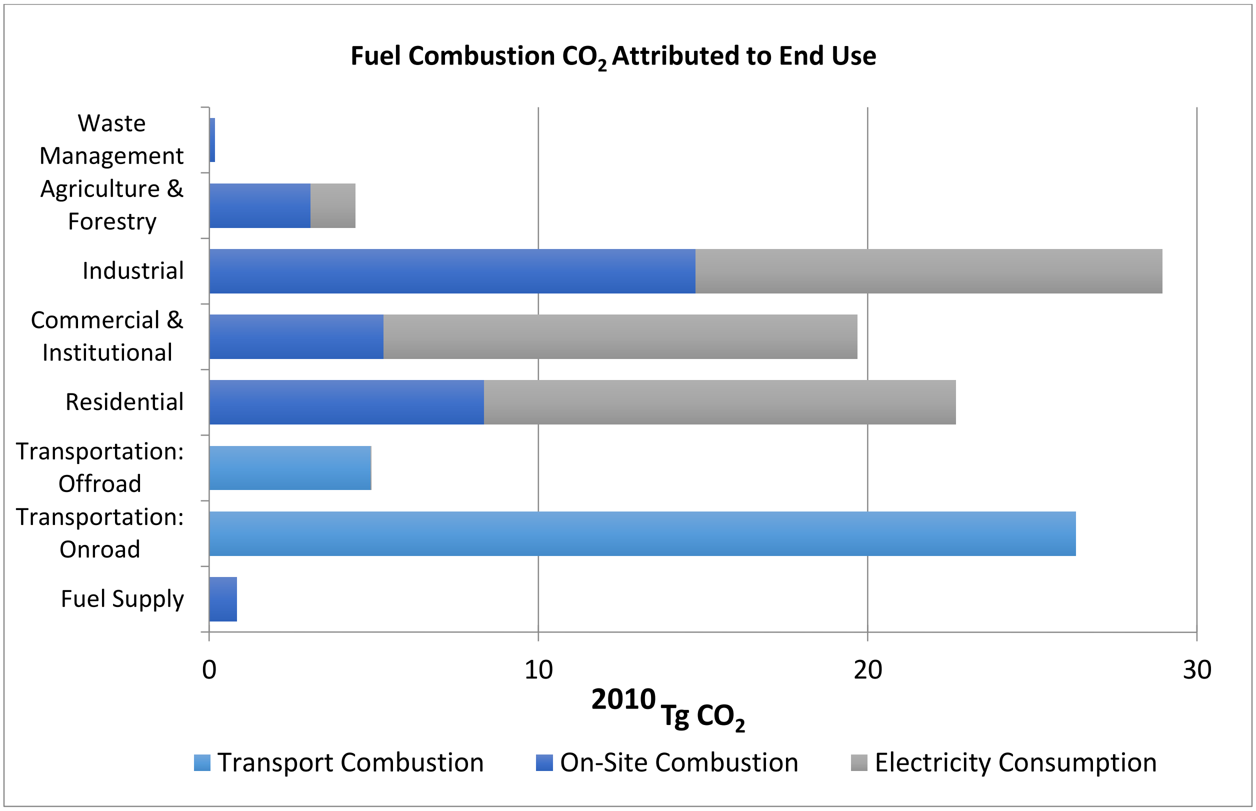
Figure II-3. Baseline Contribution by GHG



To support assessment of GHG mitigation opportunities, attribution of fuel combustion emissions to end use sector is important. Figure II-4 provides this attribution for Minnesota. Here, CO_2 emissions from both direct fuel combustion and indirectly from electricity consumption are attributed to their end use (in this case, emissions from the PS sector are allocated to the end user). The current structure and detail of the baseline does not allow for full attribution of fuel use and electricity consumption to waste management or fuel supply sectors. For example, solid waste transportation emissions are part of Transportation; similarly, electricity consumption related emissions are part of the RCI sector. Electricity consumption in the fuel supply subsector (natural gas transmission and distribution) is probably small.

Figure II-4 indicates the need to identify opportunities for GHG mitigation across both electricity consumption and fuel use in the RCII sectors. On-road transportation is also shown to be a substantial contributor to overall fuel combustion CO_2. The adjoining pie chart provides a snapshot of fuel combustion CO_2 attributed to electricity consumption, on-site fuel combustion (e.g. for industrial use or heating buildings), and transportation.

Figure II-4. Attribution of 2010 End Use Fuel Combustion CO_2



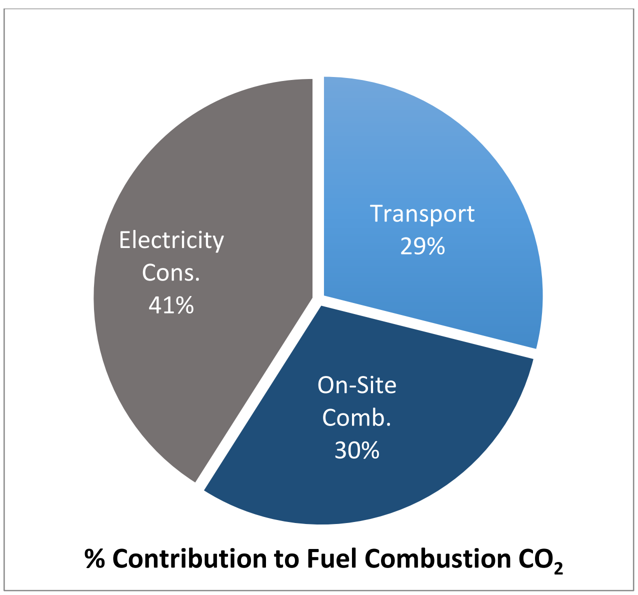


Figure II-5 provides another view of the economy-wide baseline. The GHG emissions values are also shown in five-year increments for each sector. As shown in the figure, net GHG emissions in the BAU forecast are expected to remain fairly constant. In the supporting data table below this figure Table II-1, the sector-level contributions to GHG emissions growth indicate that the Energy Supply, Transportation, and Waste Management sectors are expected to have negative contributions to growth (meaning expected reductions in the future under BAU conditions). The RCI and Industry sectors are expected to contribute moderately to emissions growth. Of the growth indicated for the Agriculture, Forestry & Other Land Use (AFOLU) sectors, over 80% of that is attributed to the FOLU subsector. For more detail on sector level emission baselines, see the individual sections for each sector in Chapter III.2.

Figure II-5. BAU Net GHG Emissions by Sector

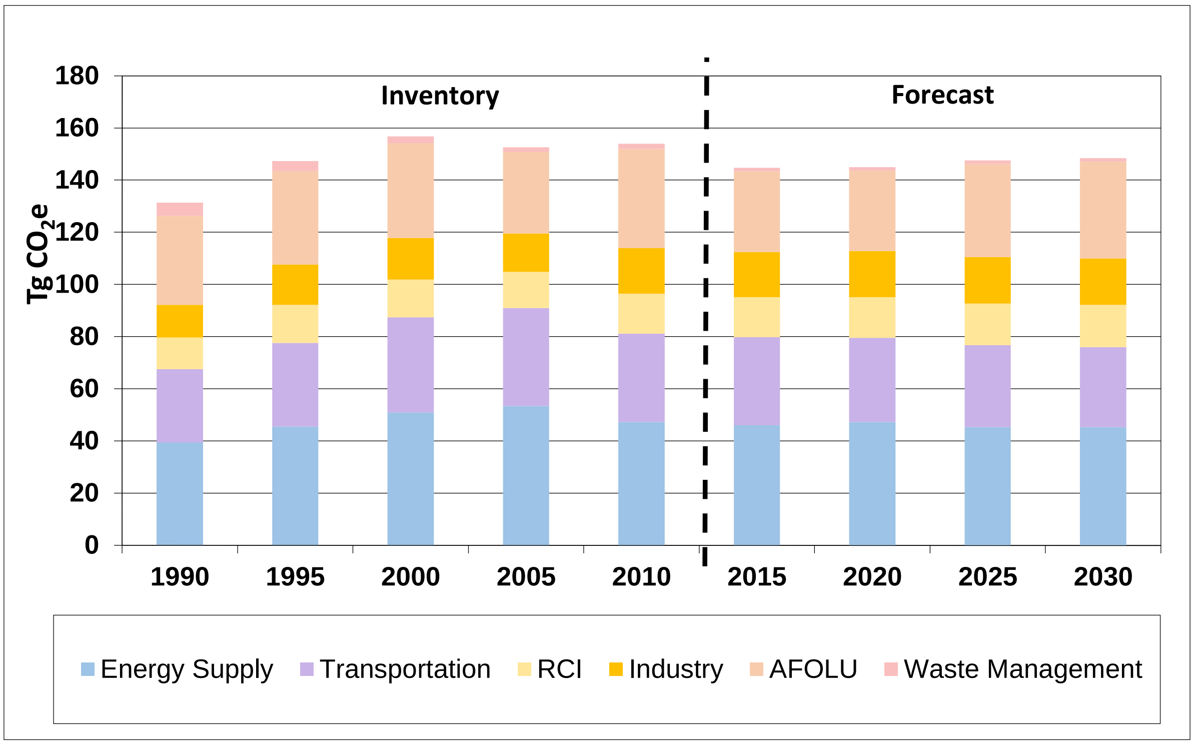


Table II-1. Sector-Level Contributions to GHG Emissions Growth

Sector	Tg CO_2e									
	1990	1995	2000	2005	2010	2015	2020	2025	2030	Contribution to 2015-2030 Growth
Energy Supply	39	46	51	53	47	46	47	45	45	-20%
Transportation	28	32	37	38	34	34	32	31	31	-87%
RCI	12	15	14	14	15	15	16	16	16	23%
Industry	12	15	16	15	17	17	18	18	18	19%

AG and FOLU	34	36	36	31	38	31	31	36	37	168%
Waste Management	5.0	3.7	2.6	1.8	1.9	1.4	1.4	1.3	1.3	-3%
TOTAL NET Emissions	**131**	**147**	**157**	**153**	**154**	**145**	**145**	**147**	**148**	**100%**

Estimates of "carbon intensity" are a common way to compare the emissions of one source, one sector, or one geographic area to another. Figure II-6 provides a comparison of varying measures of Minnesota's population-based carbon intensity to the US national intensity. Minnesota's carbon intensity is expected to fall through the BAU forecast period, whether measured on a gross-basis, net basis, or even when excluding the entire FOLU sector (e.g. due to higher levels of uncertainty in these estimates). However, in all cases, the Minnesota estimates are higher than the national values. The likely primary drivers of this higher intensity for the state include: greater than average energy requirements for space heating purposes; relatively high carbon intensity of power supply; presence of high energy consuming industries (e.g. iron ore and petroleum refining); a significant agricultural industry; and a comparatively low population.

Figure II-6. Carbon Intensity, Per Capita

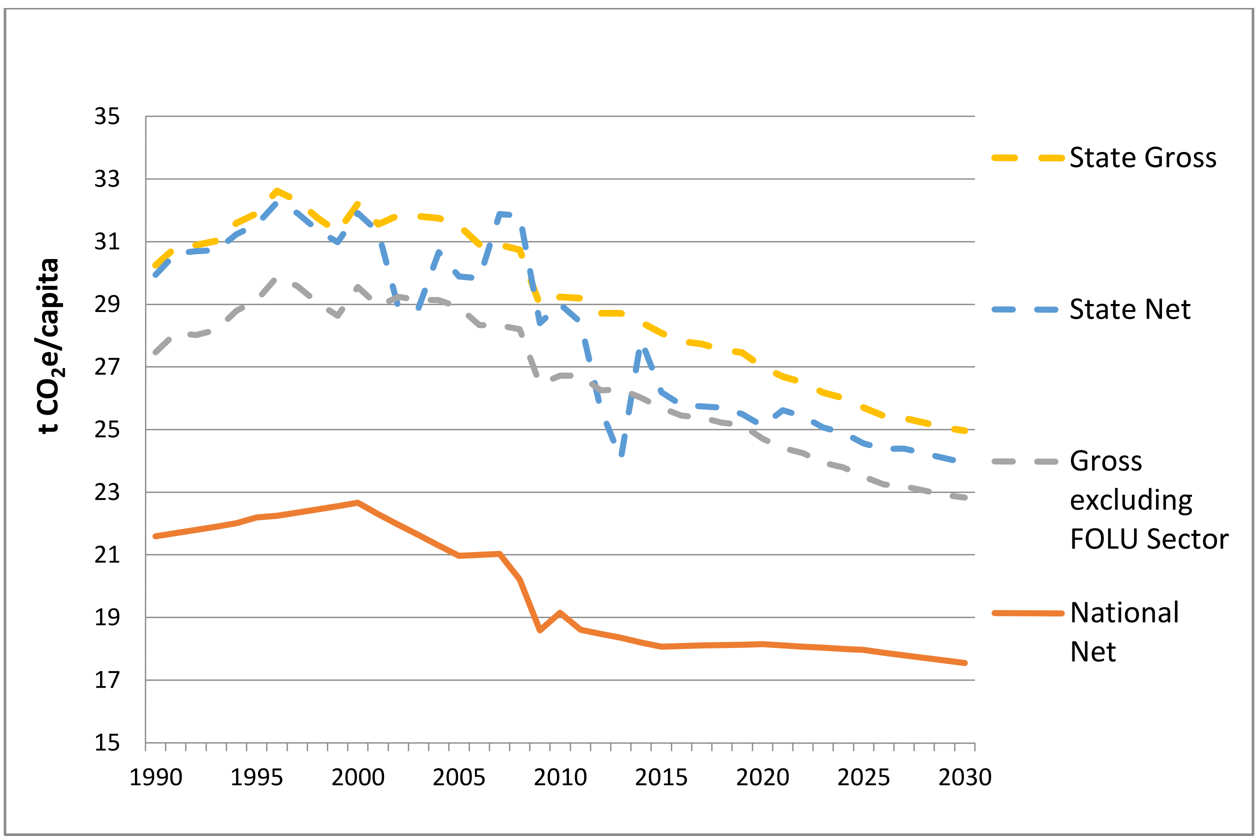
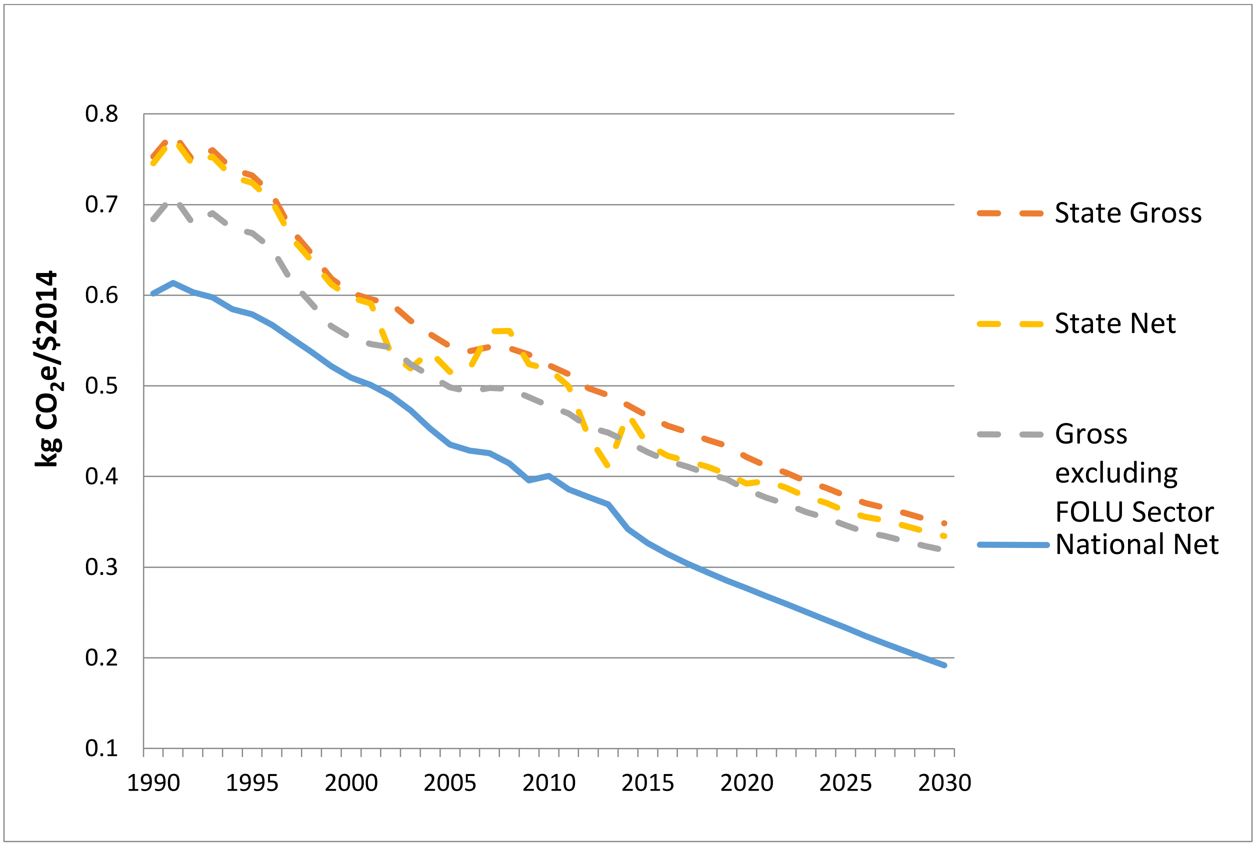


Figure II-7 provides another comparison of carbon intensity. This one indicates the emissions produced per unit of economic output (total economy-wide emissions divided by total gross state product or for national emissions, total domestic product). This summary also indicates expected reductions in future carbon intensity at both the state and national levels. Minnesota's intensity is expected to remain above that of the US as a whole due to the structure of the industry sector, high-energy requirements for space heating, and size of the agriculture sector.

Figure II-7. Carbon Intensity, Per $GSP



See Appendix B for more details on the construction of the Minnesota GHG baseline.

Key Sectors

As shown above, GHG emissions contributions are relatively even by each sector of the economy. In most states, there are two or three key sectors that receive focused attention in GHG mitigation planning. Since that is not the case for Minnesota, details for each sector baseline are presented at the beginning of the discussion on GHG mitigation opportunities for each sector in Chapter III.2.

Chapter III. Minnesota CSEO Recommendations

Policy Development Concepts, Methods, and Guidelines

For the CSEO project a set of policies was selected through a screening process with MN agency team members. The policies were screened based on their expected potential to reduce GHG emissions and promote economic growth in the State (both gross State product and employment). From this initial screening over two dozen policies were selected for further development and analysis.

To support subsequent policy implementation impacts analysis, additional work was carried out by both CCS and MN agencies to enhance the State's GHG inventory and forecast (baseline). This work included updates by MPCA in the energy supply (ES) sector and by CCS and other MN agency contacts to fill some baseline gaps [e.g. a forecast for the crop production sector, a baseline for the Forestry & Other Land Use (FOLU) sector]. Baseline documentation is provided in the appendices to this report. Also, CCS worked with MN agency contacts to develop a set of avoided electricity system costs and emissions for use in impacts analysis corresponding to the expected marginal resource mix for power consumption in the State.

CCS worked with MN agency members to develop policy descriptions and designs (goals and timing) for each policy within a template format. These individual policy templates are assembled into sector level appendices to this report. Following policy design, CCS began work on the direct (microeconomic) impacts assessment of each policy, while MN agency team members continued working on other aspects of policy development including, implementation mechanisms, related policies and programs, key uncertainties, feasibility issues, and co-benefits.

The direct impacts assessment captured the expected energy and GHG impacts of policy implementation as well as net direct societal costs. Following completion of the direct impacts assessment of each policy, an assessment was made of whether any intra-sector overlaps existed to avoid double counting. Methods to adjust for any overlaps were developed and applied. Finally, an assessment was made of any overlaps between sectors (inter-sector overlaps). These are most common among electricity supply and demand sectors; but for CSEO were also found between biofuels supply (in the Agriculture sector) and biofuels consumption (in the Transportation sector).

Output from the direct impacts assessment was then used to construct inputs for analyzing indirect economic impacts (macroeconomic impacts). A macroeconomic model, REMI-PI+, was used to model indirect impacts that include changes to GSP, employment, and incomes

Table III-1 provides a list of the policy options that were selected for initial analysis and that were recommended for the final set of CSEO policy options. Therefore, in some cases, the numbering of policy options is not sequential. Appendix X provides the initial set of CSEO policy options selected for analysis. The initial set of CSEO policy options contained an ES sector policy option that would be used to assess Clean Air Act Section 111d compliance and the need for additional mechanisms (price and non-price) to achieve the necessary reductions in the power supply subsector. That assessment is presented in Chapter IV of this report.

Table III-1. Final Recommended CSEO Policy Options

Sectors:	AG	FOLU	WM	ES	RCII	TLU	CPP
AG-1. Nutrient Management in Agriculture							
AG-2. Soil Carbon Management in Agriculture: Increased Use of Cover Crops							
AG-3. Soil Carbon Management in Agriculture: Increased Use Conversion of Row Crops to Perennial Crops							
AG-4. Advanced Biofuels Production							
AG-5. Biofuels Consumption (Existing Biofuels Statute)							
FOLU-3. Urban Forests: Maintenance and Expansion							
FOLU-4. Tree Planting: Forest Ecosystems							
FOLU-5. Conservation on Private Lands							
WM-1. Wastewater Treatment: Energy Efficiency							
WM-2. Front-End Waste Management: Source Reduction							
WM-3. Front-End Waste Management: Re-Use, Composting & Recycling							
ES-1. Increase the Renewable Energy Standard							
ES-2. Efficiency Improvements, Repowering, Retirement, and Upgrades to Existing Plants							
RCII-1. Incentives and Resources to Promote Combined Heat and Power (CHP) for Biomass and Natural Gas							
RCII-2. Zero Energy Transition/Codes (SB2030)							
RCII-4. Increase Energy Efficiency Requirements							
RCII-5. Incentives and Resources to Promote Thermal Renewables							
TLU-1. Transportation Pricing							
TLU-2. Improve Land Development and Urban Form							
TLU-3. Met Council Draft 2040 Plan							

Sectors:	AG	FOLU	WM	ES	RCII	TLU	CPP
TLU-4. Zero Emissions Vehicle Standard							
CPP. Estimates comprehensive effects of CSEO policy recommendations affecting 111(d) relevant portions of state electricity supply and demand.							

Consistency and Customization

For each CSEO policy option, CCS worked with Minnesota agency staff to develop design parameters needed to support the quantification of direct and indirect impacts and subsequent policy option implementation. These include:

- Timing: start and stop dates for the proposed policy options, as well, as any phase in or ramp up/down schedules.
- Level of effort: quantitative goals for the proposed action.
- Coverage of implementing or affected parties: this includes geographic boundaries and the specific types of entities or groups that will be required to implement the policy option.
- Other definitional issues or eligibility provisions: e.g. such as renewable fuel definitions, small business definitions, hydro-power size classes, etc.

In addition, the instruments or mechanisms used to implement each policy option must be defined, at least in general terms, to capture potential variations in effectiveness. This is particularly true for differences in price and non-price incentives and mandatory versus voluntary approaches). A variety of instruments or mechanisms exist, including:

- Voluntary agreements
- Technical assistance
- Targeted financial assistance: e.g. grants, production credits, low cost loans, loan guarantees
- Taxes or fees
- Cap and trade
- Codes and standards
- Disclosure and reporting
- Information and education
- Others: e.g. pilot programs or projects

The impacts of each are policy option specific and will vary by circumstance. For instance, price instruments, such as taxes and cap and trade, may perform better for policy options that are price responsive in comparison to those that are relatively unresponsive to price. Similarly, non-price instruments, such as codes and standards, may perform better where significant market barriers exist and require barrier removal. Mandatory actions may have higher compliance or market penetration rates.

CSEO policy option developers all worked from the same policy option template to achieve consistency across policy options and sectors. However, the policy option template offers significant flexibility in policy option design, so that each policy option can be highly customized to best fit the needs of Minnesota. Details of policy option design can be found in the respective sector appendices (F.1 through F.6).

Direct (Micro), Integrative, and Indirect (Macroeconomic) Impact Analysis

Direct impacts (also referred to as "microeconomic" impacts) include the estimated change from business as usual conditions in electricity, fuels or materials consumption, GHG emissions, and net direct costs that are expected as a result of policy option implementation. Details of the approach taken for estimating direct costs are provided in Appendix E.

The approach to evaluating indirect or macroeconomic impacts on jobs, income, economic growth, and prices that arise from implementation of new policy options are covered in Chapter III.1. These impacts also include distributional impacts, such as the differential impacts related to size, location, and socio-economic character of affected households, entities, and communities (this topic is often framed as fairness and equity). For instance, this would include disparate effects on small versus big business or wealthy versus low income households.

For direct impacts, the two key analytical endpoints are: cost effectiveness (CE), which is a measure of the implementation costs for every metric ton (t) of GHG avoided (expressed as $\$/tCO_2e$); and net societal costs/savings, presented as the net present value (NPV) of the stream of costs/savings incurred to implement the policy option over the planning period. These assessments include avoided costs due to policy option implementation, such as the avoided BAU cost of investment in infrastructure or services from efficiency measures. Net societal costs or savings are expressed in terms of a financial base year. For this project, the year 2014 is the financial base year. The CSEO planning period is from 2015 through 2030.

For all policy option analyses, energy and GHG impacts were assessed on the basis of the full energy-cycle, based on the availability of data and relevance. This means that net GHG reductions due to lower fuel or materials demand are quantified along with the net direct emissions impact at the point of combustion/use (i.e. upstream energy and GHG impacts were quantified, wherever possible). Since upstream GHG impacts cannot always be presumed to occur within the State's boundaries, these impacts were reported separately (as potentially out of State reductions). However, wherever CE is reported, it is based on full energy-cycle emissions accounting.

Whether the analytical end-point is net energy impact, net GHG impact, or net direct societal costs, the general equation for determining these net benefits or costs was as follows:

Net Change = PSc – BAU

The net change brought about by implementing a policy option or action was always derived by subtracting the business as usual (BAU) value from the value estimated for the policy option scenario (PSc). During direct impacts analysis, this general equation is applied to any cost-benefit metric that is being analyzed (as described in the next section, it was also used to determine net macroeconomic impacts). These metrics were estimated on an annual basis and included: energy production, energy consumption, changes in land management, GHG emissions, and changes in direct societal costs (e.g. investment costs, operating and maintenance costs, energy costs, etc.).

For some policy options, where important energy/GHG impacts are expected to occur after the end of the planning period, additional assessment of these impacts are reported. These impacts are important for policy options where substantial investments are needed for new long-lived infrastructure and where full GHG reduction potential is not reached until some point in time after the planning period (e.g. transportation or new buildings infrastructure; land management policy options, such as reforestation). The individual sector-level policy option documents (PODs) in Appendix F provide these details.

Integration (Interaction and Overlaps) Assessment

The initial micro-economic analysis of each policy option was done on a "stand-alone" basis. This assumes that the policy option is to be implemented all by itself, and the results were calculated against BAU conditions as documented in the GHG inventory and forecast.

Policy options will often have overlapping or interacting effects with others that are being implemented at the same time. These interactions/overlaps can occur between policy options within the same sector (intra-sector) or between policy options in separate sectors (inter-sector). An example of an intra-sector overlap would be a policy option that reduces waste emplacement in landfills and another that addresses landfill gas capture. By implementing the first policy option, there will be less waste being emplaced in landfills (as compared to BAU), which will reduce the amount of methane generated in the future and the possible GHG reductions. As well, with implementation of the second policy option, there will be less methane being emitted (as compared to BAU). This will reduce the potential reductions that could be achieved by reducing landfill waste emplacement (assuming no landfill gas collection and control under BAU conditions).

A common example of inter-sector interactions/overlaps occurs between electricity energy efficiency (EE) policy options in the RCII sector and clean electricity generation policy options in the ES sector. This can occur due to the difference in electrical grid carbon intensity between the BAU forecast and the intensity that results from implementation of all ES supply-side policy options. Chapter III.1 provides details on how the inter-sector interaction/overlap analysis was done for CSEO.

Another common area for interaction/overlap is biofuels supply and demand policy options. For CSEO, this occurs between the biofuels production and consumption policy options developed in the Agriculture sector (Policy Options AG-4 and AG-5). The overlap between AG-4 and AG-5 was addressed by analyzing the results of these two policy options implemented together as a package (the "biofuels package"). The inter-sector overlap with policy options in the TLU sector was addressed separately and is further described in Chapter III.2-3 below.

Identification of intra-sector policy option interactions and overlaps and the methods used to address them is provided at the beginning of the individual sector PODs provided in Appendix F. Inter-sector interaction/overlap assessment is addressed in Chapter III.1.

Indirect Impacts (Macroeconomic) Analysis Methodology

Climate policy analysis often includes an assessment of the direct financial losses and gains likely to be associated with a given policy. Policymakers and decision-makers frequently seek to understand how regulated parties will be affected by any combination of cost increases or decreases, additional or lowered compliance costs, subsidies or taxes, and many other potential financial changes that policies can bring about. Cost-benefit analysis practices seek to expand the understanding of policy impacts beyond these direct impacts by including assessments of some indirect or distributed benefits as well. Social costs of carbon and value assessments of the health benefits of reducing emissions of a certain pollutant are examples of indirect or non-monetary impacts often included in such assessments.

Macroeconomic analysis is distinct in that it seeks specifically to understand how the direct financial and economic impacts of a policy drive responsive changes throughout the rest of the economy, and how those direct and responsive changes all contribute to a single overall change to an area's total employment, consumption, production and earnings levels. These are most commonly expressed as the number of jobs supported by a region's economy, and the estimate of a region's gross state product (GSP).

Though there are many dynamics through which different actors in the economy interact, one important way in which changes move quickly between sectors is through *intermediate demands*, which are the demands that producers of goods and services make on one another in order to deliver their own goods and services to market. Increasing or reducing needs for a good or service will, in turn, increase or reduce the need for all the inputs required for its production. Those inputs can come from all around the economy. Each of these inputs will have its own demand for inputs as well, and those inputs will, in course, have inputs of their own. By following these linkages (almost always in the form of specialized software packages), macroeconomic models are capable of quantifying projections of how a change in one sector will affect every other sector.

A second important mechanism is that of price and quantity equilibria. As policies create new supplies or demands for various goods and services, or as they increase or decrease prices for the same, economies adjust as producers and consumers shift their activity levels in response. These changes can influence the total scale of the economy, or just the total size of a given sector's sales. They also affect buying power and costs of production for businesses. Direct impact analyses typically do not seek to understand these responses to policy initiatives.

A third important way (which factors heavily in some of Pennsylvania's Work Plans) in which changes translate through the economy is through *changes in consumer spending*. Consumers spend on a very wide range of products and services, ranging from basic needs such as food, clothing, shelter, and transportation to a comprehensive range of investment and consumption choices. If a policy influences the level of money available to households to be allocated without restriction, that policy will immediately drive changes in demand in an impressive array of sectors around the economy.

The first step in this process for CSEO was a full review of each policy's descriptive documentation and spreadsheet analyses which informed the emissions-reduction and cost-effectiveness impacts. From these documents CCS developed a) the quantified estimates of expenses, savings, and cost and price changes, and b) understandings of which actors are expected to be on the supply and demand side of each changed financial flow or cost/price change.

The second step was the development of a full list of macroeconomic modeling inputs, which represent not only the spending, savings and cost/price changes, but also the necessary responsive changes to keep financial flows balanced. For example, if a given policy calls for consumers to spend \$10 on equipment and save \$20 on energy, then there is a net gain of \$10 to the consumer (which they will spend or otherwise put to use), a net gain of \$10 to the seller of the equipment (which they will also put to use), and a \$20 loss to the energy supplier (which will require some adjustment for the supplier to absorb). Not only the original spending changes driven by the policy but also these responsive actions must be identified and quantified.

The third step was to utilize the REMI Policy Insight Plus (REMI PI+) macroeconomic modeling software, which is a dynamic economic forecasting model specific to the Pennsylvania economy and capable of modeling changes to 160 distinct and interconnected productive sectors. This software is the current leader in future scenario economic modeling power, and CCS analysts have significant experience utilizing this tool for greenhouse gas policy analysis. It is from this modeling effort that all results presented in this report were developed.

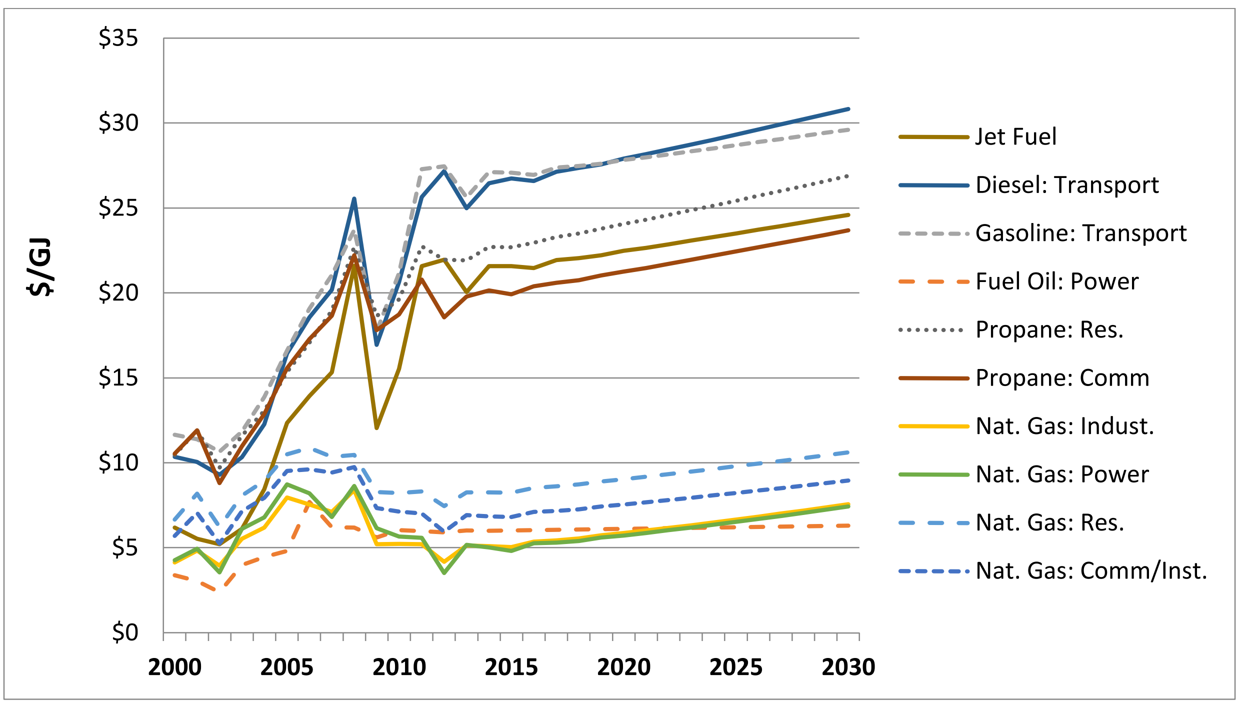
Throughout this effort, CCS bound the macroeconomic modeling work to a requirement to be consistent with the pre-existing analysis, assumptions and design of Work Plans. This is a significant principle, and is necessary to ensure that the macroeconomic analysis represents the Work Plan rather than some other policy with different parameters. Crucially, all assumptions about effectiveness and scale of these policies were retained from the cost-effectiveness analyses. The only independent decisions about design made as part of the macroeconomic analysis had to do specifically with modeling economic impacts. As such, the policy outcomes and projected policy effectiveness were defined before the macroeconomic analyses, and these analyses represent projections of the economic impacts when those outcomes occur. CCS did not, as part of this process, independently assess or verify the likely effectiveness of the emissions-reduction or cost-effectiveness analysis.

It is also worthwhile to keep in mind that while models predict values in extreme detail, the reporting here represents a decision to round results to a level of precision more appropriate to the circumstances. Projections of economic impacts fifteen years in the future are automatically of low precision because many underlying assumptions (such as energy prices, technological advancement, and worker productivity) are highly unpredictable – as is the overall size of the economy so far in the future. As such, results were rounded significantly, and results close to zero are described as neutral, meaning that no clear impact of any significance can be reasonably inferred from such a result. The most valuable information to be taken from these results is an understanding of the direction and the intensity of the pressure each policy can be expected to put on levels of overall economic activity.

Common Assumptions and Metrics for the Sectors

To support the economy-wide impacts analysis of CSEO policy options, an array of supporting data are required starting with the GHG emissions baseline. As described in Chapter II, the baseline was largely developed by MPCA and includes historic and forecasted estimates of energy consumption, "activity" data for non-energy emissions sources (e.g. waste generation, industrial processes and agricultural activity), emission factors, and additional information. Additional information required to conduct policy option impacts analysis includes forecasts of fuel prices (wholesale and retail), electricity prices, emission factors for the upstream fuel supplies and materials consumption, and other information through the end of the CSEO planning period (2030). Examples of these supporting data, shown below, were pulled together through support and review of CSEO Project workgroup members.[2]

Figure III-1. Retail Fuel Price Forecast



[2] Common sources of fuel and retail electricity data include: the US DOE Energy Information Administration's (EIA's) Annual Energy Outlook 2014 with data supplementation by Minnesota Department of Commerce. Upstream emission factors for fuels: Argonne National Labs GREET model; default run on US average fuels.

Figure III-2. Retail Electricity Price Forecast

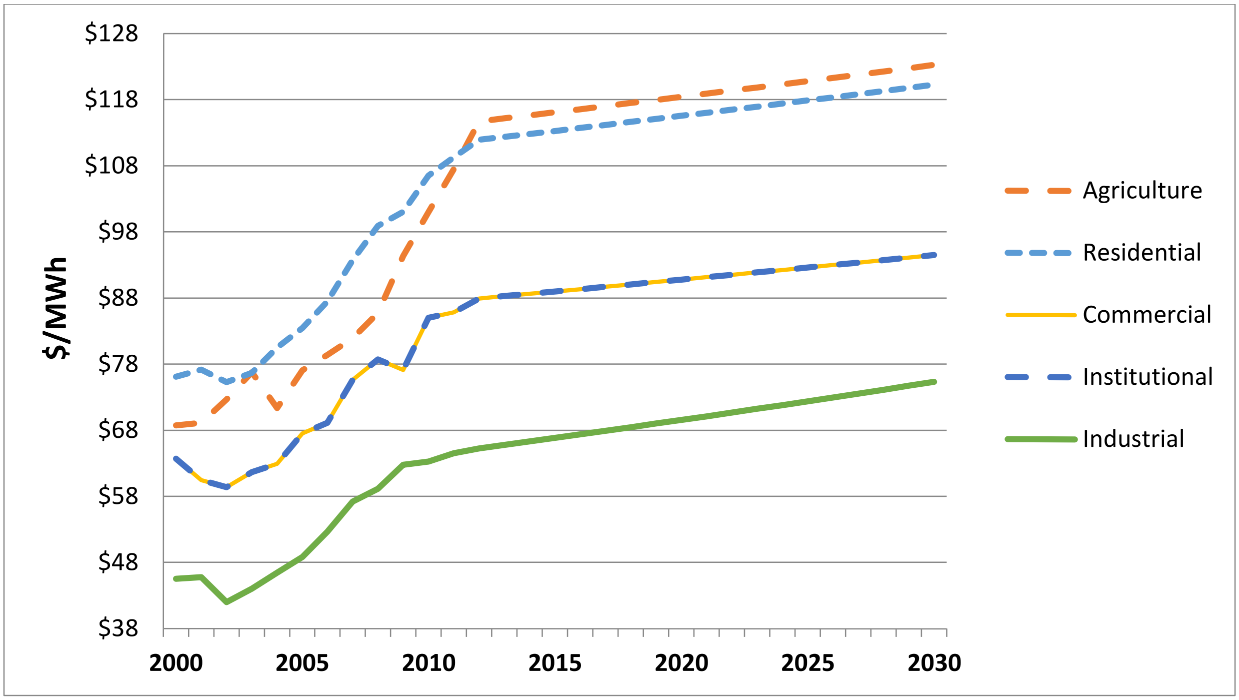
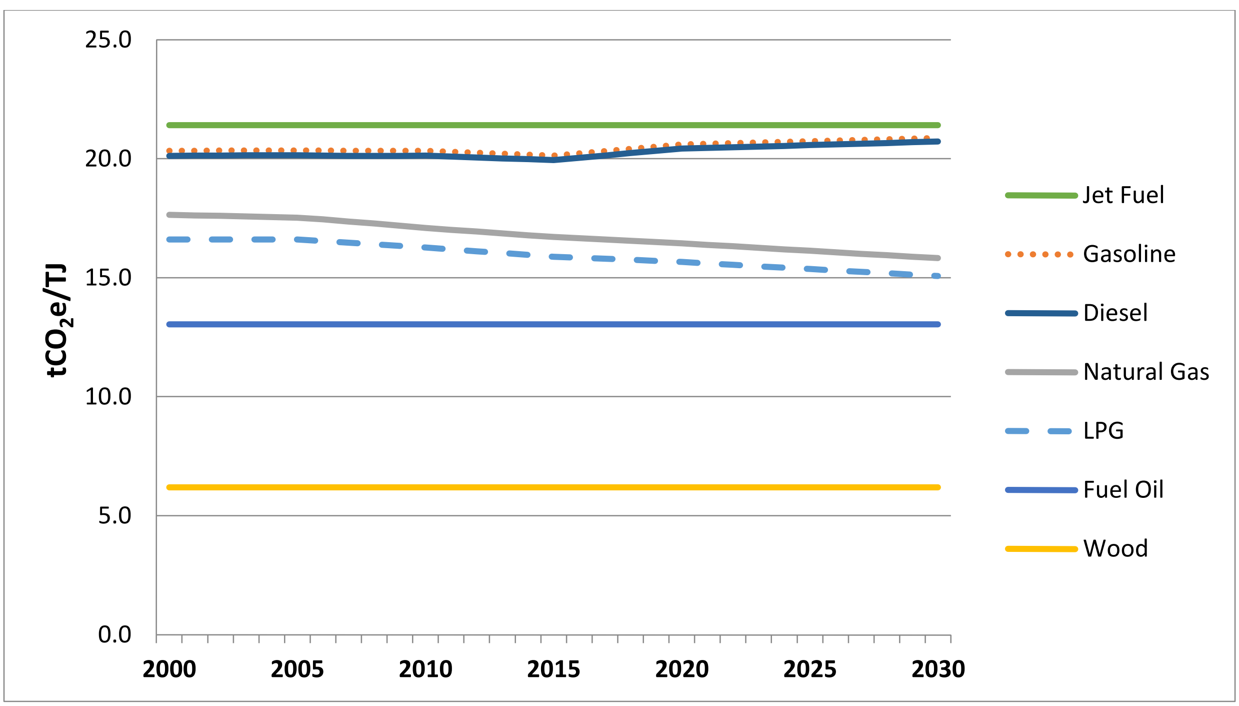


Figure III-3. Upstream GHG Emission Factors for Fuel Supplies



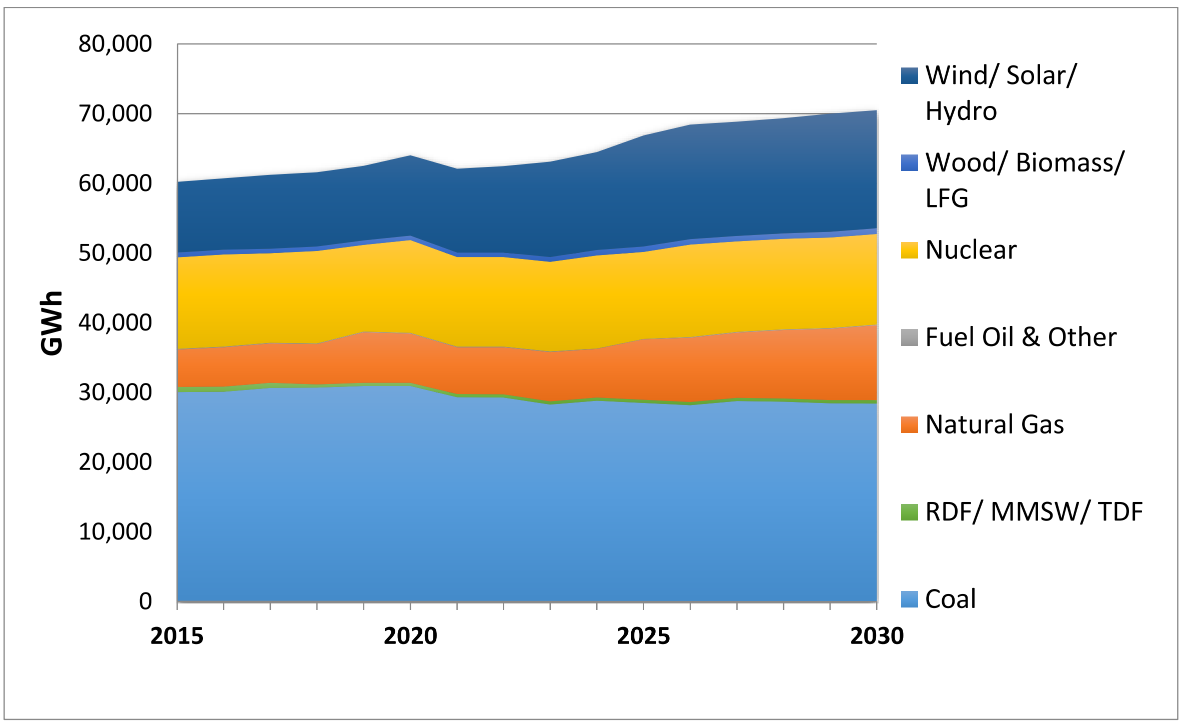
Electricity Supply & Demand Interactions Assessment

An important dataset for assessing the direct impacts of any policy option that affects the electricity system includes estimates of the avoided costs of generation and of the carbon intensity of avoided generation. These "avoided system metrics" are used to assess the net societal costs and GHG reductions for any policy option that either produces electricity (for example, renewable electricity or RE) or reduces consumption (such as energy efficiency or EE). The first step in developing these metrics is to define the "marginal resource mix" for the area being studied:

The marginal generator is the last power plant that is brought online (dispatched) or taken offline to match supply and demand in any given hour. Therefore, the marginal resource mix represents generation from the last set of power plants dispatched/taken off-line to balance supply with demand.

Figure III-4, below provides a summary of the net generation forecast by primary energy source that underlies the estimate of the power sector GHG emissions baseline.

Figure III-4. Net Generation Forecast for Minnesota



Input from the Energy Supply workgroup members provided definitions for the generation resources to be considered "on the margin" for additions of different types of added RE or EE resources, as shown in Table III-2 below.

Table III-2. Marginal Resource Mix Assumptions

System Impact	Marginal Resource Mix: 2012	Marginal Resource Mix: 2030
1. Measures that reduce demand across all hours of the day (EE, combined heat and power, and others)	80% coal: 20% NG	50% coal: 50% NG
2. New wind additions	80% coal: 20% NG	50% coal: 50% NG
3. New solar additions	60% coal: 40% NG	40% coal: 60% NG

Notes:

NG – natural gas. Natural gas generation is presumed to be 90% combined-cycle (NGCC) technology and 10% gas combustion turbine (NGCT). A very small amount of oil-fired generation (<1.0%) during the early years of the planning period was also factored into the marginal resource mix for System Impact #1.

The carbon intensities (expressed as tCO_2e/MWh avoided) for each system impact were calculated using emission rates for different types of generation derived from the GHG baseline, taking into account the 2012-2030 transitions in the marginal resource mix noted above. Two different sets of marginal carbon intensities are shown in Table III-3 below, corresponding to avoided generation and avoided retail sales. The set corresponding to avoided retail sales includes the expected transmission and distribution (T&D) losses of about 5.8% through the planning period. The most commonly applied set of carbon intensities was the set developed for System Impact #1 on the basis of avoided retail sales (gray shaded cells), since these reflect the GHG savings for reduced consumption from the grid (for example, from new EE programs).

Table III-3. Carbon Intensities of the Marginal Resource Mix

Year	tCO_2e/MWh of Generation			T&D Losses (% of sales)	tCO_2e/MWh of Retail Sales Avoided		
	80:20 Coal:Gas Trending to 50:50 Coal:Gas (System Impact #1)	Wind Power (System Impact #2)	Solar Power (System Impact #3)		80:20 Coal:Gas Trending to 50:50 Coal:Gas (System Impact #1)	Distributed Wind Power (System Impact #2)	Distributed Solar Power (System Impact #3)
2012	0.928	0.928	0.827	5.86%	0.982	0.982	0.876
2013	0.913	0.913	0.814	5.85%	0.966	0.966	0.862
2014	0.905	0.905	0.809	5.82%	0.958	0.958	0.857
2015	0.885	0.885	0.792	5.81%	0.936	0.936	0.839
2016	0.873	0.873	0.783	5.81%	0.924	0.924	0.828
2017	0.865	0.865	0.778	5.81%	0.916	0.916	0.823
2018	0.859	0.859	0.774	5.82%	0.909	0.909	0.819
2019	0.853	0.853	0.773	5.81%	0.903	0.903	0.818
2020	0.847	0.847	0.769	5.79%	0.896	0.896	0.813
2021	0.827	0.827	0.750	5.84%	0.875	0.875	0.794
2022	0.816	0.816	0.742	5.85%	0.864	0.864	0.785
2023	0.809	0.809	0.737	5.85%	0.856	0.856	0.780
2024	0.798	0.798	0.728	5.83%	0.845	0.845	0.770
2025	0.781	0.781	0.710	5.79%	0.826	0.826	0.751
2026	0.770	0.770	0.701	5.77%	0.814	0.814	0.742
2027	0.756	0.756	0.690	5.86%	0.800	0.800	0.730
2028	0.743	0.743	0.679	5.79%	0.786	0.786	0.718
2029	0.730	0.730	0.668	5.79%	0.772	0.772	0.706
2030	0.716	0.716	0.656	5.77%	0.758	0.758	0.694
Growth Rate, 2015-2030	**-1.40%**	**-1.40%**	**-1.25%**	**-0.05%**	**-1.40%**	**-1.40%**	**-1.25%**

Since carbon intensities shown above only address emissions from the generation sources themselves, an additional set of carbon intensities were also developed to estimate emissions associated with fuel supplies (that is, the “upstream” GHGs emitted during fuel extraction, processing, shipping, refining, and distribution). For System Impact #1, these values ranged from about 0.085 to 0.095 tCO_2e per MWh of avoided retail sales through the planning period.

Along with the carbon intensities of the marginal resource mix, a set of avoided electricity system costs were developed. These costs capture the capital costs, fixed and variable O&M, and fuel costs for each of the marginal resources (coal-fired steam, NGCC and NGCT plants). A key reference source used to construct levelized costs of electricity generation for each resource type is referenced below.[3] The values derived to represent weighted-average avoided costs by year for each of the three sets of resource mix assumptions provided above are summarized in Table III-4 below. The most commonly applied factors are shaded and correspond to EE measures.

Table III-4. Avoided Electricity System Costs for the Marginal Resource Mix

Year	$/MWh Generated			$/MWh Avoided Retail Sales		
	80:20 Coal:Gas Trending to 50:50 Coal:Gas (System Impact #1)	Wind Power (System Impact #2)	Solar Power (System Impact #3)	80:20 Coal:Gas Trending to 50:50 Coal:Gas (System Impact #1)	Wind Power (System Impact #2)	Solar Power (System Impact #3)
2012	$77.89	$29.09	$47.44	$77.89	$82.45	$30.79
2013	$80.91	$31.38	$51.33	$81.26	$85.64	$33.22
2014	$85.51	$35.08	$57.22	$85.27	$90.49	$37.13
2015	$87.51	$36.29	$58.90	$86.68	$92.59	$38.40
2016	$89.74	$37.74	$60.82	$88.93	$94.96	$39.93
2017	$92.39	$39.63	$63.33	$91.35	$97.76	$41.93
2018	$95.18	$41.61	$65.86	$93.90	$100.72	$44.03
2019	$98.68	$44.28	$69.38	$96.90	$104.42	$46.85
2020	$101.95	$46.68	$72.37	$99.88	$107.85	$49.38
2021	$104.55	$48.37	$74.37	$101.94	$110.66	$51.20
2022	$108.00	$50.88	$77.50	$104.48	$114.32	$53.86
2023	$111.98	$53.89	$81.20	$107.43	$118.53	$57.04
2024	$115.62	$56.52	$84.35	$110.09	$122.36	$59.82
2025	$118.23	$58.12	$86.13	$112.18	$125.07	$61.48
2026	$122.41	$61.26	$89.90	$115.48	$129.47	$64.79
2027	$126.49	$64.27	$93.48	$118.77	$133.90	$68.03
2028	$130.73	$67.40	$97.15	$121.96	$138.30	$71.31
2029	$135.23	$70.75	$101.06	$125.52	$143.06	$74.84
2030	$140.00	$74.31	$105.17	$129.23	$148.08	$78.59
Growth Rate, 2015-2030	**3.18%**	**4.89%**	**3.94%**	**3.18%**	**4.89%**	**3.94%**

During impacts analysis, the avoided system metrics above were applied to all policy options with an electricity system impact to estimate GHG reductions and net societal costs associated with avoided electricity generation. The "stand-alone" results for each policy option assume

[3] Lazard's Levelized Cost of Energy Analysis – Version 8.0, September 2014.

that the policy option will be implemented by itself. The stand-alone results compare implementation of each policy option to the emissions and costs of a "business as usual" electrical system. The stand-alone results for each policy option are described in more detail in Chapter III.2 below, as well as in the sector-specific appendices to this Report (Appendices F.1 thru F.6).

As long as the overall projected output of the marginal resource mix under the BAU forecast has not been exceeded by the cumulative electricity system impacts of all of the CSEO policies combined (that is, by the sum of all EE and new RE and combined heat and power generation), then the stand-alone results do not need to be adjusted to account for structural changes to the electricity system. However, if the cumulative electricity system impacts exceed the size of the marginal resource mix, then under real operating conditions, adjustments to how the electricity system operates will be needed—including which plants are built and run—beyond the marginal resources assumed. In order to appropriately model changes in costs and emissions when system impacts exceed the marginal resource mix, adjustments to the avoided system metrics would be needed. That is, a new set of "Plan Scenario" avoided system metrics (avoided costs and avoided emissions factors) would be needed.

The electricity system for CSEO is not necessarily limited to generation sources within the State's boundaries; and this is consistent with the way in which the GHG baseline for MN is assessed. The baseline for the power sector is constructed on a "consumption-basis" meaning that the GHG emissions associated with power consumption – regardless of generation location – are considered. Therefore, this includes net imports of power to the State. This creates obvious complexities in assessing net CSEO policy impacts, since it implies some knowledge of not only what policies will be implemented in MN but also within the rest of the States that support the regional grid.

Although there is a lack of information on how other States in the region will implement policies affecting regional electricity supply and demand, an assessment of the size of the overall CSEO policy impacts against the generation sources within MN is useful to gauge whether or not the initial assumptions of the marginal resource mix are still valid following policy implementation. Figure III-5 shows the size of the marginal resource mix defined for CSEO, including all MN coal and natural gas generation and net fossil imports (expected to be mostly a combination of coal and natural gas generation sources). The in-State portion of the mix is dominated by coal-fired generation, but becomes more reliant on gas-fired generation over time as older coal plants are phased out and NGCC plants are phased in.

Figure III-5. Size of the BAU Marginal Resource Mix

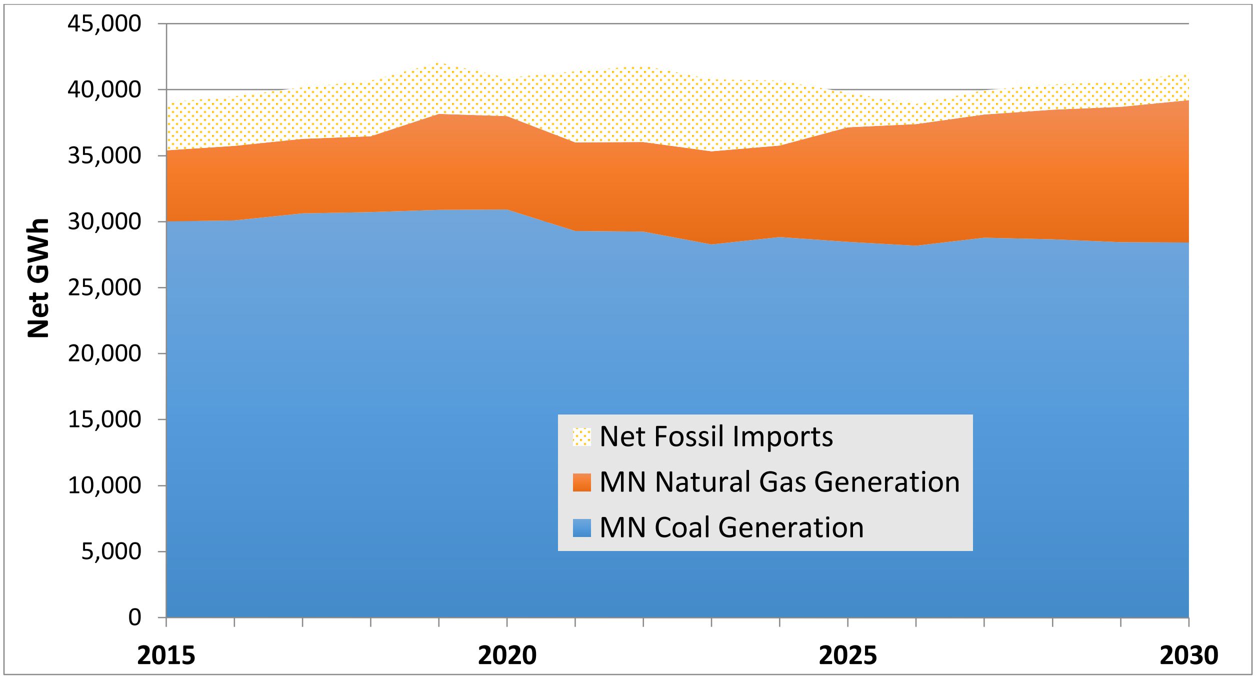


Figure III-6 provides a summary of the impacts on the marginal resource mix due to implementation of ES-2. This includes a shift of generation from coal to a combination of wind and natural gas starting in about 2023. ES-2 calls for repowering and replacement, respectively, of two units of Xcel Energy's Sherburne County (Sherco) coal-fired generating station.

Figure III-6. CSEO Marginal Resource Mix ES-2 Impacts

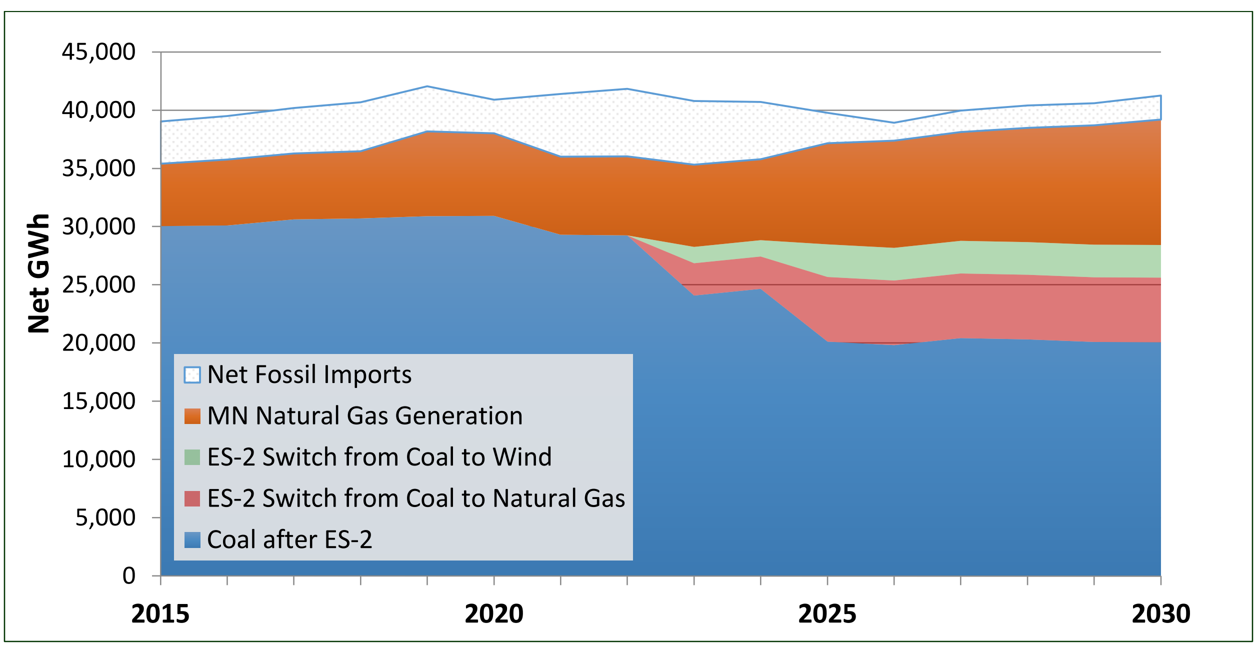
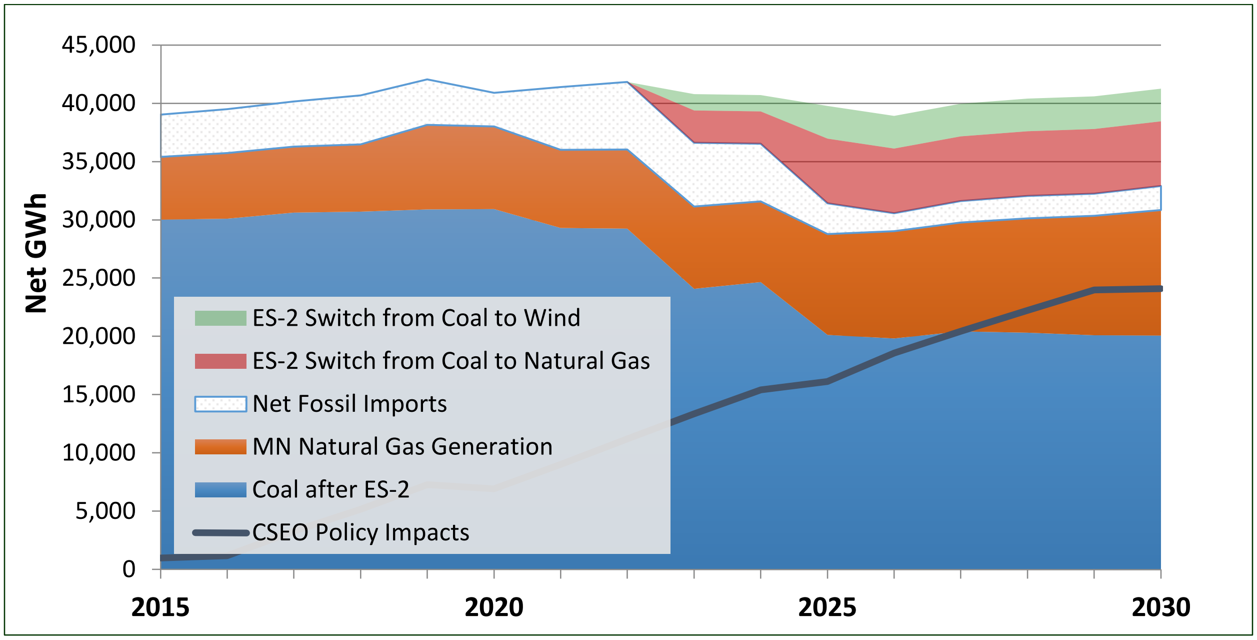


Figure III-7, shows the total gigawatt-hours (GWh) saved and displaced through implementation of the EE and CHP elements in the demand-side sector policies, plus the deployment of additional renewable generation in policy option ES-1. These total impacts are shown in the "CSEO Policy Option Impacts" trend line. Since the total displaced generation indicated by this line does not exceed the overall size of the marginal coal, natural gas and net fossil imports based generation during the planning period, even by 2030, then it there is no need for adjustment of the avoided system metrics due to the size of the CSEO policy impacts.

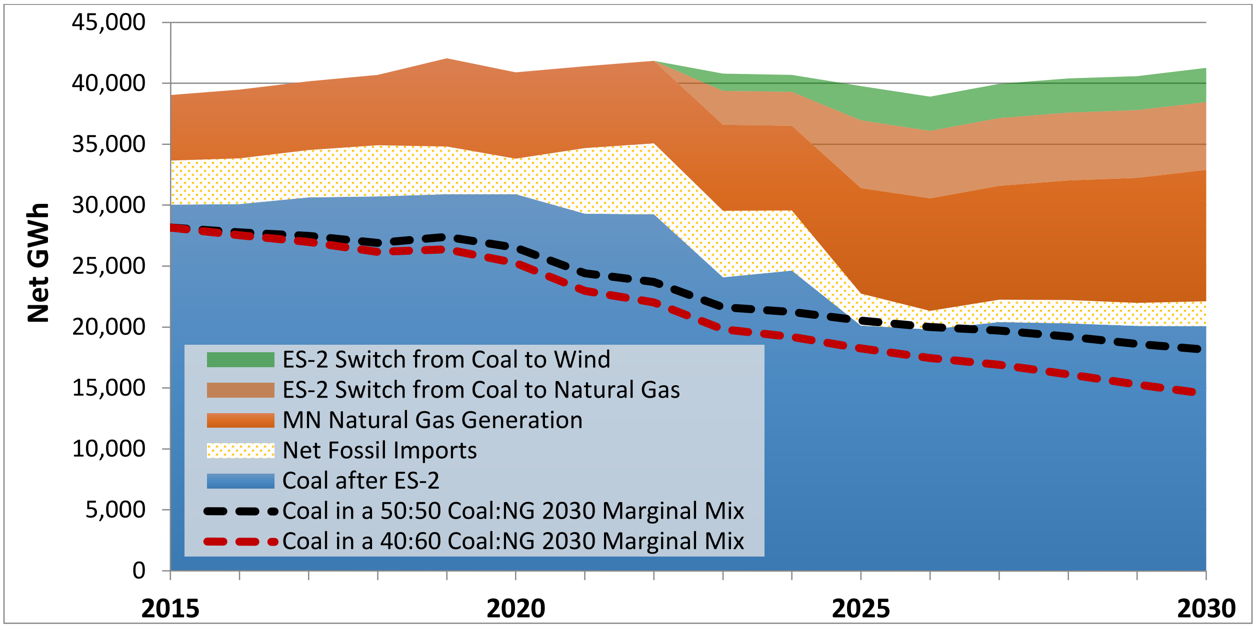
Figure III-7. CSEO Policy Impacts Compared to the Marginal Resource Mix



As indicated in the discussion of the marginal resource definitions above, not only does the marginal resource mix assumed for avoided generation specify the overall marginal resource mix (coal and natural gas-fueled generation), it also describes how that mix is expected to change during the CSEO planning period. As noted in Table III-2, the marginal resource mix is expected (and assumed, for modeling purposes) to include progressively larger proportions of natural gas relative to coal during the latter years of the planning period.

Figure III-8 shows the amount of coal-based generation needed to support the original (BAU) definitions of marginal resources plotted with the resource mix that remains after implementation of ES-2 (re-powering of/replacement of the Sherco units with natural gas). As indicated by the black dotted line, for a 2030 50:50 mix of coal and natural gas, the implementation of ES-2 will remove enough coal-fired generation in the years 2025 and 2026 to create a very small deficit of up to about 400 GWh per year. However, this does not include any additional coal in the net fossil imports. Since any coal in the imported power would like more than make up for this small deficit, there is little need to develop a revised avoided system metrics. Any slight revisions to the marginal system metrics in these two years would have negligible impacts on the estimated GHG reductions and costs for CSEO policies.

Figure III-8. CSEO Electricity System Policy Option Impacts



Additional Potential Electricity Supply and Demand Interactions

Two additional potential interactions between RCII and ES policies were considered, but ultimately considered to be not applicable to the RCII and ES options as designed. First, both ES-1 (expanded renewable energy standard) and RCII-1 (promotion of CHP) include expanded use of biomass/wood-fired CHP. Even combined with the gas-fired CHP included in RCII-1, however, the total CHP included in RCII-1 and ES-1 is significantly less than the industrial, institutional, and commercial technical potential for CHP described in a recent assessment for Minnesota.[4] As such, it was presumed that the biomass-fired CHP objectives of the RCII-1 and ES-1 policies are additive, not overlapping.

Second, ES-1 applies an expanded renewable energy standard as a fraction of retail sales of electricity. Energy efficiency and CHP investments in RCII and other demand-side policies will reduce sales of electricity, so the GHG reductions and costs for ES-1 policy required adjustment. The total electricity demand reductions for all CSEO policies ranged from about 5,100 GWh in 2020 to nearly 18,700 GWh in 2030. This represents 7 to 24% of forecasted electricity demand.

[4] Minnesota Department of Commerce (2014), *Minnesota Combined Heat and Power Policies and Potential: Conservation Applied Research & Development (CARD) FINAL REPORT*, dated July, 2014, and available as https://mn.gov/commerce/energy/images/CHPRegulatoryIssuesandPolicyEvaluation.pdf.

Therefore, the ES-1 renewable energy requirements (and associated costs and GHG reductions) were lowered by fractional reduction in forecasted demand in each year of the planning period.

Transportation Biofuels Interactions Assessment

All four TLU policies involve reducing gasoline emissions, and therefore these policies need to account for the overlap with the two biofuel policies, AG-4 and AG-5, also referred to as the "biofuels package". The biofuels package supports the production and consumption of advanced biofuels in the State (for CSEO analysis purposes, advanced forms of ethanol production was presumed). As more advanced biofuels are consumed by Minnesota vehicles, the average fossil carbon content of these fuels will be reduced. Since the GHG reductions for the TLU policies were measured against a BAU fuel supply containing MPCA's expected ethanol content (and hence, fossil carbon content), the carbon content of fuels consumed as a result of implementation of the CSEO biofuels package needs to be considered and appropriate adjustments made to remove the overlapping GHG reductions (in this case, between the TLU and Agriculture sector policies).

The overlap was addressed based on the change in carbon content of gasoline (tCO_2/TJ) that occurs as a result of adding more advanced ethanol into the fuel supply forecast. This essentially lowers the carbon content slightly during the years where the biofuels package introduces more advanced ethanol into the fuel supply (advanced ethanol displaces an energy equivalent of gasoline for each unit volume displaced). The overlapping emission reductions between the TLU and Agriculture sector policies was addressed by adjusting the TLU policy option GHG reductions downward using the adjusted gasoline carbon content values. This resulted in a reduction in the sum of GHG savings for all four TLU options by 0.7% in 2020 and 1.2% in 2030.

Chapter IV. Policy Option Recommendations and Results

Introduction

This section provides a summary of each individual CSEO policy options and its associated direct, integrated, and indirect impacts. See Chapter III.1 above for a discussion of the approaches, definitions and terminology that are applied for policy option impact screening, design, and analysis during the CSEO project.

Each CSEO policy option analysis was designed for implementation over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation occurring within the next one to two years.

Direct Impacts of CSEO Policies

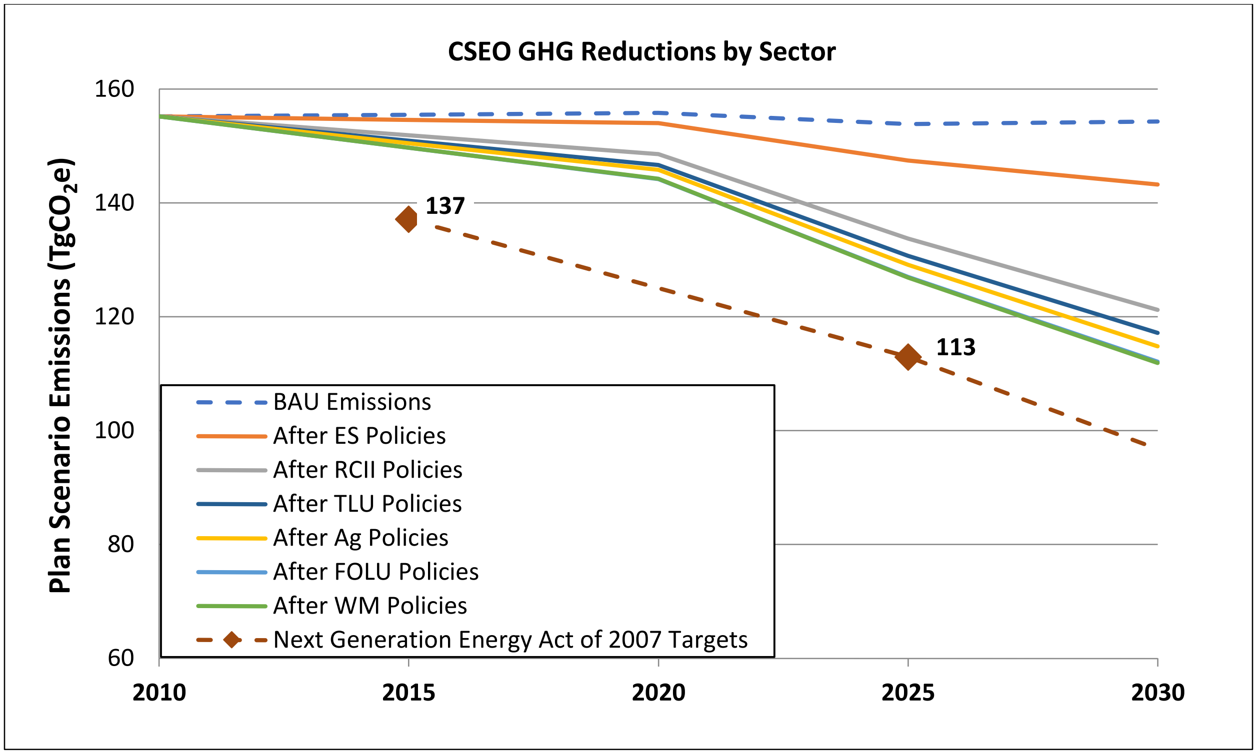
Figure III-9 provides a summary of the GHG reductions expected from full implementation of all CSEO policies. The emissions remaining during the Plan Scenario (PS) only indicate those within the State (expected upstream impacts are excluded). Also, these reductions are net of any intra- and inter-sector interactions and overlaps among the CSEO policies. The chart indicates that most emission reductions (78% in 2030) will occur as a result of policy option implementation in the ES and RCII sectors.

Also plotted on the chart are the Minnesota Next Generation Energy Act (NextGen) targets for 2015 and 2025. The 2007 Act calls for reducing the State's emissions 15% below 2005 levels by 2015, 30% below 2005 by 2025, and 80% below 2005 by 2050. On a gross emissions basis[5], the targets would be 137 $TgCO_2e$ in 2005 and 113 $TgCO_2e$ in 2025. After all CSEO policies are fully implemented, there is still expected to be a shortfall of about 14 $TgCO_2e$ in GHG reductions to meet the State's 2025 target. Note that the emission reductions included here only include those expected to occur within the State; not the full energy-cycle reductions, which include some out-of-State reductions. For example, in 2025, there is an expected additional 6 $TgCO_2e$ of upstream GHG reductions associated with full implementation of policies (e.g. embedded GHGs in fuels and materials that are produced outside of the State).

By 2030, in-State GHG emissions are expected to be 112 $TgCO_2e$, rather than at levels (97 $TgCO_2e$) that would put the State on a trajectory to meet the 2050 goal.

[5] Gross emissions exclude carbon sequestration in building products, landfilled waste, and rural and urban forests.

Figure IV-1 GHG Impacts of CSEO Policy Option Implementation



GHG abatement potentials (the expected emissions reductions) of each individual policy option, as well as sector level expected abatement potentials, are presented in the Figure IV-2 below.

Figure IV-2 GHG Reductions for CSEO Policies

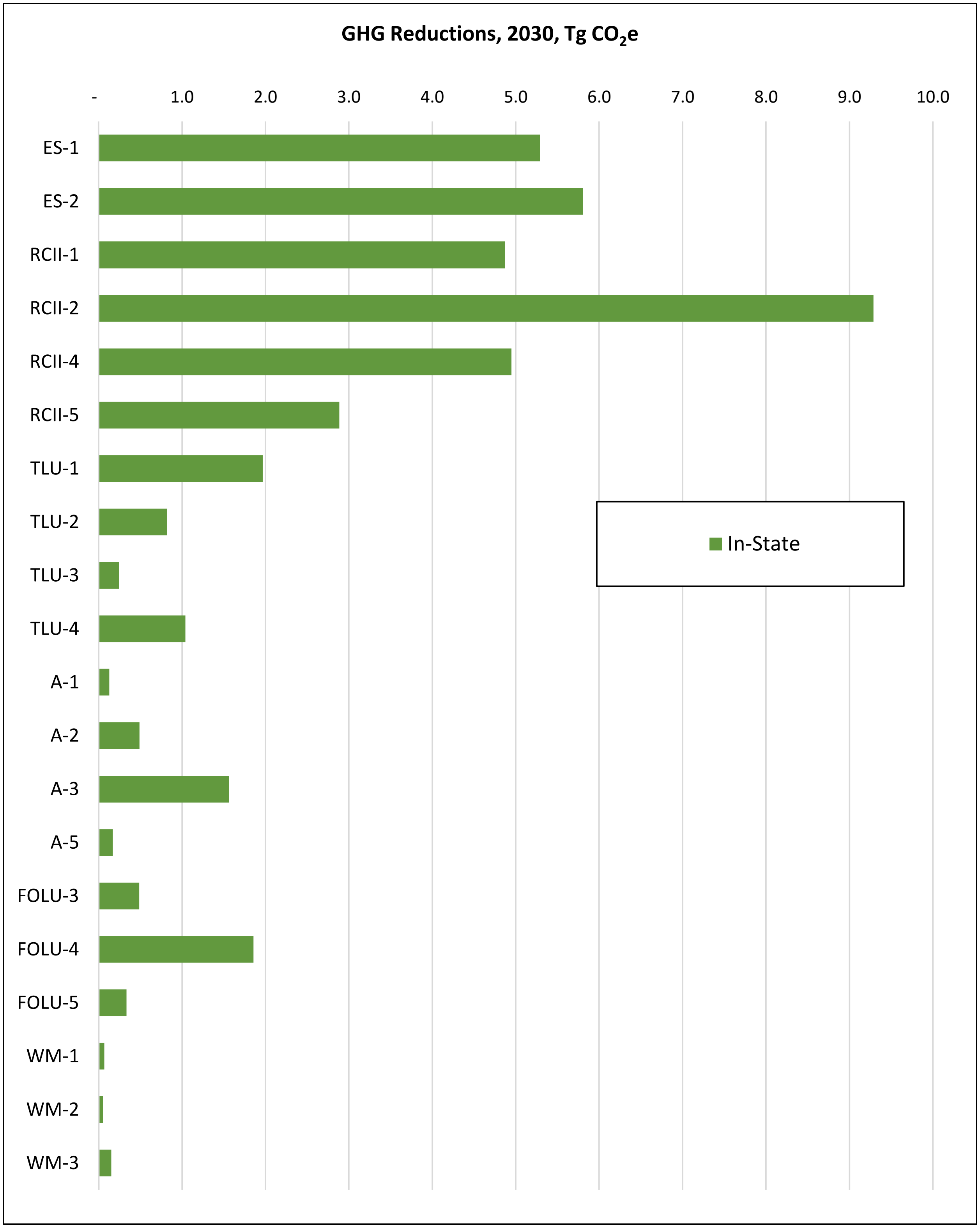


Table IV-1 below provides a summary of the direct impacts of individual CSEO policies and sectors. The values provided are based on the assumption that the policies are implemented on an individual, stand-alone basis (on interactions and overlaps they may occur if policies are implemented simultaneously are considered here).

Table IV-1 Stand Alone Impact Summary of CSEO Policies

CSEO Options Direct Stand-Alone Analysis Impacts								
Sector of the Economy	**Policy Option ID**	**Policy Option Title**	**GHG Reductions**				**Costs**	
			Annual CO_2e Reductions (In-State)		**2030 Cumulative (In-State)**	**2030 Cumulative (Total, In-state + Out-of-State)**	**Net Costs (NPV)[a] 2015-2030 $Million**	**Cost Effectiveness[b] $/$tCO_2e$**
			2020 Tg	**2030 Tg**	**$TgCO_2e$**	**$TgCO_2e$**		
Energy Supply	ES-1	Increase Renewable Energy Standards (40% goal)	1.9	7.5	67	75	($620)	($8.20)
	ES-1	*Increase Renewable Energy Standards (50% goal)[c]*	2.4	13	98	110.35	($404)	($3.66)
	ES-2	Efficiency Improvements, Repowering, Retirement, and Up Grades to Existing Plants	0	6.3	44	39	$752	$19
	ES Sector Totals		**1.9**	**14**	**111**	**114**	**$132**	**$1.16**
Residential, Commercial, Industrial and Institutional	RCII-1	Incentives and Resources to Promote Combined Heat and Power (CHP) for Biomass and for Natural Gas.	2.2	4.9	46	50	($1,112)	($22)
	RCII-2	SB2030/Zero Energy Transition/Codes	0.92	9.3	54	60	($2,050)	($34)
	RCII-4	Increase Energy Efficiency Requirement (2.5% annual electric energy savings)	1.4	4.7	36	42	($1,882)	($45)

	RCII-4	*Increase Energy Efficiency Requirement (2% annual electric energy savings)[d]*	*1.0*	*3.2*	*25*	*29*	*($1,272)*	*($44)*
	RCII-5	Incentives and Resources to Promote Thermal Renewables.	0.8	3	22	30	$872	$29
	RCII Sector Totals		**5.3**	**22**	**157**	**182**	**($4,171)**	**($23)**
Transportation and Land Use	TLU-1	Transportation Pricing - Total	1.5	2.03	22	28	$2,718	$96
		- PAYD Insurance Component	0.46	1	8.8	11	($2,160)	($189)
		- Carbon Tax Component	0.58	0.57	7.1	9.2	$1,898	$205
		- Fuel Tax Component	0.45	0.42	5.8	7.6	$2,980	$394
	TLU-2	Improve Land Development and Urban Form - Total	0.31	0.82	6.96	8.17	($425)	($52)
		- Reduced Home Energy Needs Component	0.31	0.82	6.9	8.1	($351)	($43)
		- Reduced VMT Component	0.0027	0.008	0.064	0.064	($74)	($1,155)
	TLU-3	Metropolitan Council Draft 2040 Plan	0.083	0.25	2	2.6	($330)	($126)
	TLU-4	Zero Emission Vehicle Standard (100%) renewable electricity	0.09	1.25	6.4	7.9	$3,278	$417
	TLU-4	*Zero Emission Vehicle Standard (0%) renewable electricity[e]*	*(0.02)*	*(0.4)*	*(2.10)*	*(1.10)*	*$3,237*	*N/A*
	TLU Sector Totals		**2**	**4.4**	**37**	**47**	**$5,241**	$112
Agriculture	AG-1	Nutrient Management in Agriculture	0.036	0.14	1.1	2.8	($131)	($46)
	AG-2	Soil Carbon Management: Increased Use of Cover Crops	0.059	0.49	3.1	3.6	($1,346)	($377)
	AG-3	Soil Carbon Management: Increased Conversion of Row Crops to Perennial Crops	0.62	1.6	14	14	($2,104)	($153)
	AG-4	Advanced Biofuels Production	*Not Applicable - Results of this supply-side policy option are combined with those from AG-5 (demand-side policy option)*					
	AG-5[e]	Existing Biofuel Statute	0.12	0.17	1.8	3.5	$462	$133
	A Sector Totals		**0.83**	**2.4**	**19**	**24**	**($3,119)**	**($132)**

Forestry and Other Land Use	FOLU-1	Protect Peatlands and Wetlands	*Not Quantified*					
	FOLU-2[f]	Manage for Highly Productive Forests - Intermediate Stand Treatments	*Not Applicable*					
	FOLU-3[g]	Urban Forests: Maintenance and Expansion 40% Canopy Goal	0.086	0.49	3.2	3.2	$1,806	$568
	FOLU-4[h]	Tree Planting: Forest Ecosystems	1.4	1.9	30	34	$187	$5.60
	FOLU-5[l]	Conservation on Private Lands	0.14	0.34	3	3	$1,261	$421
	FOLU Sector Totals		**1.6**	**2.7**	**36**	**40**	**$3,254**	**$81**
Waste Management	WM-1	Waste Water Treatment - Energy Efficiency	0.051	0.068	0.89	0.99	($56)	($56)
	WM-2	Front-End Waste Management - Source Reduction	(0.002)	0.057	0.073	9.4	($277)	($30)
	WM-3[J]	Front-End Waste Management - Re-Use, Composting & Recycling	(0.110)	0.15	-0.45	27	($817)	($30)
	Waste Management Sector Totals		**(0.058)**	**0.28**	**0.52**	**37**	**($1,150)**	**($31)**
CPP	**Clean Power Plan**		**8.56**	**17.0**	**199.2**	**N/A**	**($398)**	**($2.0)**

Notes:

[a] Net Present Value of fully implemented policy option using 2014 dollars ($2014).

[b] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.

[c] ES-1 50% is an alternative scenario evaluated in the ES sector, and is not included in the "Totals" row calculation.

[d] 2% annual electric energy savings scenario is an alternative scenario of RCII-4 policy evaluated for a reference, and is not included in the “Totals” row calculation

[e] TLU-4 0% renewable electricity is a sensitivity scenario not included in “Totals” row calculation. This sensitivity scenario increases net GHG emissions above the baseline, thus cost effectiveness calculation is not applicable.

[f] Net emissions were found to be positive for this policy option; therefore, no cost effectiveness could be calculated.

[g] Full benefits are realized when considering the full life-span of planted trees. 2015-2085 Cumulative Reduction = 67 TgCO2e; NPV = $2,208; 2085 CE = $33

[h] Full benefits are realized when considering the full life-span of planted trees. 2015-2085 Cumulative Reduction = 108 TgCO2e; NPV = $183; 2085 CE = $1.76

[l] Full benefits are realized when considering the full life-span of planted trees. 2015-2085 Cumulative Reduction = 25 TgCO2e; NPV = $1,304; 2085 CE = $53

[J] Assumes full implementation of WM-2.

Table IV-2 provides a summary of the direct impacts analysis for all CSEO policies, including all inter-sector overlaps and adjustments. These results include:

- Expected in-state emission reductions in 2020, 2030, and cumulatively through 2030; the direct implementation costs during the planning period, and
- Estimated cost effectiveness (CE).

Note that the value for cost effectiveness (CE) is calculated on the basis of full energy-cycle emission reductions, not just the reductions that occur within the State. More discussion of this issue follows at the end of this section.

Note also that these results have been adjusted to account for interactions and overlaps that occur both within (intra-) and between sectors (inter-).

Additionally, this table summarizes indirect, or macro-economic impact of the policies (individual and sector level).

Table IV-2 Inter-Sector Integrated Impact Summary of CSEO Policies

			Direct Impacts		
Policy Option	**Policy Option Title**	**2030 Annual In-State Reductions (Tg CO_2e)**	**Total Reduction 2015-2030[a] ($TgCO_2e$)**	**Net Costs 2015-2030[b] ($2014MM)**	**CE[c] ($2014/$tCO_2e$)**
ES-1	40% Renewable Generation by 2030	5.3	62	$(360)	$(5.8)
ES-2	Energy Supply Scenario #1	5.8	38	$854	$22
Energy Supply Totals		**11.1**	**100**	**$494**	**$4.9**
RCII-1	CHP for Biomass and NG	4.9	49	$(1,117)	$(23)
RCII-2	SB2030/Zero Energy Transition/Codes	9.3	60	$(2,050)	$(34)
RCII-3	Reduce High GWP GHGs	-	*Not Quantified*		
RCII-4	Increase EE Requirements	4.9	40	$(1,814)	$(45)
RCII-5	Thermal Renewables	2.9	30	$842	$28
Residential, Commercial & Institutional Totals		**22**	**180**	**$(4,140)**	**$(23)**
TLU-1	Transportation Pricing and Move Minnesota Plan	2.0	28	$2,718	$98

Policy Option	Policy Option Title	2030 Annual In-State Reductions (Tg CO_2e)	Direct Impacts: Total Reduction 2015-2030[a] ($TgCO_2e$)	Direct Impacts: Net Costs 2015-2030[b] ($2014MM)	Direct Impacts: CE[c] ($2014/$tCO_2e$)
TLU-2	Improve Land Development and Urban Form	0.82	8.2	$(425)	$(52)
TLU-3	Metropolitan Council Draft 2040 Plan	0.25	2.6	$(330)	$(127)
TLU-4	Zero Emission Vehicle Standard	1.04	6.7	$3,278	$489
Transportation & Land Use Totals		**4.1**	**45**	**5,241**	**$116**
AG-1	Nutrient Management	0.13	2.7	$(127)	$(47)
AG-2	Soil Carbon Management: Cover Crops	0.49	3.6	$(1,346)	$(377)
AG-3	Soil Carbon Management: Row to Perennial Crops Conversion	1.6	14	$(2,104)	$(153)
AG-4	Advanced Biofuels Production	*Quantified as Part of AG-5*			
AG-5	Existing Biofuel Statute	0.17	3.5	$462	$133
Agriculture Totals		**2.4**	**23**	**$(3,115)**	**$(133)**
FOLU-2	Manage for Highly Productive Forests		*Not Quantified*		
FOLU-3	Urban Forests: Maintenance and Expansion 40% Canopy Goal	0.49	3.4	$1,806	$525
FOLU-4	Tree Planting: Forest Ecosystems	1.9	34	$187	$5.6
FOLU-5	Conservation on Private Lands	0.34	3.0	$1,261	$421
Forestry & Other Land Use Totals		**2.7**	**40**	**$3,254**	**$81**
WM-1	Waste Water Treatment - Energy Efficiency	0.068	0.99	$(56)	$(56)
WM-2	Front-End Waste Management - Source Reduction	0.057	9.4	$(228)	$(24)
WM-3	Front-End Waste Management - Re-Use, Recycling & Composting	0.15	27	$(817)	$(30)
Waste Management Totals		**0.28**	**37**	**$(1,101)**	**$(29)**
CPP		**199.2**	**N/A**	**$(398)**	**$(2.0)**

			Direct Impacts		
Policy Option	Policy Option Title	2030 Annual In-State Reductions (Tg CO_2e)	Total Reduction 2015-2030[a] ($TgCO_2e$)	Net Costs 2015-2030[b] ($2014MM)	CE[c] ($2014/$tCO_2e$)
Total Integrated Plan Results		**42**	**426**	**$634**	**$1.5**

Notes:
Totals and subtotals may not add exactly due to rounding.
[a] GHG reductions include those that occur within the State as well as upstream emissions that may occur outside MN's boundaries.
[b] The net present value (NPV) of direct implementation costs for the policy on a net societal basis.
[c] Cost effectiveness of the policy (total reductions divided by the NPV of implementation costs.

Figure IV-3 provides a bar chart showing the cumulative 2015 - 2030 GHG reductions for each policy option on both an in-state basis, as well as a full energy-cycle basis. As indicated by this chart, some policy options produce significant GHG reductions via reduced demand for fuels or materials (e.g. solid waste management, biofuels production and consumption). A large fraction of these reductions could occur outside of the State's boundaries; however, available data do not allow for geographic attribution of reductions. This issue doesn't reduce the importance of these reductions (i.e. a tCO_2e emitted in China contributes as much to climate change as one emitted in Minnesota). Also, since some of these upstream reductions will occur in Minnesota, they can be viewed as "additional insurance" toward progress in achieving the State's GHG reduction target.

Figure IV-3 Comparison of In-State and Out of State GHG Reductions

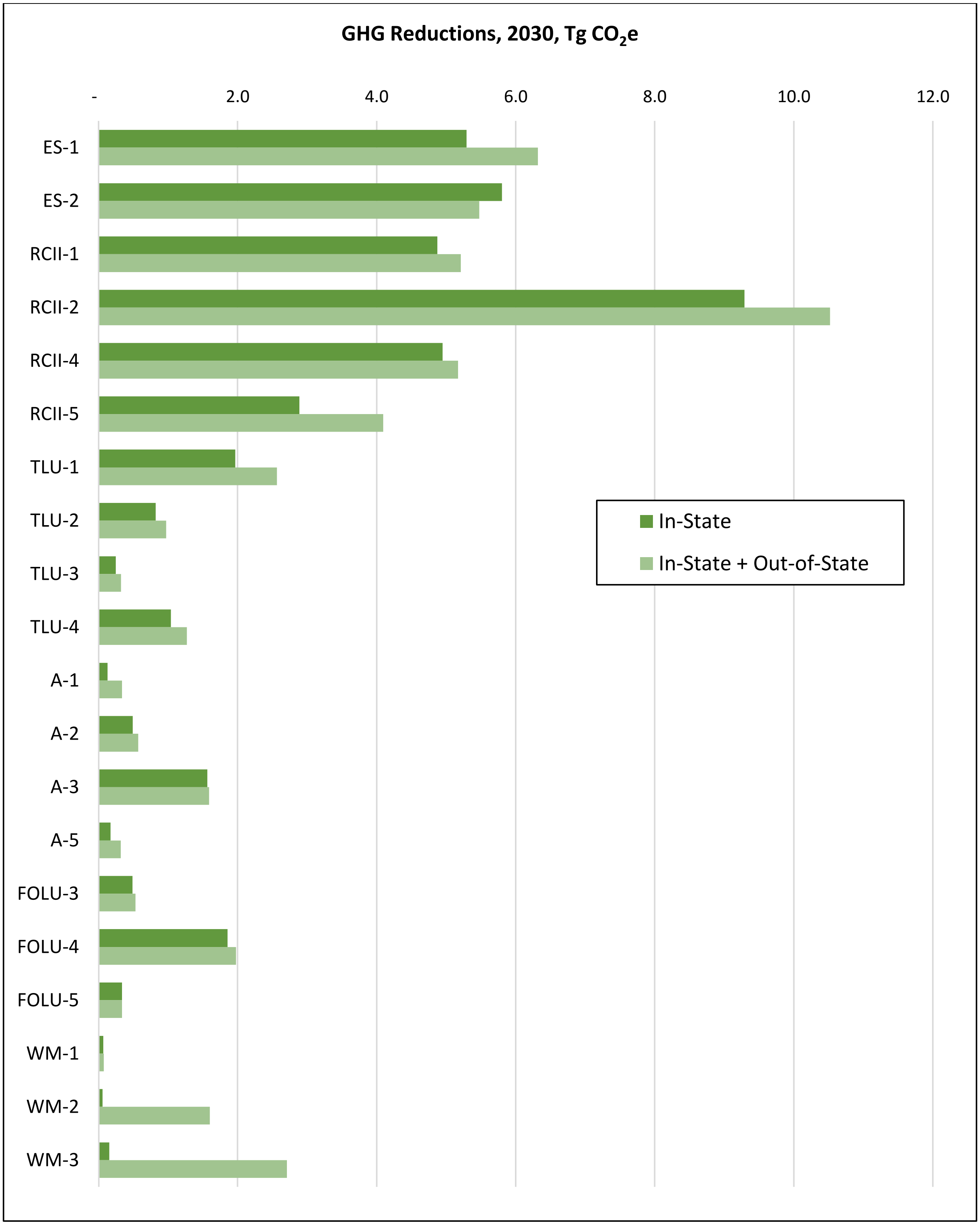
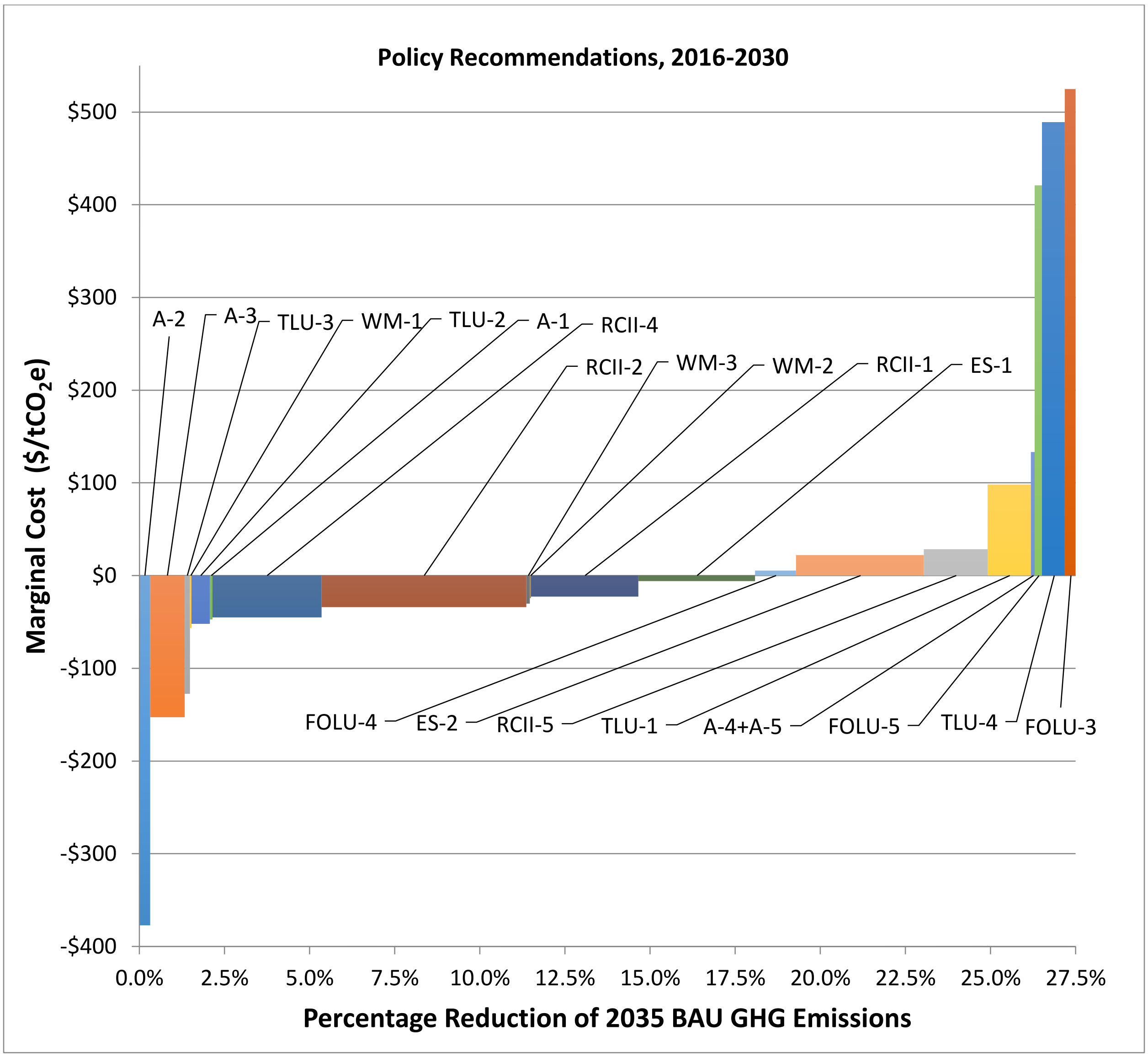


Figure IV-4 below provides the marginal abatement cost curve (MACC) for implementing all CSEO policy options. It was constructed by charting CE on the Y-axis and the percentage reduction of in-State 2030 BAU emissions achieved by the policy option. The results shown indicate that if all policy options are fully implemented as designed, nearly 28% of the 2030 BAU emissions would be reduced. Further, about half of the reductions are expected to be achieved with net societal cost savings. While these negative values represent net cost savings, it is important to note that most of these policy options are still expected to require significant up-front investments.

Figure IV-4 CSEO Marginal Abatement Cost Curve



Indirect (Macroeconomic) Impacts of CSEO Policy Recommendations

The tables and figures below show the Indirect (Macroeconomic) impacts of policy recommendations, including gross state product (GSP), Employment, and Personal Income impacts compared to BAU scenario. GSP and Personal Income are used in 2015$ in the table and figure, and employments are measured in individual jobs.

The graph below expresses the overall economic impact from each scenario in a single score, and compares those scores. CCS created this single score (a Macroeconomic Impact Index) in order to encapsulate in one measurement the relative macroeconomic impacts (including jobs, GSP and incomes) of each policy. We have found in our own work and in the literature that indexed scores can be helpful to many readers when comparing options with multiple characteristics.

To produce this score, CCS set the results from the absolute best-case scenario (i.e. the implementation of all CSEO policies with all their optimal sensitivities in place) equal to 100, with that scenario's jobs, GSP and incomes impacts weighted equally at one third of the total score. Each policy's jobs, GSP and income impacts are scaled against that measure, and given a total score. The overall score indicates how significant a policy's impact is projected to be. Negative impacts are scaled the same way, except that those impacts are given negative scores and pull down the total score of the policy.

These scores are calculated separately for the final year of the study (2030), the average impact over the 2016-2030 period, and the cumulative impact of the policies over that period. While each scenario has one line, the relative importance of jobs, income and GSP remain visible as differently-shaded segments of that line. I_GSP, I_Jobs, and I_Income represent the index score for GSP, Jobs and Income, respectively.

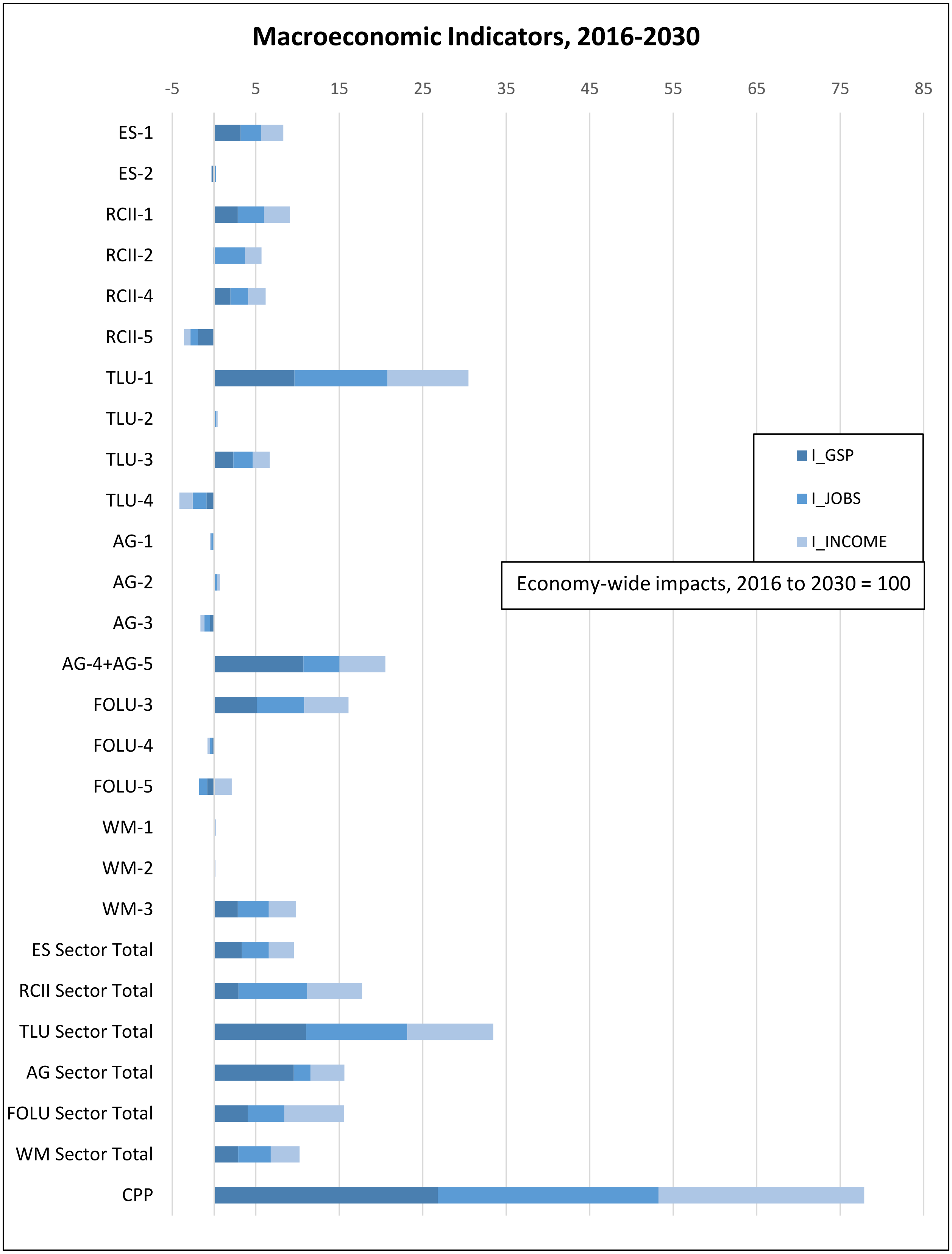
Table IV-3 Macroeconomic Impacts of Policy Recommendations

Indirect Macroeconomic Summary Impacts Results									
Scenario	Gross State Product (GSP, $2015 MM)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 MM)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
ES-1 40% Renewables Target	$390	$180	$2,650	2,900	1,510	22,580	$310	$140	$2,080
ES-1 50% Renewables Target	*$540*	*$230*	*$3,420*	*3,690*	*1,820*	*27,290*	*$430*	*$180*	*$2,700*
ES-2	$(70)	$(40)	$(310)	170	310	2,470	$(20)	$-	$(20)

ES Sector (ES-1 @ 40%)	**$320**	**$160**	**$2,340**	**3,070**	**1,670**	**25,020**	**$290**	**$140**	**$2,050**
ES Sector (ES-1 @ 50%)	***$540***	***$240***	***$3,580***	***4,720***	***2,380***	***35,650***	***$480***	***$200***	***$3,060***
RCII-1	$510	$200	$3,030	3,840	2,330	35,020	$430	$210	$3,190
RCII-2	$(70)	$(10)	$(90)	6,020	2,750	41,190	$340	$130	$2,010
RCII-4	$140	$140	$2,110	1,430	1,560	23,340	$160	$140	$2,140
RCII-5	$(350)	$(150)	$(2,080)	(1,680)	(690)	(9,610)	$(150)	$(60)	$(810)
RCII Sector	**$260**	**$210**	**$3,150**	**9,820**	**6,080**	**91,270**	**$800**	**$440**	**$6,660**
TLU-1	$710	$690	$10,320	8,140	8,230	123,400	$780	$660	$9,890
TLU-2	$-	$-	$(30)	500	220	3,290	$30	$10	$150
TLU-3 Low Transit Capital Cost	$90	$40	$610	830	450	6,740	$40	$20	$300
TLU-3 High Transit Capital Cost	$130	$170	$2,480	1,330	1,720	25,860	$80	$140	$2,070
TLU-4 High EV prices	$(710)	$(350)	$(5,320)	(7,910)	(3,750)	(56,240)	$(860)	$(370)	$(5,550)
TLU-4 Falling EV Prices	$140	$(60)	$(970)	(810)	(1,220)	(18,300)	$(60)	$(110)	$(1,620)
TLU Sector with Low Transit Capital Cost	**$100**	**$370**	**$5,590**	**1,580**	**4,560**	**68,360**	**$(10)**	**$320**	**$4,790**
TLU Sector with High Transit Capital Cost	***$130***	***$500***	***$7,450***	***2,080***	***6,420***	***96,350***	***$30***	***$440***	***$6,550***
TLU Sector Falling EV Prices	***$950***	***$620***	***$9,290***	***8,670***	***7,680***	***115,170***	***$800***	***$580***	***$8,720***
TLU Sector High Transit Capital & Falling EV Prices	***$980***	***$790***	***$11,800***	***9,170***	***8,950***	***134,270***	***$830***	***$700***	***$10,490***
AG-1	$(10)	$-	$(70)	(360)	(200)	(2,960)	$(20)	$(10)	$(120)
AG-2	$-	$10	$110	70	230	3,380	$20	$20	$300

AG-3	$20	$(40)	$(530)	1,170	(490)	(7,420)	$60	$(30)	$(490)
AG-4+AG-5	$1,130	$820	$11,470	3,610	3,420	47,820	$540	$400	$5,580
Ag Sector	**$980**	**$680**	**$10,200**	**810**	**1,490**	**22,300**	**$350**	**$280**	**$4,150**
FOLU-3	$380	$370	$5,500	4,420	4,180	62,670	$460	$360	$5,410
FOLU-4	$(10)	$(20)	$(230)	(130)	(210)	(3,160)	$(10)	$(20)	$(280)
FOLU-5 farms lose crop income	$(110)	$(90)	$(1,300)	(1,350)	(1,060)	(15,900)	$-	$70	$1,010
FOLU-5 farms keep crop income	$(80)	$(60)	$(880)	(920)	(720)	(10,750)	$120	$140	$2,160
FOLU Sector Farms Lose Crop Income	**$260**	**$260**	**$3,960**	**2,940**	**2,910**	**43,610**	**$450**	**$410**	**$6,130**
FOLU Sector Farms Keep Crop Income	***$290***	***$290***	***$4,340***	***3,340***	***3,220***	***48,340***	***$570***	***$490***	***$7,290***
WM-1	$-	$-	$30	90	80	1,130	$10	$10	$90
WM-2	$10	$-	$30	150	60	930	$10	$-	$70
WM-3	$240	$200	$3,040	3,290	2,750	41,210	$320	$220	$3,340
WM Sector	**$250**	**$210**	**$3,100**	**3,530**	**2,890**	**43,280**	**$340**	**$230**	**$3,500**
ES+RCII (40% target)	**$580**	**$360**	**$5,420**	**12,840**	**7,720**	**115,830**	**$1,080**	**$580**	**$8,630**
ES+RCII (50% target)	**$780**	**$440**	**$6,600**	**14,340**	**8,390**	**125,880**	**$1,260**	**$640**	**$9,610**
CPP (ES-1 40%)	**$2,669**	**$1,831**	**$27,463**	**26,480**	**18,796**	**281,940**	**$2,605**	**$1,604**	**$24,063**
CPP (ES-1 50%)	**$2,894**	**$1,914**	**$ 28,716**	**28,140**	**19,507**	**292,610**	**$2,798**	**$1,672**	**$25,078**
Overall Economy Default Scenario	**$2,190**	**$1,910**	**$28,650**	**22,090**	**20,460**	**306,970**	**$2,330**	**$1,890**	**$28,370**
Overall Economy Best Case Scenario	**$3,250**	**$2,380**	**$35,680**	**30,820**	**24,630**	**369,440**	**$3,240**	**$2,260**	**$33,910**

Figure IV-5 Macroeconomic Indicators of Policy Recommendations



Notes:

The graph above expresses the overall economic impact from each scenario in a single score, and compares those scores. CCS created this single score (a Macroeconomic Impact Index) in order to encapsulate in one measurement the relative macroeconomic impacts (including jobs, GSP and incomes) of each policy. We have found in our own work and in the literature that indexed scores can be helpful to many readers when comparing options with multiple characteristics.

To produce this score, CCS set the results from the absolute best-case scenario (i.e. the implementation of all CSEO policies with all their optimal sensitivities in place) equal to 100, with that scenario's jobs, GSP and incomes impacts weighted equally at one third of the total score. Each policy's jobs, GSP and income impacts are scaled against that measure, and given a total score. The overall score indicates how significant a policy's impact is projected to be. Negative impacts are scaled the same way, except that those impacts are given negative scores and pull down the total score of the policy.

These scores are calculated separately for the final year of the study (2030), the average impact over the 2016-2030 period, and the cumulative impact of the policies over that period. While each scenario has one line, the relative importance of jobs, income and GSP remain visible as differently-shaded segments of that line.

In each of the subsections that follow a brief discussion of each sector's GHG baseline is followed by a description of key drivers of baseline trends and key policy response strategies designed to improve economic, energy, and environmental benefits as well summaries of the recommended CSEO policy options and their direct and indirect impacts.

1. Energy Supply

The Energy Supply (ES) sector covers sources of electricity, heat, and fuel supply for buildings, facilities, manufacturing, and other stationary uses. Most important of these in Minnesota (MN) is the electricity supply subsector, which includes emissions from all sources of generation used to supply the state's consumption of power. In 2010, the ES sector contributed over 30% of the state's greenhouse gas (GHG) emissions and in 2030, the sector is still expected to contribute about the same amount of the emissions total. Important drivers to these emissions levels are growth in retail electricity sales and the efficiency and operating characteristics of the state's power generation fleet (e.g., fuel and technology choices).

Strategies that can be applied to reduce emissions and bolster economic performance include: increased naturally occurring renewable electricity generation (e.g., wind, solar); low emitting technologies and fuels such as nuclear power; efficiency upgrades or re-powering of existing power plants to lower carbon technologies or fuels; and fuel switching, especially to locally-sourced low carbon fuels.

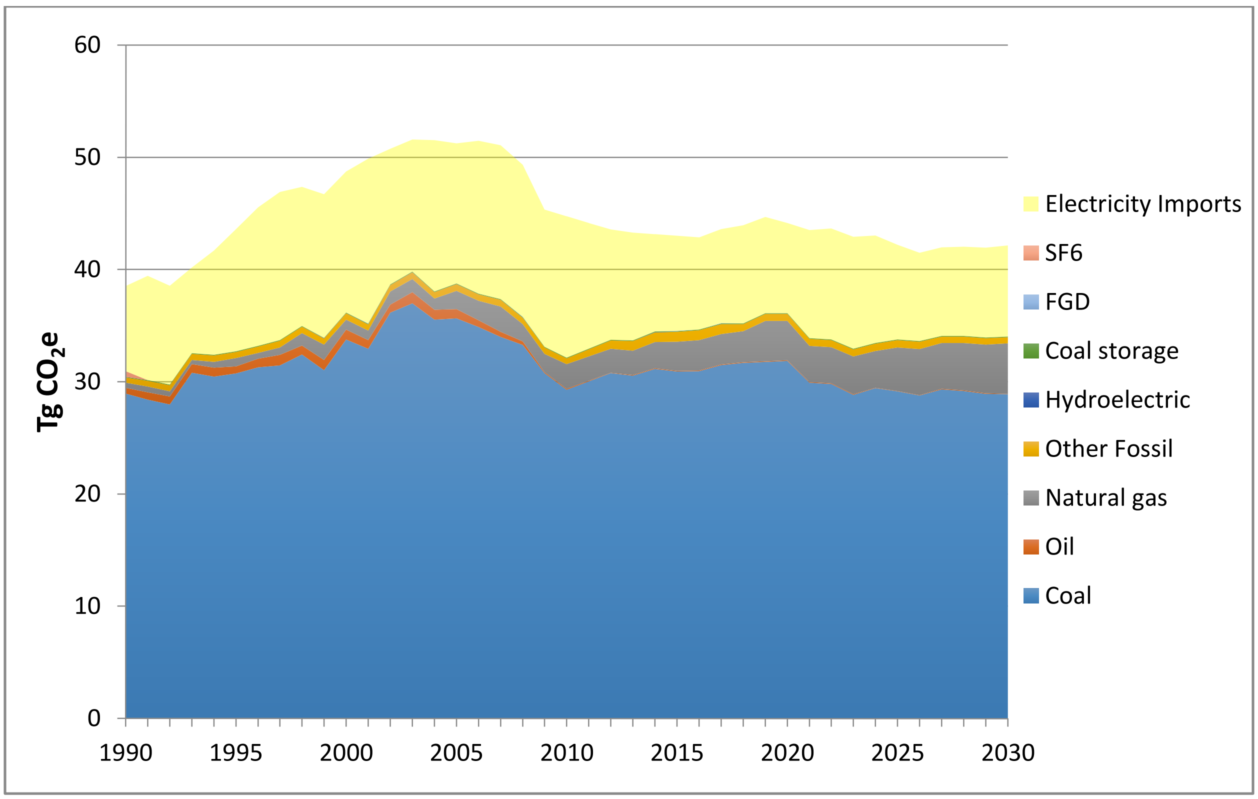
Baseline and Emissions Sources

The GHG emissions baseline for the ES sector is detailed in Figure IV-6. This baseline is constructed on an electricity consumption accounting basis, which means that the emissions associated with Minnesota's net imports of electricity are included (transparent wedge at the top of the chart). Coverage includes emissions from fuel combustion at power generation facilities, as well as a number of non-energy sources described further below. The baseline is dominated by in-state coal-based power generation sources. Imported electricity is the next highest contributor toward emissions, followed by in-state natural gas-fired generation sources. Note that Minnesota categorizes fuel supply sources, such as natural gas transmission and distribution and oil refining in the Residential, Commercial, Industrial, and Institutional (RCII) sector.

Smaller emissions contributors, most of which are too small to show up in Figure IV-6, are: sulfur hexafluoride emissions from electrical distribution equipment (SF_6); carbon dioxide emissions from chemicals used in flue gas desulfurization (FGD) equipment; methane emissions from hydroelectric reservoirs and coal storage piles; oil-fired generation resources; and other fossil fuel generation resources.

ES sector emissions are shown to decline slightly during the forecast period. These reductions are primarily brought on by slightly lower generation from in-state coal, and increasing generation from natural gas and renewables (mostly wind) through 2030. See Chapter II for more information on the contribution of the ES sector to the state's GHG baseline.

Figure IV-6 ES Sector GHG Baseline



CSEO Policy Options

Two policy options were developed for the ES sector. These are detailed in Policy Option Documents Appendix F.1 and are summarized as follows:

ES-1. Increase Renewable Energy Standards

Legislation passed in 2013 supports the investigation of higher levels of renewable energy use in Minnesota, starting with increasing the Renewable Electricity Standard (RES) to 40% by 2030, and to higher proportions thereafter. State legislation also sets the goal that by 2030, 10% of the retail electric sales in Minnesota be generated by solar energy. This policy option aims to expand RES to 40% by 2030. A 50% RES was also evaluated (see Appendix F.1 for details).

ES-2. Efficiency Improvements, Repowering, Retirement, and Upgrades to Existing Plants

Of the 24 utility-owned coal-fired boilers operating in Minnesota, most have been retrofitted to meet Clean Air Act requirements (1758 MWs), repowered with natural gas (776 MWs), or are retired or scheduled to retire by 2020 (734 MWs). While it is not inconceivable that plants retrofitted within the last 10 years would be soon repowered or retired, it is unlikely given the size of these recent investments and resulting impacts to ratepayers.

Decisions remain pending on the future of Minnesota's three largest coal-fired boilers at Xcel Energy's Sherburne County (Sherco) generating plant. Due to their size, they are also the largest emitters of carbon dioxide (CO_2) in the state. The newest and largest of these boilers, Sherco 3, has been retrofitted with advanced mercury controls and is the most efficient boiler in the Minnesota fleet. However, Units 1 and 2 are susceptible to both mercury and Regional Haze requirements, and may therefore be useful to analyze for some combination of repowering or retirement strategies.

Three scenarios were evaluated for Sherco Units 1 and 2 including: 1) repowering Unit 1 by 2025 and retirement of Unit 2 by 2023; 2) retirement of both plants by 2020; and 3) repowering of Unit 1 by 2020 and retirement of Unit 2 by 2020. Scenario 1 was chosen for the purposes of analyzing integrative effects with other sectoral policies.

Direct and Indirect Policy Option Impacts

Table below provides a summary of the direct impacts of the ES policy options. These results assume that each policy option is fully implemented on a stand-alone basis against the business as usual baseline. As indicated, the ES policy options are expected to achieve 1.9 $TgCO_2e$ in-state reductions in 2020 and 14 $TgCO_2e$ in 2030. On a cumulative basis, the policy options would achieve 114 $TgCO_2e$ reductions through 2030. Net societal costs for both policy options are $111 million ($2014). The total cost effectiveness of these policy options is $1.2 /$tCO_2e$ (this value includes additional upstream GHG reductions from the fuel supply that may not occur within Minnesota). Total GHG reductions are lower than in-state GHG reductions for ES-2 because upstream emissions for natural gas are higher than for coal; therefore, switching from coal to natural gas results in lower in-state emissions but higher out-of-state emissions.

Table IV-4 . ES Policy Options, Direct Stand-Alone Impacts

Stand-Alone Analysis							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual CO_2e Reductions[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/tCO_2e$
ES-1	Increase Renewable Energy Standards (40% goal)	1.9	7.5	67	75	-$620	-$8.2
ES-2	Efficiency Improvements, Repowering, Retirement, and Up Grades to Existing Plants	0.00	6.3	44	39[e]	$752	$19
Totals		**1.9**	**14**	**111**	**114**	**$132**	**$1.16**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] Total GHG reductions are lower than in-state GHG reductions for ES-2 because upstream emissions for natural gas are higher than for coal; therefore, switching from coal to natural gas results in lower in-state emissions but higher out-of-state emissions.
Note: Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

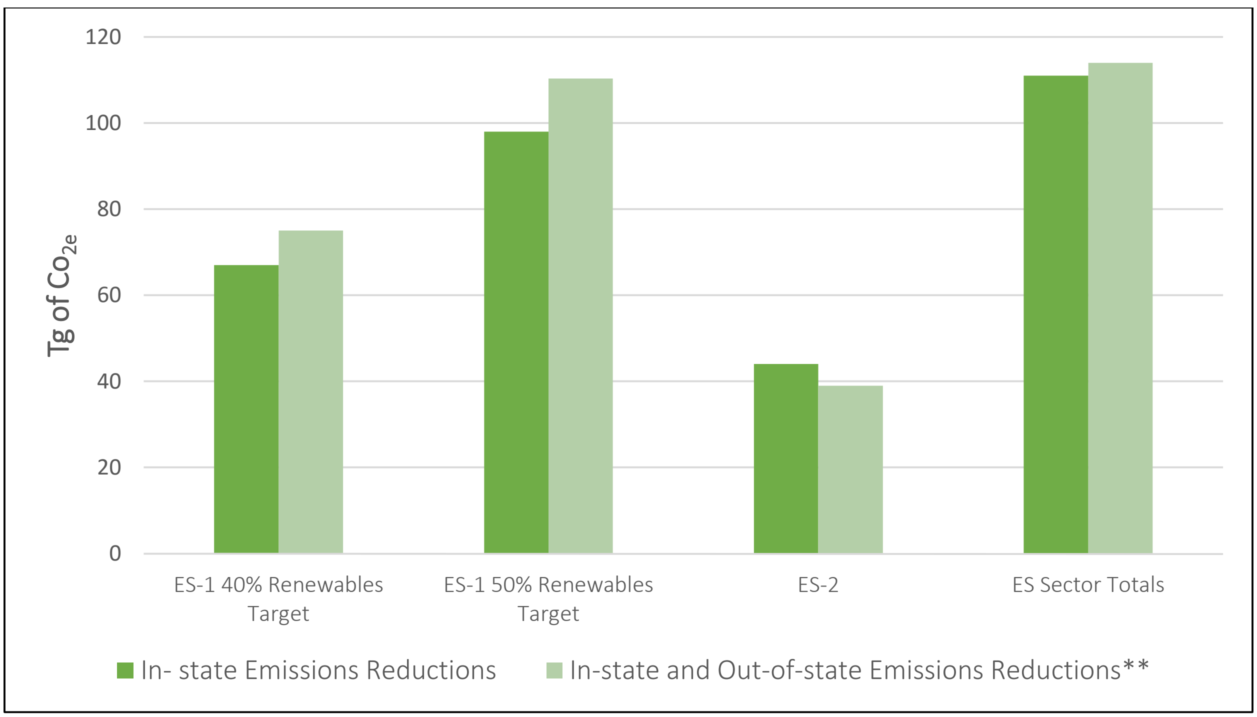
Table IV-5 ES Policy Options, Intra-Sector Interactions & Overlaps

Intra-Sector Interactions & Overlaps Adjusted Results							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Cost[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/tCO_2e$

ES-1	Increase Renewable Energy Standards (40% goal)	1.9	6.9	63	74	-$430	-$5.8
ES-2	Efficiency Improvements, Repowering, Retirement, and Up Grades to Existing Plants	0.00	5.8	41	38	$854	$22
Total After Intra-Sector Interactions/Overlap		**1.9**	**13**	**104**	**112**	**$424**	**$3.8**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
Note: Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Figure IV-7 ES Policies GHG Emissions Abatement, 2016-2030



Notes:
* All Policies Total's comprise emissions reductions achieved by ES-1 40% (default) policy and ES-2 policy.
** Total in and out-of-state emissions reduction are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Table IV-6 Macroeconomic (Indirect) Impacts of ES Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	**GSP[a] ($2015 MM)**			**Employment[b] (Individual)**			**Personal Income[c] ($2015 MM)**		
	Year 2030[d]	**Average (2016-30)[e]**	**Cumulative (2016-2030)[f]**	**Year 2030**	**Average (2016-2030)**	**Cumulative (2016-2030)**	**Year 2030**	**Average (2016-2030)**	**Cumulative (2016-2030)**
ES-1 40% Renewables Target (Default) (ES-1 40%)	$394	$177	$2,652	2,900	1,510	22,580	$311	$138	$2,075
ES-1 50% Renewables Target (ES-1 50%)	$538	$228	$3,416	3,690	1,820	27,290	$434	$180	$2,695
ES-2	-$73	-$39	-$309	170	310	2,470	-$16	-$3	-$22
ES Sector with ES-1 40% (Default) (ES Sector Total 40%)	**$319**	**$156**	**$2,336**	**3,070**	**1,670**	**25,020**	**$294**	**$137**	**$2,050**
ES Sector with ES-1 50% (ES Sector Total 50%)	**$542**	**$239**	**$3,579**	**4,720**	**2,380**	**35,650**	**$485**	**$204**	**$3,058**

Notes:
[a] Gross State Production changes in Minnesota. Dollars expressed in $2015.
[b] Total employment changes in Minnesota.
[c] Personal Income changes in Minnesota. Dollars expressed in $2015.
[d] Single final year value. Year 2030 is the final year of analyses in this project.
[e] Average value from the year 2016 to the year 2030. The average value is calculated from the first year of the policy implementation through the year 2030 if implementation of the policy starts after year 2016.
[f] Cumulative value from 2016-2030 time period.

Figure IV-8 Net Job Creation for ES Policies and ES Sector by Ascending Order, 2016-2030

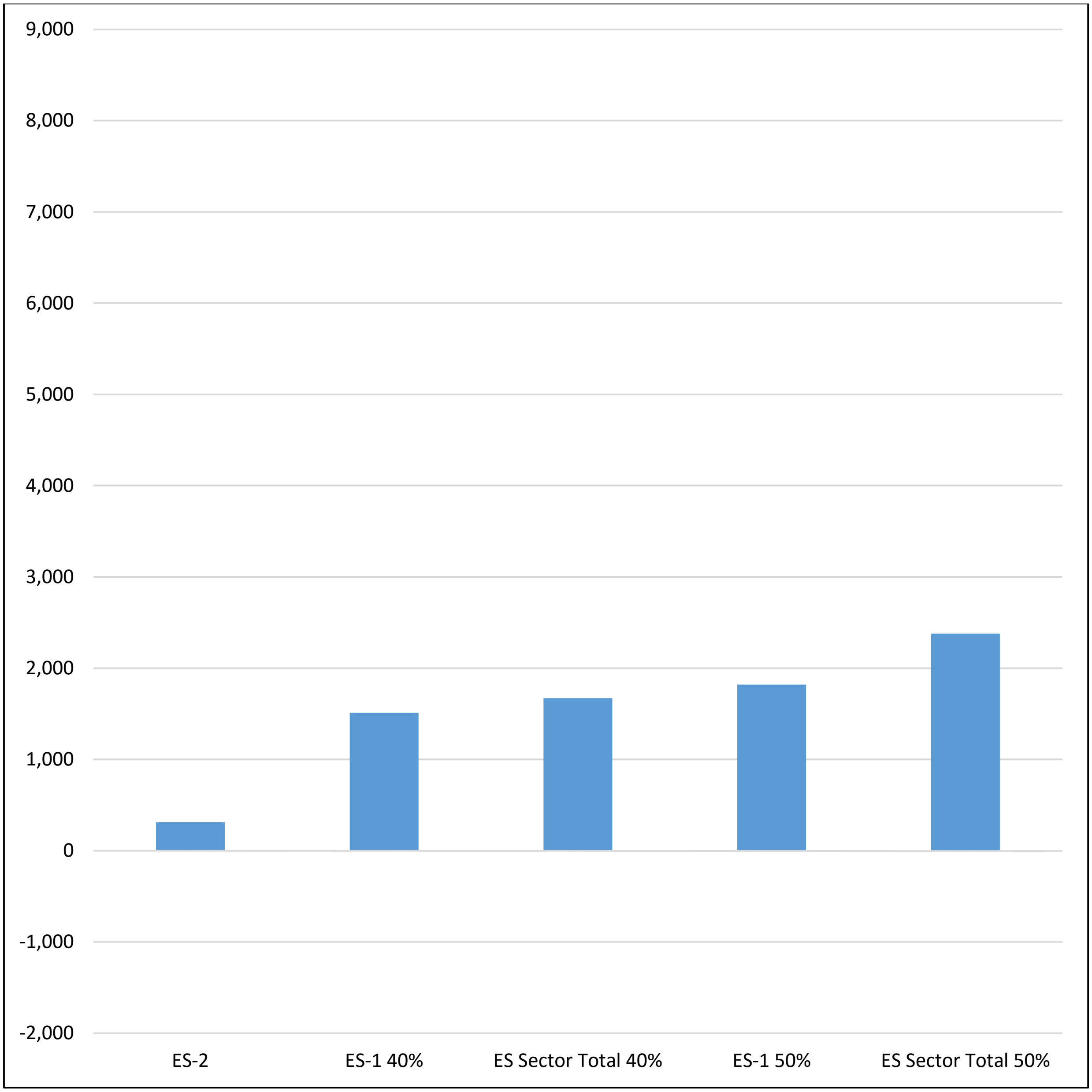
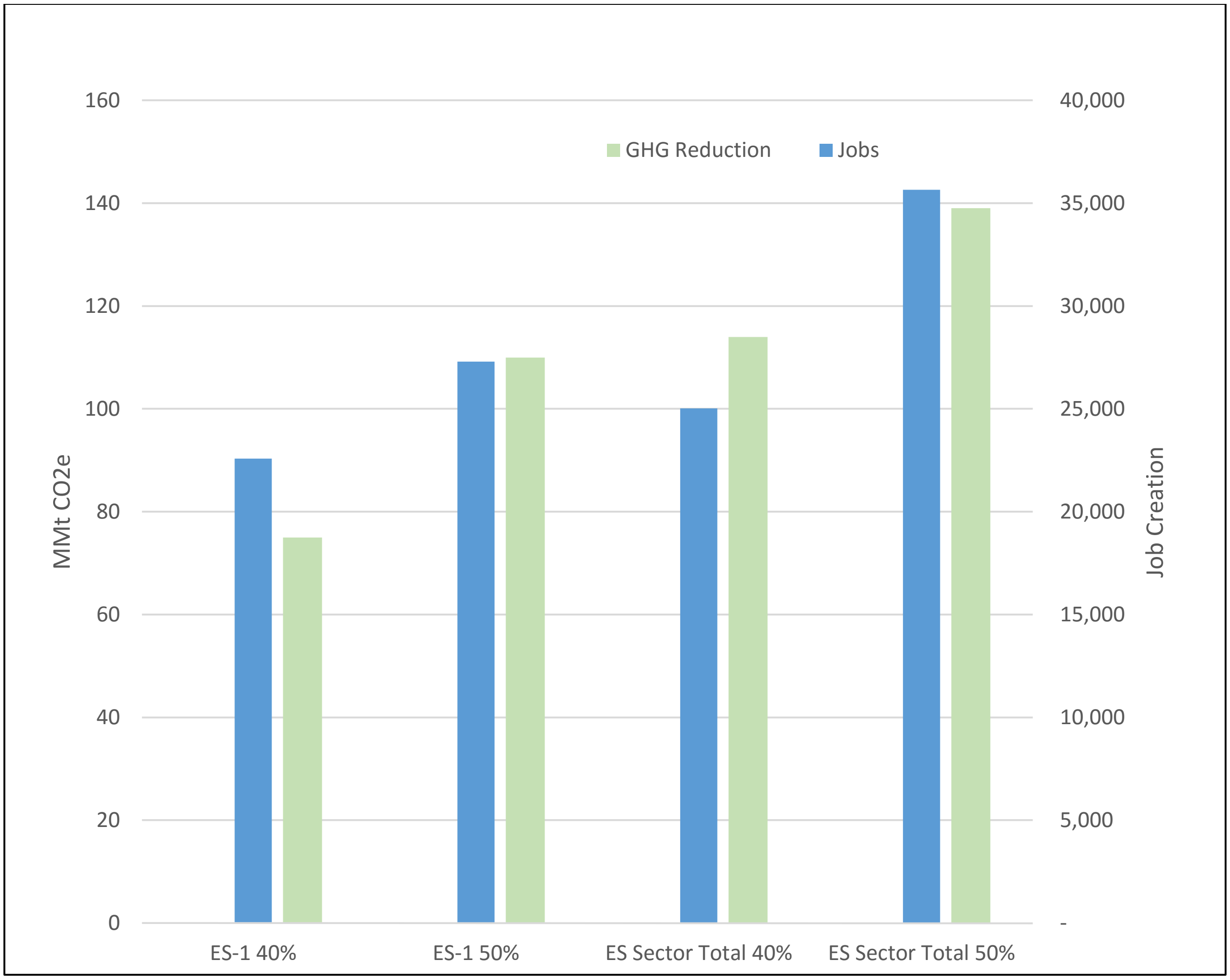


Figure below summarizes a potential for job creation and GHG emissions abatement of ES sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure IV-9 Job Gains and GHG Reduction by ES Policy Recommendations, 2016-2030



Macroeconomic Indicators

Graphs below present the overall macroeconomic impacts of each policy in ES sector, as well as the sector-level impacts, by using the Macroeconomic Impact Index. Jobs, Income, and GSP indicators are combined in a blended score indicating an overall macroeconomic impact of a policy or a set of policies on GSP, income and employment. In this project, the three variables are weighted equally, and indexed based on the maximum value among all the policies in the project. I_GSP, I_Jobs, and I_Income represent the index score for GSP, Jobs and Income, respectively.

Figure IV-10 ES Macroeconomic Indicators, Final Year 2030

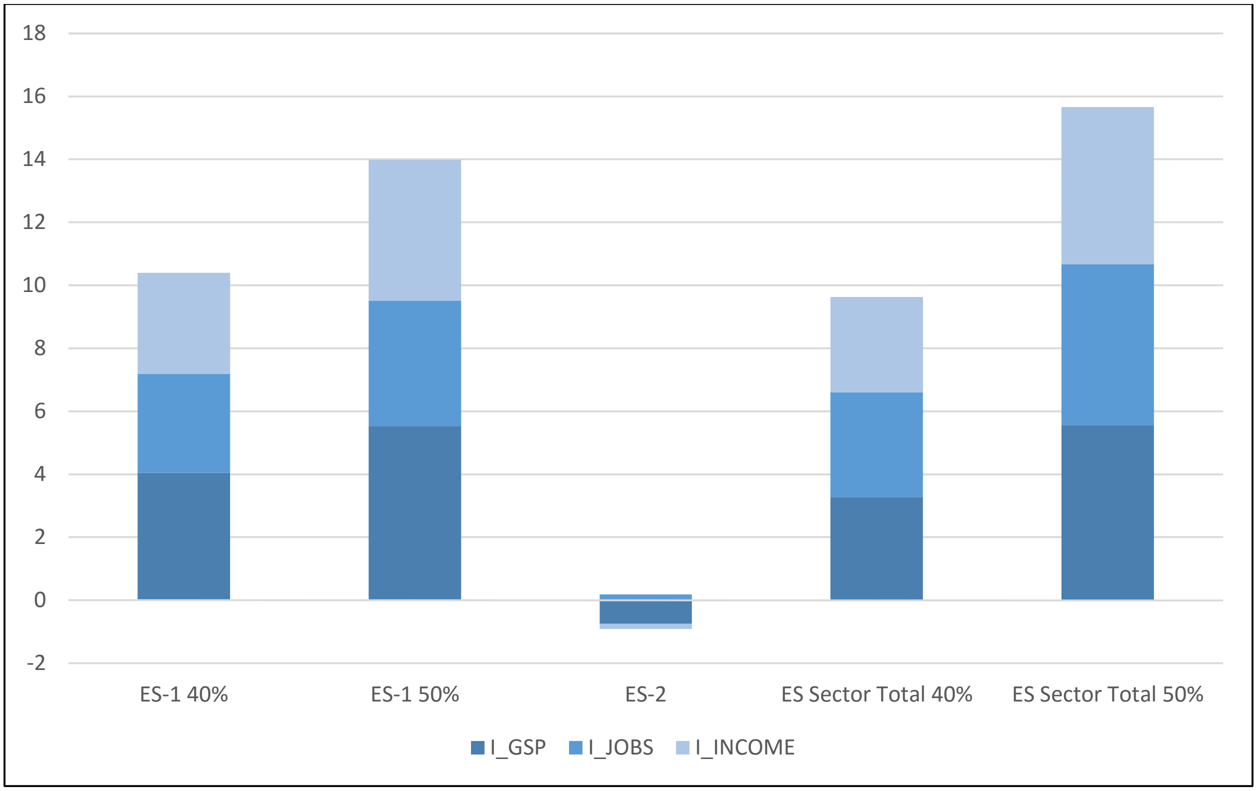


Figure IV-11 ES Macroeconomic Indicators, Average Annual

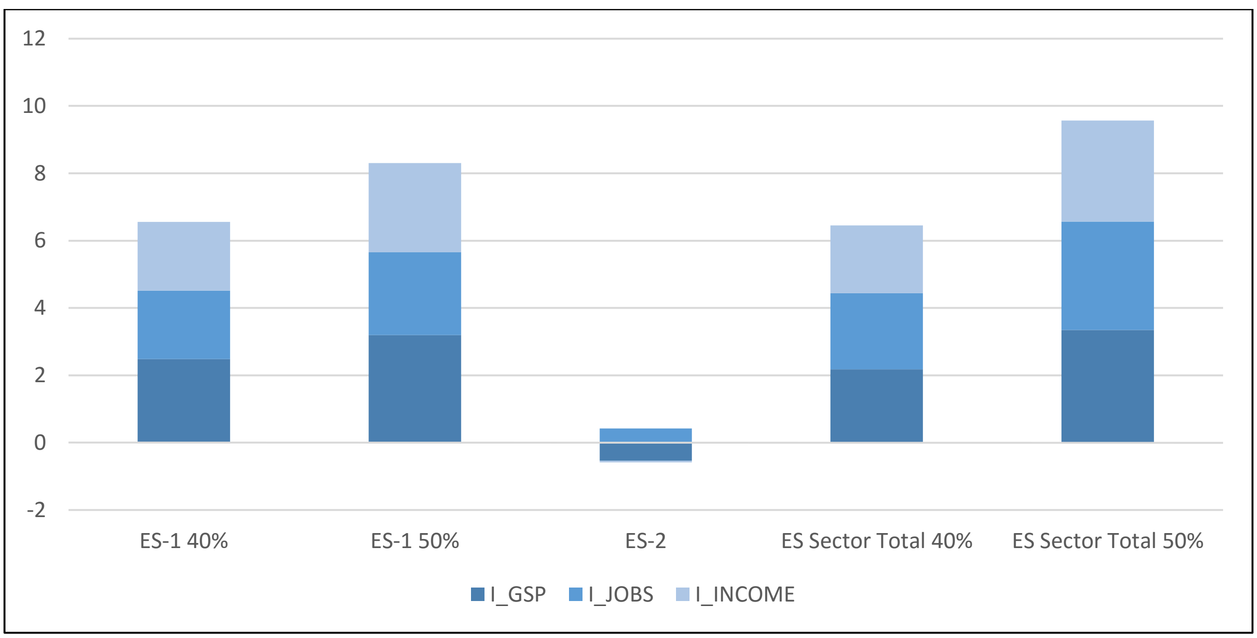
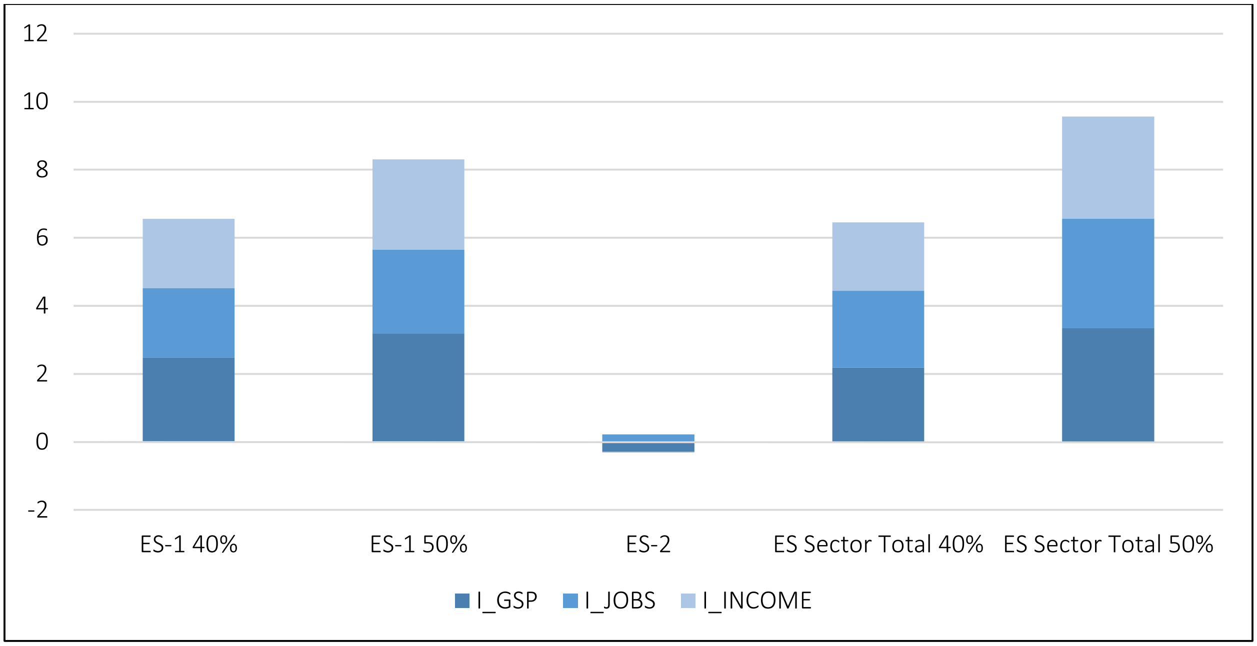


Figure IV-12 ES Macroeconomic Indicators, 2016-2030



From the line and bar graphs that follow, it is evident that the renewable energy standard (ES-1) has by far the larger impacts than the partial shutdown and partial repowering of the Sherburne County facility (ES-2). Its impact on the broader economy, driven by a cost-effective shift to renewables, generates progressively more and more economic activity (measured by GSP) over time. New jobs appear, at a rate of between 100 and 200 per year, as a result of this growth.

The more aggressive version of ES-1, which targets the higher 50% of total energy supply from renewables, outperforms its 40% alternative as well. The fundamentals of the policy are magnified by scaling up the spending shifts involved in this policy.

ES-2, by contrast, produces a small number of new employment positions, but drives slightly negative changes to overall GSP, and to total incomes. The relative savings involved with shutting down and the cost of developing new resources balance out somewhat differently in this policy, and it does not produce the same upward pressure on the total size of the economy.

In line graphs below, dashed lines represent chosen sensitivity scenarios. In bar graphs below, those sensitivity scenarios are presented in light colors.

Figure IV-13 ES GSP Impacts ($2015 MM)

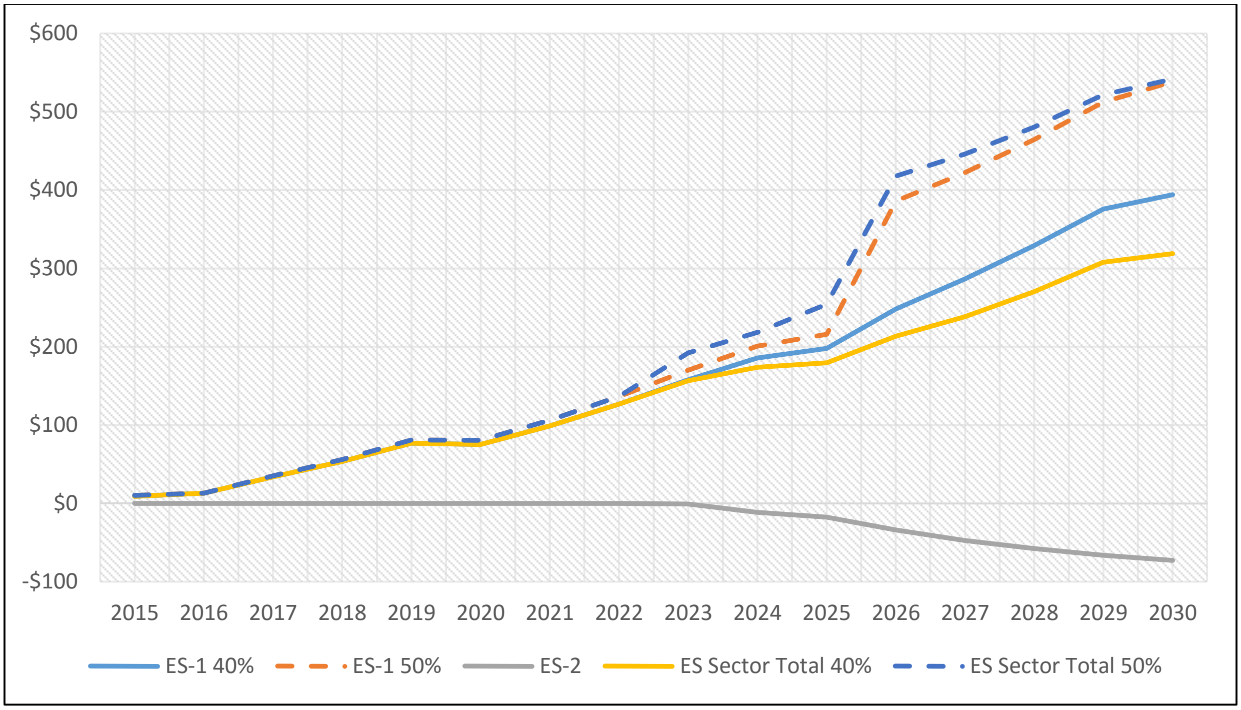


Figure IV-14 ES Employment Impacts 2016-2030 (Jobs)

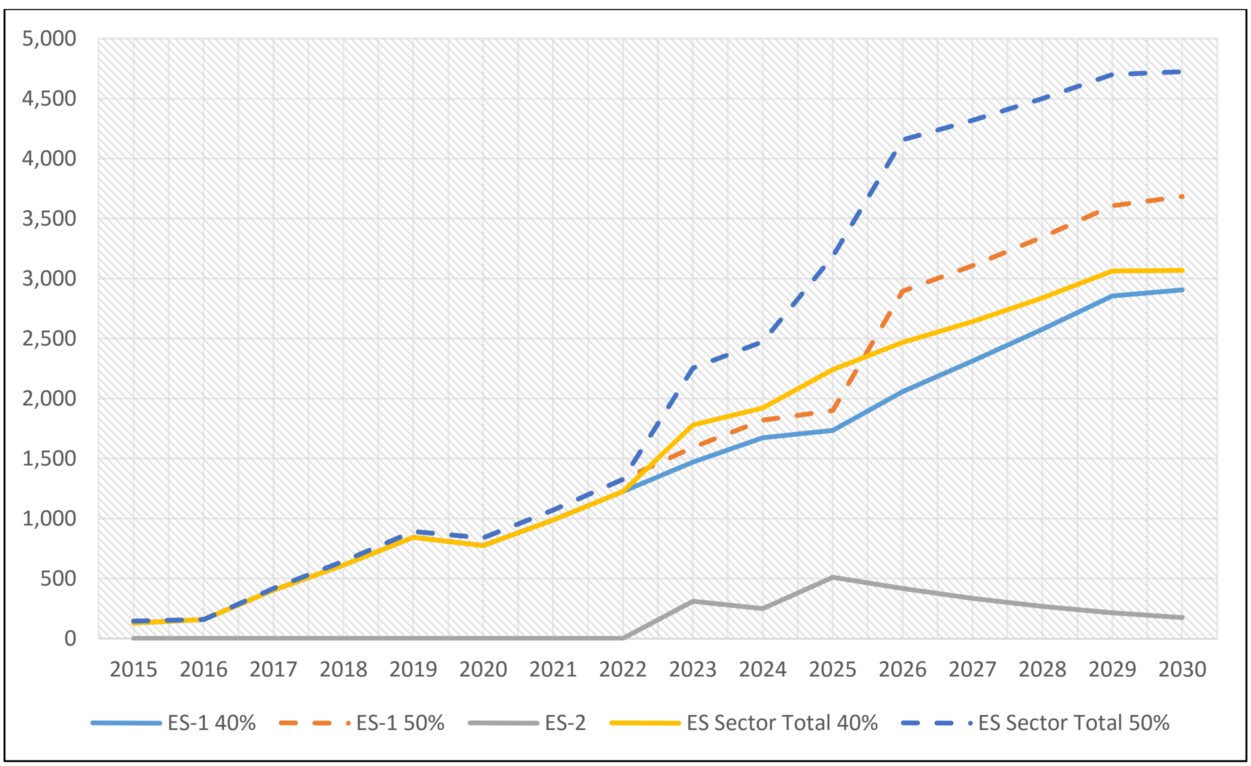


Figure IV-15 ES Income Impacts ($2015 MM)

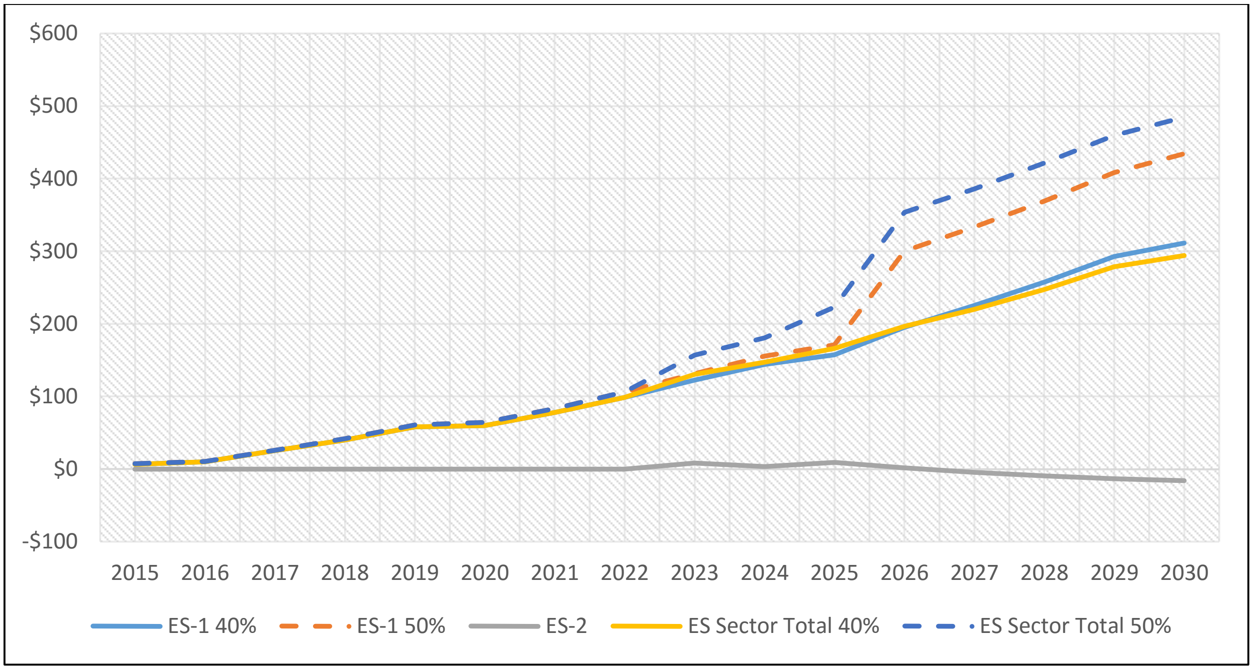


Figure IV-16 ES GSP Impacts, Average Annual ($2015 MM)

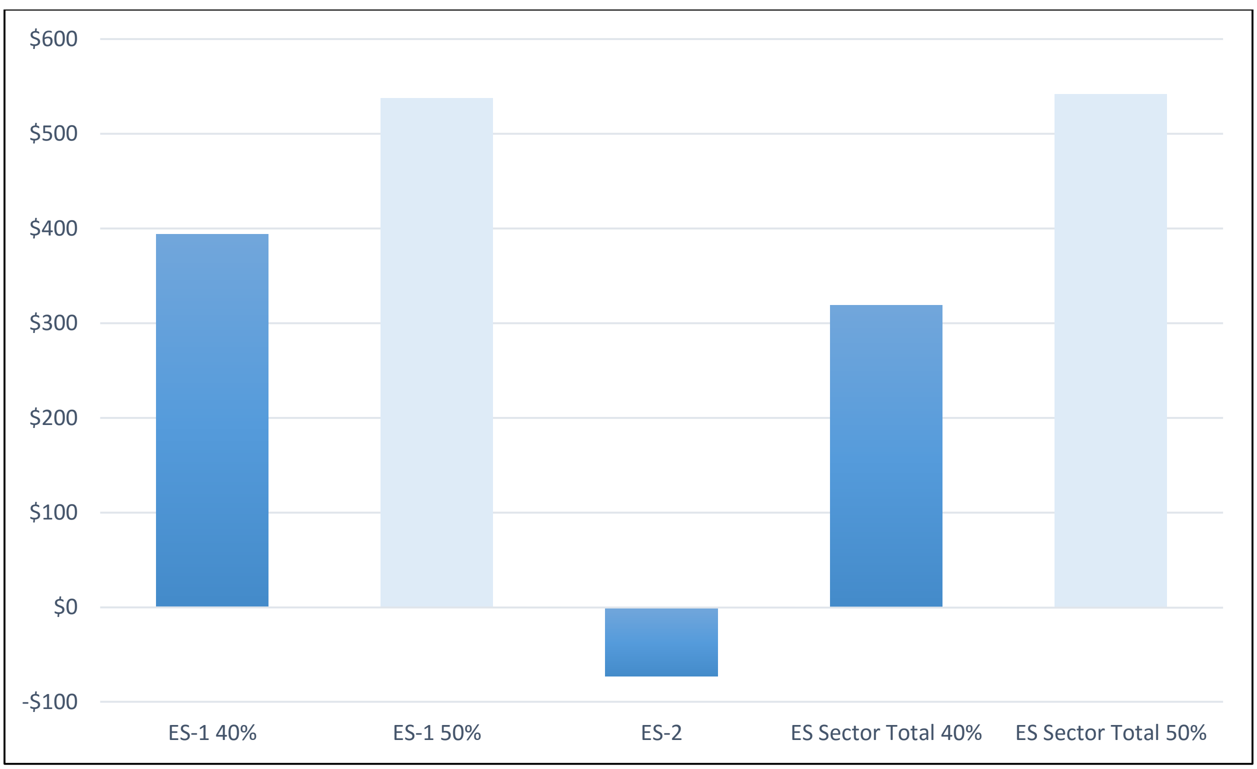


Figure IV-17 ES GSP Impacts, 2016-2030 ($2015 MM)

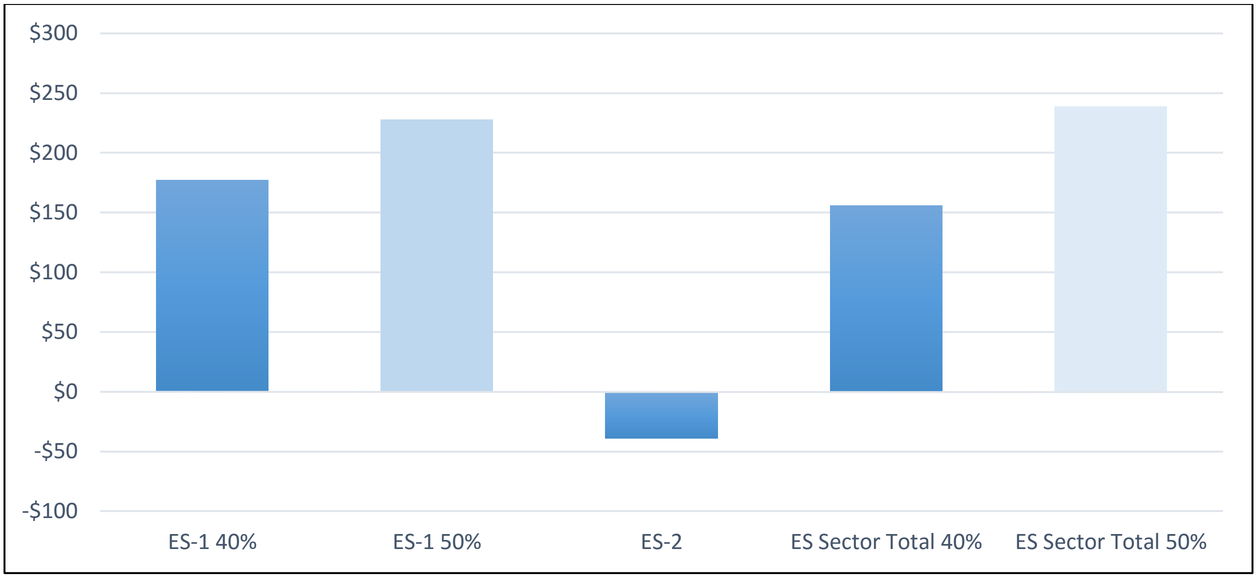


Figure IV-18 ES GSP Impacts, Year 2030 ($2015 MM)

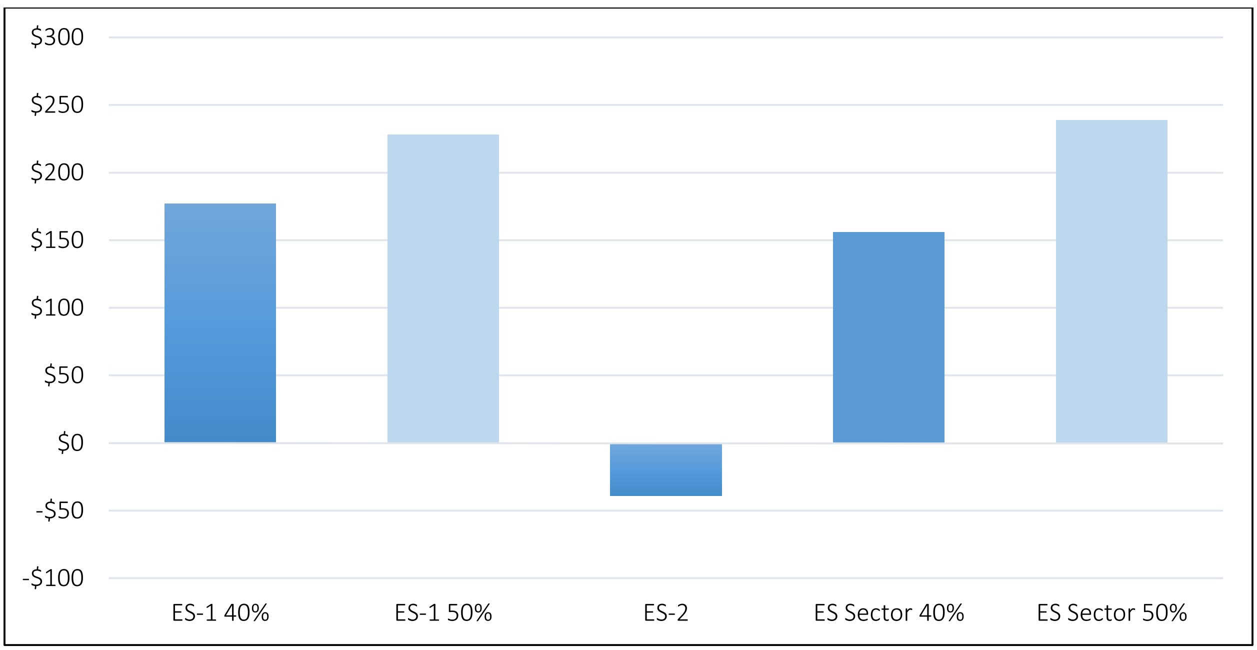


Figure IV-19 ES Employment Impacts, Average Annual (Jobs)

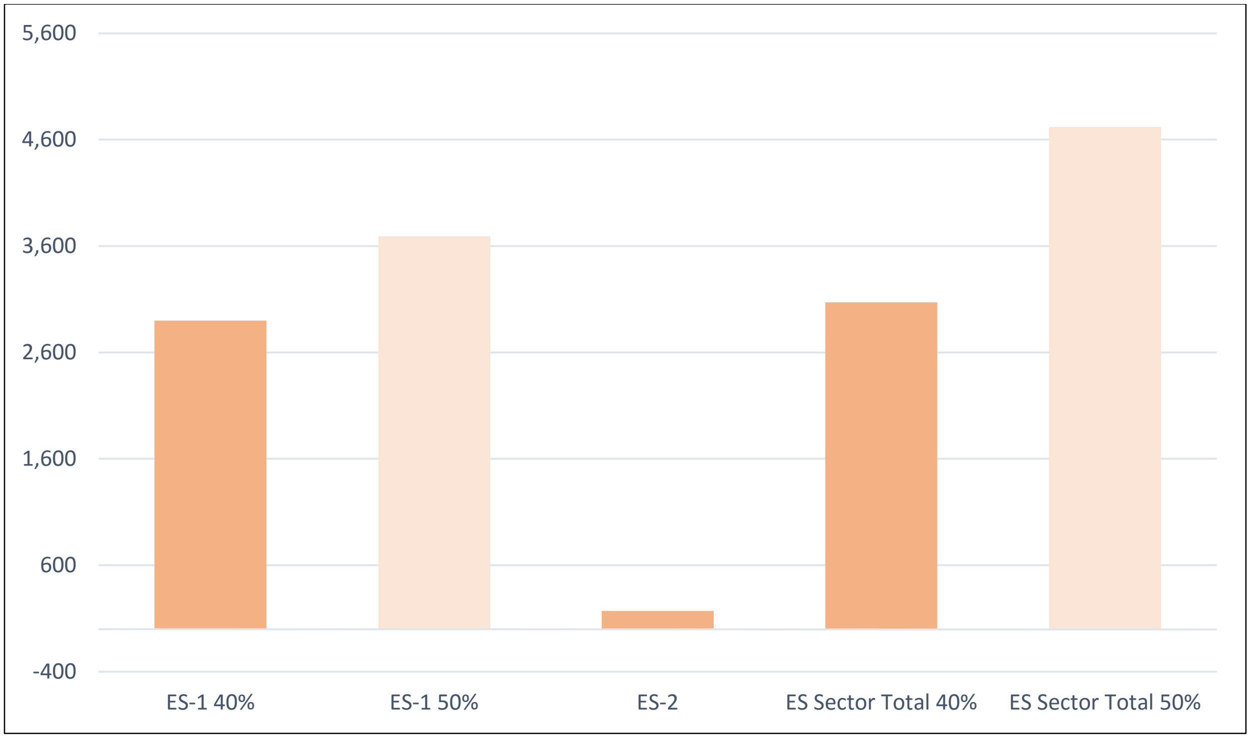


Figure IV-20 ES Employment Impacts, 2016-2030 (Job Years)

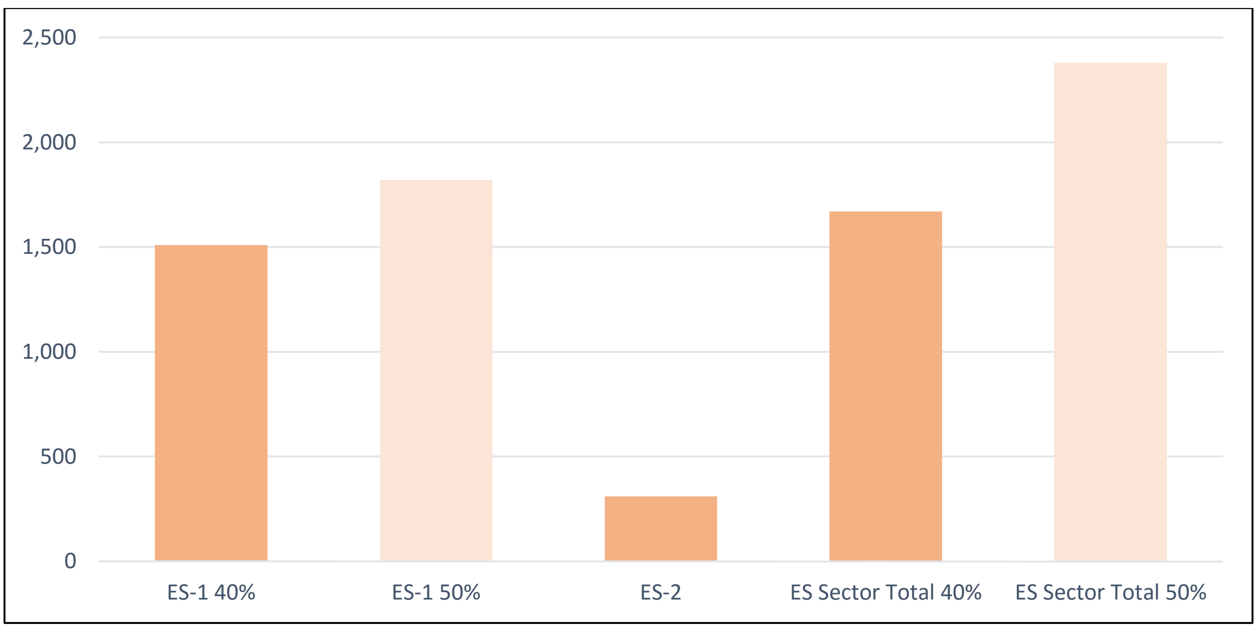


Figure IV-21 ES Employment Impacts, Year 2030 (Jobs)

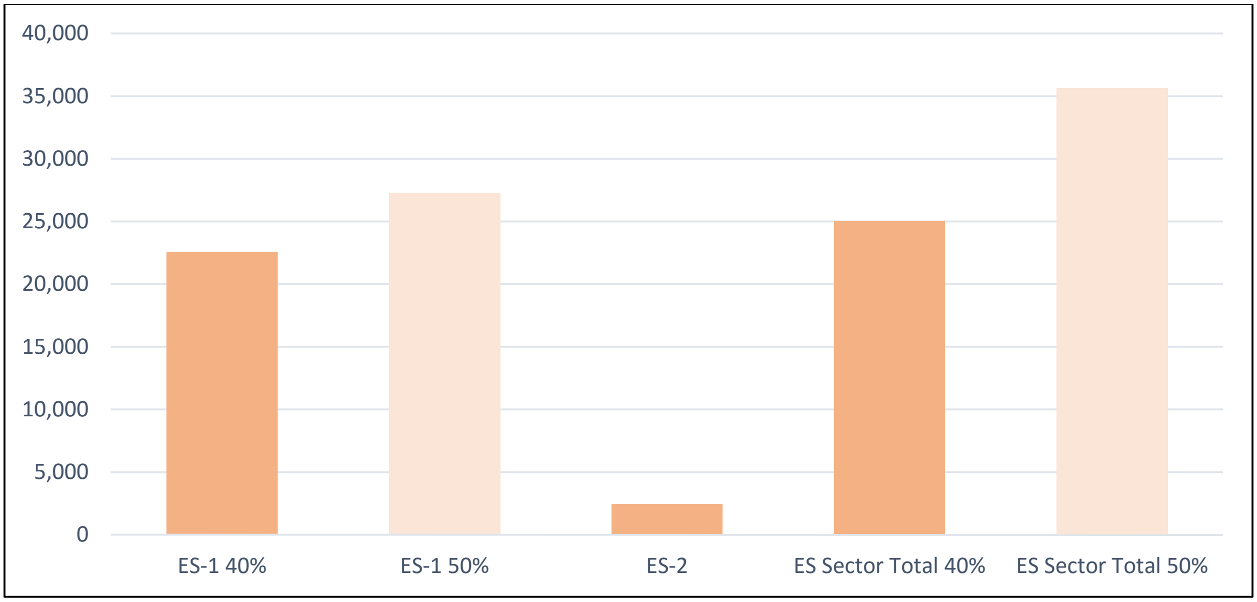


Figure IV-22 ES Income Impacts, Average Annual ($2015 MM)

Figure IV-23 ES Income Impacts, 2016-2030 ($2015 MM)

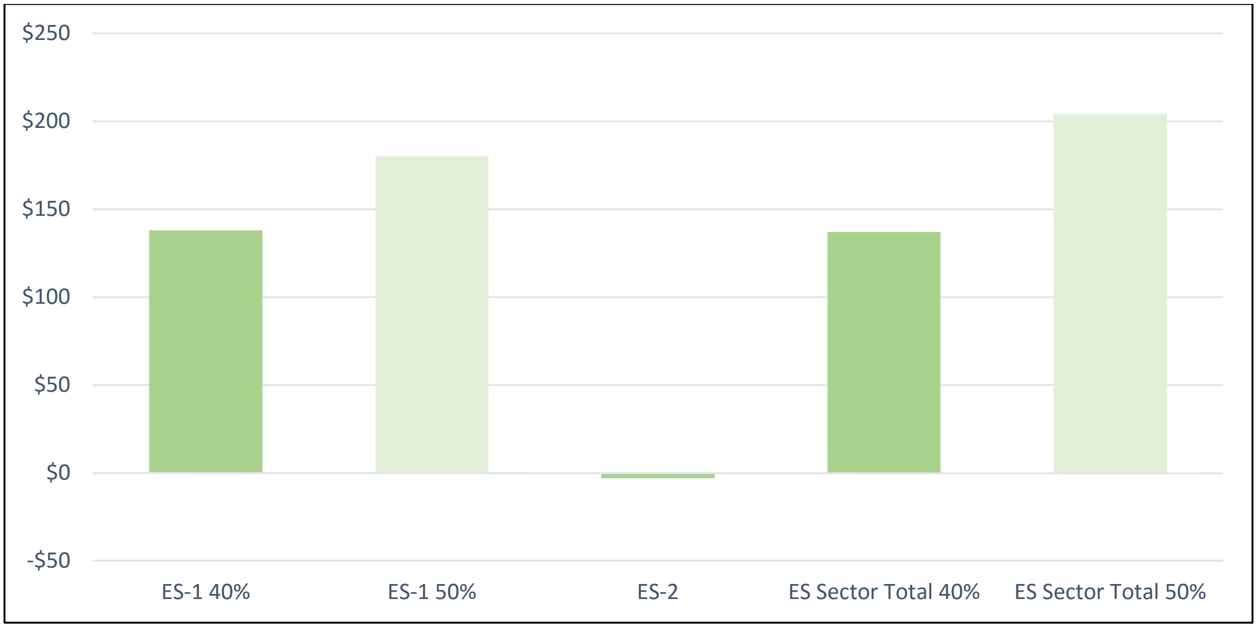
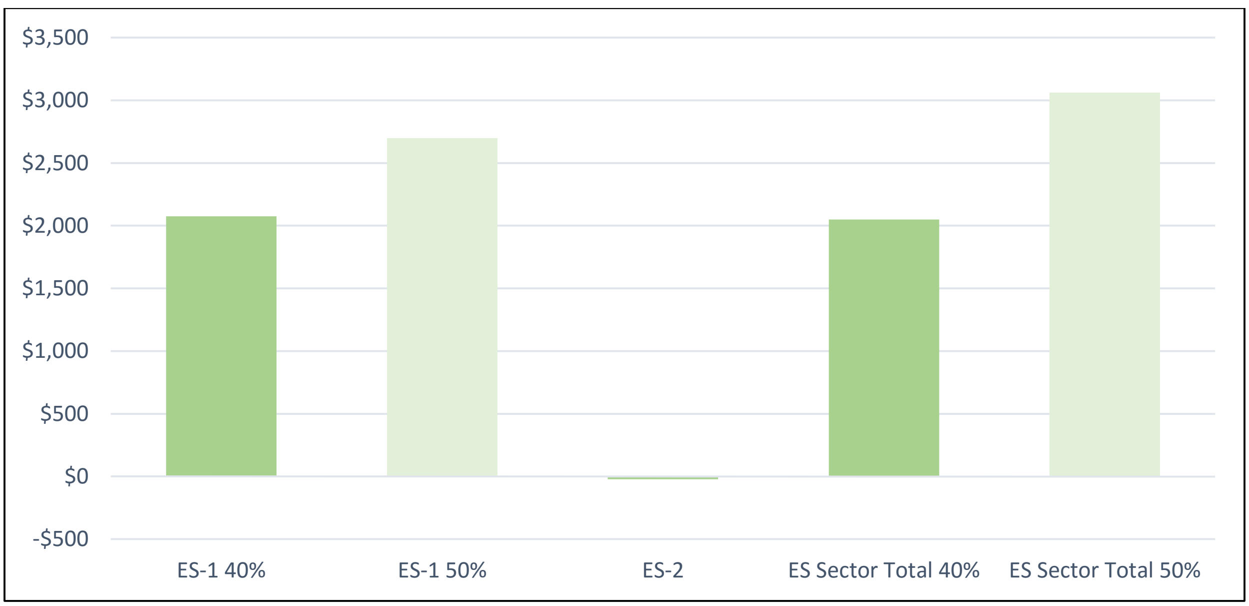


Figure IV-24 ES Income Impacts, Year 2030 ($2015 MM)



2. Residential, Commercial, Institutional, and Industrial Sector

The Residential, Commercial, Institutional, & Industrial (RCII) sector covers energy consumption (fuels and electricity) in buildings, facilities, municipal infrastructure, and industrial process. It also covers non-energy (process) emissions in the Industrial subsector. In 2010, the RCII sector contributed about 21% of the state's emissions (these are just the direct greenhouse gas [GHG] emissions; emissions from the consumption of power are included in the Energy Supply sector). The sector's contribution to state total emissions is expected to be about 23% in 2030. The important GHG drivers in this sector include power consumption by each subsector, the consumption of fuels for both space heating and industrial process heat, and process emissions in petroleum refining and taconite induration (iron ore pelletization).

Strategies that can be employed to reduce GHG emissions and produce positive economic outcomes include: energy efficiency (EE) measures for homes, institutions, and businesses; distributed renewable energy (RE) generation (such as rooftop solar); commercial and industrial process improvements; and fuel switching to lower carbon fuels sourced within the state (e.g., biomass).

Baseline and Emissions Sources

The GHG emissions baseline for the RCII sectors is provided in figure below. In the figure, historic emissions are shown divided into three categories -- Residential, Commercial (including institutional), and Industrial. In all sectors, historical and forecast emissions include emissions from the energy sector-emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from combustion of coal and coal products, oil products, and natural gas, and emissions of CH_4 and N_2O from combustion of wood and other biomass-based fuels--and non-energy emissions. Overall, the GHG impacts of RCII emissions are dominated by CO_2 emissions from energy use. Not directly included in the figure are emissions associated with RCII use of electricity. Most electricity used in Minnesota is consumed in the RCII sectors, but these emissions are tracked in the ES Sector (Chapter II).

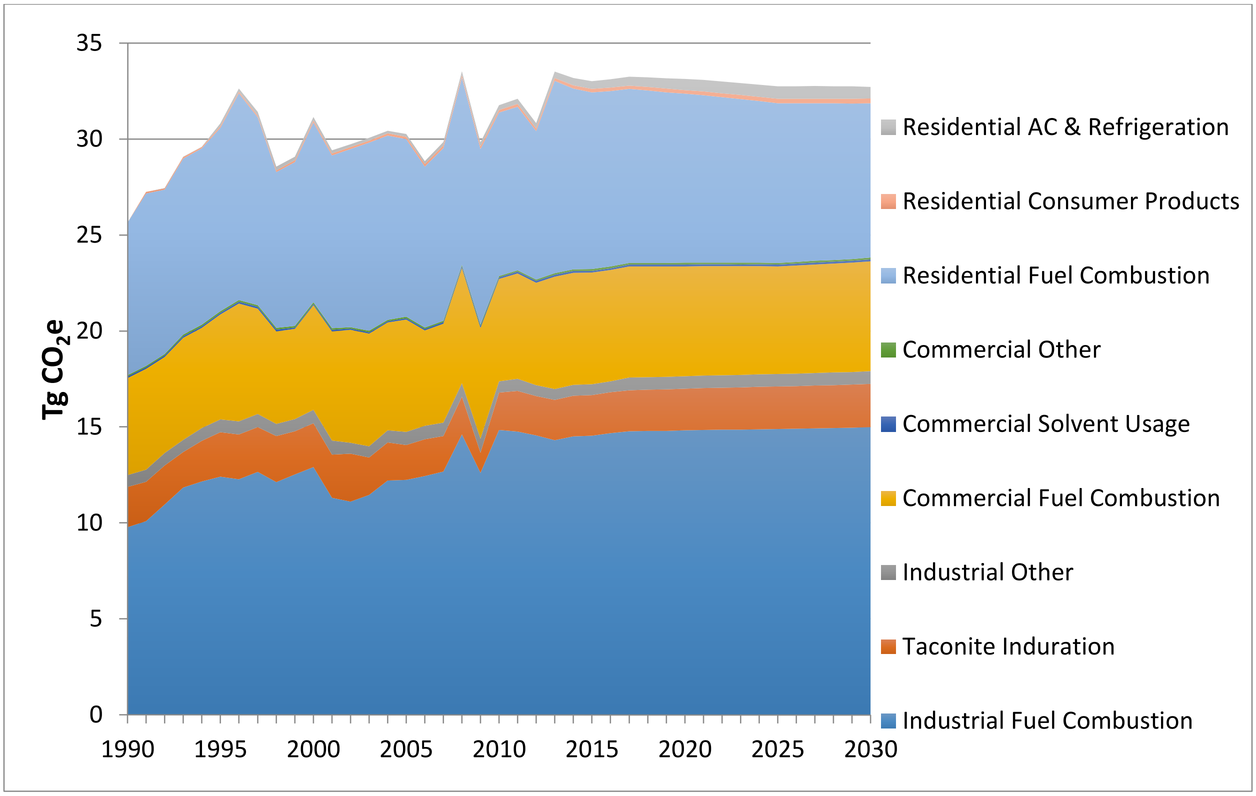
In the residential sector, emissions from fuel combustion are further broken into four end-uses: space heating, water heating, cooking, and clothes drying (see Appendix B for details). Non-energy sources of GHGs in the residential sector include food additives, soaps, shampoos and detergents, urban lawn fertilizer, air conditioning refrigerants, refrigerator refrigerants, and aerosols. The residential sector is also credited with carbon stored in wood in residential structures. Overall, residential sector emissions, expressed as CO_2 equivalents, are forecast to slowly decline after 2016. Emissions from fuel use dominate the residential sector, primarily natural gas with liquefied petroleum gas (LPG) accounting for most of the rest. The residential sector receives an "emissions credit" varying from 0.7 to 1.1 $TgCO_2$ per year for carbon sequestered in wood used in housing. This credit largely offsets non-energy emissions from the sector.

In the commercial/institutional sector, emissions from fuel combustion also dominate total GHG emissions, but fuel combustion emissions fall slowly over time, from about 5.9 $TgCO_2e$ in 2012 to about 5.7 $TgCO_2e$ in 2030. Of note for the non-energy commercial sector emissions space cooling and refrigeration emissions are forecast to more than double, from about 1.0 $TgCO_2e$ in 2012 to 2.3 $TgCO_2e$ in 2030.

Overall industrial sector emissions in Minnesota are projected to rise slowly over the forecast period. Emissions from fuel combustion account for slightly less than three quarters of CO_2e emissions throughout the forecast. Non-energy emissions from the industrial sector include CO_2 and CH_4 emissions from a variety of industrial processes, as well as sulfur hexafluoride (SF_6)

used in magnesium die casting, perfluorocarbons (PFC) and hydrofluorocarbons (HFC) used in semiconductor manufacture, HFC and PFC used as solvents, and HFCs from foam insulation manufacturing and appliances. Non-energy emissions are dominated by two categories, namely CO_2 from "induration taconite flux"--the processing of low-grade iron ores--and CO_2 from the oil refining industry. Both of these sources are forecast to rise somewhat over time.

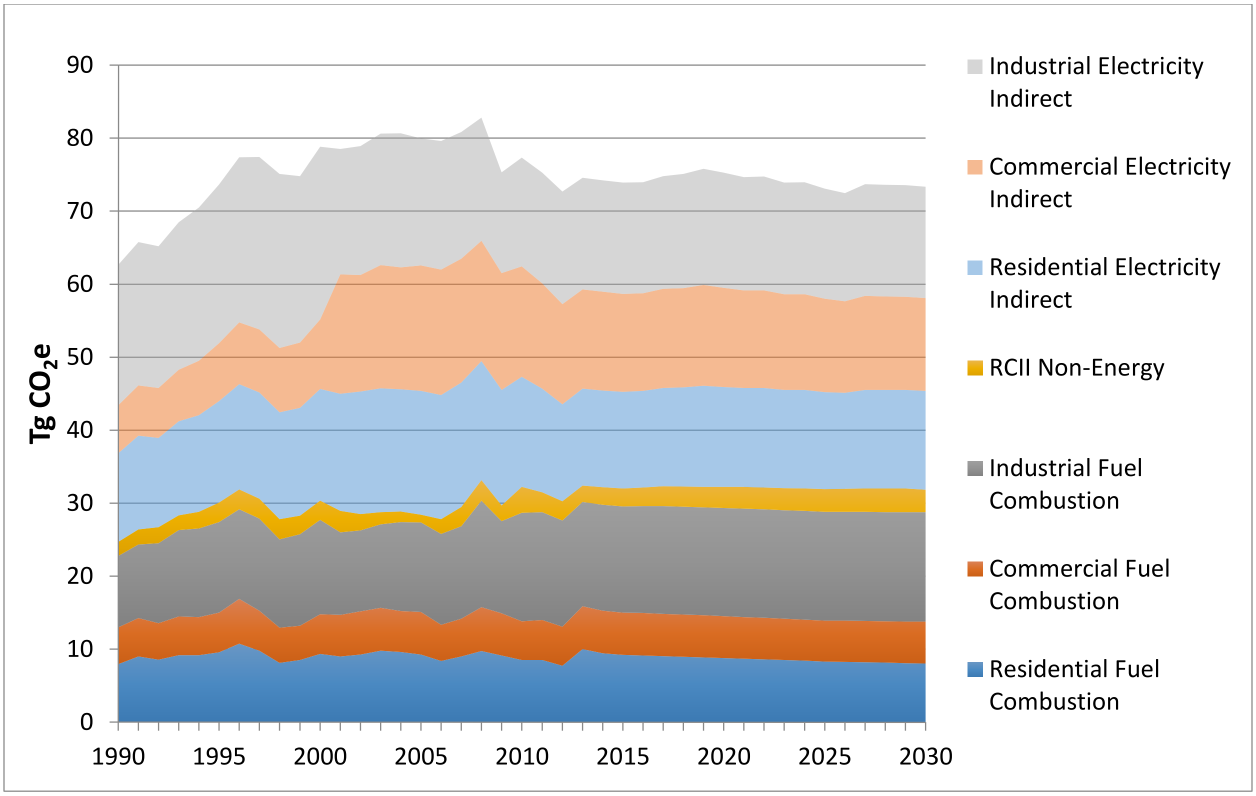
Figure IV-25 RCII Sectors GHG Baseline



Notes: This chart excludes ~1 $TgCO_2$ annually for carbon storage in residential building materials.

Figure below provides another summary of the RCII sector baseline. This summary focuses on energy consumption for the sector, both direct use of fuels, as well as electricity consumption (shown as "indirect" transparent wedges in the chart). Non-energy emissions (e.g., from industrial processes) are shown to represent only a small portion of the overall emissions for the sector. Electricity consumption related emissions account for well over half of the emissions through both the historical and forecast periods.

Figure IV-26 RCII GHG Baseline for Energy Consumption



Notes: The Commercial subsector emissions in this chart also include the Institutional subsector.
RCII Non-Energy represent net emissions including carbon storage in residential building materials.

See Chapter II for more information on the contribution of the RCII sector to the state's GHG baseline. See Appendix B for more details on the development of the RCII baseline.

CSEO Policy Options

Five policies were developed for the RCII sectors. These are detailed in Appendix F.2 and are summarized as follows:

RCII-1. Combined Heat and Power (CHP) for Natural Gas or Biomass

Combined heat and power (CHP) systems reduce fossil fuel use and reduce GHG emissions by recovering heat that is usually wasted as reject heat in power plants for useful purposes (heating buildings, domestic hot water, industrial process heat, or conversion to cooling energy for air conditioning or industrial cooling energy). Additionally, reductions are achieved in implementing both through the improved efficiency of the CHP systems, relative to separate heat and power technologies, and by avoiding transmission and distribution losses associated with moving power from central power stations that are located far away from the point of electricity end use. RCII-1 includes targets for implementing CHP systems fueled with natural gas, and systems fueled with biomass (typically wood) to displace central grid electricity and natural gas and fossil fuels use for commercial and industrial space, water, and process heating and cooling. The overall goals of this option are to implement 800 MW of gas-fired CHP and 300 MW of biomass-fired CHP by 2030.

RCII-2. SB2030/ Zero Energy Transition/Codes

Operating and maintaining buildings involve the consumption of large amounts of energy. In 2011, Minnesota's residential and commercial sectors consumed 39.6% of the total energy consumed in the state--the residential sector at 21.3% while the commercial/institutional sector consumed 18.3%. Making a transition to "Zero Energy" buildings means constructing highly energy efficient buildings and phasing in the use of renewable energy sources--such as solar thermal, solar photovoltaic, and biomass-fired heat use--to provide for the remaining energy needs of the buildings, and in some cases to export energy for use outside the building (for example, electrical energy sent to the local grid). Initiatives such as the national Architecture 2030, Zero Energy Ready, and Minnesota's Sustainable Building 2030 (SB2030) provide guidance for this option. Existing building energy codes specify minimum requirements for new and renovated buildings, but these codes will not make buildings "zero energy" in time for Minnesota to accomplish its climate change goals. Stretch goals can be achieved by adopting SB2030 as an appendix to the Minnesota Building Code, which then makes it available for local jurisdictions to use. As such, this policy option will provide incentives for or mandates construction of buildings so that net zero energy use in new and renovated buildings is achieved incrementally by 2030.

RCII-3. Reduce High Global Warming Potential (GWP) Greenhouse Gases

This policy option was not moved forward to final CSEO recommendations due to current limitations on effective policy option design and impacts analysis.

RCII-4. Increase Energy Efficiency Requirement

Minnesota utilities must comply with utility energy efficiency resource standard (EERS) requirements established in the Conservation Improvement Program (CIP). EERS standards require utilities to offer their customers energy efficiency programs that result in the reduction of annual sales by a specified amount annually. This option increases the requirements of the existing EERS by increasing the EERS for electric utilities to 2.5% annually, while allowing utilities to count electric energy savings from energy utility infrastructure (EUI) improvements and electricity displaced by combined heat and power projects (CHP) on top of a minimum savings goal of 1.5% from end-use efficiency. For gas utilities, this option retains the EERS of 1.5%, with a minimum savings goal of 1.0% for end-use efficiency and the addition of CHP as an eligible technology that could satisfy the remaining 0.5% of the overall requirement.

RCII-5. Incentives and Resources to Promote Thermal Renewables

Minnesota has a significant resource of forest and other biomass, and Minnesota residences have a history of heating with wood. Significant opportunity exists to meet heating load with in-state renewable energy resources, resulting in reduced GHG emissions. In addition, recent propane infrastructure changes and severe shortages of propane in the winter of 2013-2014 highlight the benefits of more diversity in heating options to mitigate volatility in fuel pricing and availability throughout greater Minnesota. This option takes advantage of this resource and builds on existing experience with biomass fuels by establishing a renewable thermal goal of switching five percent of the total forecast heating load (measured as fuel delivered for heating use) that is currently fueled with non-electric sources including natural gas, fuel oil, and propane to renewable thermal resources--including solar heat and biomass fuel--by 2020, and 20% by 2030. To pay for incentives to encourage consumers to purchase renewable--fueled heating systems, the option includes establishment of a state-wide Renewable Thermal Incentive Fund that provides incentives for the installation of thermal renewable technologies and targets high-value customers including farmers, delivered fuel customers, low income housing authorities, and commercial users. The fund would collect 1 cent per therm (100,000 Btu.) of energy content on natural gas, fuel oil, and propane sold in Minnesota.

Direct and Indirect Policy Option Impacts

Table IV-7 below provides the direct stand-alone policy option impacts for the RCII sectors. On a stand-alone basis, the complete set of RCII policies is expected to produce in-state GHG reductions of 5.3 $TgCO_2e$ in 2020 and 22 $TgCO_2e$ in 2030. These reductions include avoided direct emissions from fossil-fueled systems such as boilers and furnaces, as well as indirect emissions avoided from the electricity sector due to reduced requirements for electricity from the central grid. The reductions are calculated net of additional emissions, for example, from gas-fired CHP or wood-fired heating systems (only N_2O and CH_4 emissions are counted for the latter). As with all results, these presume that the policies will be fully implemented as designed (see Appendix F.2 for details on the design of each policy option). On a cumulative basis, the RCII policies are expected to reduce 157 $TgCO_2e$ in-state (and 182 $TgCO_2e$ total, including upstream emissions) through 2030.

Policies RCII-1, RCII-2, and RCII-4 produce net cost savings for Minnesota. This occurs through a combination of reduced net use of fossil fuels and electricity, partially offset by the somewhat higher capital costs and outlays for biomass fuels. RCII-5 has a net positive cost for Minnesota, as the additional capital and fuel costs outweigh the savings from reduced fossil fuel use, but RCII-5 results in significant in-state investments in infrastructure, which drives positive macroeconomic impacts described in the next section. Overall, the set of RCII policies quantitatively evaluated produces a net savings of -$4.1 billion ($2014) for Minnesota in net present value terms over 2015 - 2030, yielding an average cost-effectiveness (cost per metric ton of CO_2e reduced) of -$23, based on the overall in-state plus upstream emissions total.

Table IV-7 RCII Policy Options, Direct Stand-Alone Impacts

"Stand-Alone" Analysis							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual CO_2e Reductions[a]		2030 Cumula-tive[a]	2030 Cumula-tive[b]	Net Costs[c] 2015-2030	Cost Effective-ness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/tCO₂e
RCII-1	Incentives and Resources to Promote Combined Heat and Power (CHP) for Biomass and for Natural Gas.	2.2	4.9	46	50	($1,112)	($22)
RCII-2	SB2030/Zero Energy Transition/Codes	0.92	9.3	54	60	($2,050)	($34)
RCII-3	Reduce High Global Warming Potential (GWP) Greenhouse Gases	Not Applicable - Option not quantified					
RCII-4	Increase Energy Efficiency Requirement (2.5% annual electric energy savings)	1.4	4.7	36	42	($1,882)	($45)
RCII-4	Increase Energy Efficiency Requirement (2% annual electric energy savings)[e]	*1.0*	*3.2*	*25*	*29*	*($1272)*	*($44)*
RCII-5	Incentives and Resources to Promote Thermal Renewables.	0.80	3.0	22	30	$872	$29
Totals		**5.3**	**22**	**157**	**182**	**($4,171)**	**($23)**

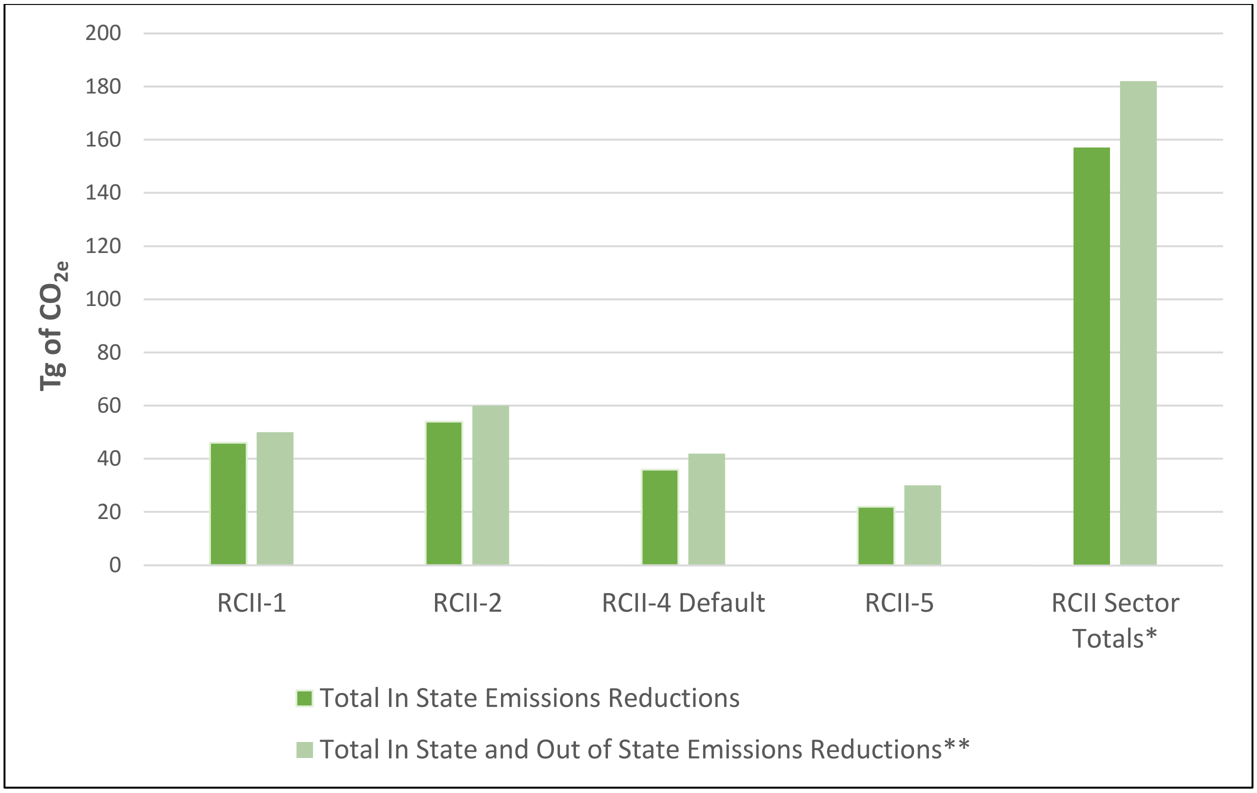
Notes:
[a] In-State (Direct) GHG Reductions
[b] Total (Direct and Indirect) GHG Reductions
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014)
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of State. Dollars expressed in 2014$.
[e] 2% annual electric energy savings scenario is an alternative scenario of RCII-4 policy evaluated for a reference, and is not included in the "**Totals**" row calculation

Table IV-8 RCII Policy Options, Intra-Sector Interactions & Overlaps

Intra-Sector Interactions & Overlaps Adjustments							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual CO_2e Reductions[a]		2030 Cumula-tive[a]	2030 Cumula-tive[b]	Net Costs[c] 2015-2030	Cost Effective-ness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/$tCO_2e$
RCII-1[e]	Incentives and Resources to Promote Combined Heat and Power (CHP) for Biomass and for Natural Gas	2.2	4.8	46	49	($1,098)	($22)
RCII-2[f]	SB2030/Zero Energy Transition/Codes	0.92	9.3	54	60	($2,050)	($34)
RCII-3	Reduce High Global Warming Potential (GWP) Greenhouse Gases	Not Applicable - Option not quantified					
RCII-4[g]	Increase Energy Efficiency Requirement (2.5% annual electric energy savings)	1.3	4.4	34	40	($1,744)	($43)
RCII-4	Increase Energy Efficiency Requirement (2% annual electric energy savings)[j]	*1.0*	*3.0*	*23*	*28*	*($1180)*	*($42)*
RCII-5[h]	Incentives and Resources to Promote Thermal Renewables	0.82	3.0	22	30	$844	$28
Total After Intra-Sector Interactions /Overlap		**5.3**	**22**	**156**	**180**	**($4,049)**	**($23)**

Notes:
[a] In-State (Direct) GHG Reductions
[b] Total (Direct and Indirect) GHG Reductions
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014)
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of State. Dollars expressed in 2014$.
[e] RCII-1 overlaps with RCII-2 in its use of gas-fired CHP in the C/I sector. Approximate overlaps are calculated on that basis.
[f] This option is used as the basis on which overlaps from other options are calculated
[g] Overlaps with RCII-1 are already removed from RCII-4 results. As RCII-4 applies to all homes and businesses, and RCII-2 only applies to new and renovated buildings, the RCII-4 overlap with RCII-2 is estimated based on an estimate of the fraction of total Minnesota building floor area that participates in RCII-2 relative to a rough estimate of the total Minnesota building floor area.
[h] This option does not overlap with RCII-1. RCII-5 overlaps with the gas savings in RCII-2 from renewable energy use that apply to new homes, and to the fraction of gas savings in RCII-4 that comes about as a result of the application of renewable energy systems included in RCII-4. The latter are not explicitly included in the RCII-4 Policy Option Document, or explicitly calculated in the estimate of the costs and impacts of RCII-4. We therefore roughly estimate the overlap between RCII-5 and RCII-4 at 10% of the natural gas impacts of RCII-4 and a corresponding share of the gas-related costs of RCII-5.
[j] 2% annual electric energy savings scenario is an alternative scenario of RCII-4 policy evaluated for a reference, and is not included in the "**Total**" row calculation.

Figure IV-27 RCII Policies GHG Emissions Abatement, 2016-2030



Notes:
* All Policies Total's comprise emissions reductions achieved by RCII default policies combined.
** Total in and out-of-state emissions reduction are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Table IV-9 Macroeconomic Impacts of RCII Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	GSP[a] ($2015 MM)			Employment[b] (Individual)			Personal Income[c] ($2015 MM)		
	Year 2030[d]	Average (2016-2030)[e]	Cumulative (2016-2030)[f]	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
RCII-1	$508	$202	$3,026	3,840	2,330	35,020	$434	$213	$3,191
RCII-2	-$69	-$6	-$91	6,020	2,750	41,190	$336	$134	$2,011
RCII-4	$137	$141	$2,111	1,430	1,560	23,340	$163	$143	$2,140
RCII-5	-$345	-$149	-$2,081	-1,680	-690	-9,610	-$154	-$58	-$809

RCII Sector Total	**$262**	**$210**	**$3,149**	**9,820**	**6,080**	**91,270**	**$801**	**$444**	**$6,658**

Notes:
[a] Gross State Production changes in Minnesota. Dollars expressed in $2015.
[b] Total employment changes in Minnesota.
[c] Personal Income changes in Minnesota. Dollars expressed in $2015.
[d] Single final year value. Year 2030 is the final year of analyses in this project.
Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Figure IV-28 Net Job Creation for RCII Policies and RCII Sector by Ascending Order, 2016-2030

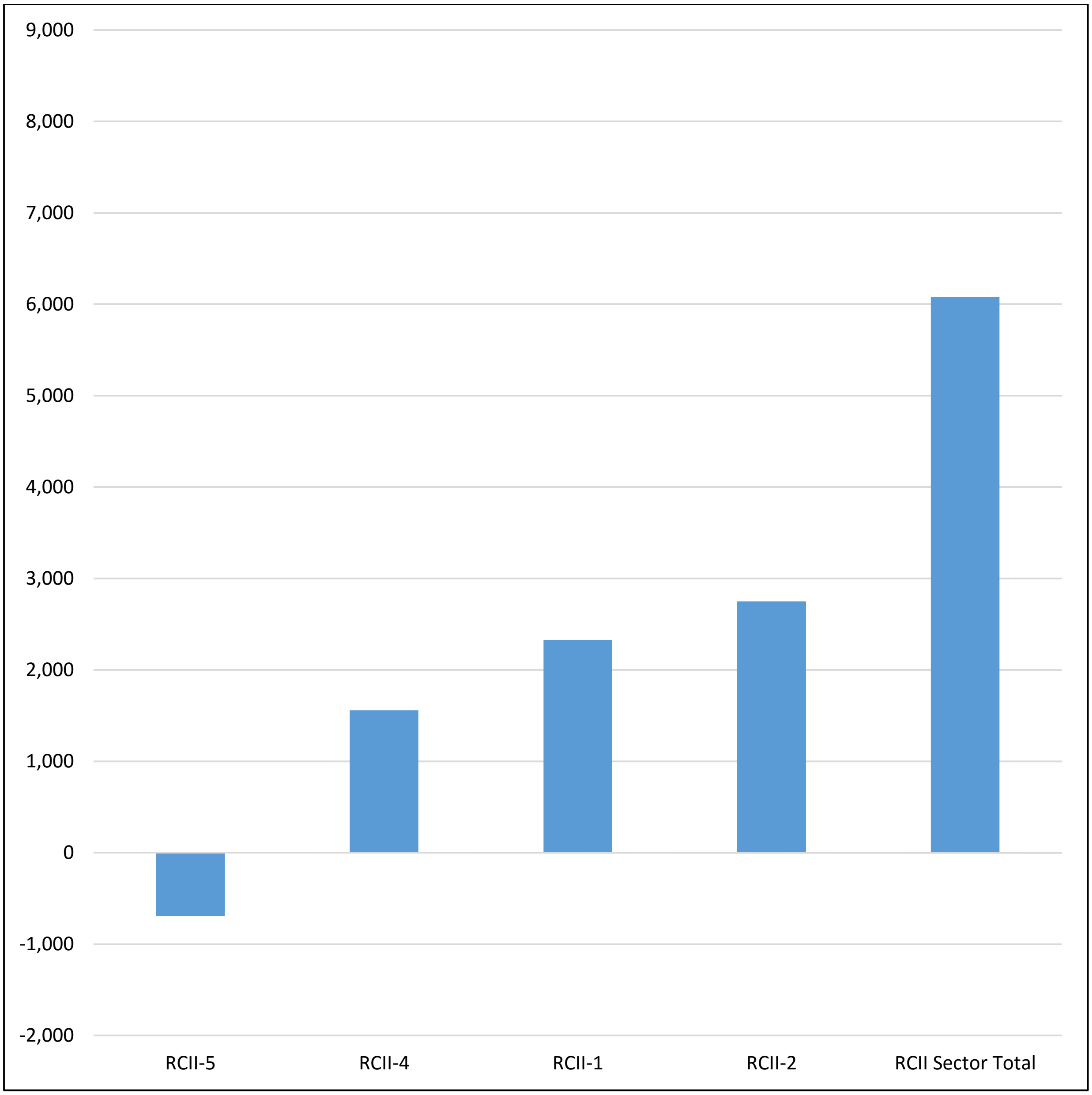
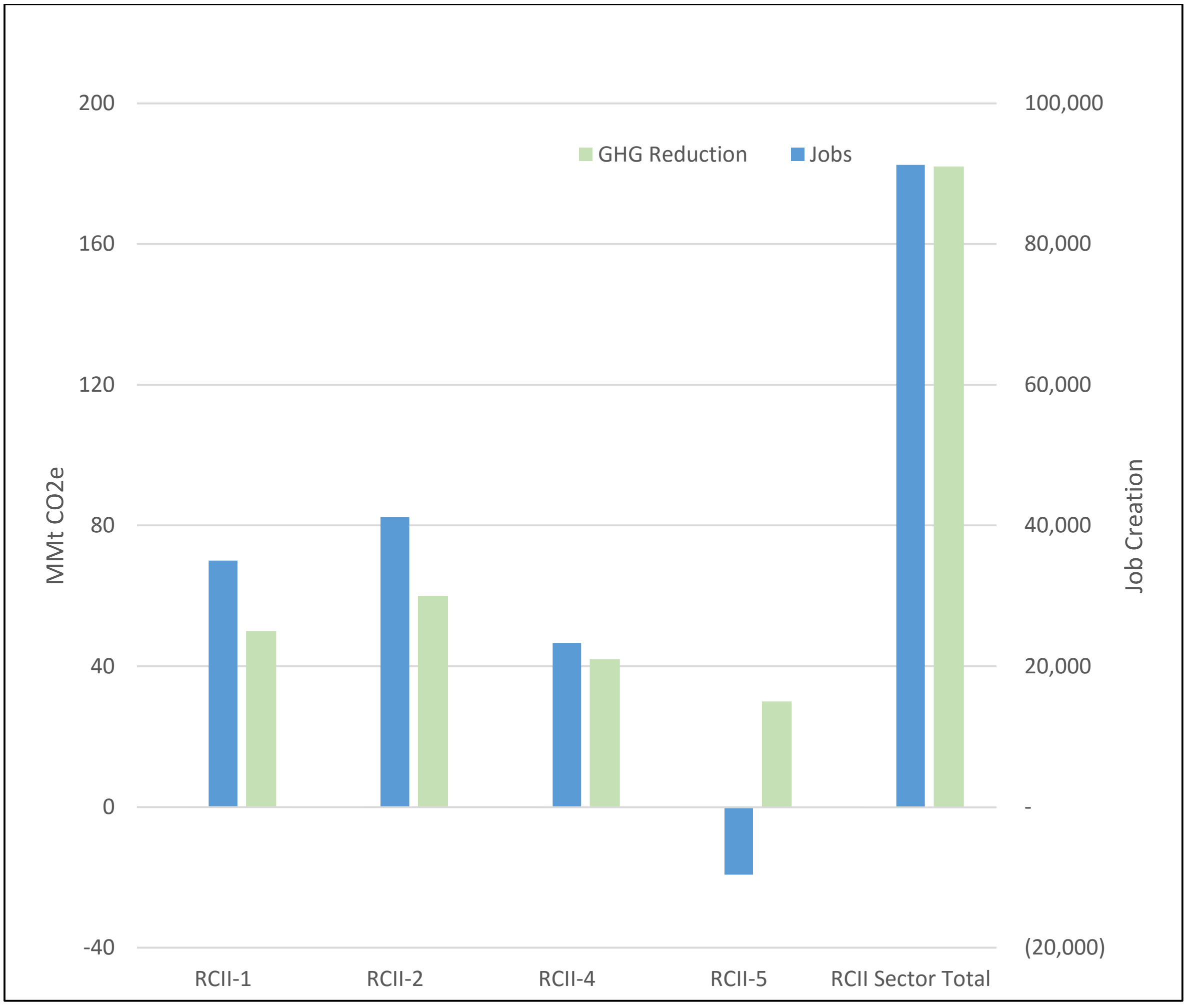


Figure below summarizes a potential for job creation and GHG emissions abatement of RCII sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure IV-29 Job Gains and GHG Reduction by RCII Policy Recommendations, 2016-2030



Macroeconomic Index

Graphs below present the overall macroeconomic impacts of each policy in RCII sector, as well as the sector-level impacts, by using the Macroeconomic Impact Index. The index is a blended score indicating an overall macroeconomic impact of a policy or a set of policies on GSP, income and employment. In this project, the three variables are weighted equally, and indexed based on the maximum value among all the policies in the project. I_GSP, I_Jobs, and I_Income represent the index score for GSP, Jobs and Income, respectively.

Figure IV-30 RCII Macroeconomic Impacts, Year 2030

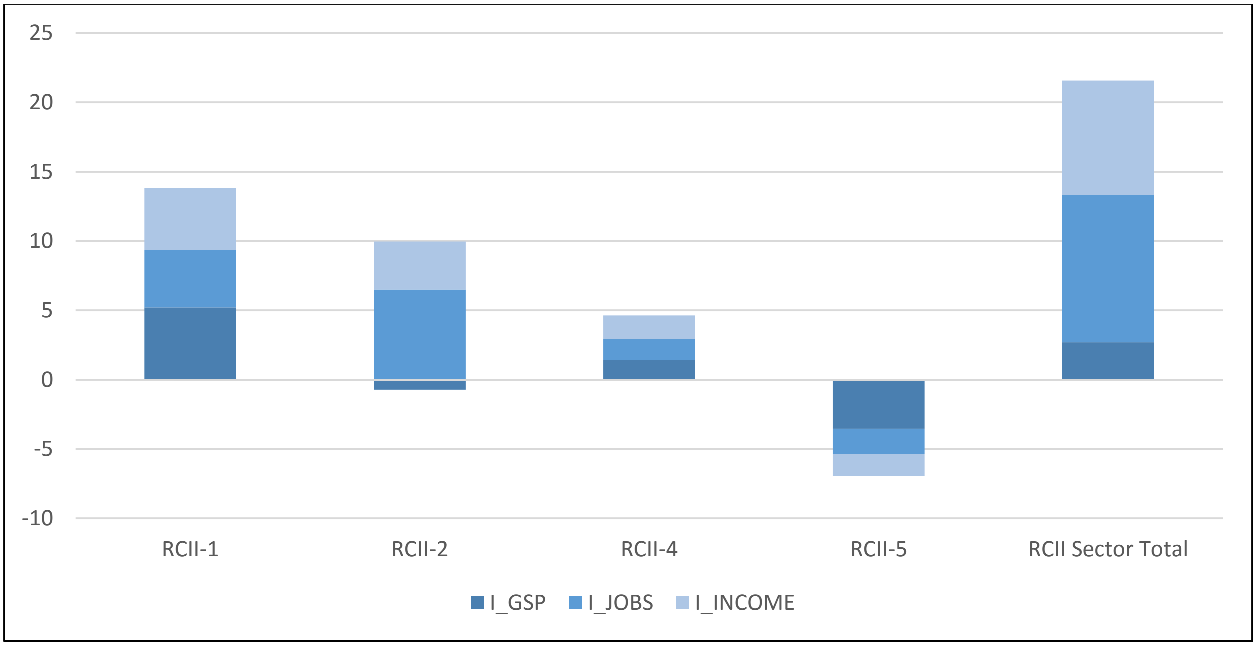


Figure IV-31 RCII Macroeconomic Impacts, Average Annual

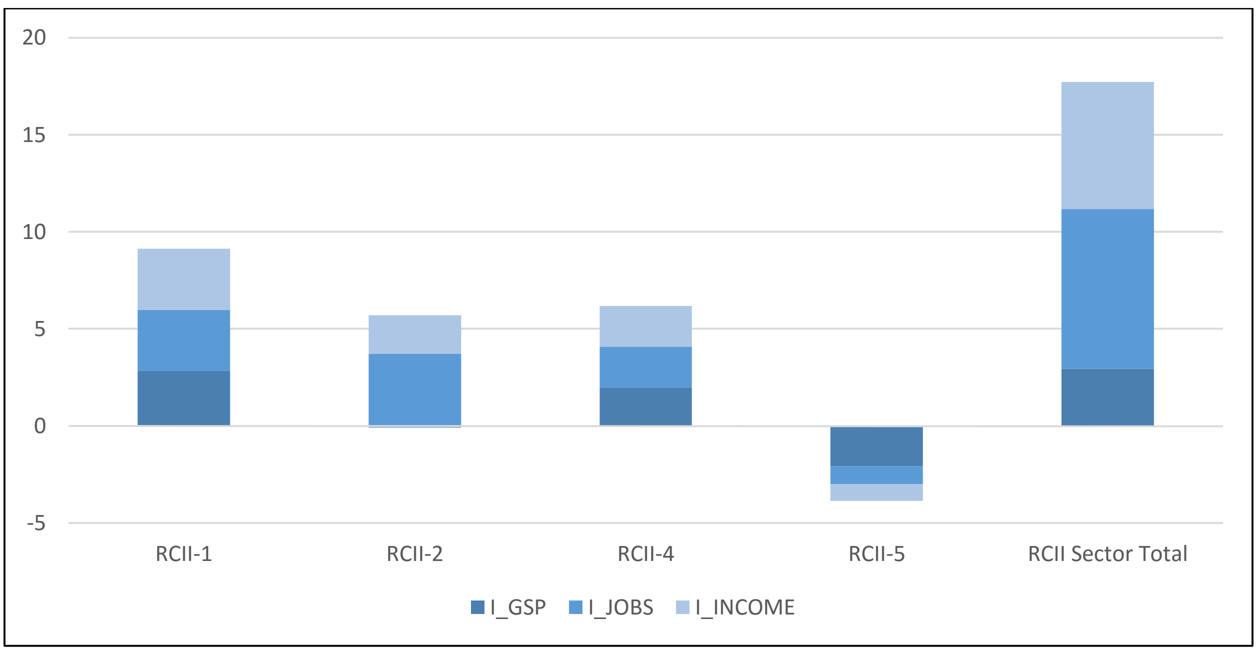
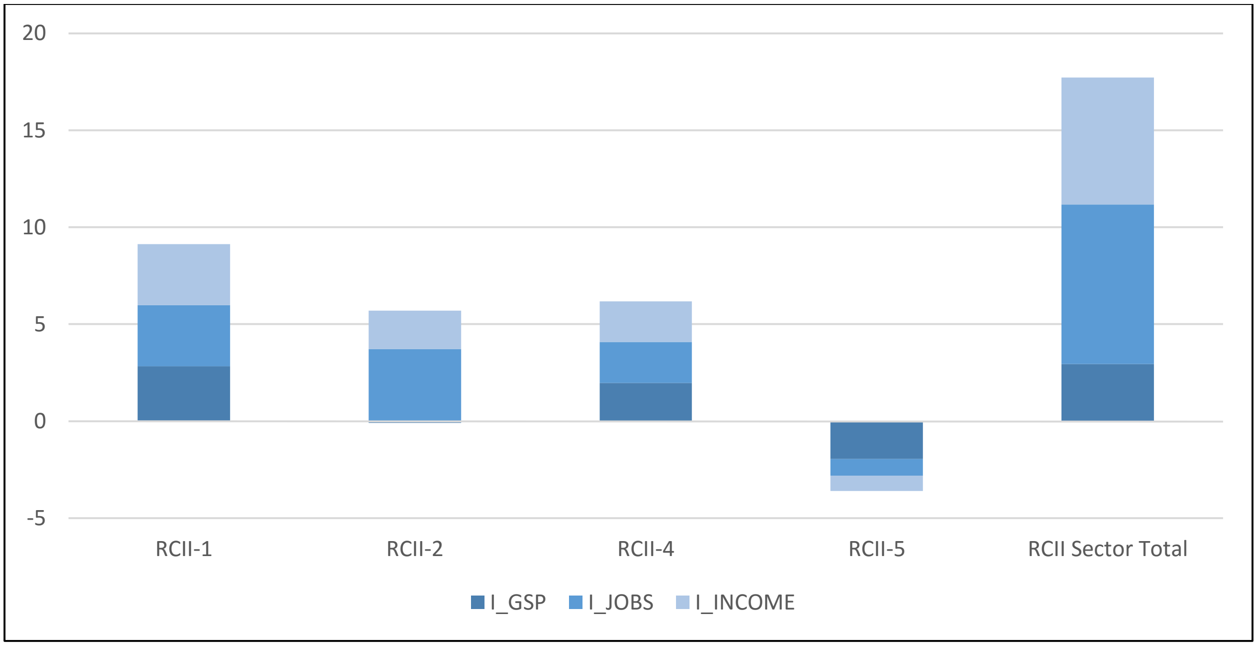


Figure IV-32 RCII Macroeconomic Impacts, 2016-2030



The RCII Sector policies, when taken together, produce significant positive economic impacts on the Minnesota economy. As a bundle, they are projected by this analysis to drive a growth of between $180 million and $270 million per year in the state's GSP through most of the 2016-2030 period.

While GSP holds steady in that range, the jobs and income levels project actually continue to rise throughout the period. Incomes reach $800 million in gains, and the state adds approximately 10,000 new full-time and part-time positions as part of this growth. This profile, where employment metrics respond more strongly than total spending levels (GSP), is a common characteristic of efficiency measures, and much of the focus of the RCII sector policies is on achieving efficiencies.

The most positive policy is RCII-1, which focuses on the implementation of combined heat and power generation (CHP) by utilities and industries. Alone, it is projected to increase GDP by approximately a half billion dollars by 2030, nearly the same amount in incomes, and total employment by 4,000 positions. This is due to a combination of the stimulus from investing in new equipment and technology and the fundamental efficiency achieved by capturing waste heat rather than having to produce that heat separately. RCII-4, which raises the statewide energy efficiency requirement, is also positive but to a smaller scale of impact.

RCII-5, which focuses on renewable thermal energy, however, fares least well. Its overall cost burden, in terms of required investments by households and by institutions and other larger buildings, is never recovered back as savings. Because not all of the expenses incurred go into sectors that are powerful in expanding the economy of the state (either because they rely on imports or because they produce few intermediate demands for other economic activity as inputs), the economy does not benefit from the spending requires as much as it suffers from the burden imposed.

RCII-2 presents a classic efficiency profile: The impact on GSP is effectively neutral, as spending on energy falls aggressively and balances out the spending gains in other sectors. But the efficiency effect – lower costs of living and doing business – drive large growth in incomes and jobs. This pattern is characteristic of efficiency policies, which seek to produce the same welfare benefit (what we use energy for, such as heat and light and productive work) on less input (smaller amounts of electricity or gas).

Line graphs and bar graphs that follow illustrate the above explained policy impacts and economic implications.

Figure IV-33 RCII GSP Impacts ($2015 MM)

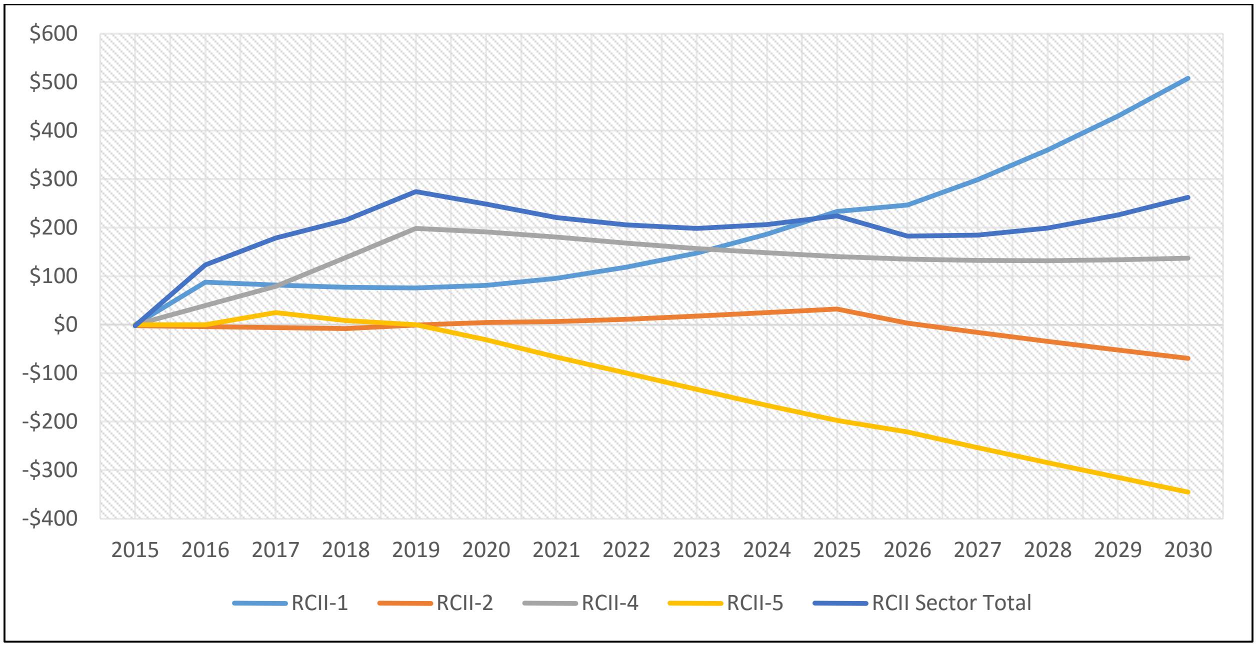


Figure IV-34 RCII Employment Impacts (Jobs)

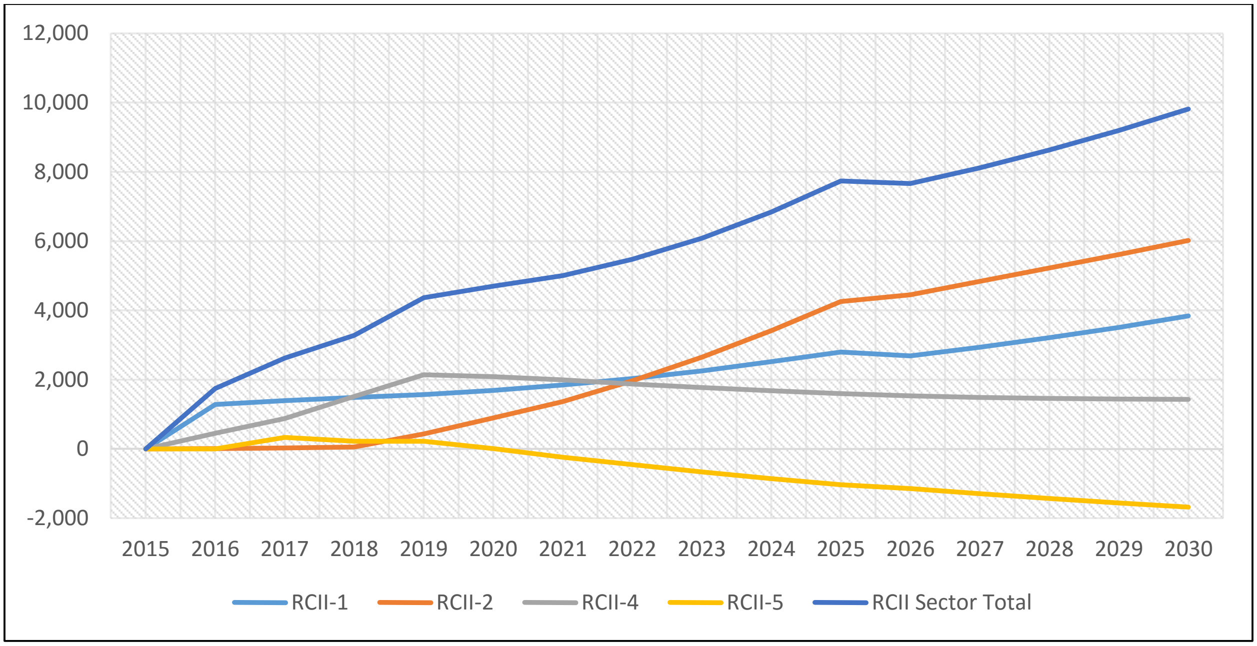
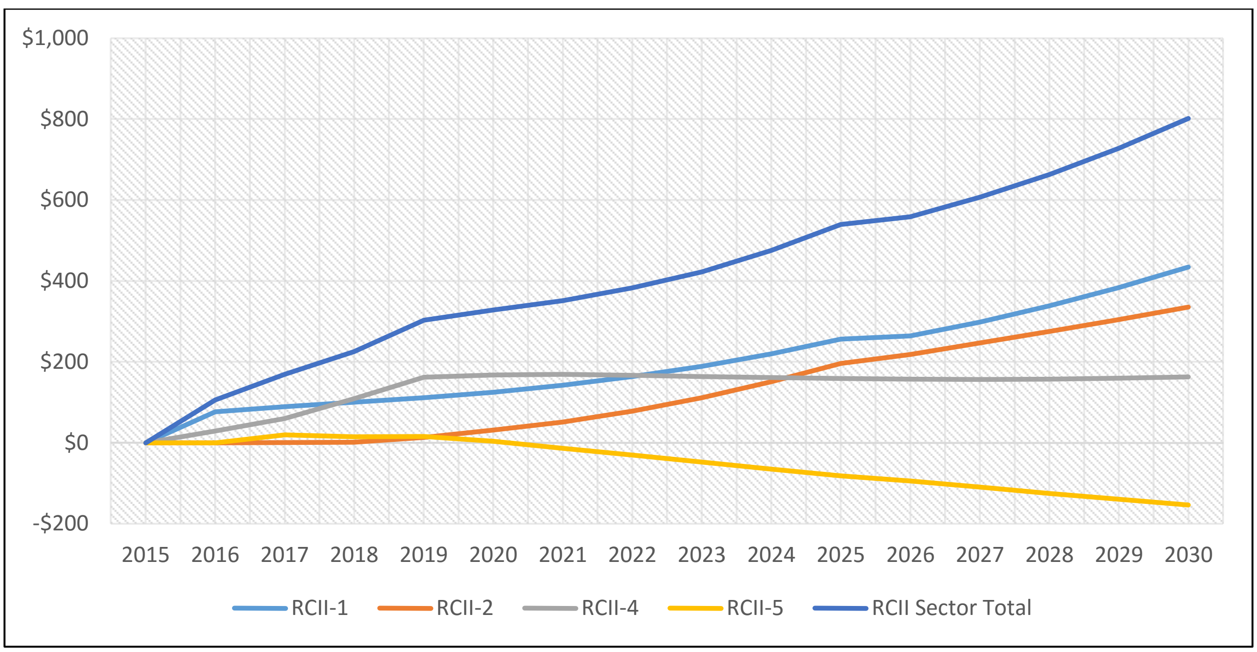


Figure IV-35 RCII Income Impacts ($2015 MM)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030).

Figure IV-36 RCII GSP Impacts, Average Annual ($2015 MM)

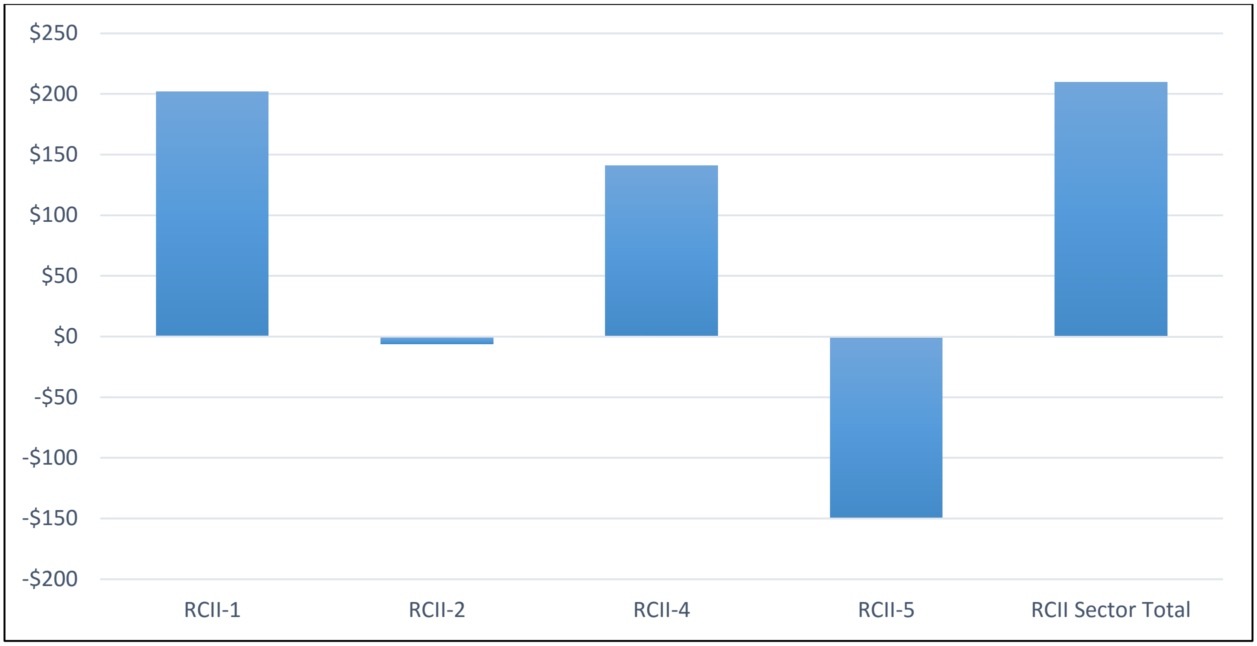


Figure IV-37 RCII GSP Impacts, 2016-2030 ($2015 MM)

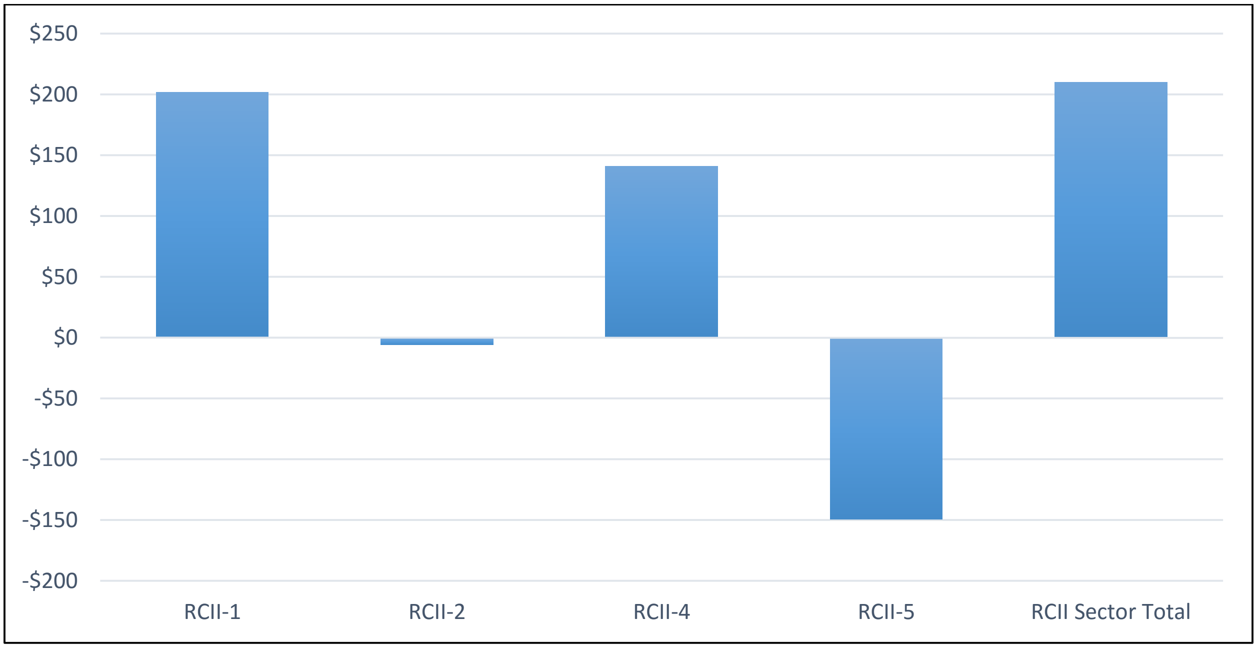


Figure IV-38 RCII GSP Impacts, Year 2030 ($2015 MM)

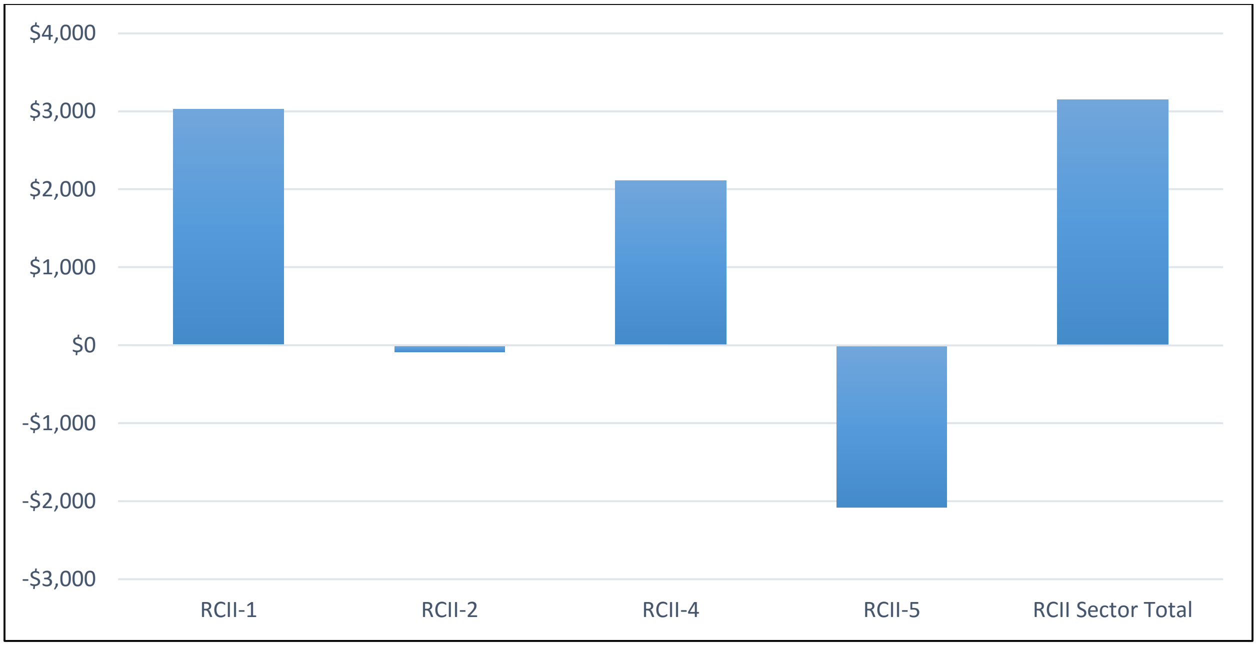


Figure IV-39 RCII Employment Impacts, Average Annual (Jobs)

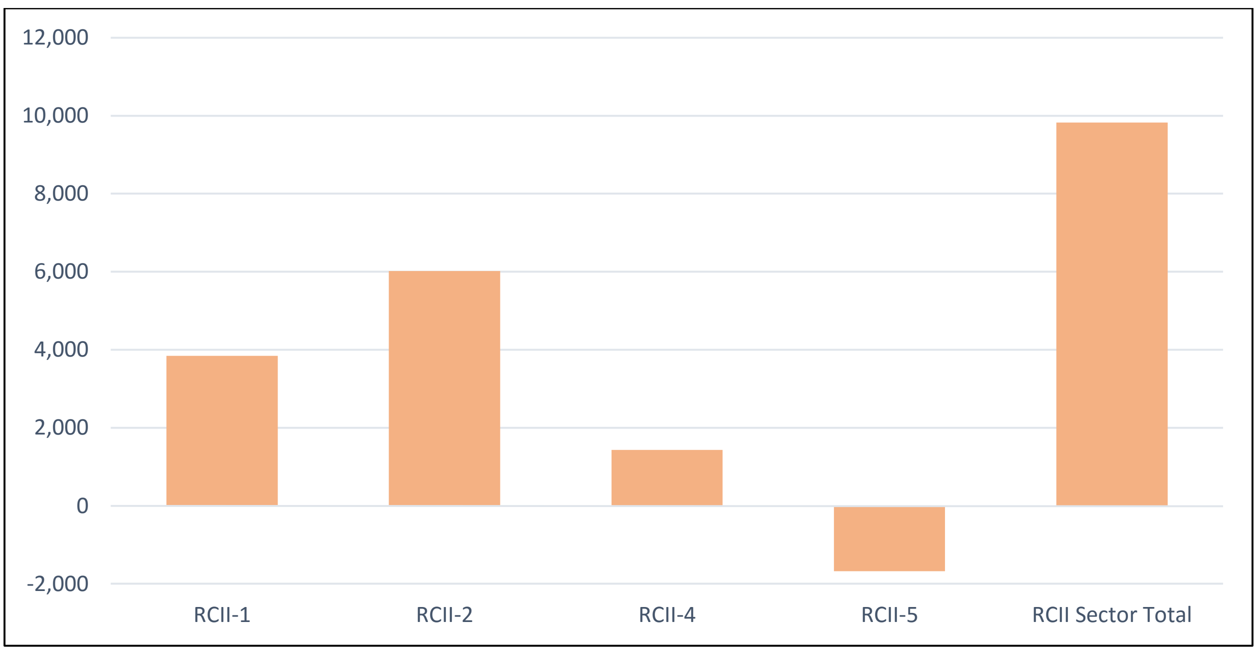


Figure IV-40 RCII Employment Impacts, 2016-2030 (Job Years)

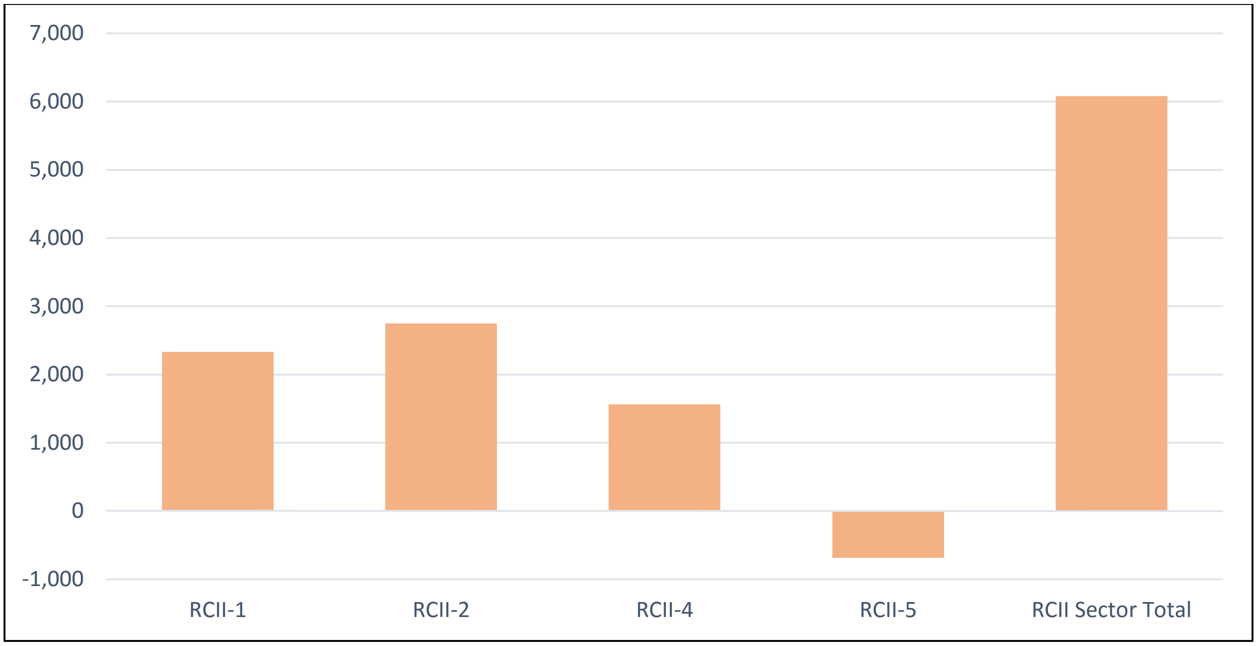


Figure IV-41 RCII Employment Impacts, Year 2030 (Jobs)

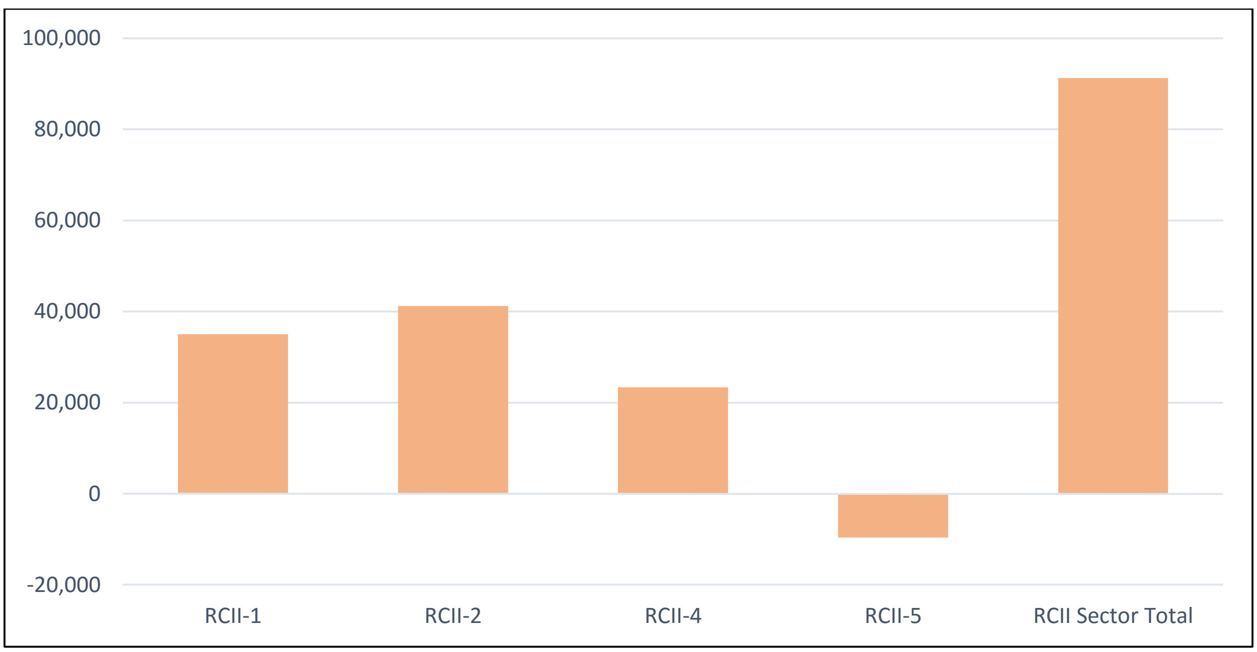


Figure IV-42 RCII Income Impacts, Average Annual ($2015 MM)

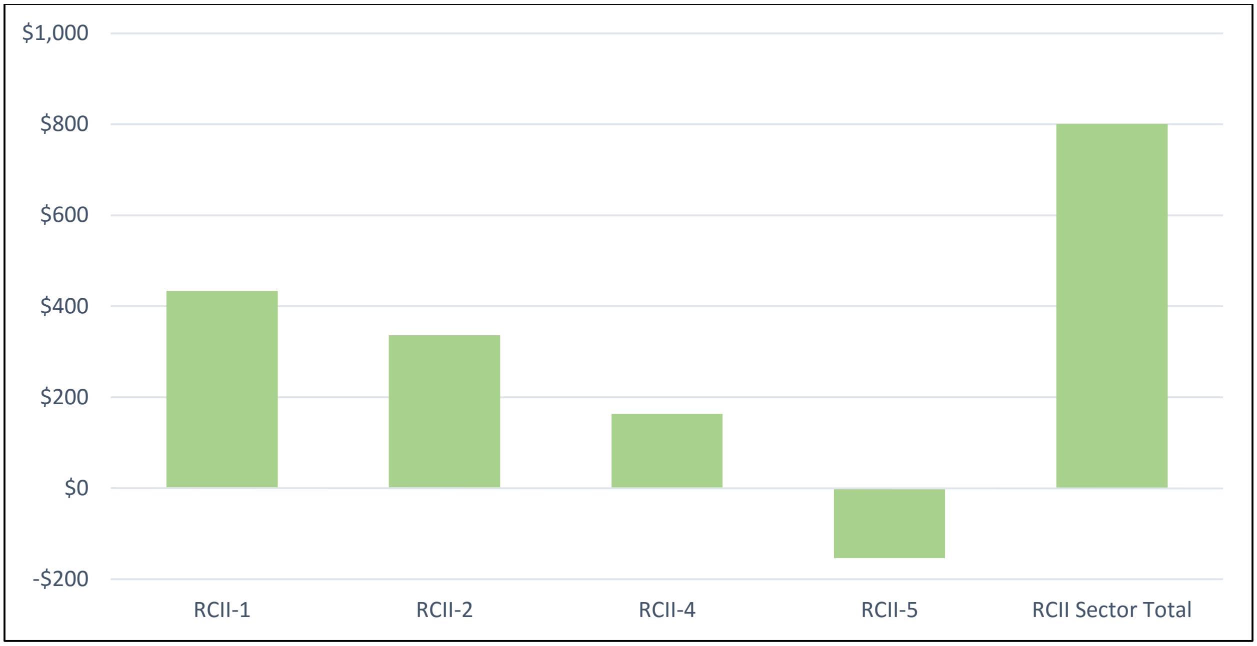


Figure IV-43 RCII Income Impacts, 2016-2030 ($2015 MM)

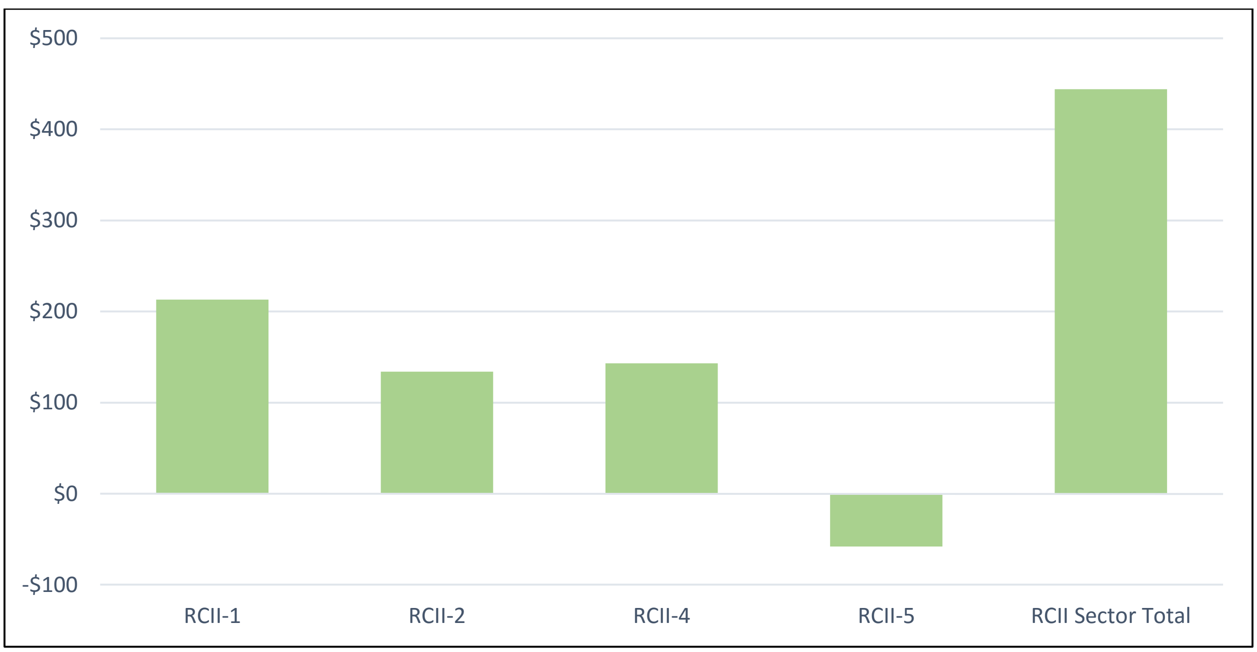
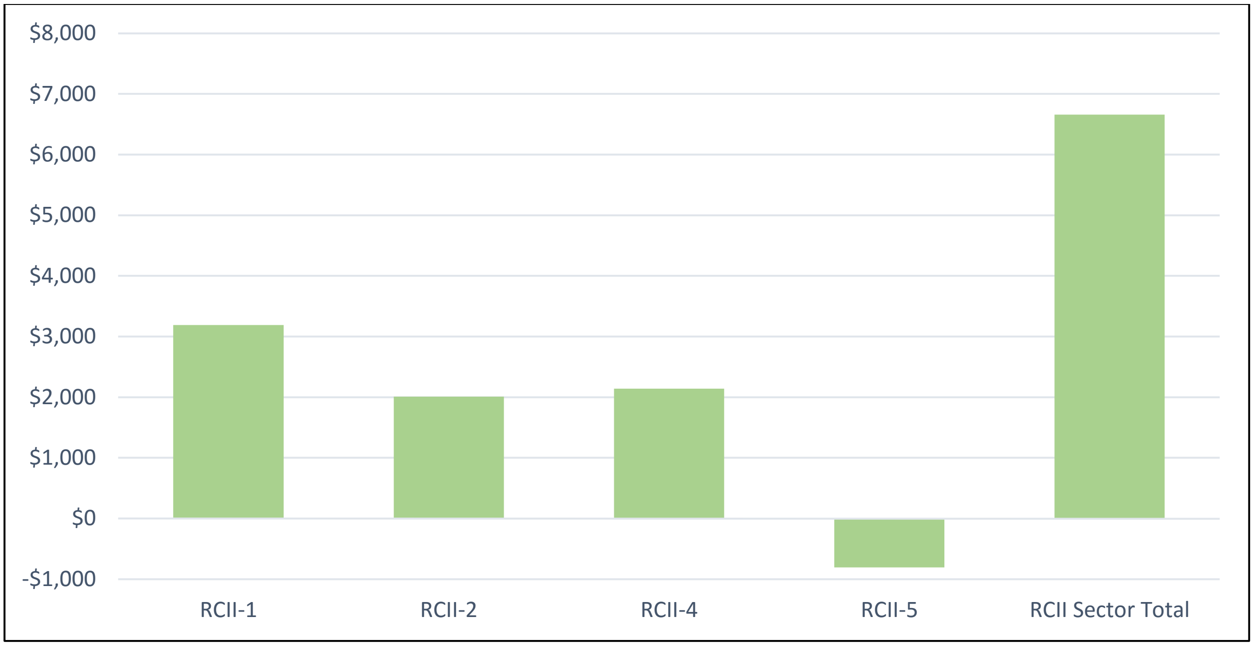


Figure IV-44 RCII Income Impacts, Year 2030 ($2015 MM)



3. Transportation & Land Use

The Transportation and Land Use (TLU) sector covers all forms of transportation, both passenger and freight (air, rail, marine vessel, and on-road vehicles). The sector contributed 22% of the state's total greenhouse gas (GHG) emissions in 2010 and is expected to contribute about the same in 2030 (21%). Of the transportation subsectors, the on-road subsector contributes the most GHG emissions (about 85% of the sector-level emissions in 2010). Key drivers of GHG emissions for the sector include: vehicle-miles traveled by Minnesota drivers; the fuel economy of vehicles on Minnesota roadways; and the carbon content of fuels used by Minnesota vehicles.

Strategies that can be employed to achieve both GHG reductions and positive economic impacts include: increases in fuel economy across the Minnesota vehicle fleet; shifting passenger trips from vehicles to lower emissions modes of travel (e.g. light rail, bus, carpooling, bikes, and pedestrian modes); developing more compact urban areas that reduce commute distances; and the use of lower carbon and locally-sourced transportation fuels.

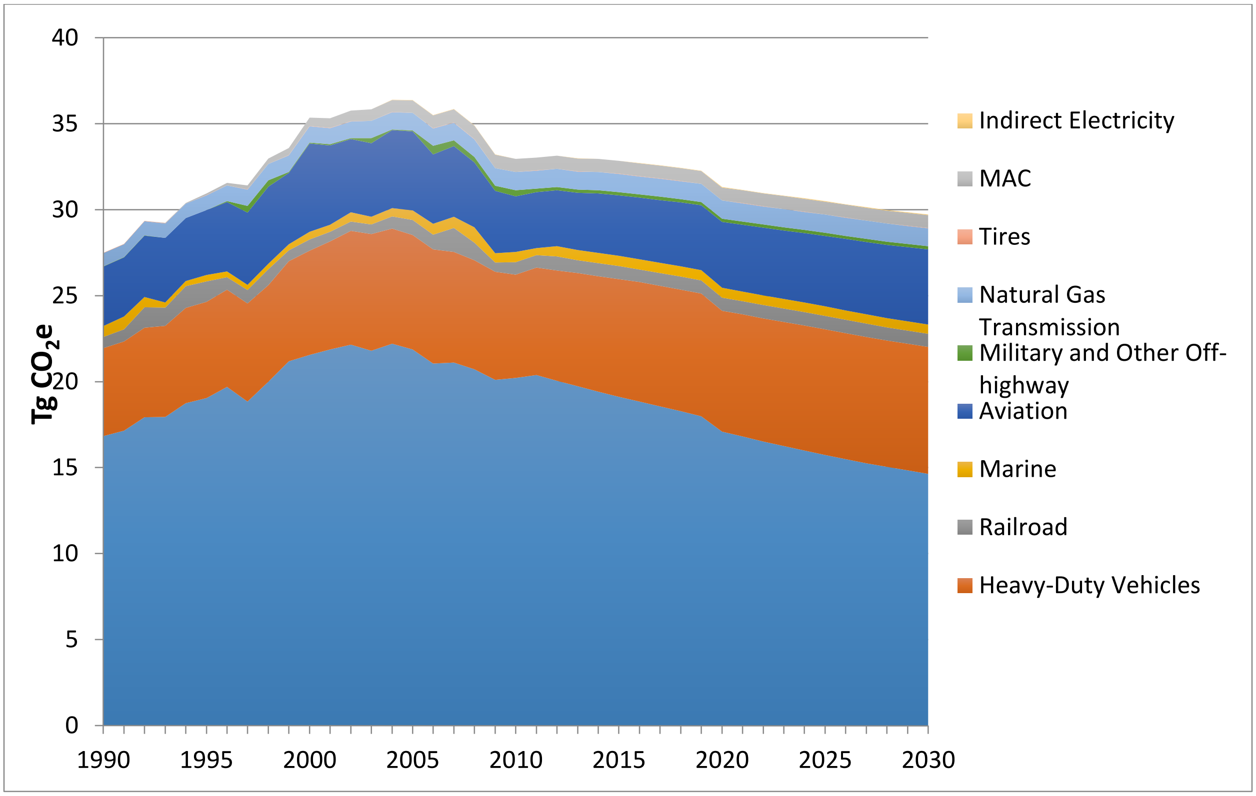
Baseline and Emissions Sources

Figure below provides a summary of the TLU GHG baseline. Emissions are dominated by light- and heavy-duty on-road vehicles. These vehicles are fueled primarily by gasoline and diesel; however, all fuels are included in the chart below (excluded are indirect emissions associated with electricity consumption in vehicles). Small contributions are made from fuel combustion in the rail, marine, aviation, military, and other off-road fuel sectors. Natural gas transmission contributions are shown to grow substantially after 2010. These come from methane (CH_4)

leaks from transmission systems. Tire wear produces carbon dioxide (CO_2) emissions, as that synthetic material breaks down (emission levels are too small to show up in the chart). Finally, mobile air conditioning (MAC) losses of refrigerants make up the rest of the baseline emissions.

GHG emissions are shown to decline during the forecast period. This is brought about primarily through an increase in the on-road vehicle fleet's efficiency as a result of the federal corporate average fuel economy (CAFE) standards, as well as efficiency standards for heavy duty vehicles.

Figure IV-45 TLU Sector GHG Baselines



CSEO Policy Options

There were four policies developed for the TLU sector. These are detailed in Appendix F.3 and are summarized as follows:

TLU-1. Transportation Pricing

Transportation pricing can reduce GHG emissions by increasing the marginal and/or total cost of driving and thereby encourage behavior changes that reduce the total vehicle trips or encouraging the purchase of more fuel-efficient vehicles. This policy option is really three policies that can be independently implemented or combined, which all seek to modify the costs of driving to change transportation behaviors:

- TLU-1A Pay-as-you-go Insurance: Provides incentives for automotive insurance companies to institute pay-as-you-go insurance pricing. This would convert an existing fixed cost for insurance into a per-mile variable cost. This policy option would therefore incentivize a reduction in vehicle miles traveled (VMT) without increasing costs on Minnesota drivers.
- TLU-1B Carbon Tax: This policy option looks at the impacts of assessing a $30 per ton societal cost for each ton of carbon. This amounts to a tax of $0.24 per gallon for E10 gasoline. This carbon tax policy option also rebates to low income households and to address equity issues.
- TLU-1C Fuel Tax: This policy option examines the impact of a 6.5% statewide wholesale fuel sales tax on gross gasoline and special fuel (including diesel) purchases. This strategy is designed to provide both funding for roads and bridges in Minnesota, and potential greenhouse gas emissions reductions.

TLU-2. Improve Land Development and Urban Form

Land use patterns and population density can have a significant impact on transportation and residential energy consumption. This policy option seeks to implement urban planning and development practices in the seven-county metropolitan area that result in greater concentration of development, more compact urban form, more locally diverse uses, and shorter trip distances, thus mitigating VMT and GHG emissions from transportation. Compact urban form, which features increased shares of households in multi-unit buildings and commercial activity in multi-tenant buildings, can also reduce heating and cooling loads, thus mitigating GHG emissions from buildings. Also, greater concentration and more compact urban form can economize on infrastructure expansion, which can further reduce GHG emissions from transportation.

Since urban form and travel behavior are mutually reinforcing factors, limiting growth of VMT will require a suite of coordinated land use and transportation actions. This policy option examines the VMT, fuel consumption and cost impacts of denser development within the seven-county Minneapolis-St. Paul Metropolitan area.

TLU-3. Metropolitan Council Draft 2040 Plan

The Metropolitan Council is currently updating the region's long range transportation plan known as the 2040 Transportation Policy Plan (2040 TPP). This plan is multimodal in character, addressing highway, transit, transitways, pedestrian facilities, bicycle facilities, freight, and aviation. Relevant objectives include reduced transportation-related air emissions; additional MNPASS managed lanes; additional transitways and arterial bus rapid transit lines; increased the use of transit, bicycling, and walking; and increased availability of multimodal travel options. This policy option examines the VMT, fuel consumption and cost impacts of the 2040 TPP, particularly with regard to expanded transit use within the seven county Metro area.

TLU-4. Zero Emission Vehicle Standard

The Zero Emission Vehicle (ZEV) Standard policy option would require automobile manufacturers, through their dealerships, to have a percentage of the total light and medium duty vehicle sales in Minnesota, designated as electric vehicle sales. Electric vehicles are designated as ZEVs because these vehicles have zero emissions from the tailpipe when operating on battery power. ZEVs are four times more efficient than gasoline powered vehicles and have the unique capability of directly using renewable solar or wind-generated electricity for power. These electric vehicles can be plugged-in and charged at night, taking advantage of off-peak electricity production, to help balance utility production load.

As adoption of EVs increases in Minnesota and other parts of the country we will have better information about their integration on of EVs with renewable energy policies and we will see what innovations evolve. For this study, much of these considerations were beyond the scope of the modeling work. To capture the full potential of EVs and illustrate the uncertainty that hinges on the power source of generation, we model two scenarios with bookend numbers:

- EVs as new demand that are met with the electricity at the margin, this is 80/20 coal/natural gas in 2015 and going to 50/50 in 2030; and
- EVs with 100% renewable energy from wind and solar power.

Direct and Indirect Policy Option Impacts

Overview

The tables below provide a summary of the microeconomic analysis of Climate Solutions & Economic Opportunities (CSEO) policies in the Transportation and Land Use (TLU) sector. Table IV-10 provides a summary of results on a stand-alone basis, meaning that each policy option was analyzed separately against baseline (business as usual or BAU) conditions. Details on the analysis of each policy option are provided in each of the Policy Option Documents (PODs) that follow within this appendix.

Direct, Stand Alone Economic Impacts

The stand-alone results provide the annual GHG reductions for 2020 and 2030 in teragrams (Tg) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030 (1 Tg is equal to 1 million metric tons). The reductions shown are just those that have been estimated to occur within the state. Additional GHG reductions, typically those associated with upstream emissions in the supply of fuels or materials, have also been estimated and are reported within each of the analyses in each POD.

Also reported in the stand-alone results is the net present value (NPV) of societal costs/savings for each policy option. These are the net costs of implementing each policy option reported in 2014 dollars. The cost effectiveness (CE) estimated for each policy option is also provided. Cost effectiveness is a common metric that denotes the cost/savings for reducing each metric ton (t) of emissions. Note that the CE estimates use the total emission reductions for the policy option (i.e. those occurring both within and outside of the state).

Results for individual parts of TLU-2 (PAYD insurance, carbon tax, and fuel tax) and TLU-3 (reduced home energy needs, reduced vehicle miles traveled [VMT]) are described within the POD for each policy option.

Integrative Adjustments & Overlaps

The second summary, Table IV-11, above provides the same values described above after an assessment was made of any policy option interactions or overlaps. The TLU-1, -2, and -3 policies all rely on a reduction of VMT. TLU-2 and TLU-3 were considered together, as described in the PODs for these policies; therefore, the estimates already account for any overlap. TLU-1 was adjusted based on the reduction in VMT from TLU-2 and TLU-3. TLU-4 was considered last, with benefits adjusted downward to account for the savings in TLU-1, TLU-2 and TLU-3.

Macroeconomic (Indirect) Economic Impacts

Table IV-12 below provides a summary of the expected impacts of TLU policies on jobs and economic growth during the CSEO planning period. This table focuses on the impact of policies on Gross State Product (the total amount spent on goods and services produced within the state), Employment (the total number of full-time and part-time positions), and Incomes (the total amount earned by households from all possible sources). These metrics represent three valuable indicators of both the overall size of the economy and that economy’s structural orientation toward supporting livelihoods and utilizing productive work.

For the purposes of macro-economic analysis of CSEO policies, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software. This particular REMI model is developed specifically for Minnesota, and is developed consistently with the design of models in use by state agency staff within Minnesota for a range of economic analyses. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

The main inputs for macro-economic analysis are microeconomic estimates of direct costs and savings expected from the implementation of individual policy options. These inputs are supplemented with additional data and assumptions necessary to complete the picture of how these costs and savings (as well as price changes, demand and supply changes, and other factors) influence Minnesota's economy. These additional data and assumptions typically regard how various actors around the state (households, businesses and governments) respond to change by changing their own economic activity. A full articulation of the general and policy-specific assumptions made by the macroeconomic analysis team is provided in the Policy Option Documents, contained as appendices to this report.

Table IV-10 TLU Policy Options, Direct Stand-Alone Impacts

Stand-Alone Analysis							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual CO_2e Reductions[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$\$/tCO_2e$
TLU-1	Transportation Pricing - Total	1.50	2.03	22	28	$2,718	$96
	- PAYD Insurance Component	0.46	1.0	8.8	11	($2,160)	($189)
	- Carbon Tax Component	0.58	0.57	7.1	9.2	$1,898	$205
	- Fuel Tax Component	0.45	0.42	5.8	7.6	$2,980	$394
TLU-2	Improve Land Development and Urban Form - Total	0.31	0.82	6.96	8.17	($425)	($52)
	- Reduced Home Energy Needs Component	0.31	0.82	6.9	8.1	($351)	($43)
	- Reduced VMT Component	0.0027	0.0080	0.064	0.064	($74)	($1,155)
TLU-3	Metropolitan Council Draft 2040 Plan	0.083	0.25	2.0	2.6	($330)	($126)
TLU-4	Zero Emission Vehicle Standard (100%) renewable electricity	0.09	1.25	6.4	7.9	$3,278	$417
TLU-4	*Zero Emission Vehicle Standard (0%) renewable electricity*[e]	*(0.02)*	*(0.42)*	*(2.1)*	*(1.1)*	*$3,237*	*N/A*
Totals		**2.0**	**4.4**	**37**	**47**	**$5,241**	$112

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] TLU-4 0% renewable electricity is a sensitivity scenario not included in "**Totals**" row calculation. This sensitivity scenario increases net GHG emissions above the baseline, thus **cost effectiveness** calculation is not applicable.

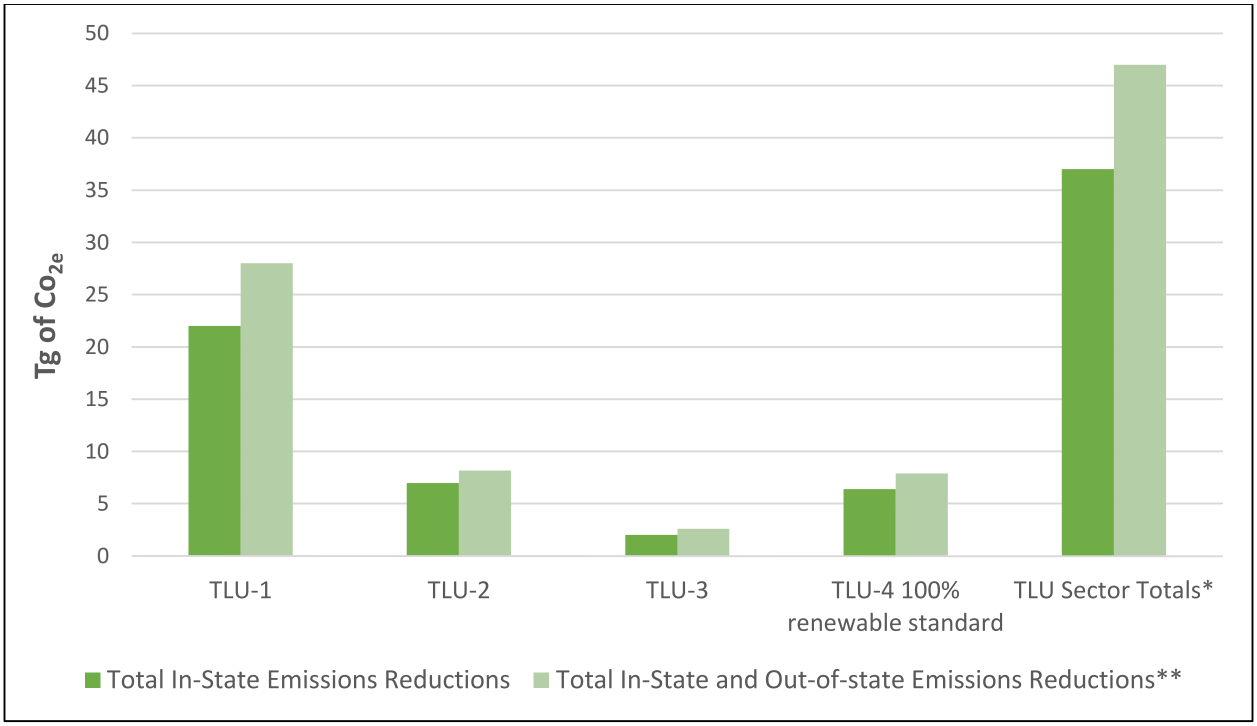
Table IV-11 TLU Policy Options, Intra-Sector Interactions & Overlaps

Intra-Sector Interactions & Overlaps Adjustments							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual CO_2e Reductions[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$\$/tCO_2e$
TLU-1	Transportation Pricing -	1.5	2.0	21	28	$2,718	$97.30

	Total						
	- PAYD Insurance	0.46	1.02	8.67	11.30	($2,160)	($191)
	- Carbon Tax	0.58	0.56	7.01	9.14	$1,898	$208
	- Fuel Tax	0.45	0.41	5.75	7.49	$2,980	$398
TLU-2	Improve Land Development and Urban Form - Total	0.31	0.82	6.96	8.2	($425)	($52)
	- Reduced Home Energy Needs Component	0.31	0.82	6.9	8.11	(351)	($43)
	- Reduced VMT Component	0.0027	0.0080	0.064	0.064	(74)	($1,155)
TLU-3	Metropolitan Council Draft 2040 Plan	0.083	0.25	2.00	2.61	($330)	($126)
TLU-4	Zero Emission Vehicle Standard (100%) renewable electricity	0.08	1.05	5.5	6.8	$3,278	$484
TLU-4	*Zero Emission Vehicle Standard (0%) renewable electricity*[e]	*(0.02)*	*(0.35)*	*(1.8)*	*(1.0)*	*$3,237*	*N/A*
	Total After Intra-Sector Interactions /Overlap	**2.0**	**4.1**	**36**	**45**	**$5,241**	$115

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] TLU-4 0% renewable electricity is a sensitivity scenario not included in "**Totals**" row calculation. This sensitivity scenario increases net GHG emissions above the baseline, thus **cost effectiveness** calculation is not applicable.
Note: Intra-Sector overlap was estimated for all TLU options. TLU-1, 2 and 3 are all options that rely on reducing VMT. The Overlaps analysis looks at TLU-2 and 3 first. These were considered together, because the SmartGAP run indicated that the impacts of these policies are additive. Therefore, no adjustments were made to TLU-2 or TLU-3. TLU-1 is adjusted based on the reduction in VMT from TLU-2 and TLU-3. The benefits of TLU-4 were then adjusted downward to account for the expected VMT reductions from BAU due to implementation of TLU-1, 2 and 3.
There is also an inter-sector overlap of results between the TLU policies and the "Biofuels Package" (Policies AG-4 and AG-5). Those policies will introduce additional advanced biofuels into the Minnesota market which will reduce the overall GHG reduction potential of each TLU policy. The adjustments for that interaction are addressed in the Inter-Sector Integration results.

Figure IV-46 TLU Policies GHG Emissions Abatement, 2016-2030



Notes:
* All Policies Total's comprise emissions reductions achieved by TLU policies combined.
** Total in and out-of-state emissions reduction are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Table IV-12 Macroeconomic Impacts of TLU Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	GSP[a] ($2015 MM)			Employment[b] (Individual)			Personal Income[c] ($2015 MM)		
	Year 2030[d]	Average (2016-2030)[e]	Cumulative (2016-2030)[f]	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
TLU-1	$711	$688	$10,319	8,140	8,230	123,400	$781	$659	$9,885
TLU-2	$4	-$2	-$31	500	220	3,290	$29	$10	$151
TLU-3 Low Transit Cost	$90	$41	$608	830	450	6,740	$43	$20	$302
TLU-3 High Transit Cost	$125	$165	$2,477	1,330	1,720	25,860	$78	$138	$2,068

TLU-4 Falling EV Price	$140	-$65	-$969	-810	-1,220	-18,300	-$56	-$108	-$1,622
TLU-4 High EV Price	-$711	-$354	-$5,315	-7,910	-3,750	-56,240	-$862	-$370	-$5,551
TLU Sector– Low Transit Cost	**$95**	**$372**	**$5,586**	**1,580**	**4,560**	**68,360**	**-$7**	**$319**	**$4,792**
TLU Sector– High Transit Cost	**$130**	**$497**	**$7,452**	**2,080**	**6,420**	**96,350**	**$27**	**$437**	**$6,555**
TLU Sector– Falling EV Price	**$946**	**$620**	**$9,293**	**8,670**	**7,680**	**115,170**	**$798**	**$581**	**$8,722**
TLU Sector– High Transit Cost & Low EV Price	**$981**	**$787**	**$11,799**	**9,170**	**8,950**	**134,270**	**$833**	**$699**	**$10,485**

As the table above shows, the macroeconomic impacts analysis of this sector comprises 5 scenarios including the sector wide analysis:

- TLU-1
- TLU-2
- TLU-3 Low Transit $: TLU-3 default scenario
- TLU-3 High Transit $: TLU-3 sensitivity scenario with high transit capital cost
- TLU-4 High EV $: TLU-4 default scenario
- TLU-4 Low EV $: TLU-4 sensitivity scenario with falling price of EV
- TLU Sector Total Low Transit $: TLU sector-wide default scenario
- TLU Sector Total High Transit $: TLU sector-wide with high transit capital cost scenario
- TLU Sector Total Low EV $: TLU sector-wide with falling price of EV scenario

TLU Sector Total Both Sensitivities: TLU sector-wide with both high transit capital cost and falling price of EV scenarios

The TLU sector has four policies. Two of them (TLU-1 and TLU-4) deal directly with the kinds of vehicles people drive and the incentives they face to drive less. Two deal with urban form and transit access (TLU-2 and TLU-3).

The vehicles policies generate large impacts on the Minnesota economy, with TLU-1 (focusing on fuel taxes, carbon taxes and pay-as-you-go insurance) producing very significant positive gains, and TLU-4 (focusing on driving adoption of electric vehicles) being weighed down in early years by electric vehicle prices. Once the vehicle prices recede (particularly after 2025), the policy trends upward and is positive in its impacts.

The urban form and transit policies, by comparison, produce relatively small impacts, outside of a short positive spike in construction spending driven by the investment by state and federal entities in new transit infrastructure.

Overall, the sector does very well as a result of TLU-1, 2 and 3, and as electric vehicle prices in TLU-4 fall gradually to parity with other vehicles (a point they reach in 2030, in this forecast), the sector's impacts trend positive again and appear to indicate further growth past 2030.

Line graphs and bar charts that follow illustrate the above explained broader economic impacts of the TLU policies.

Figure IV-47 Net Job Creation for TLU Policies and TLU Sector by Ascending Order, 2016-2030

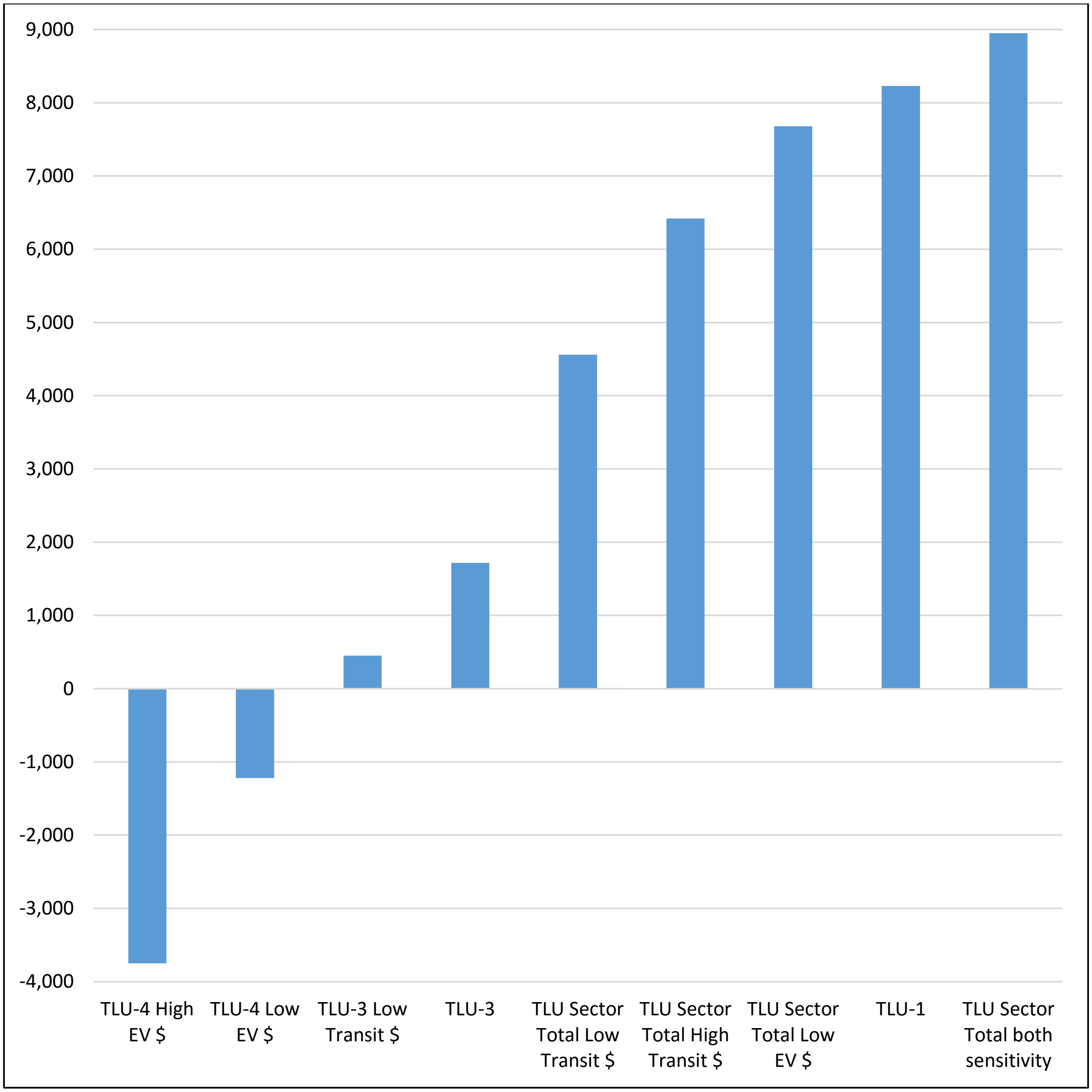
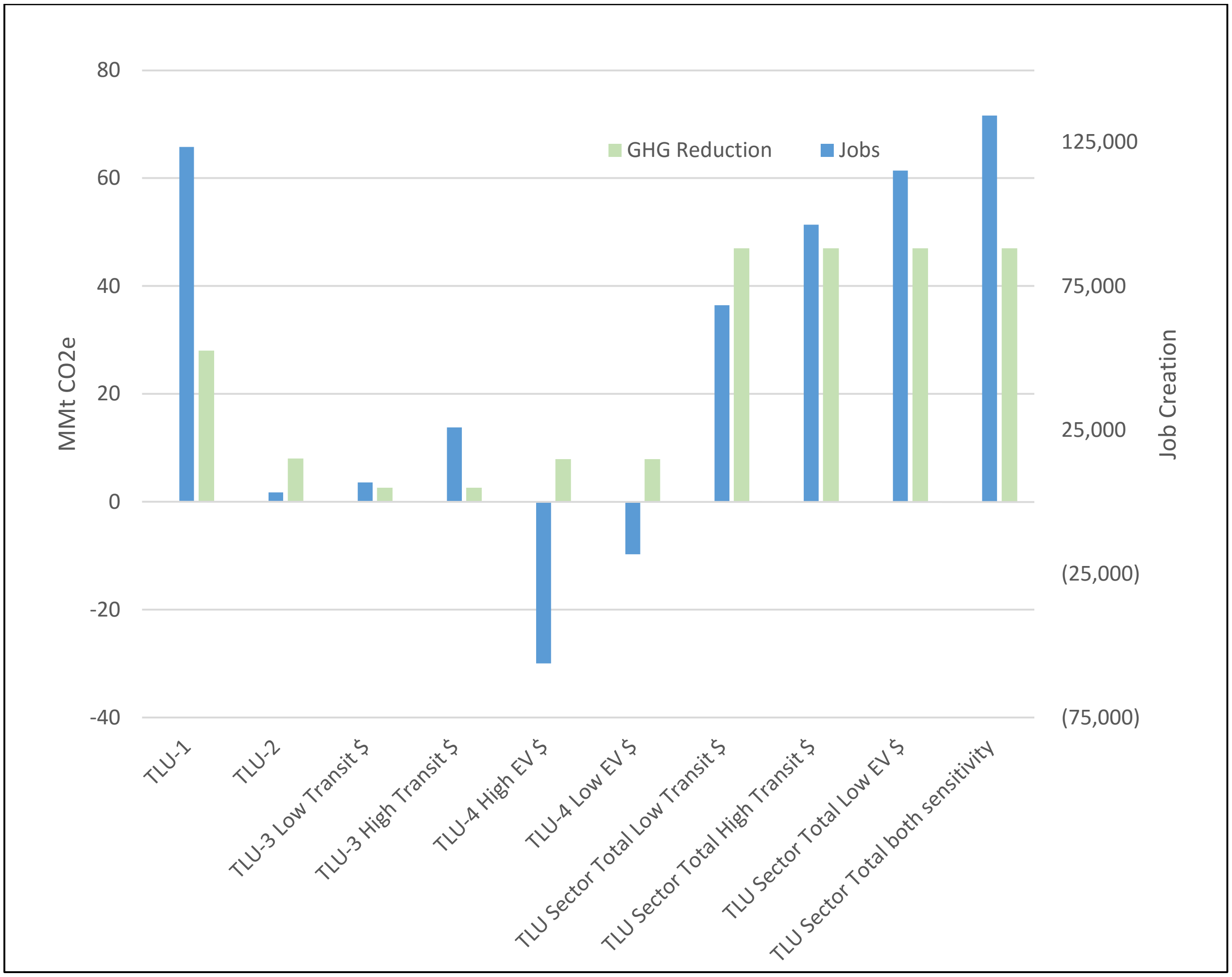


Figure below summarizes a potential for job creation and GHG emissions abatement of TLU sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure IV-48 Job Gains and GHG Reduction by TLU Policy Recommendations, 2016-2030



Macroeconomic Indicators

Graphs below present the overall macroeconomic impacts of each policy in the TLU sector, as well as the sector-level impacts, by using the Macroeconomic Impact Index. The index is a blended score indicating overall macroeconomic impact of a policy or a set of policies on GSP, income and employment. In this project, the three variables are weighted equally, and indexed based on the maximum value among all the policies. I_GSP, I_Jobs, and I_Income represent the index score for GSP, Jobs and Income, respectively.

Figure IV-49 TLU Macroeconomic Indicators, 2030

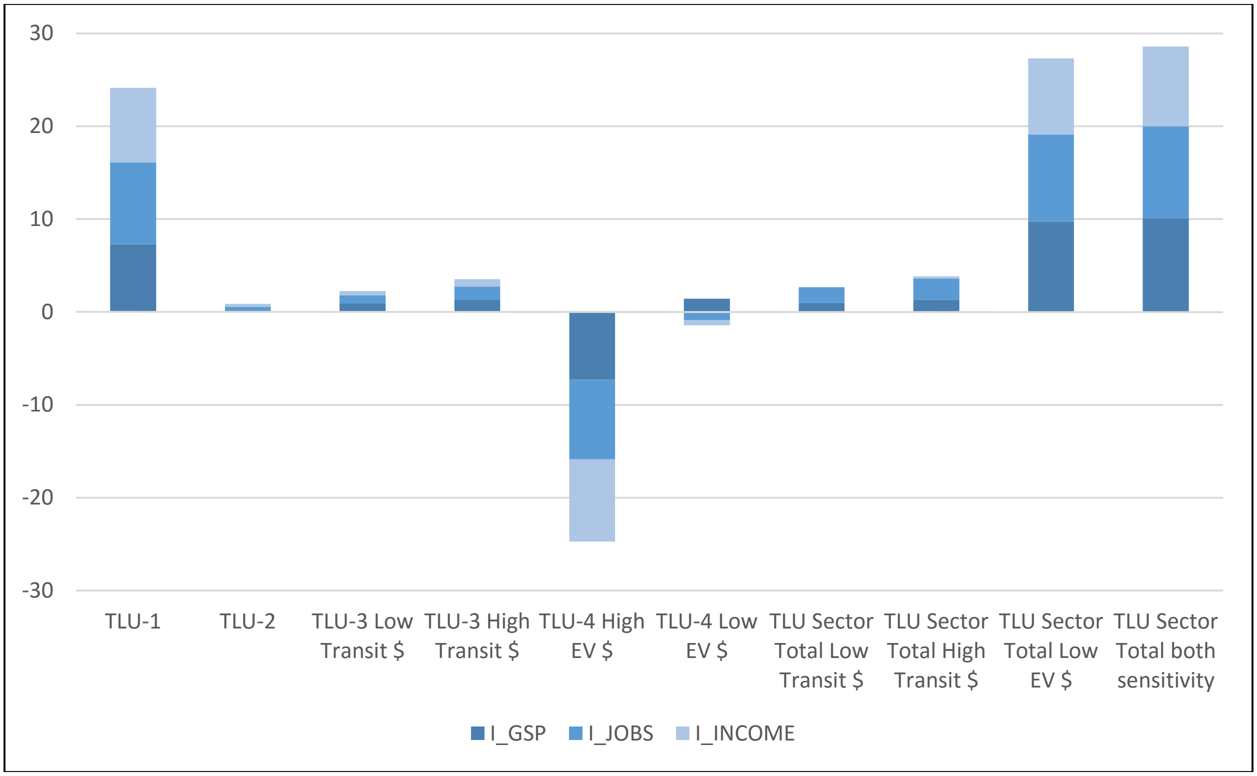


Figure IV-50 TLU Macroeconomic Indicators, 2016-2030 Average Annual

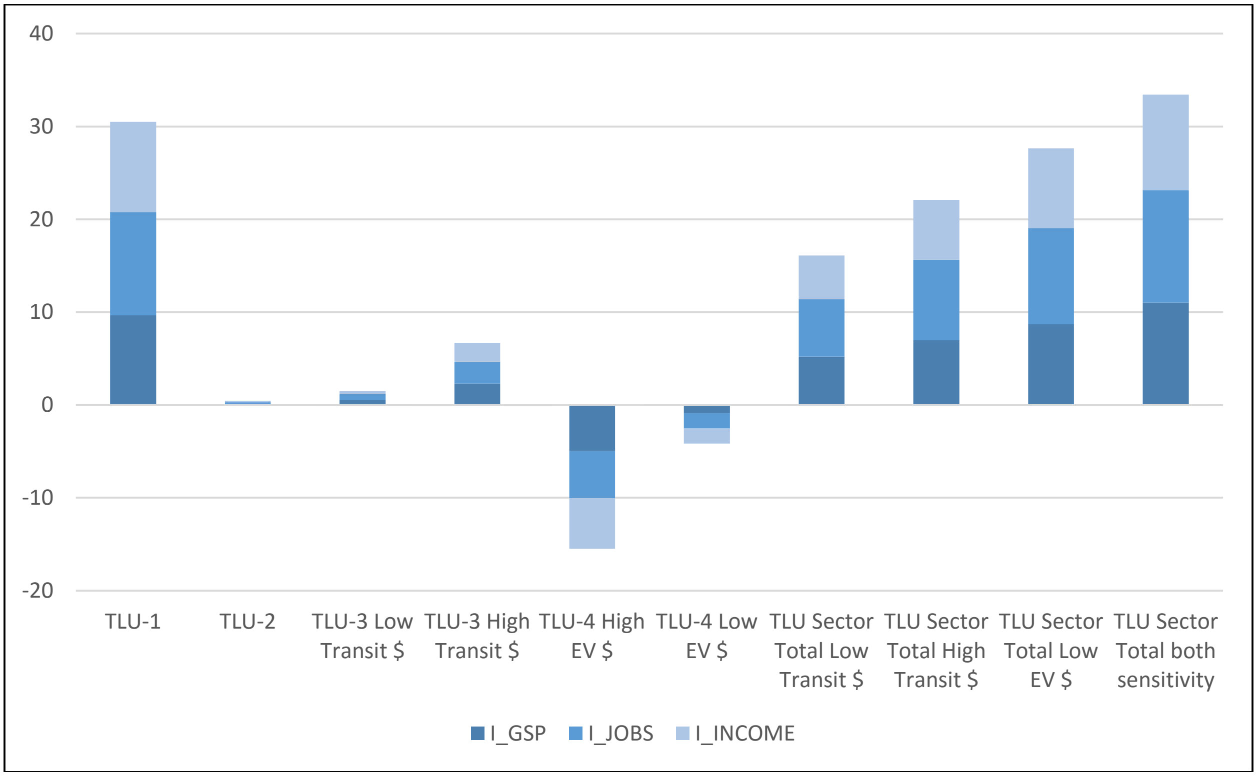
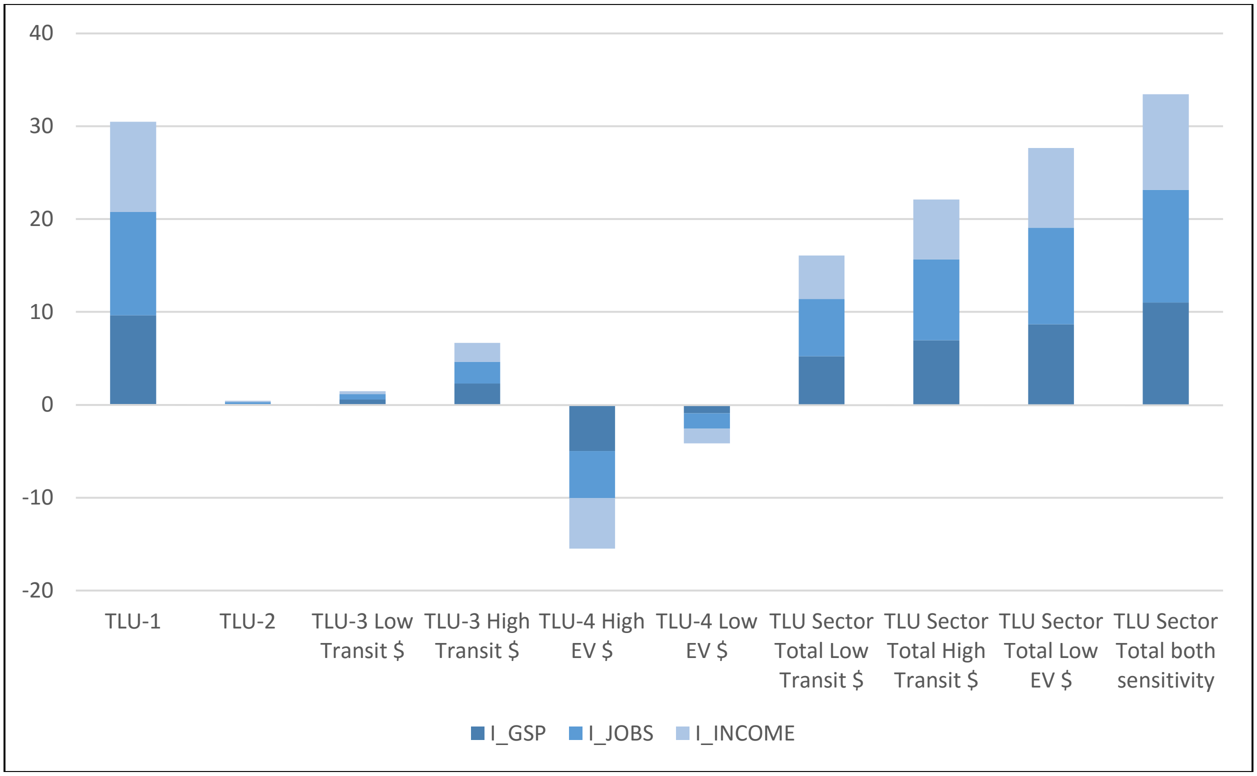


Figure IV-51 TLU Macroeconomic Indicators, 2016-2030



Graphs below show the trend of TLU policy macroeconomic impacts during the year 2015 to the year 2030.

Figure IV-52 TLU GSP Impacts ($2015 MM)

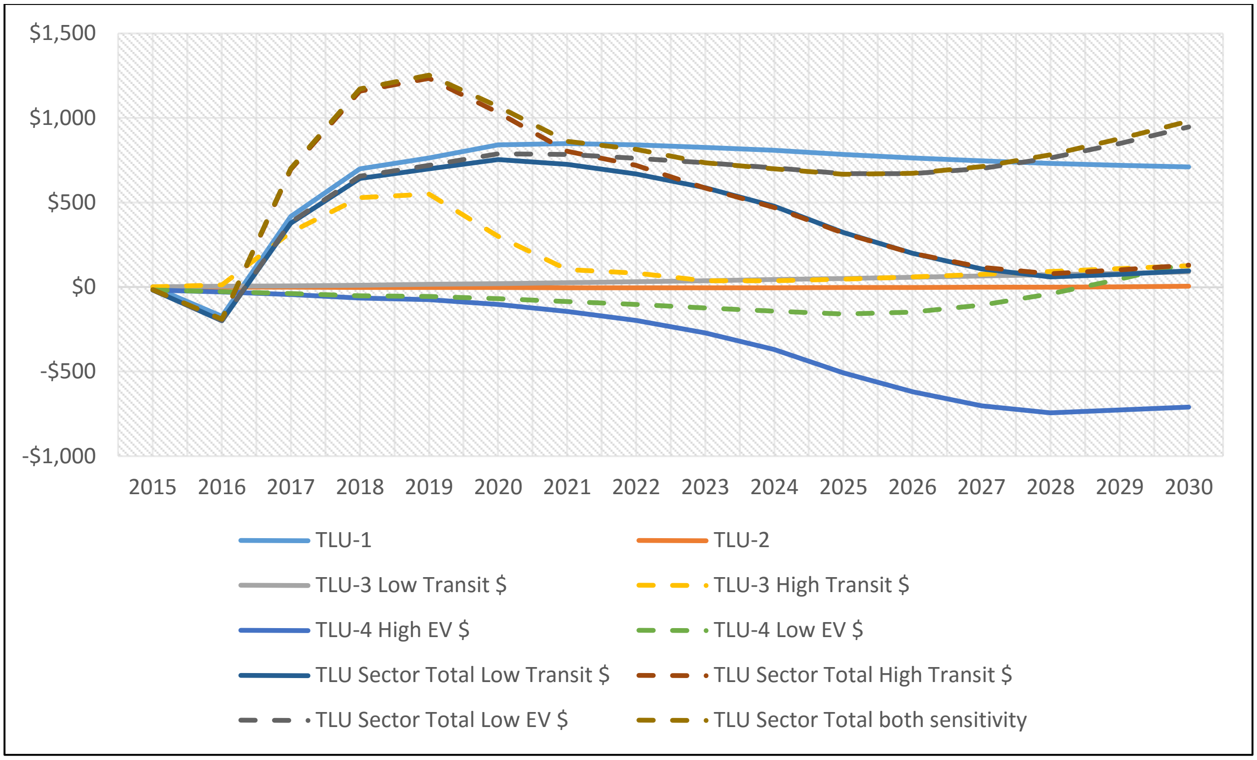


Figure IV-53 TLU Income Impacts ($2015 MM)

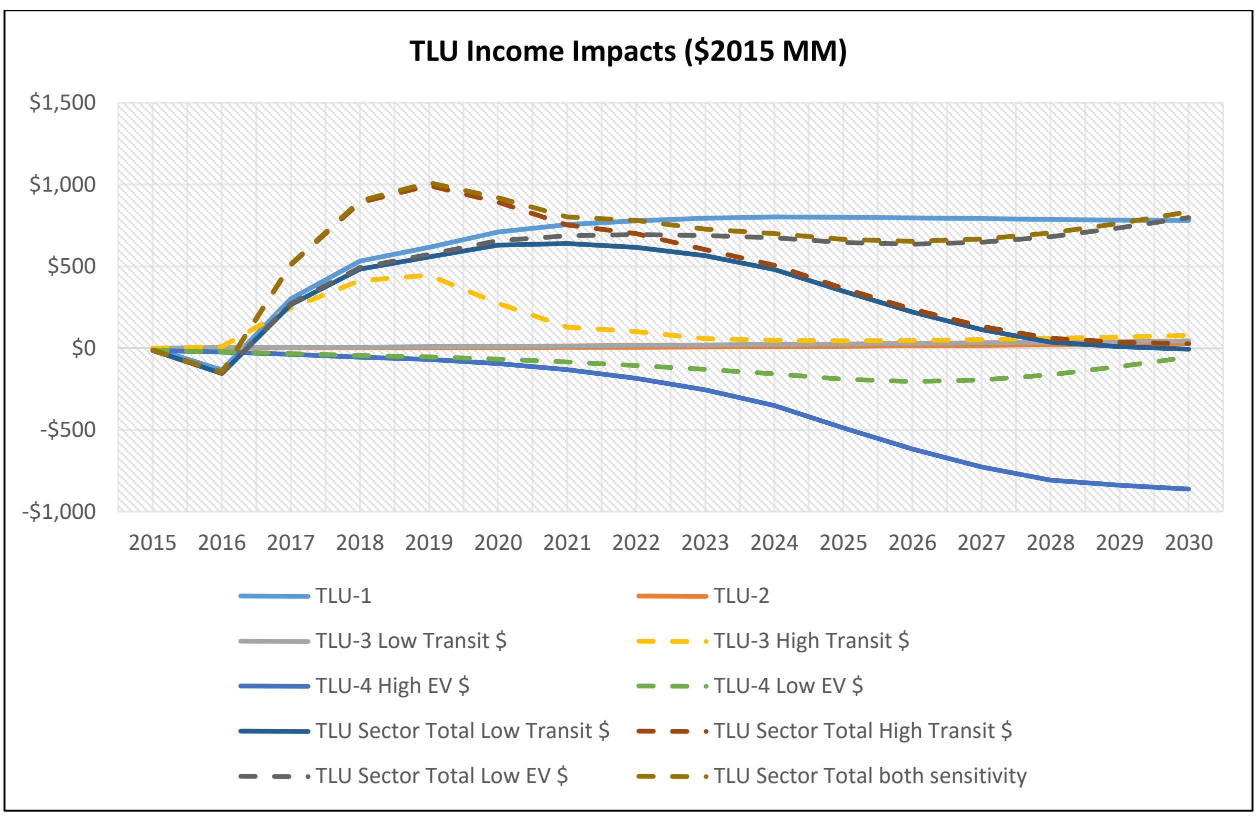
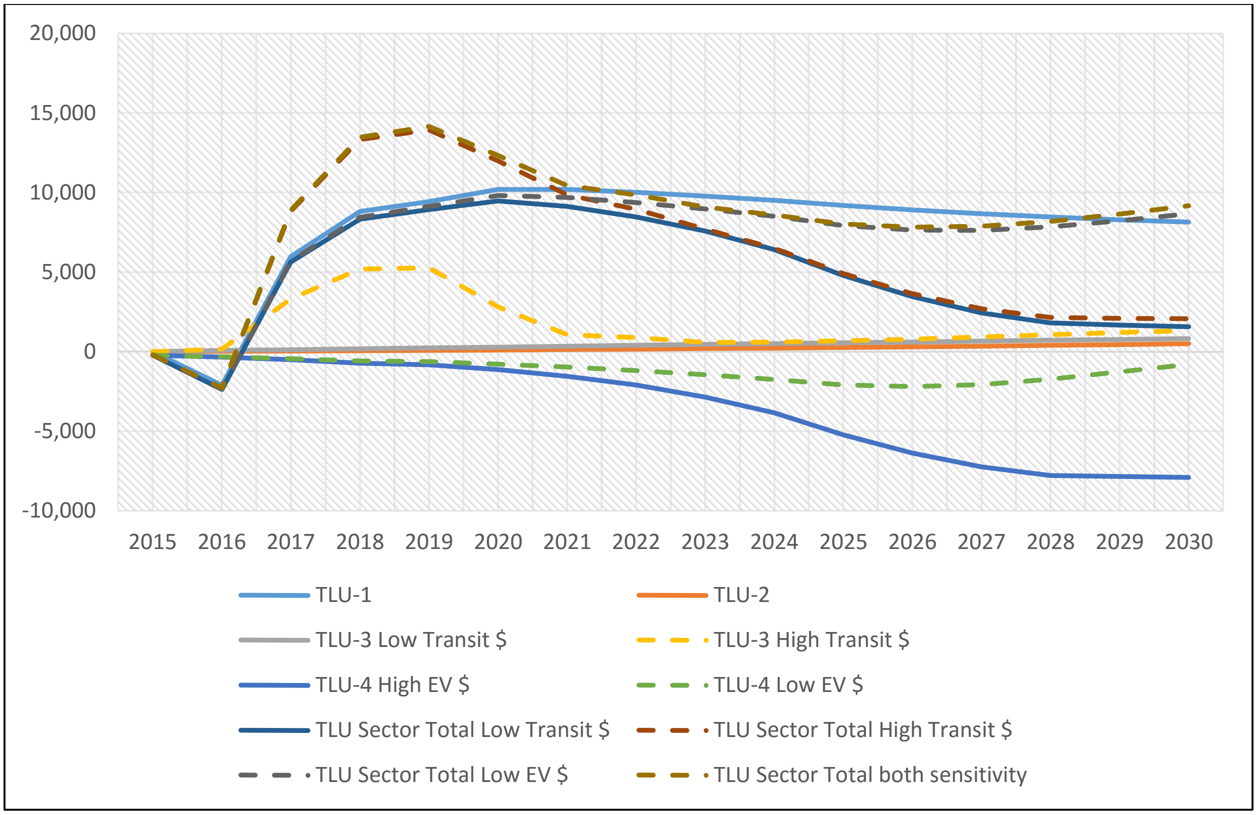


Figure IV-54 TLU Employment Impacts (Jobs)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), average (2016-2030) and cumulative (2016-2030). Lighter color indicates sensitivity scenarios.

Figure IV-55 TLU GSP Impacts, Average Annual ($2015 MM)

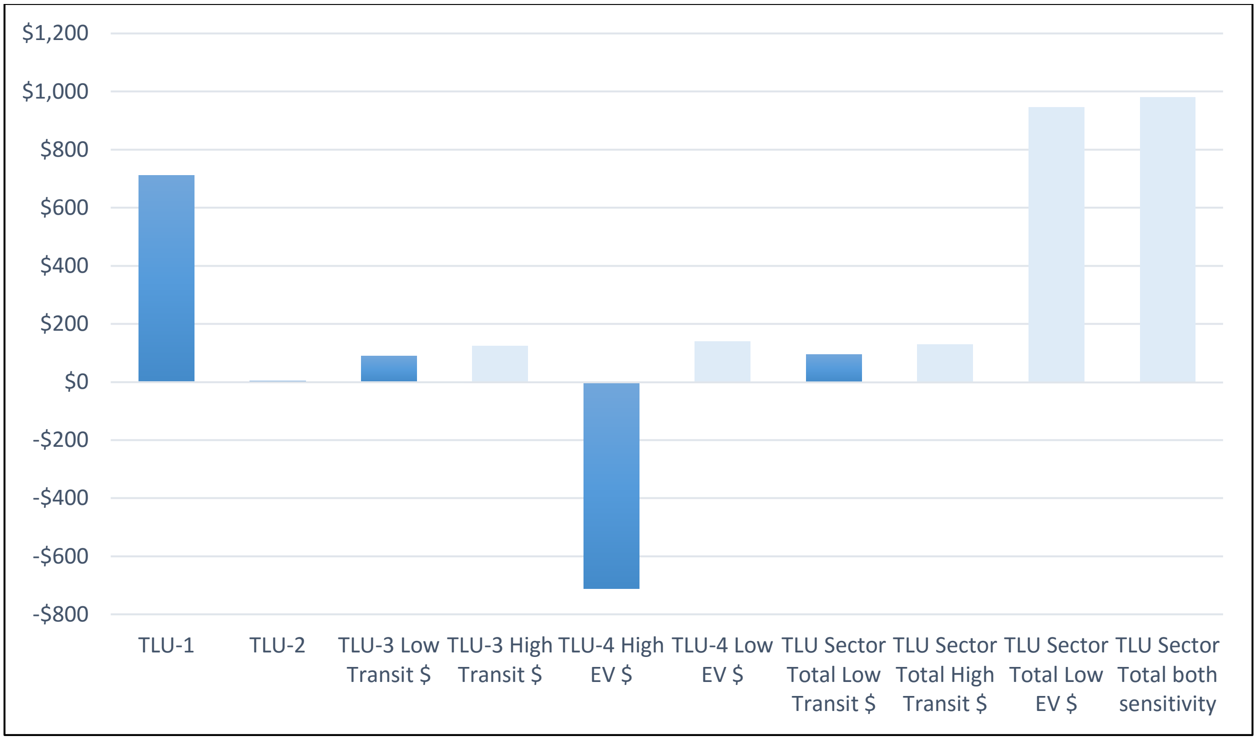


Figure IV-56 TLU GSP Impacts, 2016-2030 ($2015 MM)

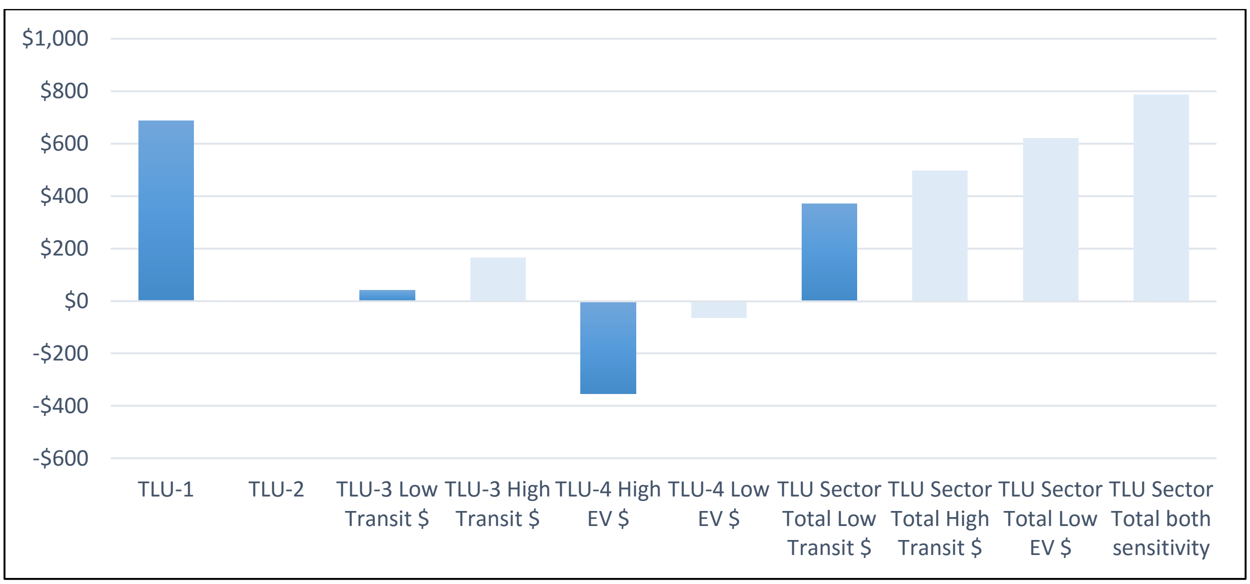


Figure IV-57 TLU GSP Impacts, Year 2030 ($2015 MM)

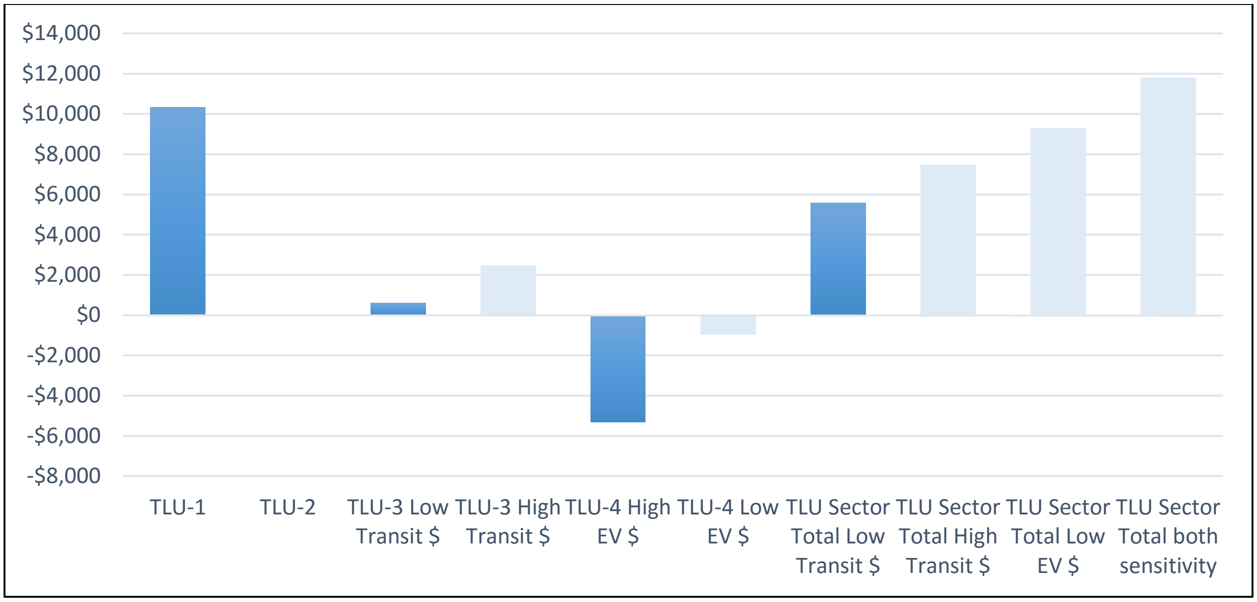


Figure IV-58 TLU Employment Impacts, 2016-2030 Average Annual (Jobs)

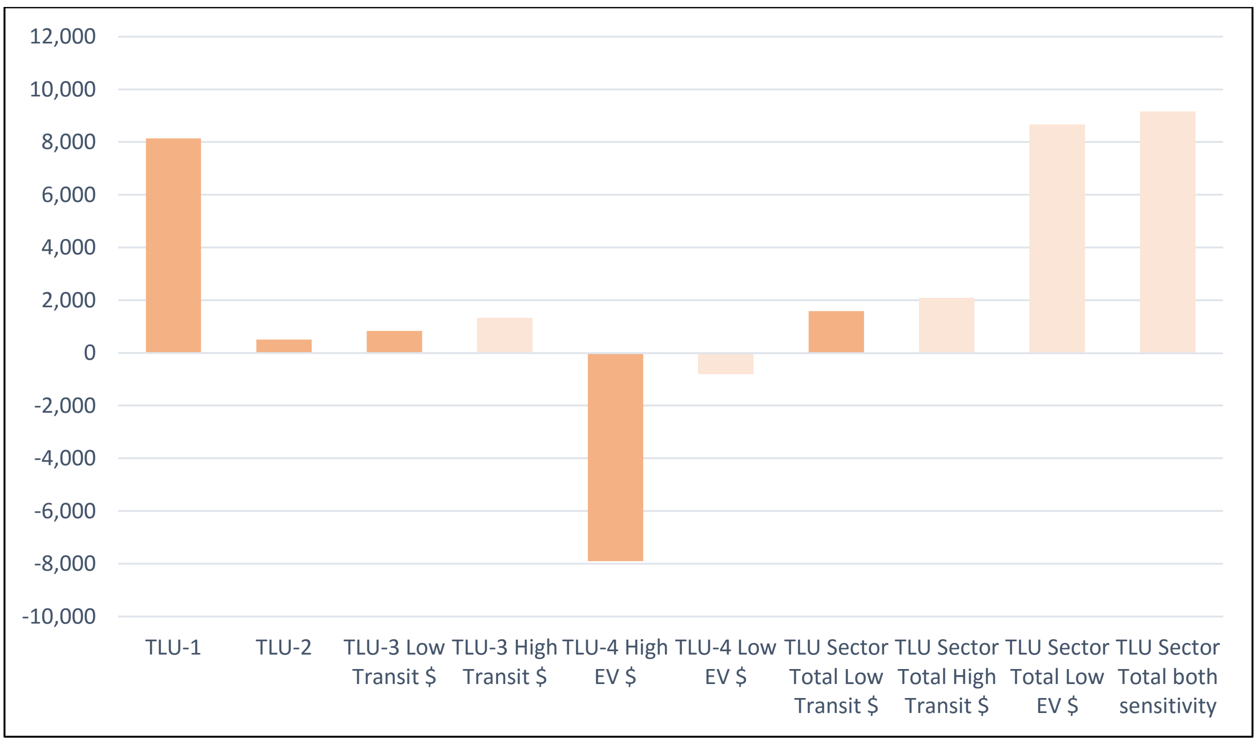


Figure IV-59 TLU Employment Impacts, 2016-2030 (Job Years)

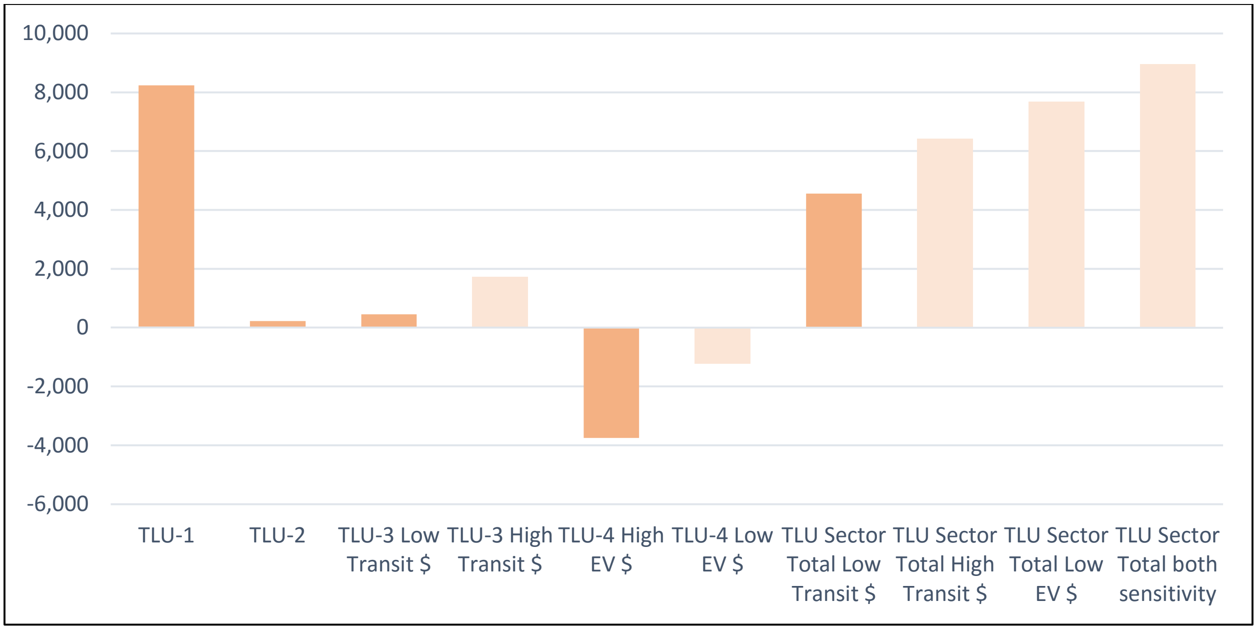


Figure IV-60 TLU Employment Impacts, Year 2030 (Jobs)

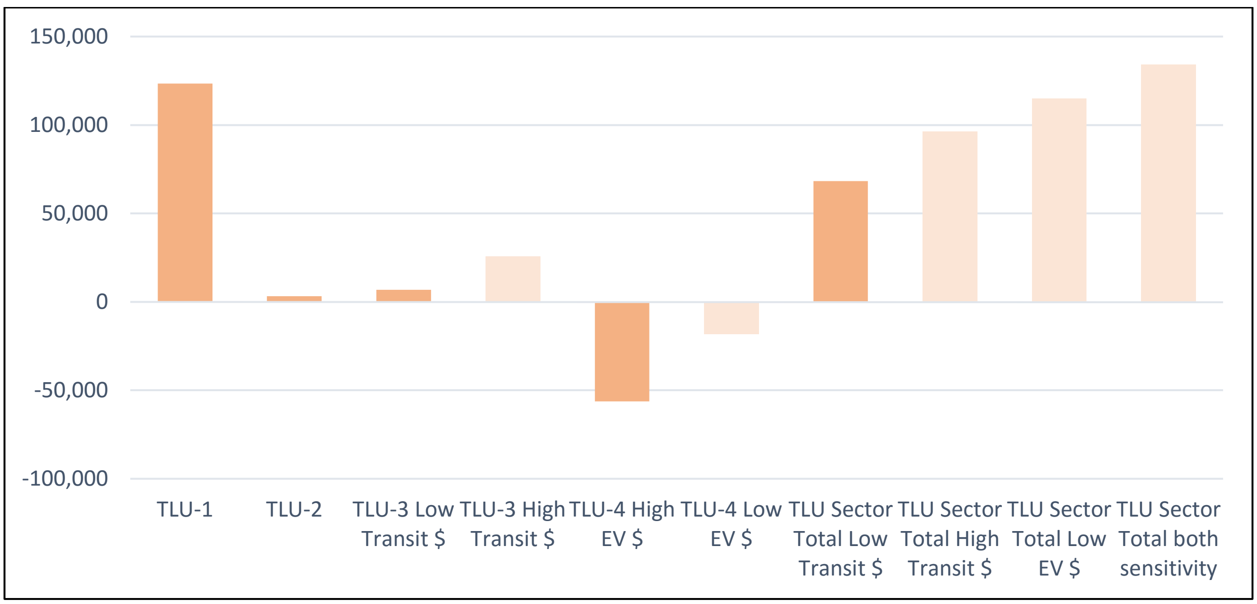


Figure IV-61 TLU Income Impacts, 2016-2030 Average Annual ($2015 MM)

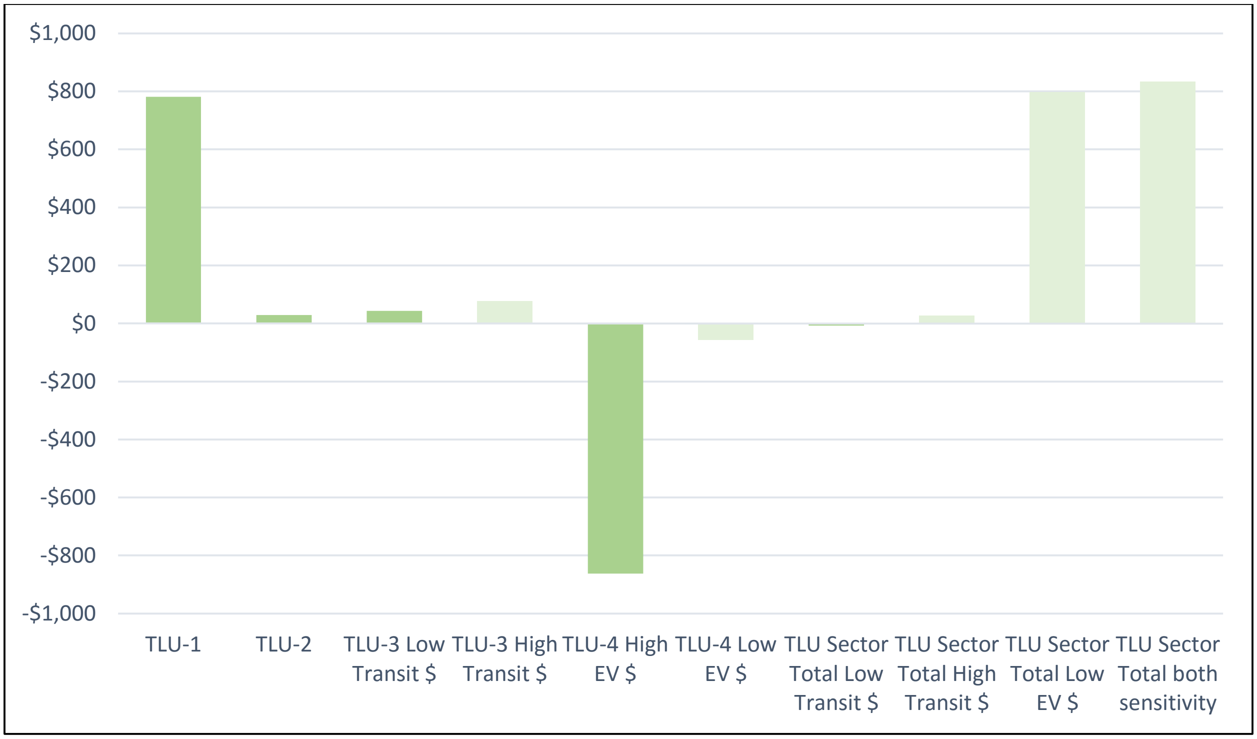


Figure IV-62 TLU Income Impacts, 2016-2030 ($2015 MM)

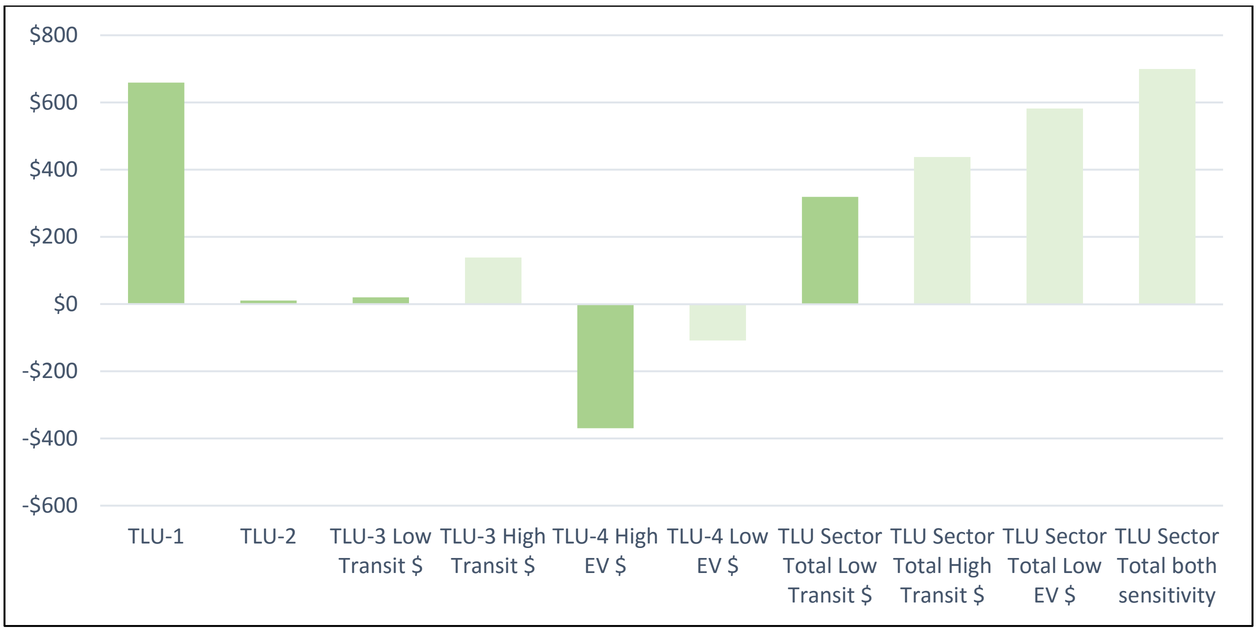
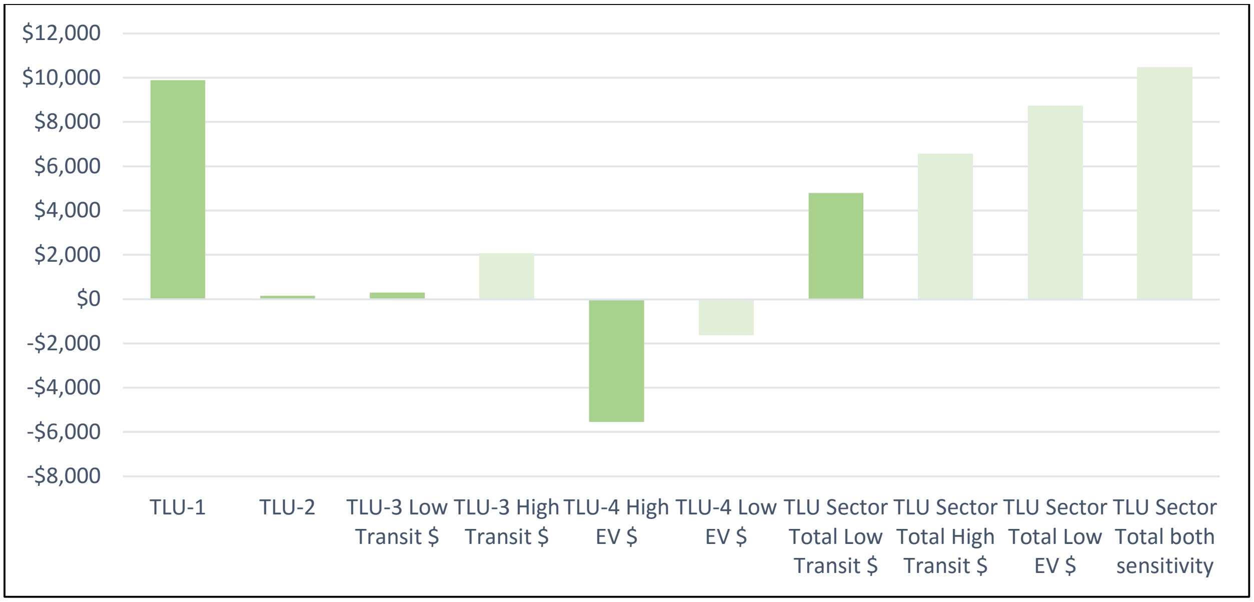


Figure IV-63 TLU Income Impacts, Year 2030 ($2015 MM)



4. Agriculture

The Agriculture sector addresses emissions sources in two primary subsectors: crop production and livestock management. This sector is important to the state's economy and is also a significant greenhouse gas (GHG) contributor (15% of Minnesota's emissions in 2010 and about 16% of Minnesota's emissions expected in 2030). Key drivers to GHG emissions include: nutrient inputs and fuel requirements for primary crops (e.g., corn, wheat and soybeans); livestock populations and manure management methods (especially for ruminant animals, such as dairy cattle); cultivation of soils with high organic carbon content; and crop residue management methods (including agricultural burning).

Strategies that could reduce GHG emissions and provide positive economic benefits include: nutrient management (e.g., reducing commercial nitrogen fertilizer inputs to Minnesota's crops); use of cover cropping or shifting annual crops to perennial cropping systems; use of improved manure management methods, such as anaerobic digestion; and production of advanced biofuels, along with programs to incentivize their use within the state.

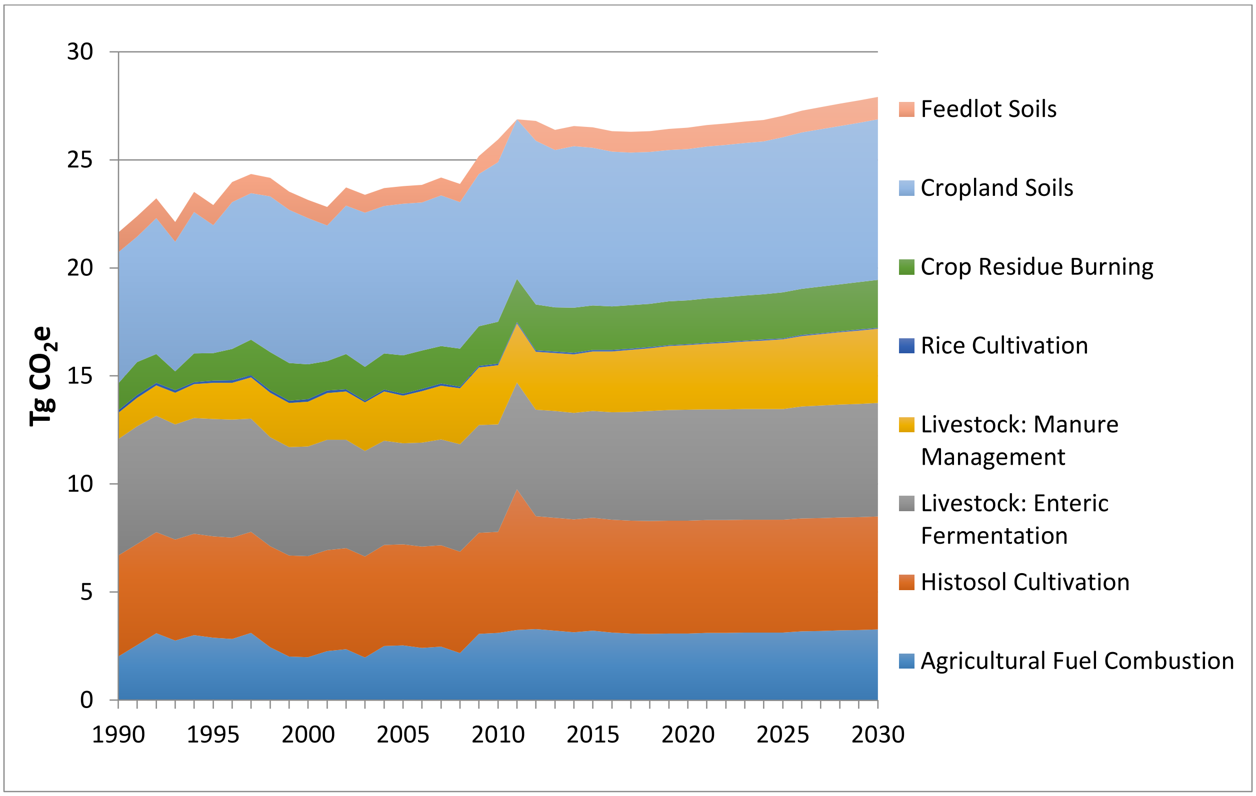
Baseline and Emissions Sources

The GHG baseline for the Agriculture sector is provided in Figure IV-57 below. Sources include: manure management and enteric fermentation in the livestock management subsector (methane [CH_4] and N_2O); synthetic and organic nitrogen inputs to crop and feedlot soils (N_2O), energy use (e.g., CO_2/CH_4/N_2O from diesel combustion); and soil management (e.g. CO_2 losses from cultivation of soils with high levels of soil carbon or "histosols"). See Chapter II for more information on the contribution of the Agriculture sector to the State's GHG baseline.

In Minnesota, key contributing sources from the crop production subsector and include nitrogen (N) inputs to soils, soils management (e.g. tillage practices, including histosol cultivation), and fuel use. The recent peak shown in Figure IV-57 for histosol cultivation stems from the adoption of GHG estimates developed for the US national inventory. Those estimates, along with the historical estimates, are multi-year in nature; placing these estimates into an annual time-series can produce peaks such as this that should not be construed as being derived actual annual estimates. Both enteric fermentation (methane emissions from the digestion systems of ruminant animals, primarily cattle) and manure management emissions are also key contributing source sectors.

Forecasted emissions for the agricultural sector are shown to increase slightly through 2030. These increases are mainly driven by expected future increases in fuel combustion and N application to produce Minnesota's primary crops: corn, soybeans, and wheat.

Figure IV-64 Agriculture Sector GHG Baseline



It is also important to note that the Agriculture (A) sector, along with the Forestry and Other Land Use (FOLU) and Waste Management (WM) sectors, can act as bio-energy feedstock sources that can reduce GHG emissions in other sectors (e.g., solid biomass for reductions of fossil fuel use in the Energy Supply [ES] and Residential, Commercial, Institutional and Industrial [RCII] sectors), liquid biofuels (mainly for reductions of fossil fuel use in the Transportation and Land Use [TLU] sector), and biogas for reductions across all sectors. In-state production of biofuels also produces important positive economic impacts. The CSEO Policy options described in the next section were selected to address some of the most important opportunities for emissions reduction and economic growth.

CSEO Policy Options

There were five Policy options developed for the Agriculture sector. These are detailed in Appendix F-4 and are summarized as follows:

AG-1. Nutrient Management in Agriculture

The nitrogen in inorganic and organic fertilizer, manure and plant-based, is the primary GHG contributor to nitrous oxide emissions during crop production. When vegetation does not fully use N fertilizer, nitrogen can (among other things) leach into groundwater, and/or be emitted into the atmosphere as N_2O. Nitrogen management practices increase efficiency of N use, reducing nitrate leaching into groundwater and surface water and N_2O emissions. This policy option includes further development, refinement and implementation of N fertilizer Best Management Practices (BMPs), but also development and use of new technologies. This includes: improved nitrogen fertilizer products and techniques such as the “4Rs”: (Right fertilizer source at the Right rate at the Right time and in the Right place), as well as precision agriculture materials and methodology (e.g., variable fertilizer rate application, drone use, plant tissue sensors, etc.). The result of changes in the above management practices, products and techniques can be measured using Nitrogen Use Efficiency (NUE).

A number of different approaches (policy option implementation mechanisms) can be applied to achieve gains in NUE. Policy Option AG-1 isn’t prescriptive as to which will be used and at what levels; however, for the purposes of policy option impacts assessment a series of possible mechanisms was applied. These included: a 40 lb. N/acre reduction in fertilizer application following application of manure or N-fixing legumes; use of nitrification or urease inhibitors; and use of precision agriculture (e.g., variable rate timing of N application, global positioning system based yield monitoring, and enhanced soil sampling).

AG-2. Soil Carbon Management: Increased Use of Cover Crops

Soils contain vast quantities of carbon and are in fact the largest terrestrial carbon pool. On a global scale, the soil carbon pool is about three times larger than the atmospheric pool. Carbon levels in soils vary depending on climate, soil parent material, vegetation type, landscape position, and human activities. Human activities significantly influence the size of soil carbon pools.

Agricultural soil carbon stocks are increased by diversifying rotations with perennials, minimizing soil disturbance, utilizing manure as a soil amendment, and incorporating cover crops where practicable. These practices are most efficient at sequestering carbon when implemented as a suite of practices rather than stand-alone activities. Minnesota has approximately 19.5 million acres of cropland. Even a modest change in soil carbon content per acre results in a significant total greenhouse gas benefit when considering all agricultural lands in the state.

AG-2 is the first of two policy options that address soil carbon management; the second is AG-3 below. Cover crops adoption is grouped into cropping systems with high opportunity/high success rate and cropping systems that currently have significant barriers limiting adoption. Targeting "low-hanging fruit" for early adoption includes: canning crops (some vegetables, sweet corn, and peas), corn silage, sugar beets, edible beans, and potatoes. Other "minor" crops, not grown on a significant number of acres, would fall into this category as well.

AG-3. Soil Carbon Management: Increased Conversion of Row Crops to Perennial Crops

This policy option seeks to achieve beyond business as usual (BAU) levels of conversion of row crops to perennial crops (grasses and legumes) for forage hayland, grazing, or biofuels production. These conversions will serve to increase carbon storage in agricultural soils and biomass and potentially reductions in fuel and fertilizer consumption. Current market forces do not provide adequate incentives for perennial crop production; and other uses of perennial products are not widely available or do not have significant market penetration (e.g., cellulosic ethanol and biofuels). This policy option includes harvested legume, pasture and hayland, and perennial plantings.

AG-4. Advanced Biofuels Production

This policy option includes production based incentives to support commercial development of advanced biofuels in Minnesota. Advanced biofuel would be sourced primarily from Minnesota biomass feedstocks from agricultural or forestry sources, or the organic content of municipal solid waste. Fuels made from biological materials tend to have lower energy-cycle emissions as compared to fossil-based sources, and thus their use provides net GHG reductions.

While the policy option does not specify which biofuels should be produced, total GHG reductions should achieve a minimum 50% improvement over the use of fossil fuels (e.g., gasoline or diesel). For the purposes of impacts analysis, a combination of ethanol production methods were assessed that could meet the level of carbon intensity required (cellulosic and energy beet production methods). This policy option has a direct linkage to Policy Option AG-5 below.

AG-5. In-State Biofuel Consumption (Support of the Existing Biofuels Statute)

This policy option addresses biofuels consumption and the combined AG-4/AG-5 policy options are often referred to in this report as the "biofuels package." From an emissions perspective, GHG reductions for biofuels production in Minnesota would not be achieved, unless these fuels were consumed in-state, thereby offsetting the use of fossil fuels. Exported fuels would serve to reduce emissions in other states; so the ability of Policy Option AG-4 to assist Minnesota to meet its goals would be limited without some assurance that the advanced biofuels would be consumed in-state.

The current Minnesota Statute 239.7911 has the following goals for in-state liquid biofuels consumption: replace gasoline with: 14% by 2015, 18% by 2017, 25% by 2020, and 30% by 2025. However, Minnesota is not on track to meet these goals and further policy option to support deployment of infrastructure and vehicles is needed. Additionally, more research and development is needed to design appropriate engines and to bring advanced biofuels to the market in a cost competitive way. This policy option should address known distribution issues and actions needed to assure that the in-state vehicle fleet is capable of consuming the biofuels at the target levels specified in state law and as produced from Policy Option AG-4 addressing advanced biofuels production.

Direct and Indirect Policy Option Impacts

Overview

The tables below provide a summary of the microeconomic analysis of Climate Solutions & Economic Opportunities (CSEO) policies in the Agriculture sector. The first table provides a summary of results on a stand-alone basis, meaning that each policy option was analyzed separately against baseline (business as usual or BAU) conditions. Details on the analysis of each policy option are provided in each of the Policy Option Documents (PODs) that follow within this appendix.

Direct, Stand Alone Economic Impacts

The stand-alone results provide the annual greenhouse gas (GHG) reductions for 2020 and 2030 in teragrams (Tg) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030 (1 Tg is equal to 1 million metric tons). The reductions shown are just those that have been estimated to occur within the State. Additional GHG reductions, typically those associated with upstream emissions in the supply of fuels or materials, have also been estimated and are reported within each of the analyses in each POD.

Also reported in the stand-alone results is the net present value (NPV) of societal costs/savings for each policy option. These are the net costs of implementing each policy option reported in 2014 dollars. The cost effectiveness (CE) estimated for each policy option is also provided. Cost effectiveness is a common metric that denotes the cost/savings for reducing each metric ton (t) of emissions. Note that the CE estimates use the total emission reductions for the policy option (i.e. those occurring both within and outside of the State).

As indicated in

Table IV-13 the combined impacts of Policy AG-4 (Advanced Biofuels Production) and Policy AG-5 addressing biofuel consumption (Existing Biofuel Statute) are provided in the overall results shown for Policy AG-5. In other portions of this appendix and the final CSEO report, these two policies are referred to as the “Biofuels Package”. In order to estimate net energy and GHG impacts, the analysis of biofuels production needs to be taken all of the way through consumption of those fuels; so separate reporting of overall policy option impacts is not done (if GHG estimates of biofuel production were provided, these would only indicate an increase in emissions, which would be misleading or confusing to most readers). Implementation of the Biofuels Package will have some overlap with on-road vehicle policies in the Transportation and Land Use (TLU) sector; these will be addressed in the *inter*-sector integration analysis and documented in the final report for the project.

Integrative Adjustments & Overlaps

The second summary table above provides the same values described above after an assessment was made of any policy option interactions or overlaps. In the Agriculture sector, overlaps were identified between the AG-1 policy option addressing nutrient management and policies AG-3 and AG-4. Essentially, implementation of the AG-3 and AG-4 policies will result in conversion of some corn to either perennial cover (AG-3) or other energy crops (AG-4). So the stand-alone reductions and costs estimated for Policy Option AG-1 were adjusted downward to account for a smaller corn production base than is currently expected in the baseline forecast.

As indicated in the

Table IV-14 there could also be some interaction of Policy Option AG-2 with Policy Option AG-1 (i.e. lower nitrogen [N] fertilization requirements achieved via cover cropping); however, the net nitrous oxide (N_2O) emissions impacts related to cover cropping are currently uncertain. Therefore, no adjustments were made relative to this interaction.

Macroeconomic (Indirect) Economic Impacts of Agriculture Policies

Table IV-15 below provides a summary of the expected impacts of Ag policies on jobs and economic growth during the CSEO planning period. This table focuses on the impact of policies on Gross State Product (the total amount spent on goods and services produced within the state), Employment (the total number of full-time and part-time positions), and Incomes (the total amount earned by households from all possible sources). These metrics represent three valuable indicators of both the overall size of the economy and that economy's structural orientation toward supporting livelihoods and utilizing productive work.

For the purposes of macro-economic analysis of CSEO policies, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software. This particular REMI model is developed specifically for Minnesota, and is developed consistently with the design of models in use by state agency staff within Minnesota for a range of economic analyses. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

The main inputs for macro-economic analysis are microeconomic estimates of direct costs and savings expected from the implementation of individual policy options. These inputs are supplemented with additional data and assumptions necessary to complete the picture of how these costs and savings (as well as price changes, demand and supply changes, and other factors) influence Minnesota's economy. These additional data and assumptions typically regard how various actors around the state (households, businesses and governments) respond to change by changing their own economic activity. A full articulation of the general and policy-specific assumptions made by the macroeconomic analysis team is provided in the Policy Option Documents, contained as appendices to this report.

Table IV-13 Agriculture Policy Options, Direct Stand-Alone Impacts

Stand-Alone Analysis							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual CO_2e Reductions[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/$tCO_2e$
AG-1	Nutrient Management in Agriculture	0.036	0.14	1.1	2.8	($131)	($46)
AG-2	Soil Carbon Management: Increased Use of Cover Crops	0.059	0.49	3.1	3.6	($1,346)	($377)
AG-3	Soil Carbon Management: Increased Conversion of Row Crops to Perennial Crops	0.62	1.6	14	14	($2,104)	($153)
AG-4	Advanced Biofuels Production	*Not Applicable - Results of this supply-side policy option are combined with those from AG-5 (demand-side policy option)*					
AG-5[e]	Existing Biofuel Statute	0.12	0.17	1.8	3.5	$462	$133
Totals		**0.83**	**2.4**	**19**	**24**	**($3,119)**	**($132)**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.

[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] Contains the total net impacts of the AG-4/AG-5 Biofuels Package.

Table IV-14 Agriculture Policy Options, Intra-Sector Interactions & Overlaps

Intra-Sector Interactions & Overlaps Adjusted Results							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Cost[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/tCO_2e$
AG-1[e]	Nutrient Management in Agriculture	0.035	0.13	1.0	2.7	($127)	($47)
AG-2[f]	Soil Carbon Management: Increased Use of Cover Crops	0.059	0.49	3.1	3.6	($1,346)	($377)
AG-3[g]	Soil Carbon Management: Increased Conversion of Row Crops to Perennial Crops	0.62	1.6	14	14	($2,104)	($153)
AG-4[h]	Advanced Biofuels Production	*Not Applicable*					
AG-5	Existing Biofuel Statute	0.12	0.17	1.8	3.5	$462	$133
Total After Intra-Sector Interactions/ Overlap		**0.83**	**2.4**	**19**	**23**	**($3,115)**	**($133)**

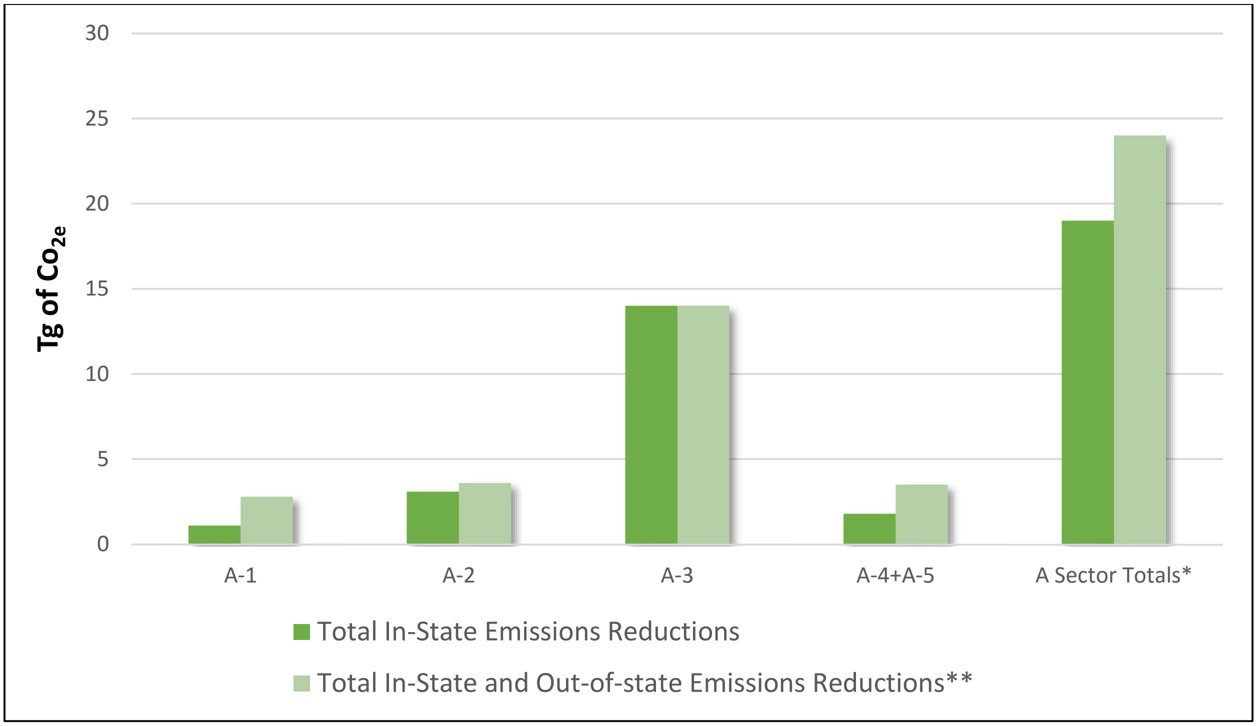
Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of State. Dollars expressed in $2014.
[e] See AG-2, AG-3, and AG-4 below.
[f] Use of cover crops on 2.25 MMacres of corn by 2030 could reduce N requirements addressed under AG-1. However, net N_2O emissions impacts from cover cropping are uncertain; so no changes were made to AG-1 as a result of implementation of AG-2.
[g] Conversion of 500,000 acres of corn to perennial crops reduces impacts and costs of AG-1.
[h] Diverted corn production to energy beets reduces the impacts and costs of AG-1.

Table IV-15 Macroeconomic (Indirect) Impacts of Agriculture Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	GSP[a] ($2015 MM)			Employment[b] (Individual)			Personal Income[c] ($2015 MM)		
	Year 2030[d]	Average (2016-2030)[e]	Cumulative (2016-2030)[f]	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
AG-1	-$9	-$5	-$73	-360	-200	-2,960	-$22	-$8	-$125
AG-2	-$2	$8	$113	70	230	3,380	$21	$20	$299
AG-3	$23	-$35	-$529	1,170	-490	-7,420	$56	-$32	-$486
AG-4+AG-5	$1,132	$819	$11,469	3,610	3,420	47,820	$539	$398	$5,576
AG Sector Total	**$980**	**$680**	**$10,203**	**810**	**1,490**	**22,300**	**$349**	**$277**	**$4,148**

Notes:
[a] Gross State Production changes in Minnesota. Dollars expressed in $2015.
[b] Total employment changes in Minnesota.
[c] Personal Income changes in Minnesota. Dollars expressed in $2015.
[d] Single final year value. Year 2030 is the final year of analyses in this project.
[e] Average value from the year 2016 to the year 2030. The average value is calculated from the first year of the policy implementation through the year 2030 if implementation of the policy starts after year 2016.
[f] Cumulative value from 2016-2030 time period.

Figure IV-65 AG Policies GHG Emissions Abatement, 2016-2030



Notes:

* All Policies Total's comprise emissions reductions achieved by Ag default policies combined.

** Total in and out-of-state emissions reduction are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Figure IV-66 Net Job Creation for AG Policies and AG Sector by Ascending Order, 2016-2030

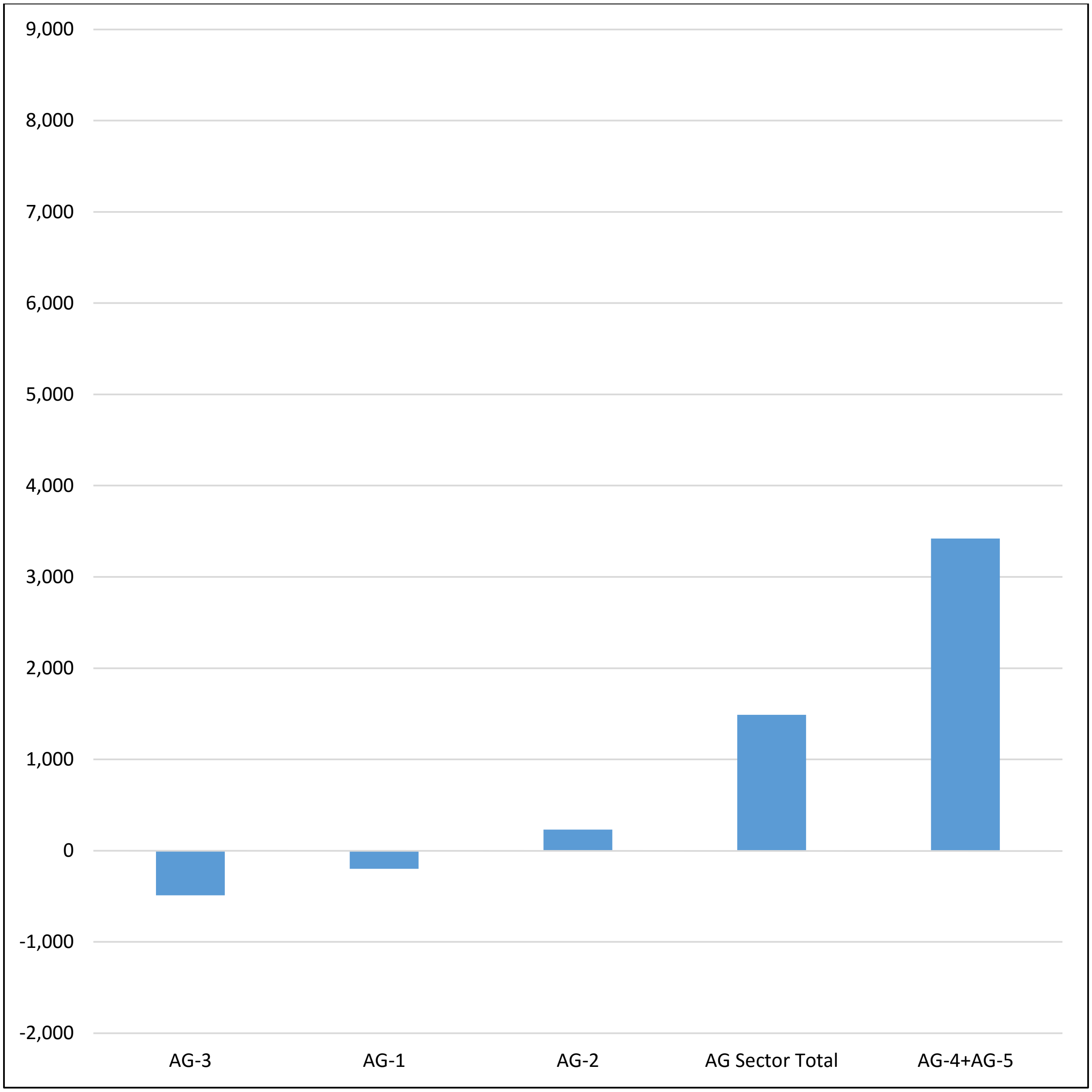
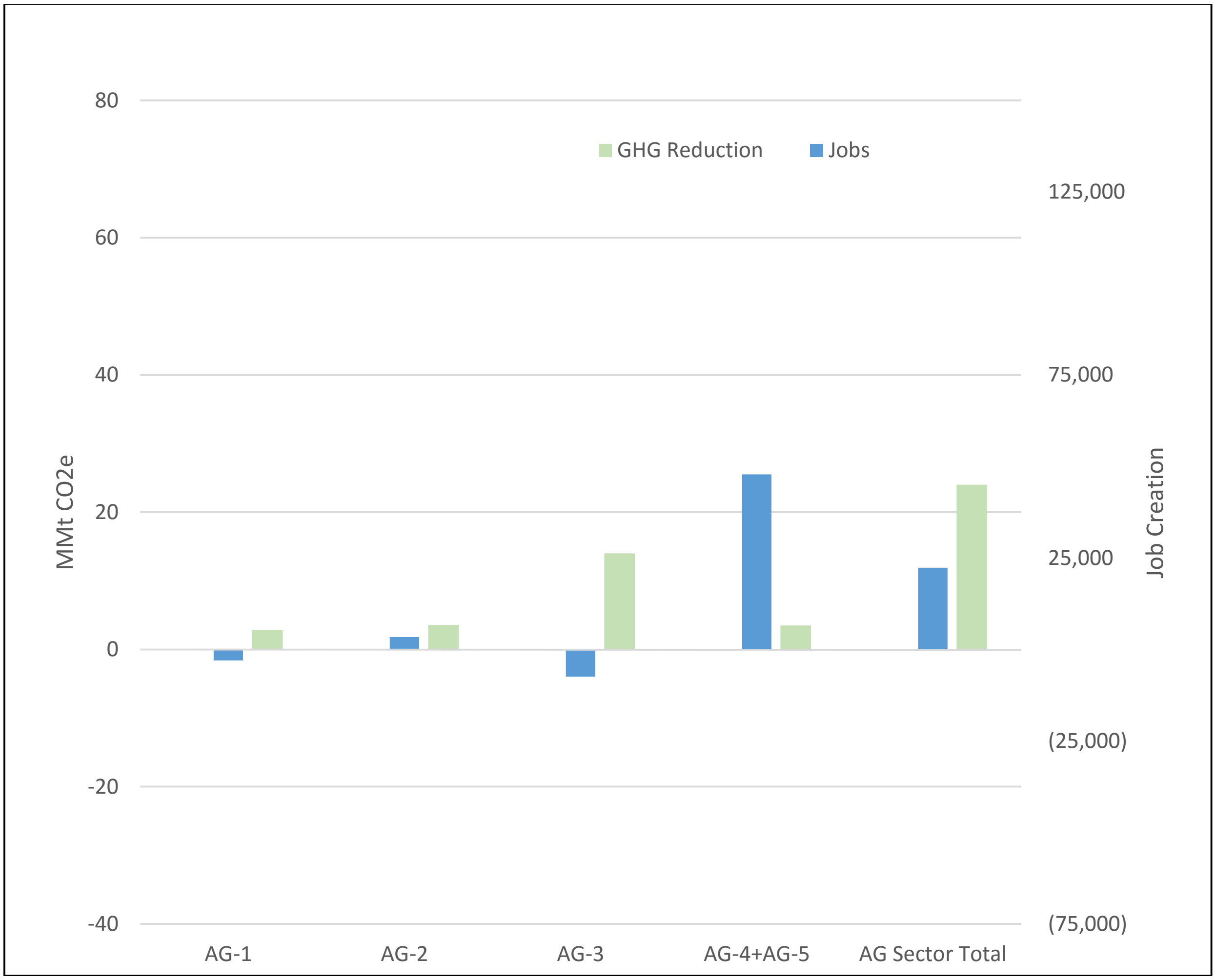


Figure below summarizes a potential for job creation and GHG emissions abatement of AG sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure IV-67 Job Gains and GHG Reduction by AG Policy Recommendations, 2016-2030



Sector level index

Graphs below present the overall macroeconomic impacts of each policy in Ag sector, as well as the sector-level impacts, by using the Macroeconomic Impact Index. The index is a blended score indicating an overall macroeconomic impact of a policy or a set of policies on GSP, income and employment. In this project, the three variables are weighted equally, and indexed based on the maximum value among all the policies. I_GSP, I_Jobs, and I_Income represent the index score for GSP, Jobs and Income, respectively.

Figure IV-68 AG Macroeconomic Indicators, 2030

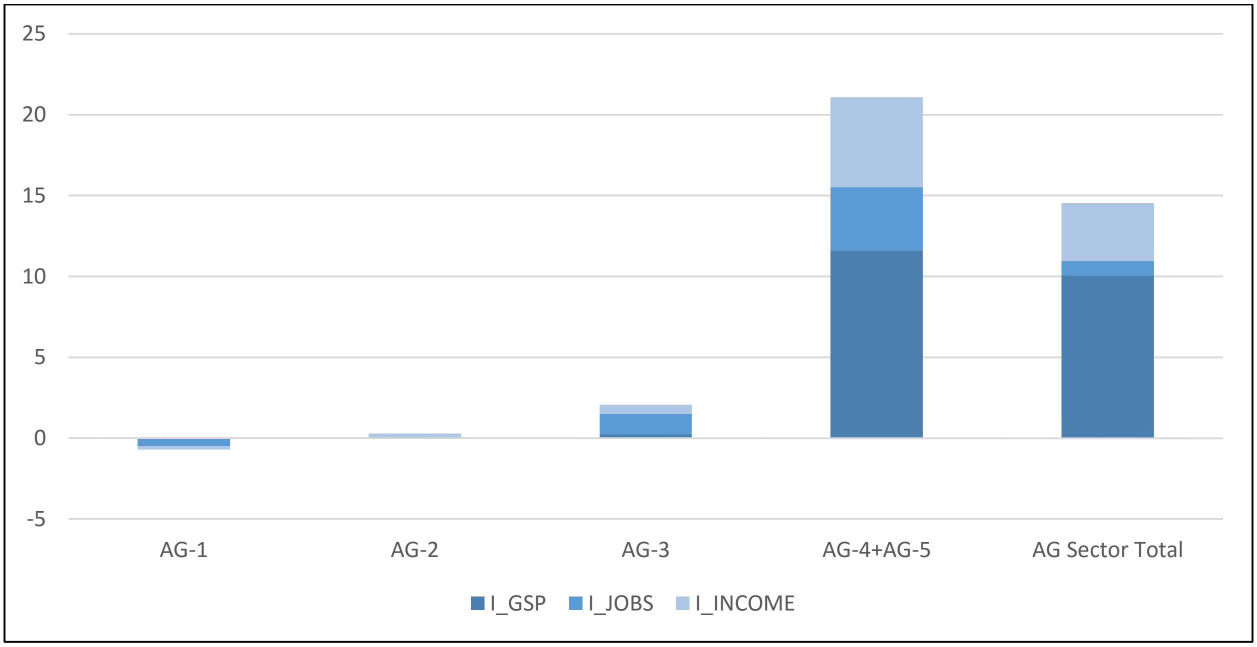


Figure IV-69 AG Macroeconomic Indicators Average Annual

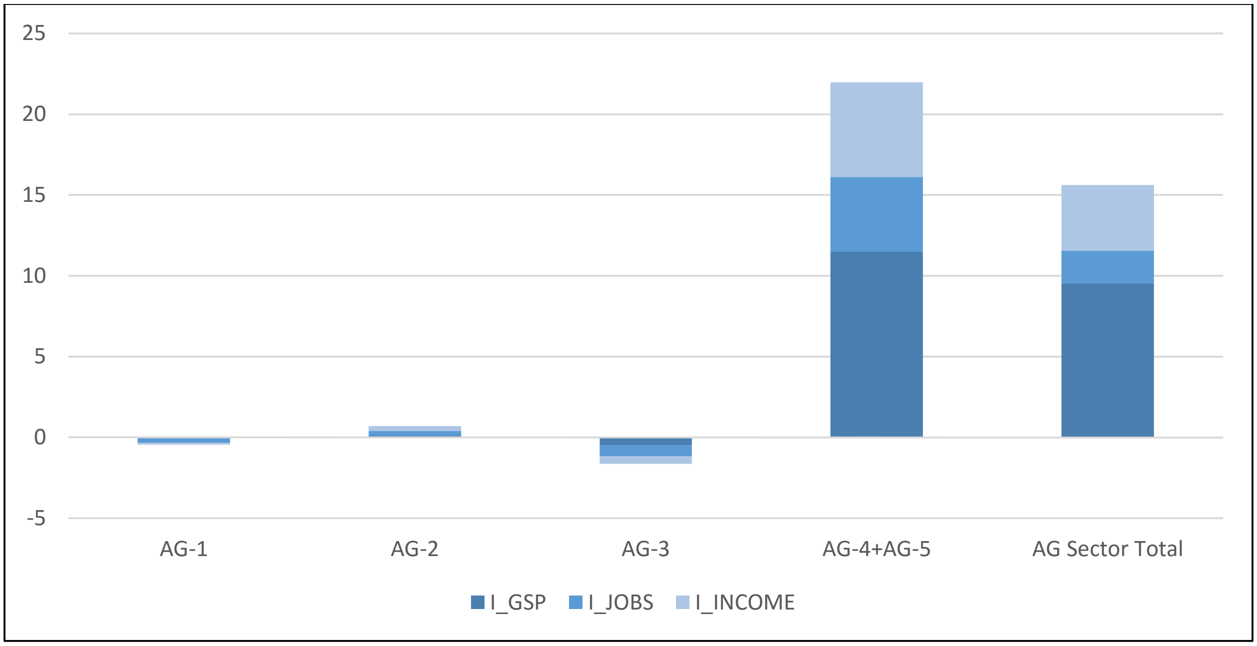
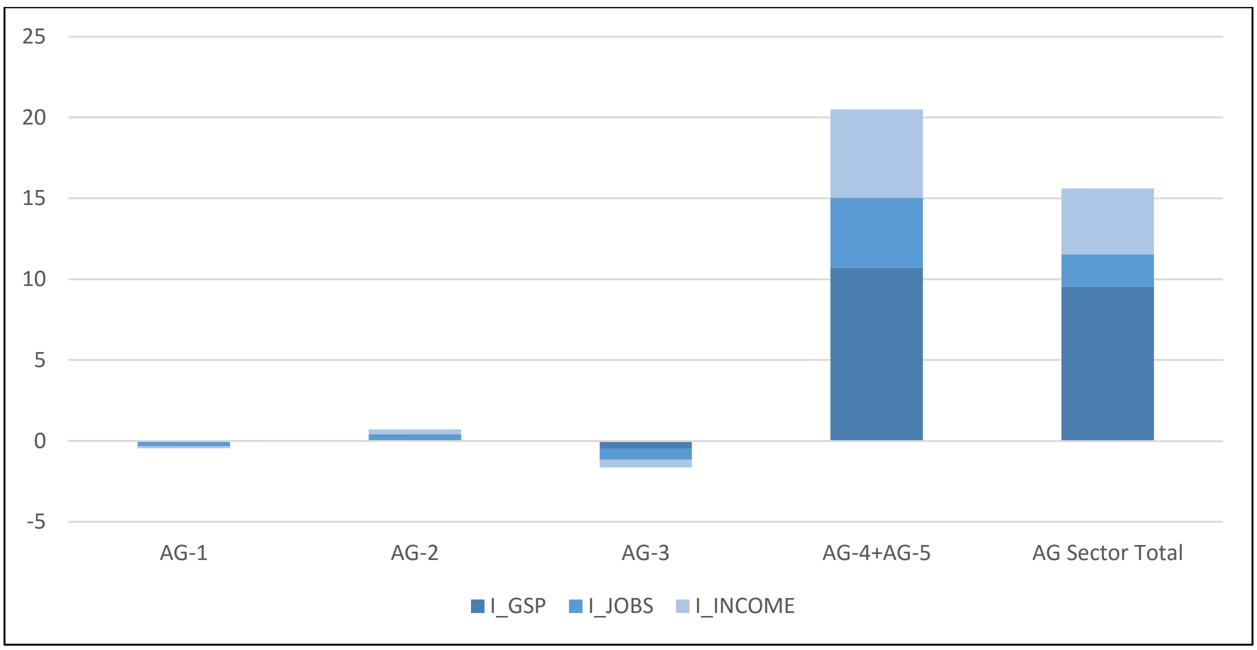


Figure IV-70 AG Macroeconomic Indicators, 2016-2030



The Agriculture sector generates significant positive impacts – around $1 billion in GSP and nearly two and half times that in income, with a few thousand jobs more than would exist in the state than if these policies were not implemented.

The Agriculture sector impact on Minnesota's economy, according to this analysis, is really the story of the biofuels policy (the combined supply and demand of biofuels from AG-4 and AG-5). While the other policies are effectively neutral in their impacts, driving very small positive or negative shifts over time, the biofuels policies together are responsible for effectively all of the GSP and income gains. They also drive all the employment gains – indeed, the other policies pull the totals slightly down. Graphs and bar charts that follow illustrate the above explained policy effects.

Figure IV-71 AG GSP Impacts ($2015 MM)

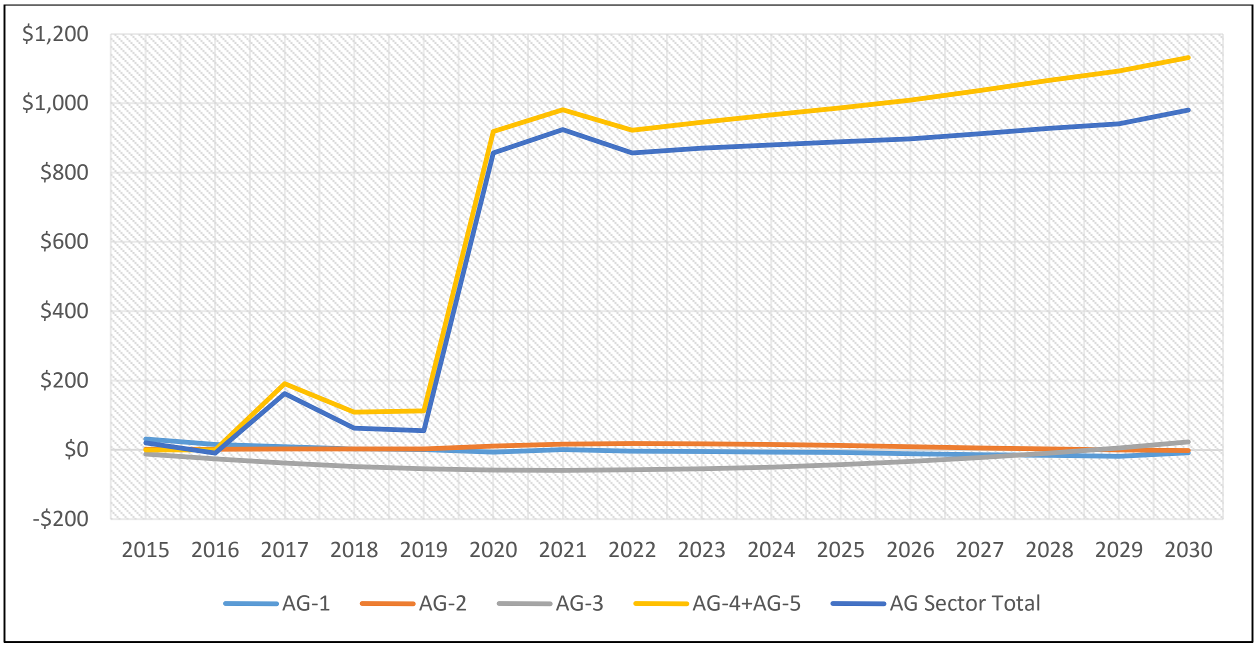


Figure IV-72 AG Employment Impacts (Jobs)

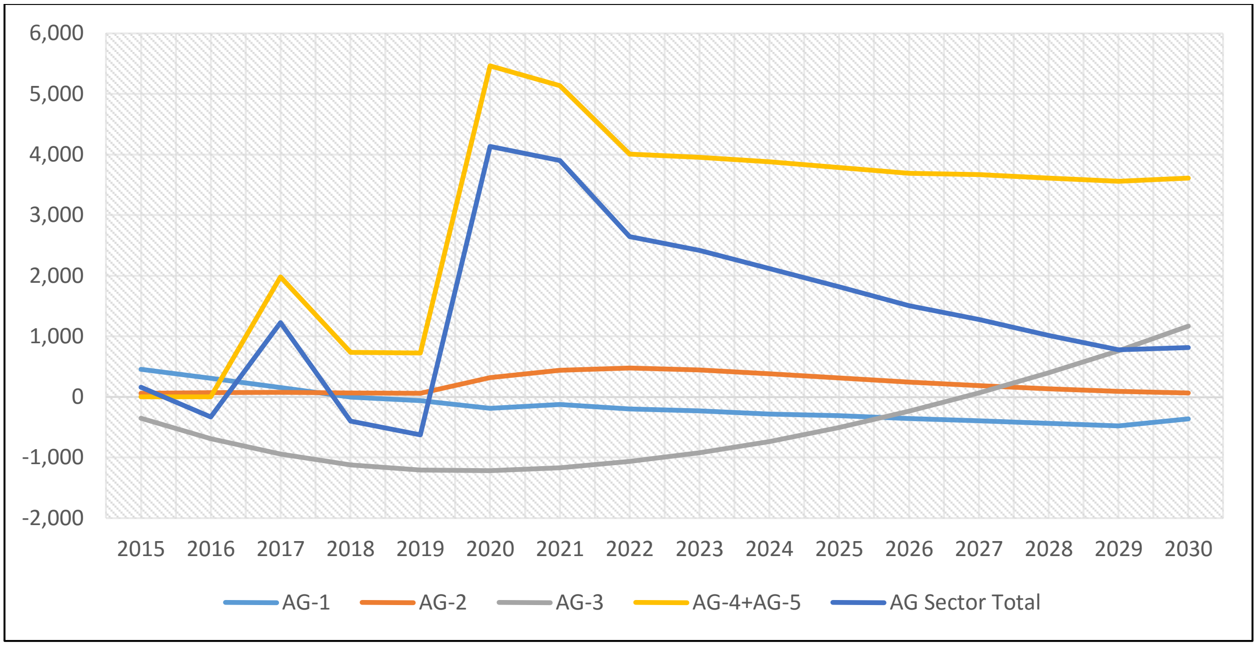
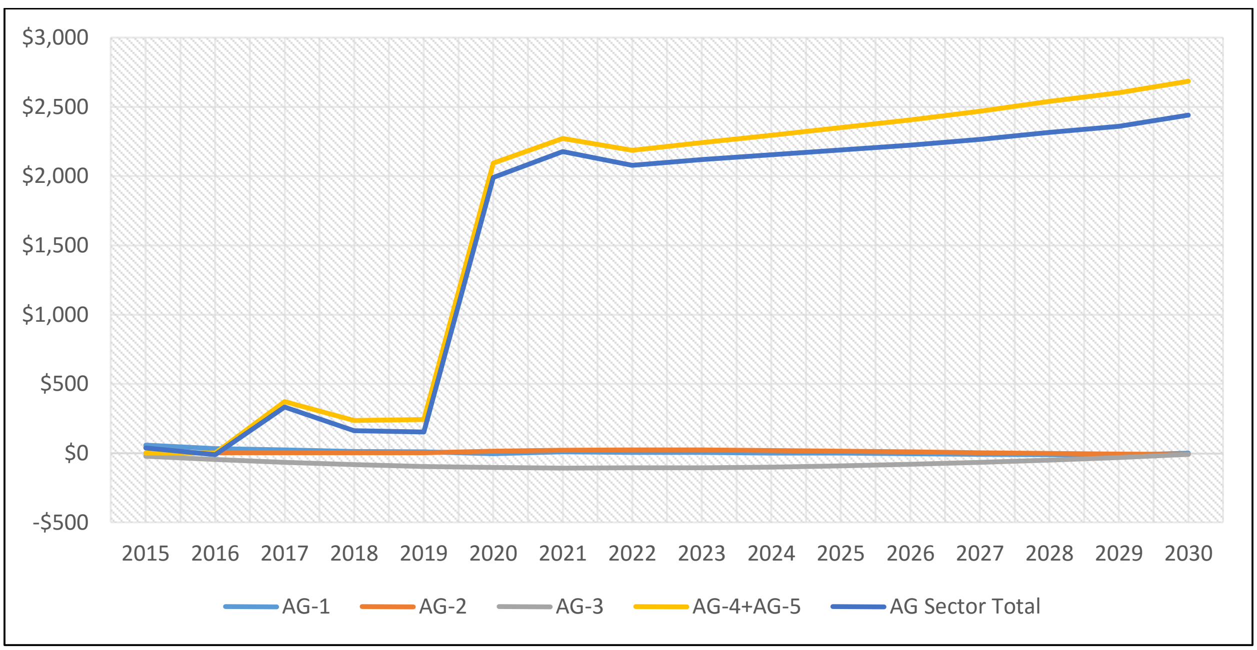


Figure IV-73 AG Income Impacts ($2015 MM)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and cumulative (2016-2030).

Figure IV-74 AG GSP Impacts, 2016-2030 Average Annual ($2015 MM)

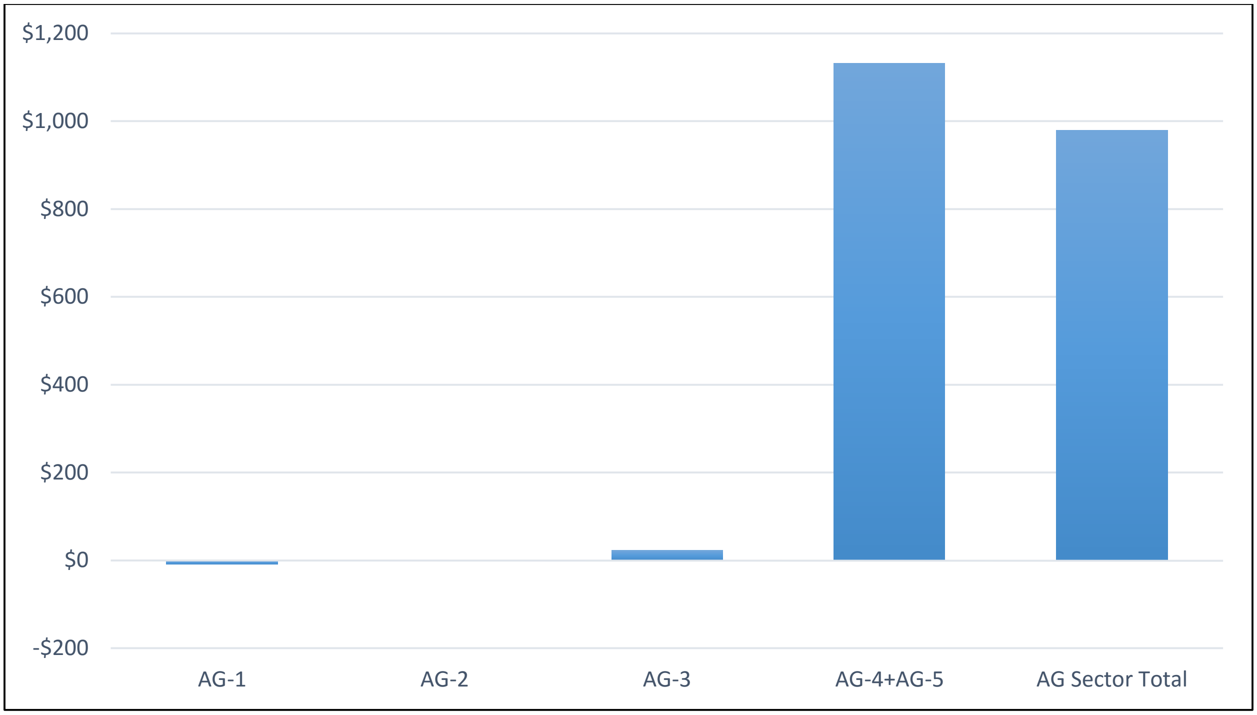


Figure IV-75 AG GSP Impacts, 2016-2030 ($2015 MM)

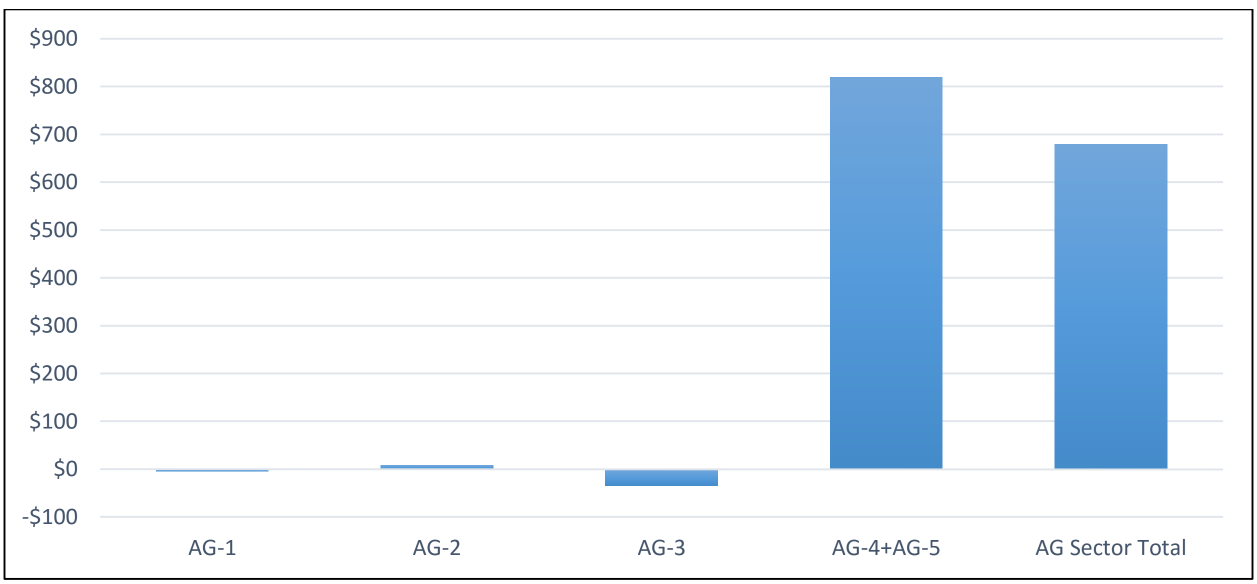


Figure IV-76 AG GSP Impacts, 2016-2030 Average Annual ($2015 MM)

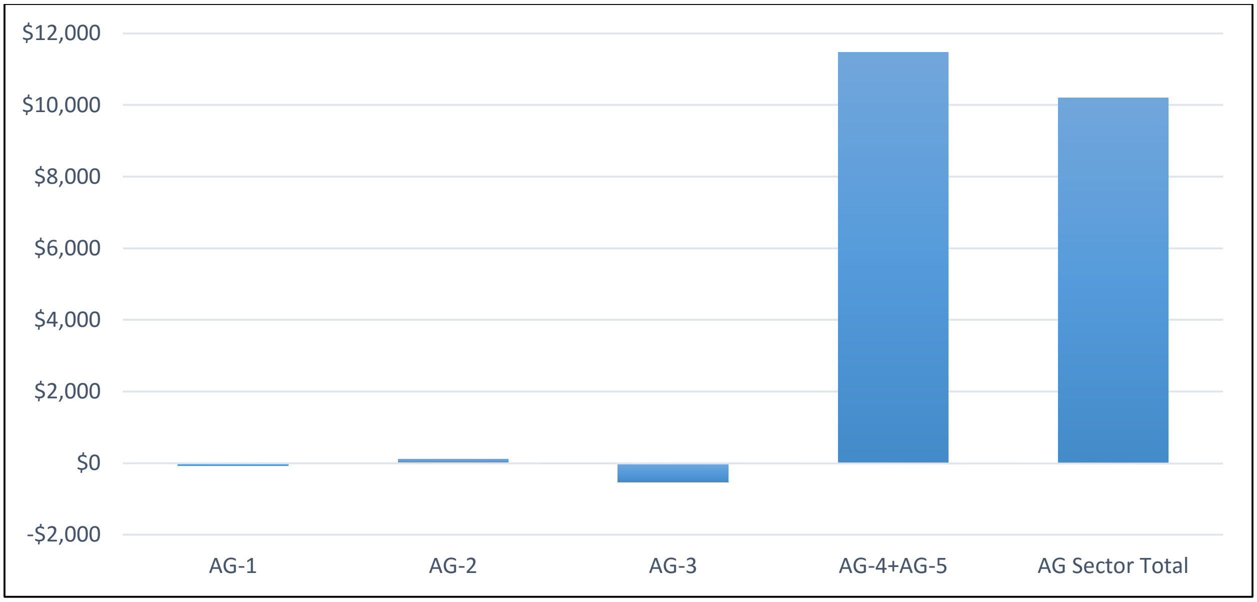


Figure IV-77 AG Employment Impacts, Average Annual (Jobs)

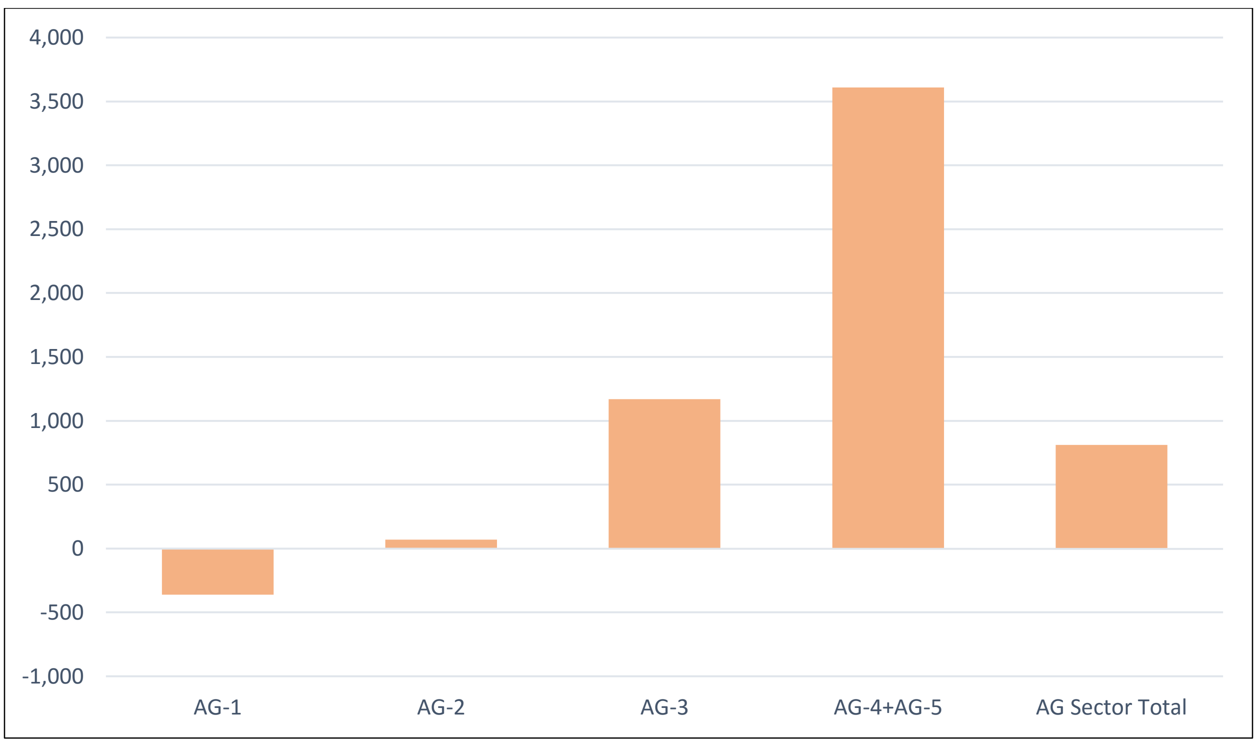


Figure IV-78 AG Employment Impacts, 2016-2030 (Job Years)

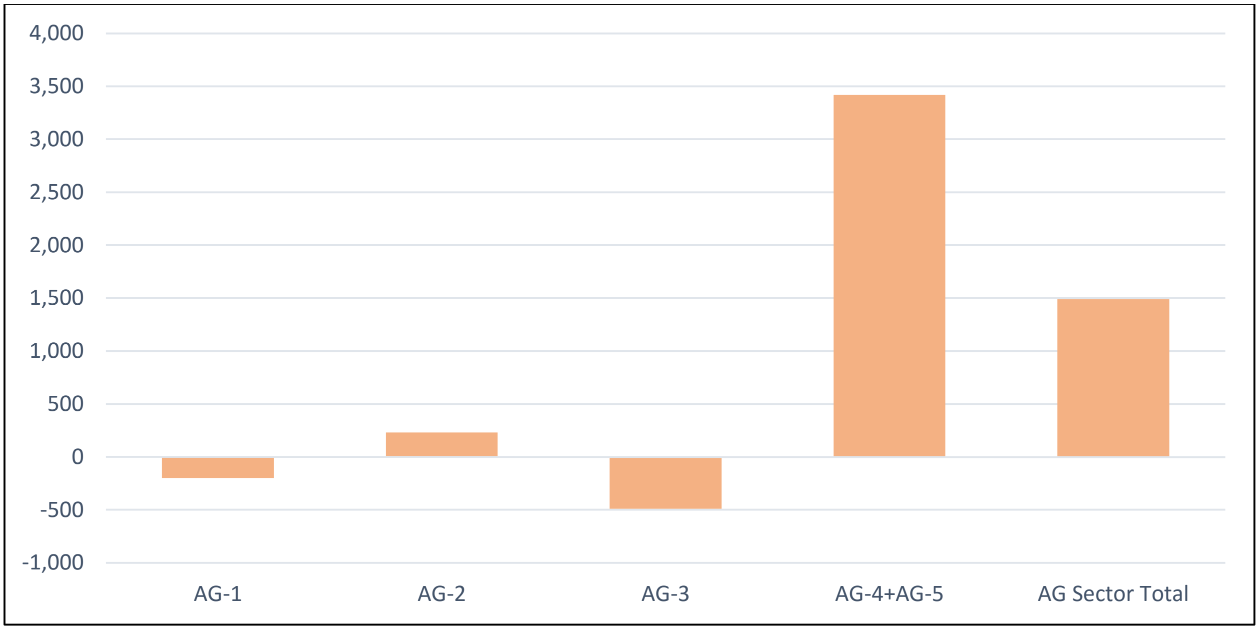


Figure IV-79 AG Employment Impacts, Year 2030 (Jobs)

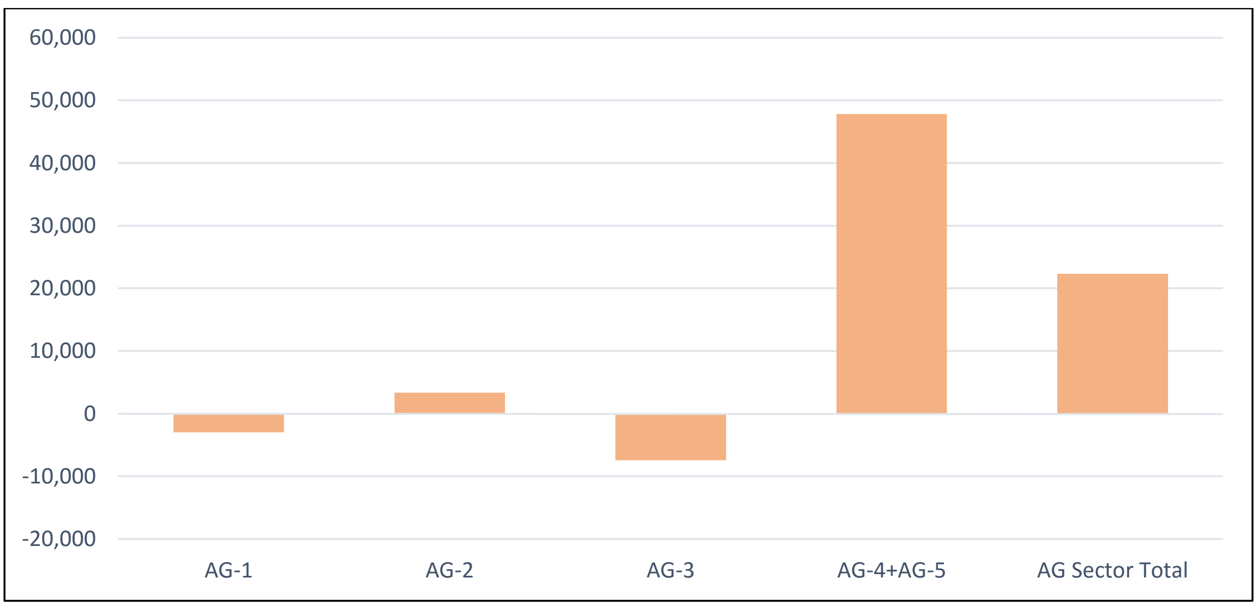


Figure IV-80 AG Income Impacts, Average Annual ($2015 MM)

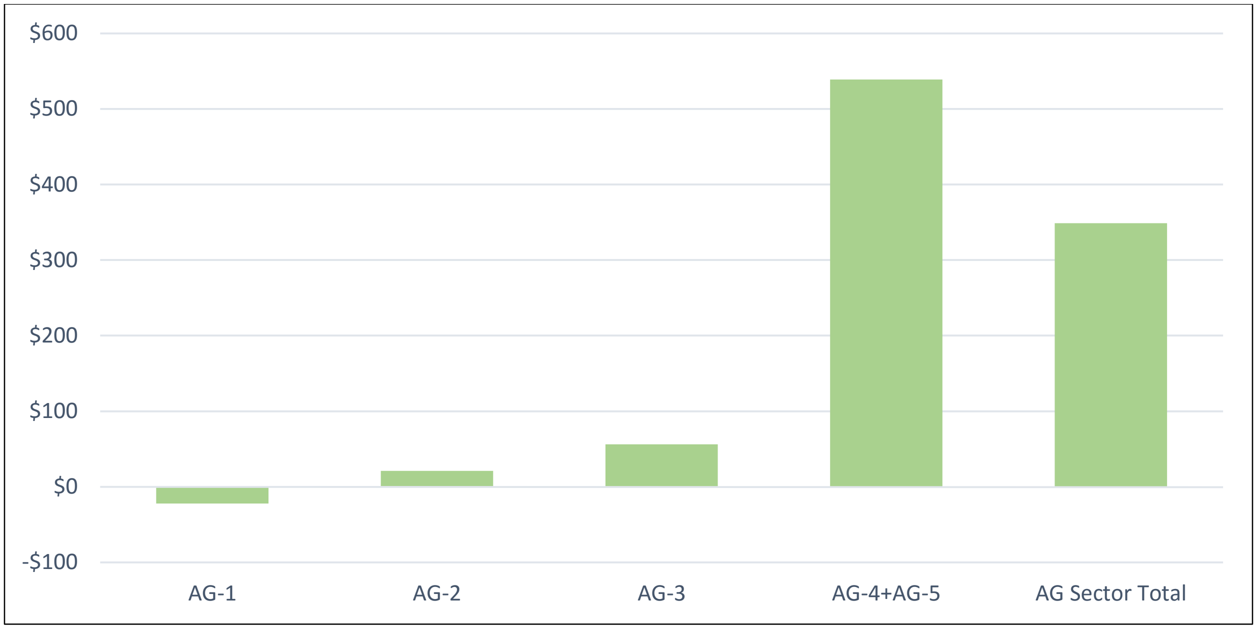


Figure IV-81 AG Income Impacts, 2016-2030 ($2015 MM)

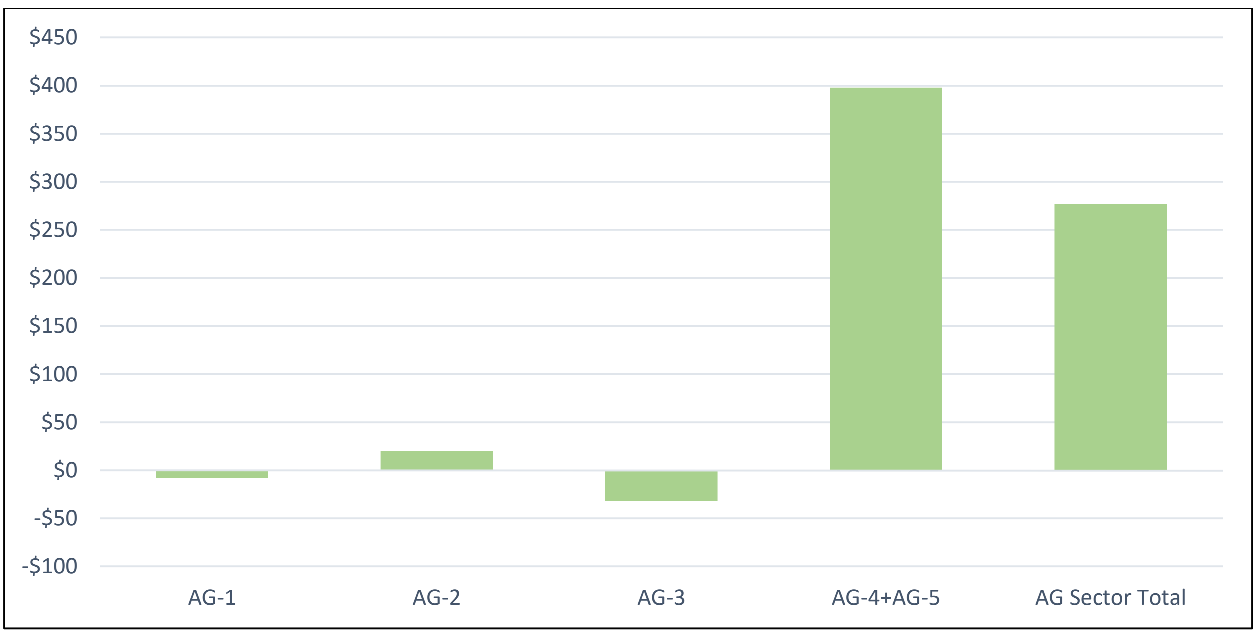
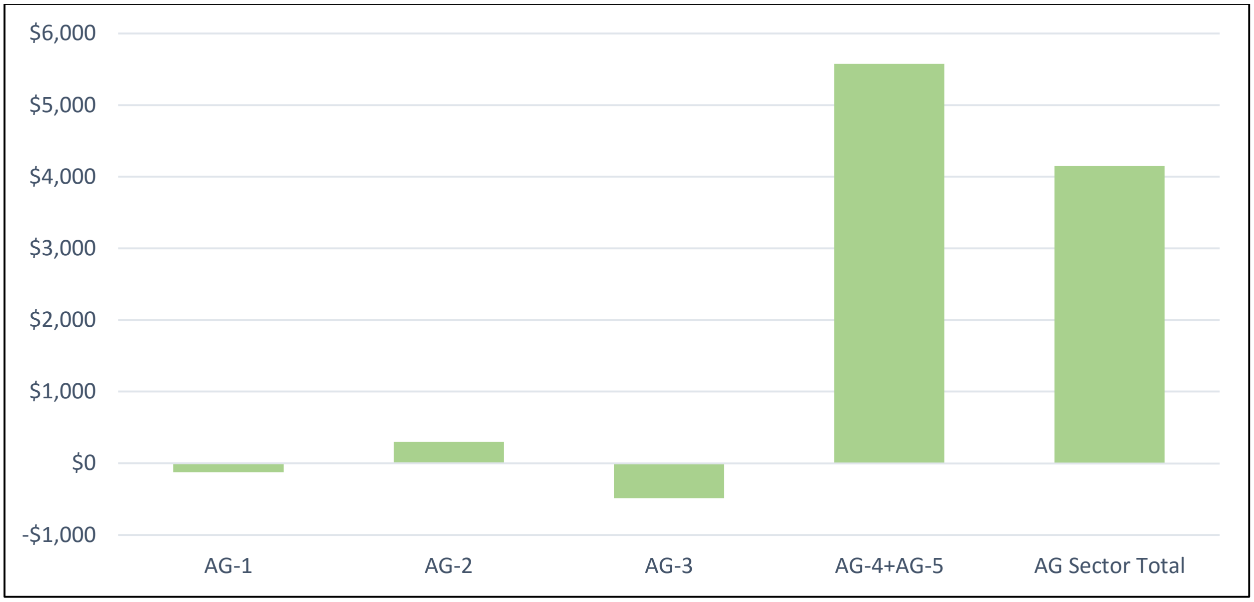


Figure IV-82 AG Income Impacts, Year 2030 ($2015 MM)



5. Forestry & Other Land Use

The Forestry and Other Land Use (FOLU) sector primarily addresses carbon sequestration in forested and urban areas (i.e. "sinks" of carbon dioxide [CO_2]). Additionally, there are sources of greenhouse gases (GHG) in this sector, including wildfires and prescribed burns, and importantly methane emissions from wetlands (an uncertain, but potentially significant source). When wetland methane emissions are included, the sector becomes a net source of GHG emissions. Contributions to state-level emissions are about eight percent in 2010 and are expected to be about five percent in 2030. Key drivers to carbon sequestration rates and GHG emissions include: coverage of rural forested areas; the health, age and species make-up of these forests; health and coverage of urban forests; wildfire; and the coverage of wetlands.

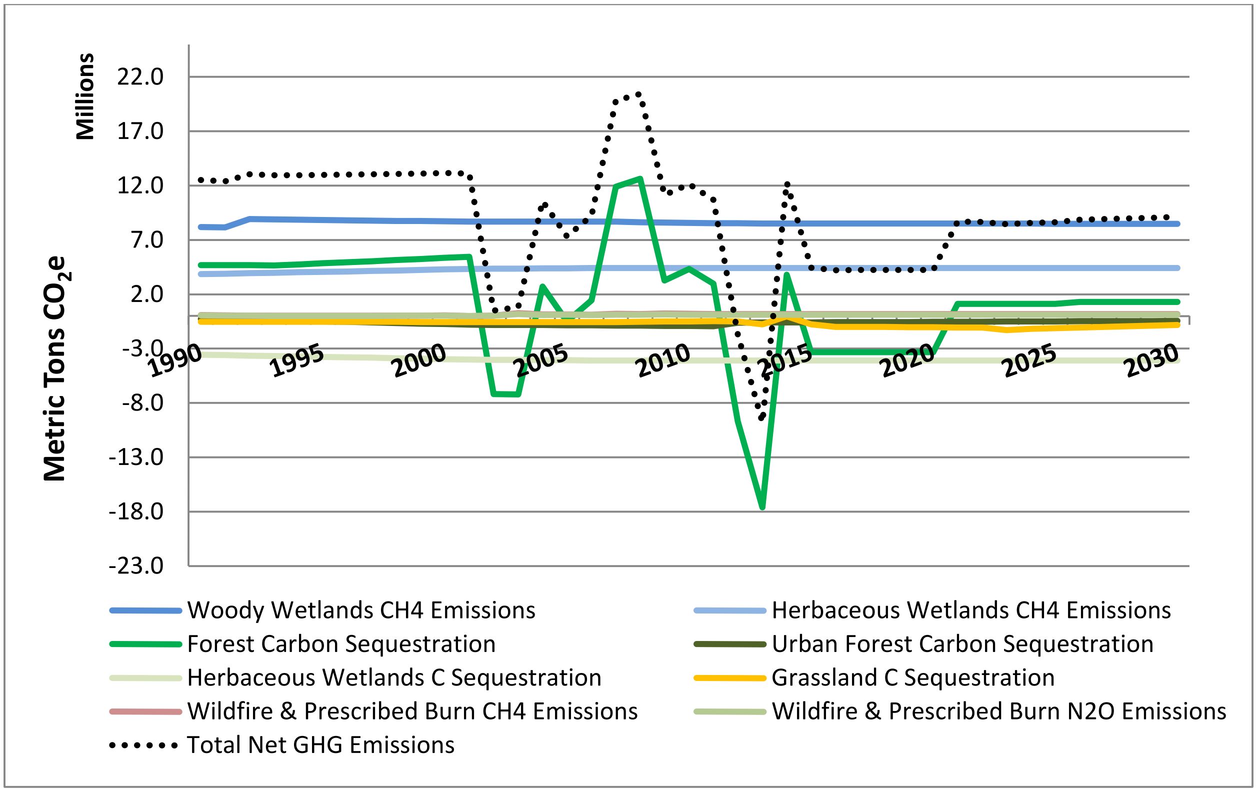
Strategies that could be employed to reduce emissions/enhance sinks and produce economic benefits include: recovery of damaged and degraded forestland; reforestation/afforestation; maintenance and/or expansion of urban forests; biomass utilization for energy or durable wood products; and tree planting programs in rural forests to improve forest productivity.

FOLU Baseline and Emissions Sources

The FOLU sector is primarily composed of net carbon sequestration across the different land uses in Minnesota. Energy use and the associated GHG emissions within the FOLU sector are captured within the Residential, Commercial, Institutional, and Industrial (RCII) sector (e.g. forest industries, rangeland, and urban forest management). There are also a small number of other non-energy related GHG sources addressed. These include methane (CH_4) releases from wetlands, CH_4 and nitrous oxide (N_2O) emissions from wildfires, and N_2O emissions from "settlement soils" (deriving from non-farm fertilizer application to urban soils). For more detail on FOLU emission sources and their contribution to the overall baseline inventory, see Chapter II and Appendix C.

Figure IV-74 below provides the FOLU GHG baseline. Carbon sequestration estimates are based on land area for a given land use and its annual sequestration rate. As these values vary from year to year, the net sequestration for a given year may be negative (net sequestration) or positive (net emissions). Urban forests, wetlands, and grasslands were net GHG sinks in all years, but these sinks are small compared to CO_2 losses from forests (in most years) and CH_4 emissions from wetlands.

Figure IV-83 FOLU Sector GHG Baseline



The addition of wetland emissions in the baseline creates a much different picture from previous sector baselines (e.g., the 2008 Minnesota baseline used in the state action plan). As shown with the dotted line in Figure IV-83, the net emissions are now positive in nearly all years of the baseline. As further described in Appendix C, these CH_4 emissions carry a high level of uncertainty.

The other key factor that drives the large changes shown in forest carbon (C) sequestration rates is the level of annual disturbance from: insects/disease, fire, and weather events. Periods with high levels of disturbance lead to large shifts in carbon sequestration levels. The Minnesota FOLU forecast anticipates higher levels of disturbance in the future, especially from insects/disease, in the post-2030 timeframe.

CSEO Policy Options

Four policy options were developed for the FOLU sector. The initial CSEO set also included FOLU-1 (Protection of Peatlands/Wetlands). However, due to a current high level of uncertainty around the net GHG impacts associated with these lands, and the associated efficacy of any GHG management intervention, policy options addressing wetlands were dropped from further development (pending a better understanding of the underlying carbon dynamics of MN's wetlands). The remaining four policy options are detailed in Appendix F.5 and are summarized as follows:

FOLU-2. Manage for Highly Productive Forests

Additional thinning of commercial stands did not increase forest carbon sequestration in our assessment of direct GHG impacts. Therefore, further development of the policy option toward a final CSEO recommendation was not conducted.

FOLU-3. Community Forests

It has long been recognized that trees conserve energy by providing shade and windbreaks. Recent and ongoing scientific evidence also recognizes that community trees provide substantial benefits for air and water quality. Specific to this policy option, trees sequester carbon and provide energy savings through shade and windbreaks. Trees also provide numerous other economic, environmental, and public health benefits. This policy option would strengthen community forests across the state by increasing and maintaining the overall tree canopy cover of community forests to 40% by 2050.

FOLU-4. Tree Planting: Forest Ecosystems

Although disturbances, such as blowdowns, fire, pest and disease outbreaks are common, natural features of forest ecosystems, they release large amounts of carbon and reduce the rate at which the state's forest as a whole removes carbon from the atmosphere. With anticipated changes in climate, the frequency and intensity of landscape-level forest disturbance (tens to a few hundreds of thousands of acres) in Minnesota likely will increase. Since younger forests accumulate carbon more quickly than do older forests, re-establishing forests without delay on disturbed sites helps maintain high levels of carbon sequestration. Dedicated resources are needed to ensure timely restoration of carbon sequestration following large disturbances on state, county, and private lands.

FOLU-5. Conservation on Private Lands

Permanent vegetation in natural ecosystems and agricultural systems sequester more carbon than do rowcrops. Restoring and protecting perennial vegetation (prairie, wetland, forest, hay and pasture) will increase carbon sequestration in soils and plant biomass. In addition, restoring wetlands will improve water quality and reduce flooding. Protecting forests sustain their ability to sequester carbon while preventing large emissions associated with forest loss.

Direct and Indirect Policy Option Impacts

Table IV-16 below provides the direct "stand-alone" policy option impacts for the FOLU sector (see Section III-A above for a discussion of "stand-alone" versus integrated impacts). On a stand-alone basis, the complete set of FOLU policy options is expected to produce GHG reductions of 1.6 $TgCO_2e$ in 2020 and 2.7 $TgCO_2e$ in 2030. As with all results, these presume that the policy options will be fully implemented as designed (see Appendix F.5 for details on the design of each policy option). On a cumulative basis, the FOLU policy options are expected to reduce GHG emissions by 36 $TgCO_2e$ through 2030.

Table IV-16 FOLU Policy Options, Direct Stand-Alone Impacts

Stand-Alone Analysis							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual CO_2e Reductions[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/$tCO_2e$
FOLU-1	Protect Peatlands and Wetlands	*Not Quantified*					
FOLU-2[e]	Manage for Highly Productive Forests - Intermediate Stand Treatments	*Not Applicable*					
FOLU-3[f]	Urban Forests: Maintenance and Expansion 40% Canopy Goal	0.086	0.49	3.2	3.2	$1,806	$568
FOLU-4[g]	Tree Planting: Forest Ecosystems	1.4	1.9	30	34	$187	$5.6
FOLU-5[h]	Conservation on Private Lands	0.14	0.34	3.0	3.0	$1,261	$421
Totals		**1.6**	**2.7**	**36**	**40**	**$3,254**	**$81**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] Net emissions were found to be positive for this policy option; therefore, no cost effectiveness could be calculated.
[f] Full benefits are realized when considering the full life-span of planted trees. 2015-2085 Cumulative Reduction = 67 $TgCO_2e$; NPV = $2,208; 2085 CE = $33
[g] Full benefits are realized when considering the full life-span of planted trees. 2015-2085 Cumulative Reduction = 108 TgCO2e; NPV = $183; 2085 CE = $1.76
[h] Full benefits are realized when considering the full life-span of planted trees. 2015-2085 Cumulative Reduction = 25 TgCO2e; NPV = $1,304; 2085 CE = $53

Table IV-17 FOLU Policy Options, Intra-Sector Interactions

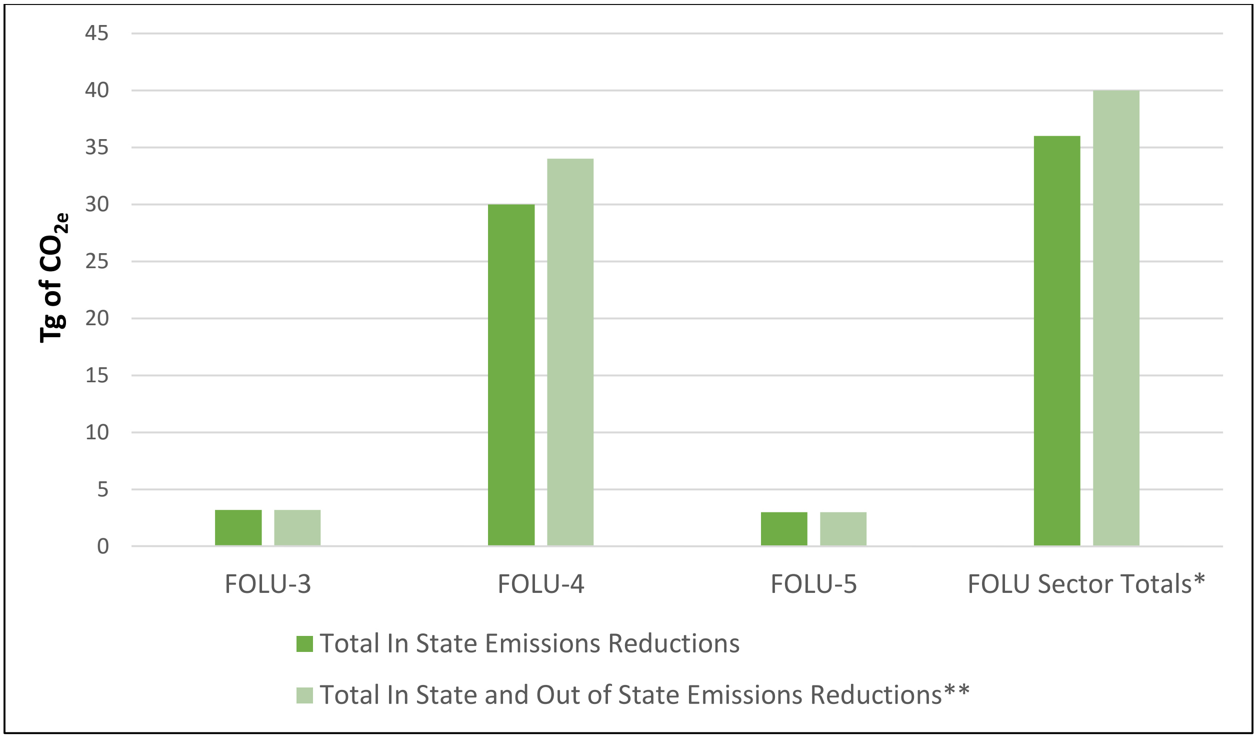
Intra-Sector Interactions & Overlaps Adjusted Results							
		GHG Reductions				Costs	
Policy Option ID	Policy Option Title	Annual[a] 2020 Tg	Annual[a] 2030 Tg	2030 Cumulative[a] $TgCO_2e$	2030 Cumulative[b] $TgCO_2e$	Net Cost[c] 2015-2030 $Million	Cost Effectiveness[d] $/tCO_2e$
FOLU-2.	Manage for Highly Productive Forests - Intermediate Stand Treatments	Not Applicable					
FOLU-3.	Urban Forests: Maintenance and Expansion 40% Canopy Goal	0.086	0.49	3.2	3.2	$1,806	$568
FOLU-4.	Tree Planting: Forest Ecosystems	1.4	1.9	30	34	$187	$6
FOLU-5.	Conservation on Private Lands	0.1	0.3	3.0	3.0	$1,261	$421
Total After Intra-Sector Interactions /Overlap		**1.6**	**2.7**	**36**	**40**	**$3,254**	**$81**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
Note: Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table IV-18 Macroeconomic Impacts of FOLU Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	GSP[a] ($2015 MM)			Employment[b] (Individual)			Personal Income[c] ($2015 MM)		
	Year 2030[d]	Average (2016-2030)[e]	Cumulative (2016-2030)[f]	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
FOLU-3	$382	$366	$5,495	4,420	4,180	62,670	$463	$361	$5,409
FOLU-4	-$10	-$15	-$232	-130	-210	-3,160	-$14	-$19	-$283
FOLU-5 farms lose income (FOLU-5 low income)	-$114	-$87	-$1,301	-1,350	-1,060	-15,900	-$3	$67	$1,010
FOLU-5 farms keep income (FOLU-5 keep income)	-$75	-$59	-$883	-920	-720	-10,750	$117	$144	$2,157
FOLU Sector Total Farms Lose Income (FOLU Sector Total Low Income)	**$258**	**$264**	**$3,961**	**2,940**	**2,910**	**43,610**	**$446**	**$409**	**$6,135**
FOLU Sector Total Farms Keep Income (FOLU Sector Total Keep Income)	**$294**	**$290**	**$4,345**	**3,340**	**3,220**	**48,340**	**$567**	**$486**	**$7,292**

Figure IV-84 FOLU Policies GHG Emissions Abatement, 2016-2030



Notes:
* All Policies Total's comprise emissions reductions achieved by Ag default policies combined.
** Total in and out-of-state emissions reduction are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Forestry and Other Land Use Sector Overview

The tables above provide a summary of the microeconomic analysis of Climate Solutions & Economic Opportunities (CSEO) policies in the Forestry and Other Land Use (FOLU) sector. The first table provides a summary of results on a stand-alone basis, meaning that each policy option was analyzed separately against baseline (business as usual or BAU) conditions. Details on the analysis of each policy option are provided in each of the Policy Option Documents (PODs) that follow within this appendix.

The stand-alone results provide the annual greenhouse gas (GHG) reductions for 2020 and 2030 in teragrams (Tg) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030 (1 Tg is equal to 1 million metric tons). The reductions shown are just those that have been estimated to occur within the state. Additional GHG reductions, typically those associated with upstream emissions in the supply of fuels or materials, have also been estimated and are reported within each of the analyses in each POD.

Also reported in the stand-alone results is the net present value (NPV) of societal costs/savings for each policy option. These are the net costs of implementing each policy option reported in 2014 dollars. The cost effectiveness (CE) estimated for each policy option is also provided. Cost effectiveness is a common metric that denotes the cost/savings for reducing each metric ton (t) of emissions. Note that the CE estimates use the total emission reductions for the policy option (i.e. those occurring both within and outside of the state).

As indicated in the first summary table, the full benefits of FOLU policies are only realized when considering the full life-span of new trees. For this reason, the costs and benefits of FOLU policies were estimated out to the year 2085. The cumulative emission reductions, NPV, and cost effectiveness for the 2015-2085 period are shown in the notes field for each policy option.

Intra-Sector Interactions & Overlaps Adjustments

The second summary table above provides the same values described above after an assessment was made of any policy option interactions or overlaps. There were no interactions of overlaps identified between the FOLU policies; therefore, the values in the second table equal those in the first table.

Indirect Economic Impacts of FOLU Policies

Table IV-19 below provides a summary of the expected impacts on jobs and economic growth during the CSEO planning period.

Table IV-19 Macroeconomic Impacts of FOLU Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
FOLU Sector Total Low Income	$258	$264	$3,961	2,940	2,910	43,610	$446	$409	$6,135
FOLU Sector Total Keep Income	$294	$290	$4,345	3,340	3,220	48,340	$567	$486	$7,292

<u>Modeling Framework and Assumptions</u>

For the purposes of macro-economic analysis of CSEO policies, Regional Economic Models, Inc. (REMI) software was used. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

The principal data sources for macro-economic modeling are microeconomic quantifications results of direct costs and savings of individual policy options. However, these inputs are also supplemented with additional data and assumptions that were made internally, based on research and expert judgement, when certain cost/savings or other conditions pertaining to policy option implementation where not specified in micro economic analysis.

REMI model used in this analysis was specifically built for the state of Minnesota, and incorporates "Standard Regional Control", which is a baseline forecast of the state' economy and demography.

Figure IV-85 Net Job Creation for FOLU Policies and FOLU Sector by Ascending Order, 2016-2030

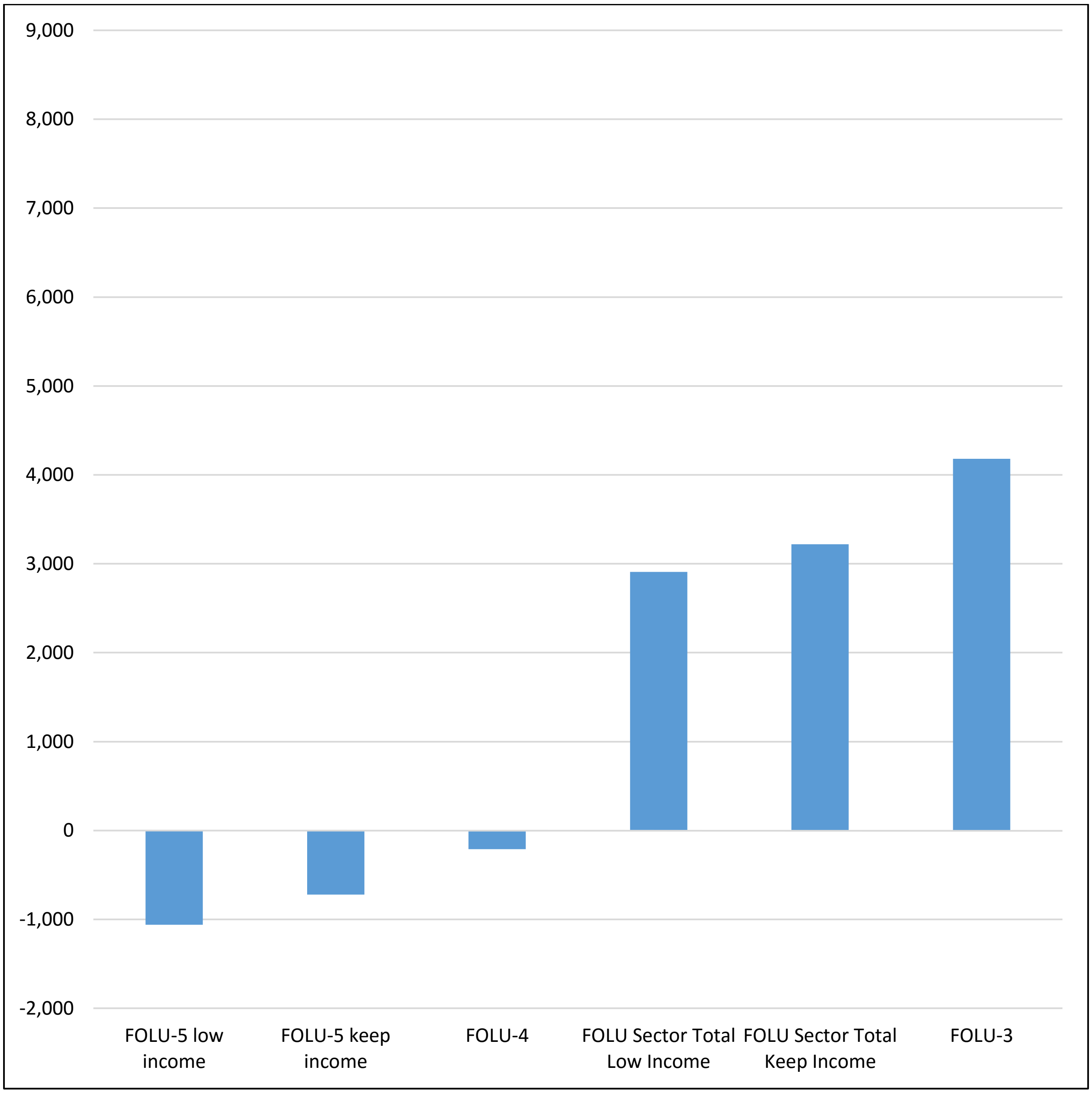
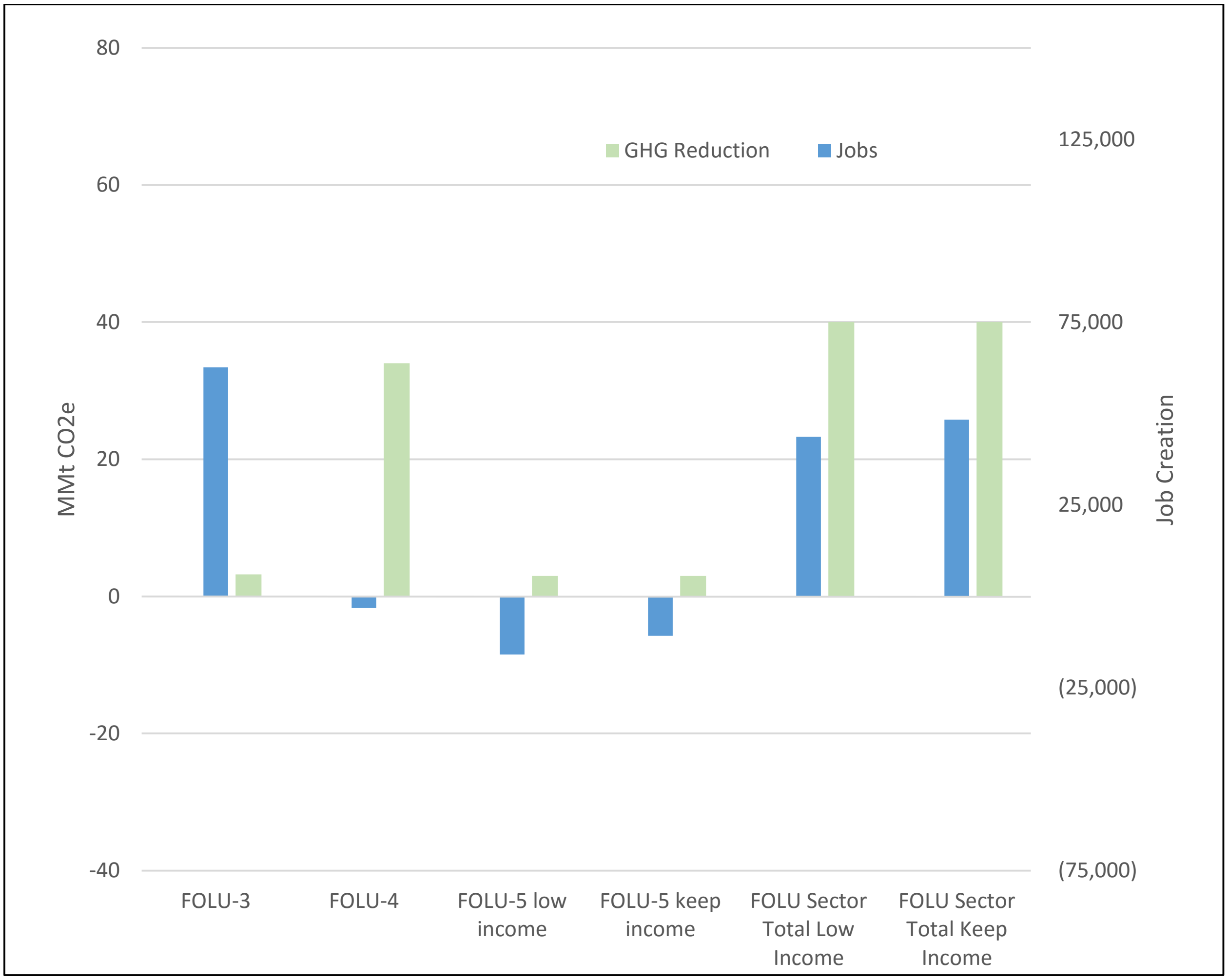


Figure below summarizes a potential for job creation and GHG emissions abatement of FOLU sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure IV-86 Job Gains and GHG Reduction by FOLU Policy Recommendations, 2016-2030



Macroeconomic index

Graphs below present the overall macroeconomic impacts of each policy in ES sector, as well as the sector-level impacts, by using the Macroeconomic Impact Index. The index is a blended score indicating an overall macroeconomic impact of a policy or a set of policies on GSP, income and employment. In this project, the three variables are weighted equally, and indexed based on the maximum value among all the policies in the project. I_GSP, I_Jobs, and I_Income represent the index score for GSP, Jobs and Income, respectively.

Figure IV-87 FOLU Macroeconomic Indicators, Year 2030

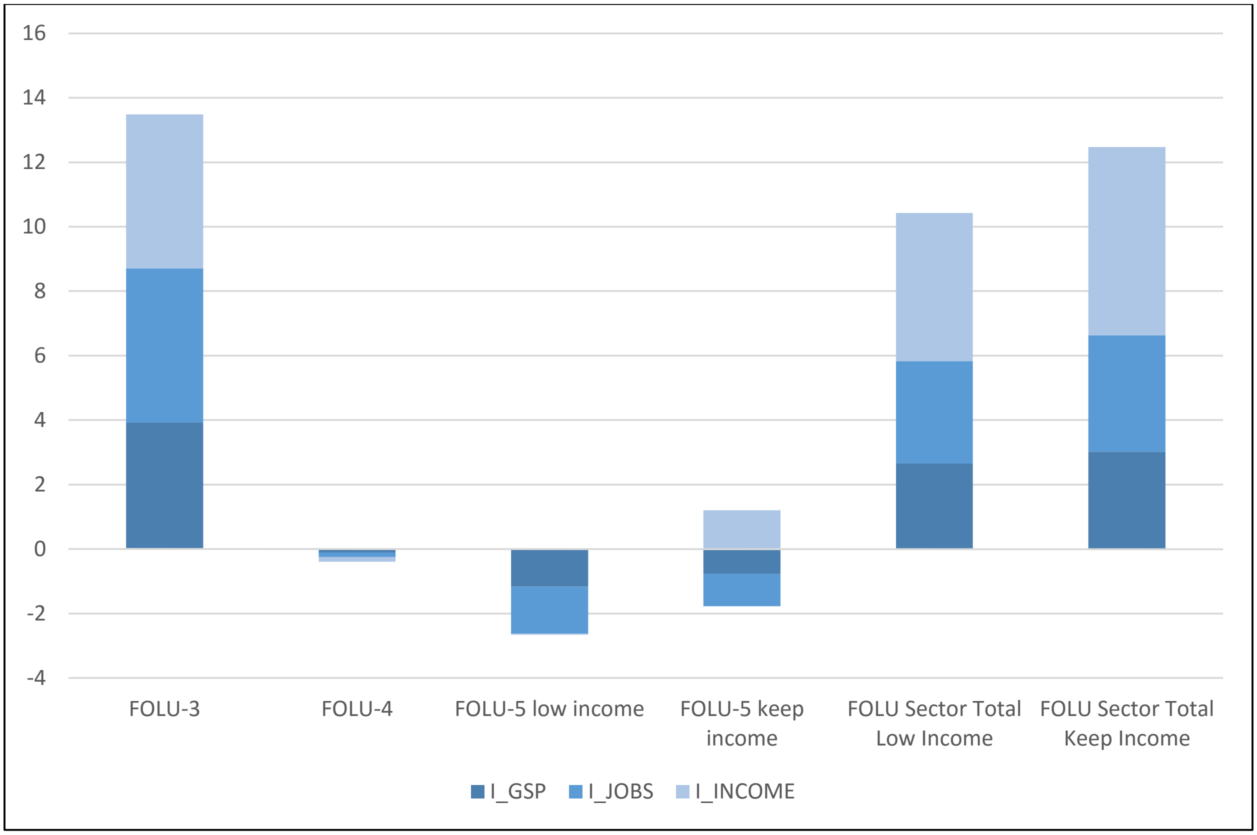


Figure IV-88 FOLU Macroeconomic Indicators, Average Annual

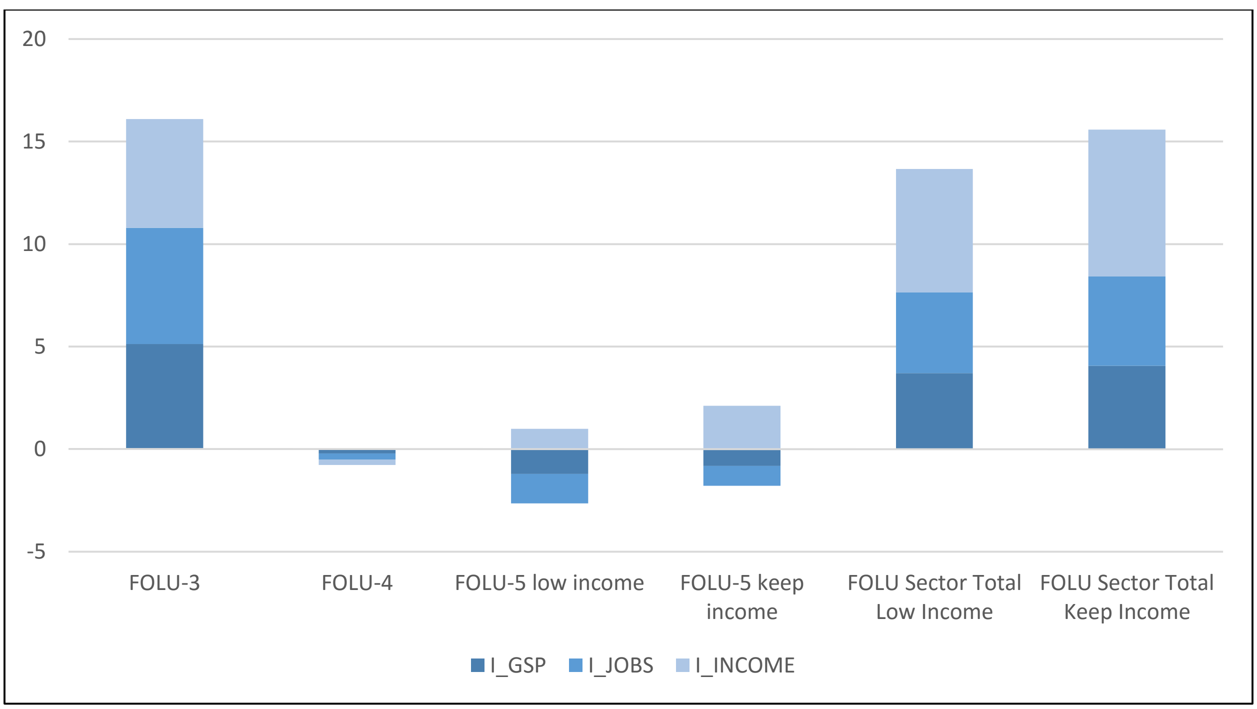
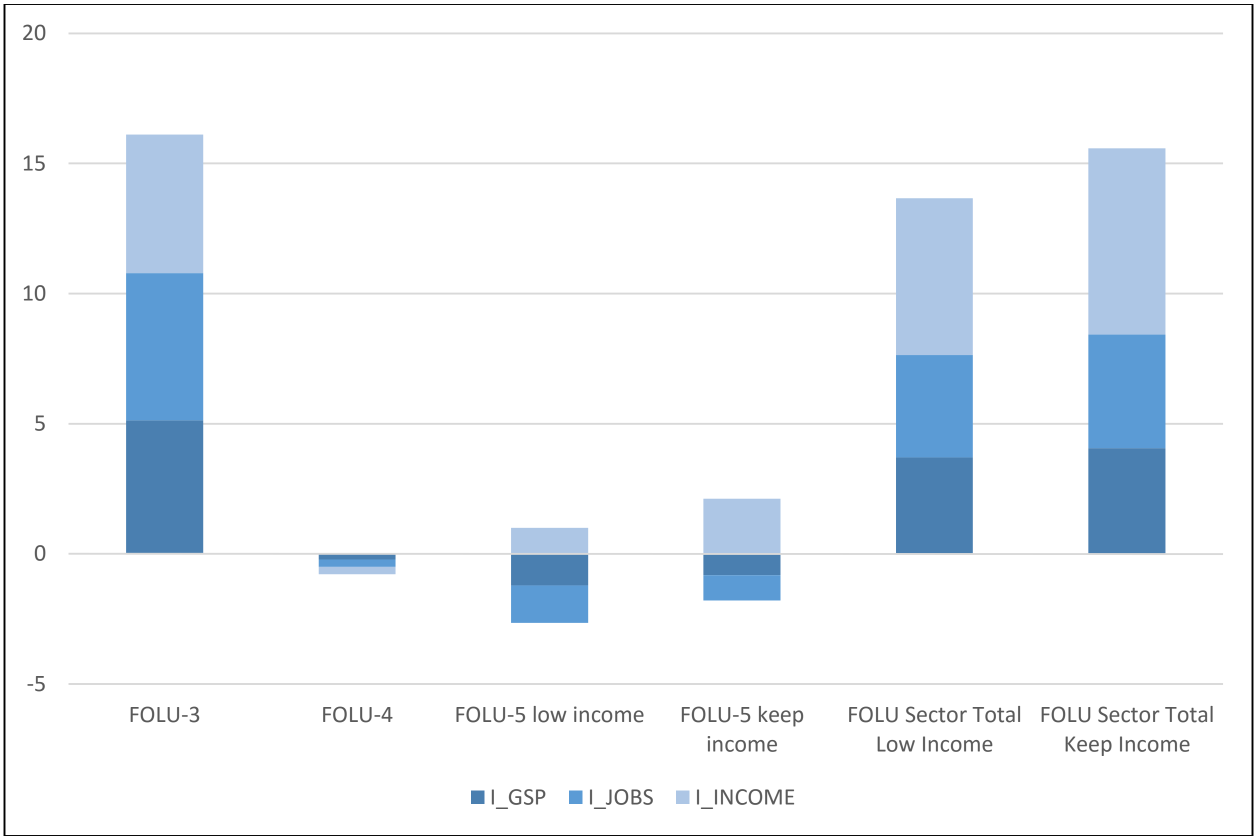


Figure IV-89 FOLU Macroeconomic Indicators, 2016-2030



Graphs below show the trend of FOLU policy macroeconomic impacts during the year 2015 to the year 2030.

Figure IV-90 . FOLU GSP Impacts ($2015 MM)

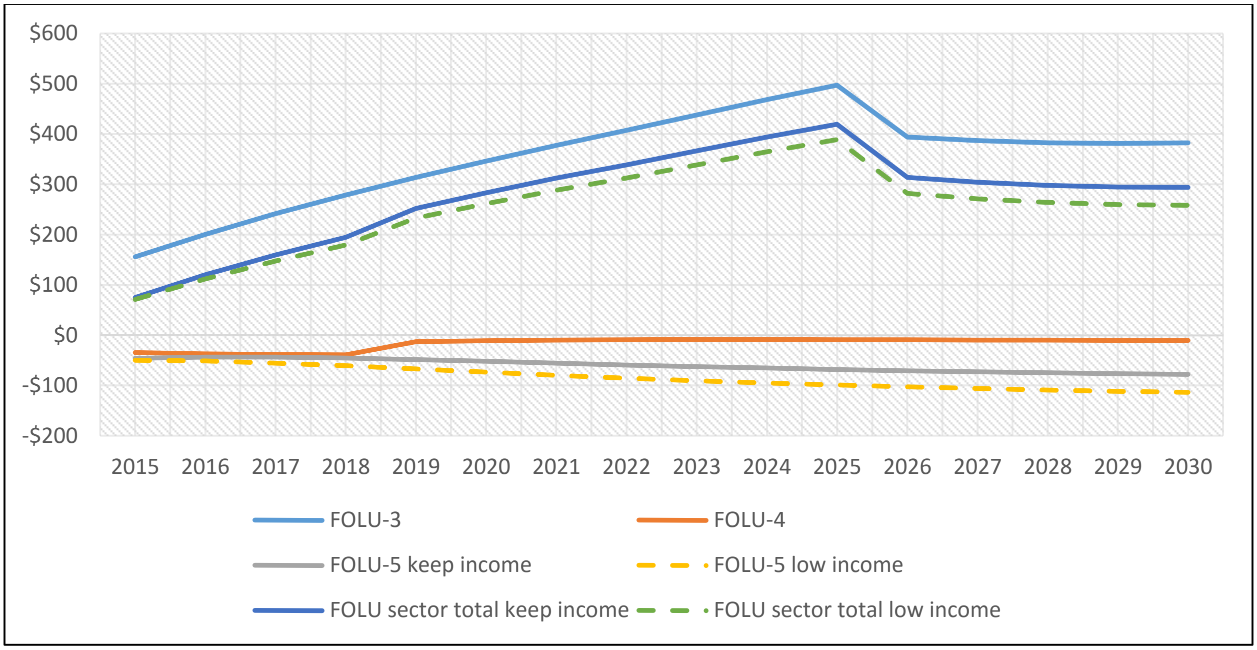


Figure IV-91 FOLU Income Impacts ($2015 MM)

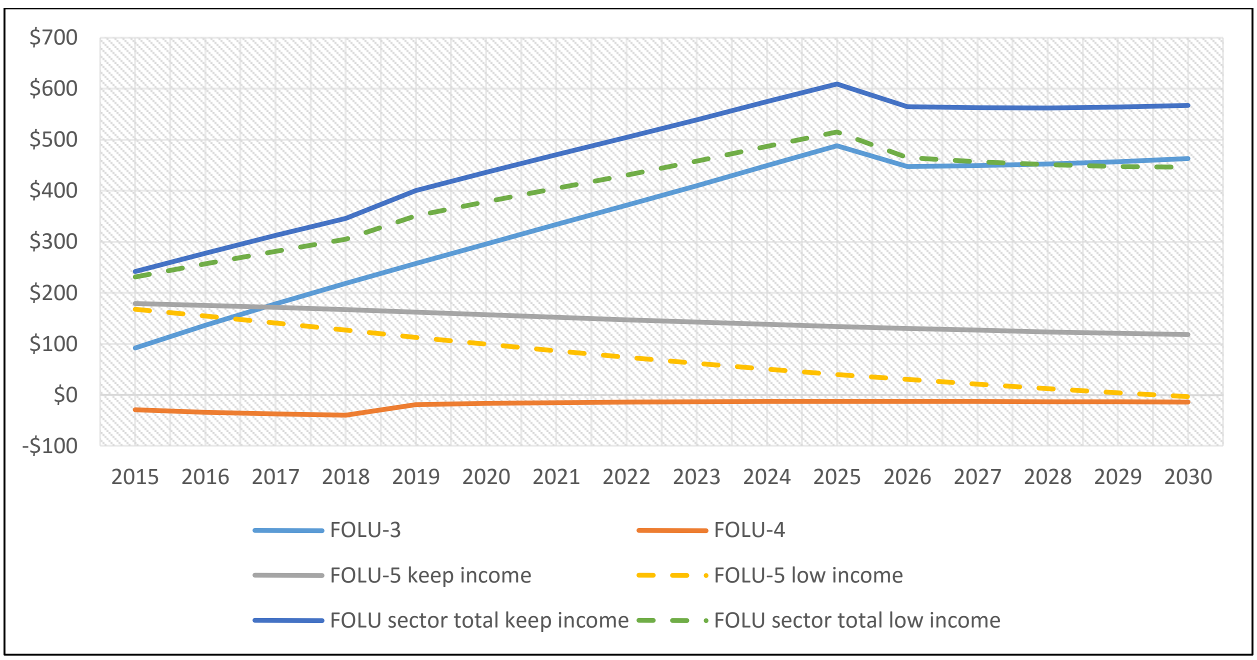
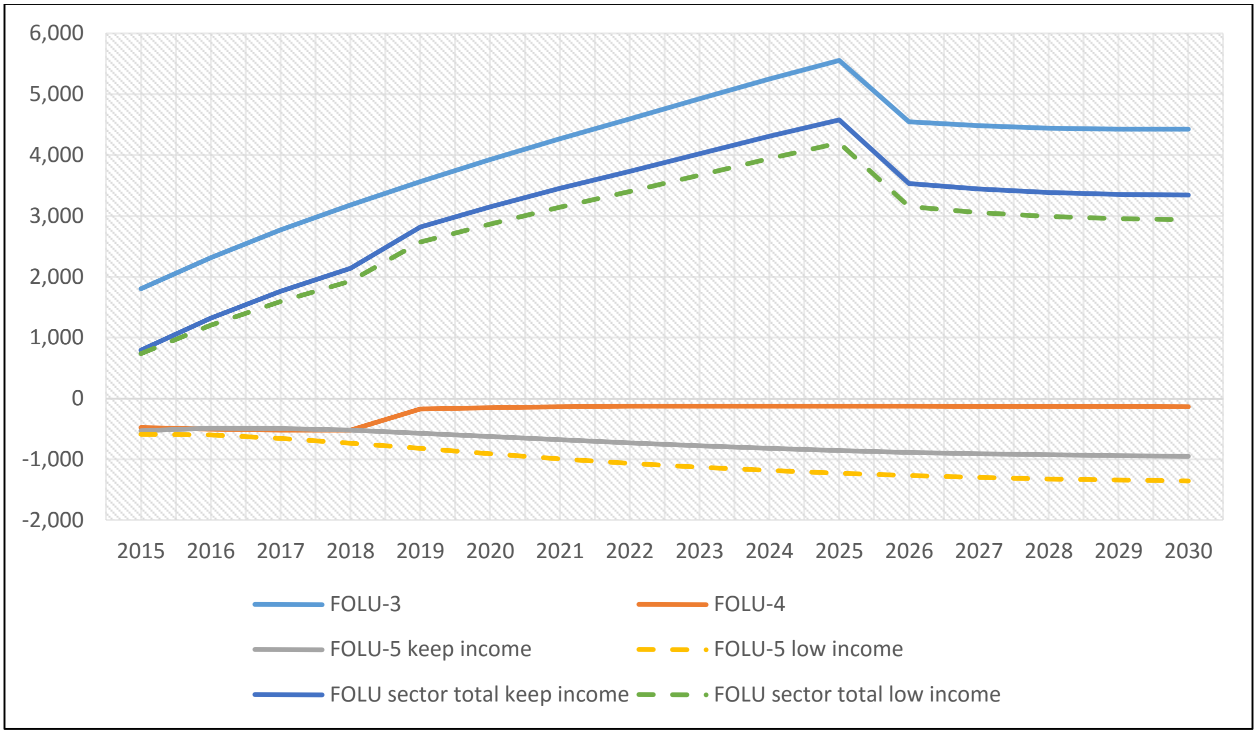


Figure IV-92 FOLU Employment Impacts (Jobs)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030). Light color means sensitivity scenarios.

Figure IV-93 FOLU GSP Impacts, Average Annual ($2015 MM)

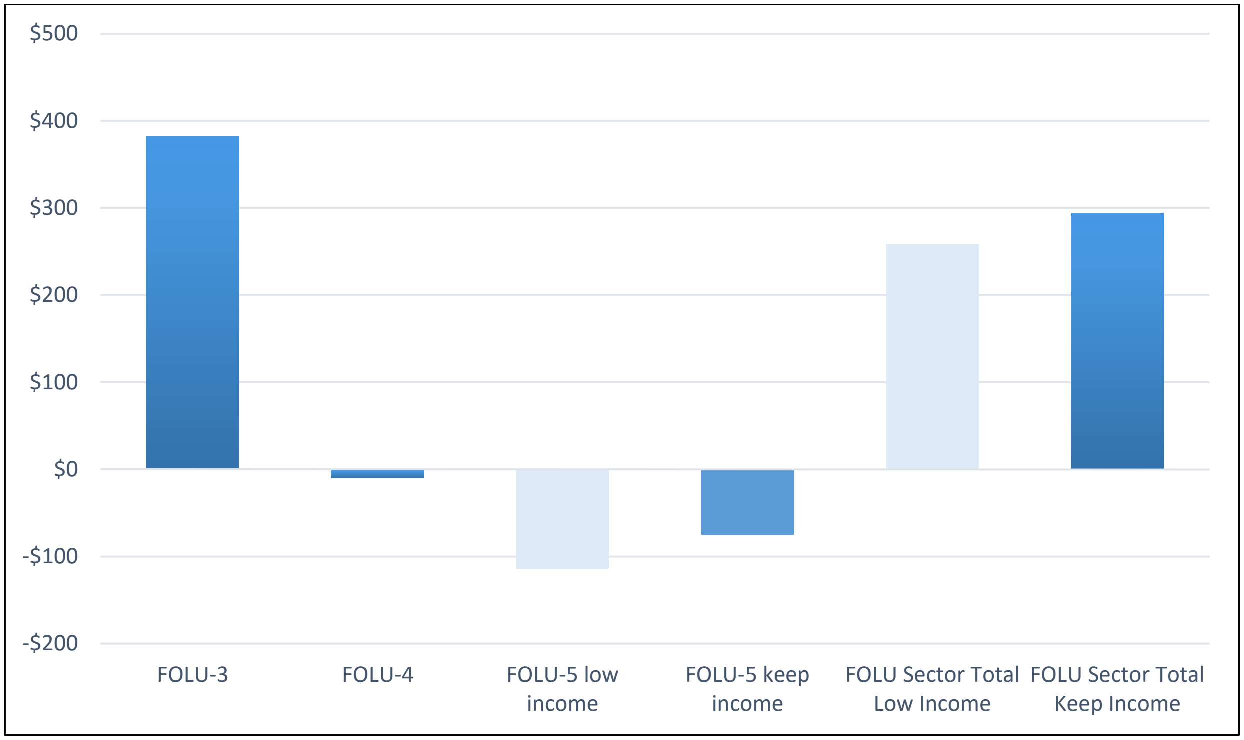


Figure IV-94 FOLU GSP Impacts, 2016-2030 ($2015 MM)

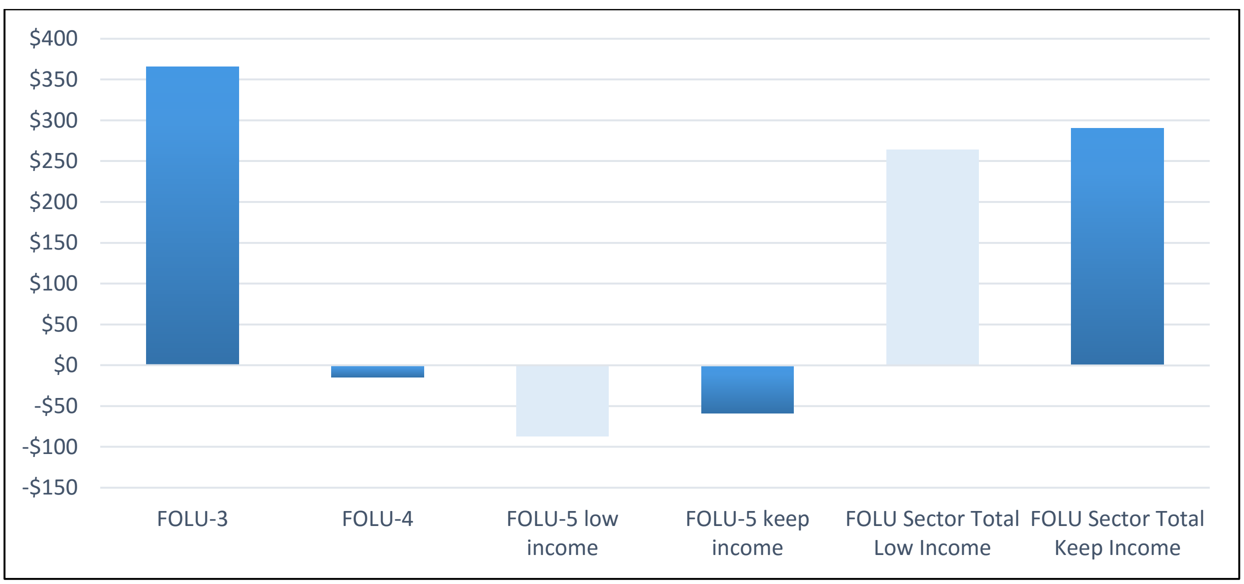


Figure IV-95 FOLU GSP Impacts, Year 2030 ($2015 MM)

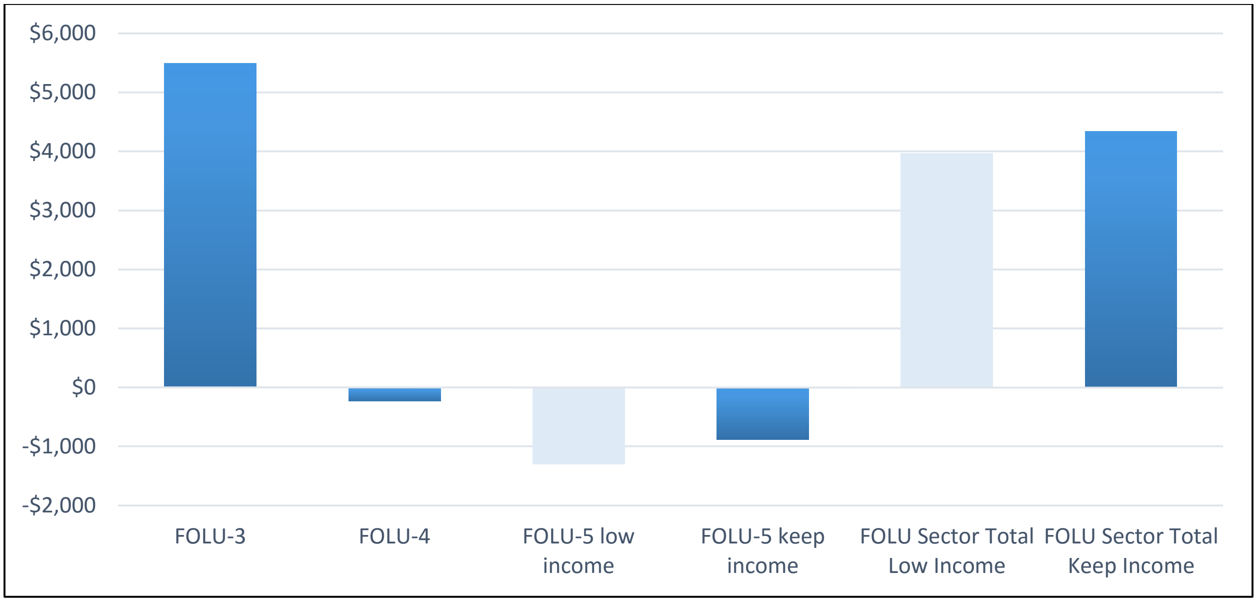


Figure IV-96 FOLU Employment Impacts, Average Annual (Jobs)

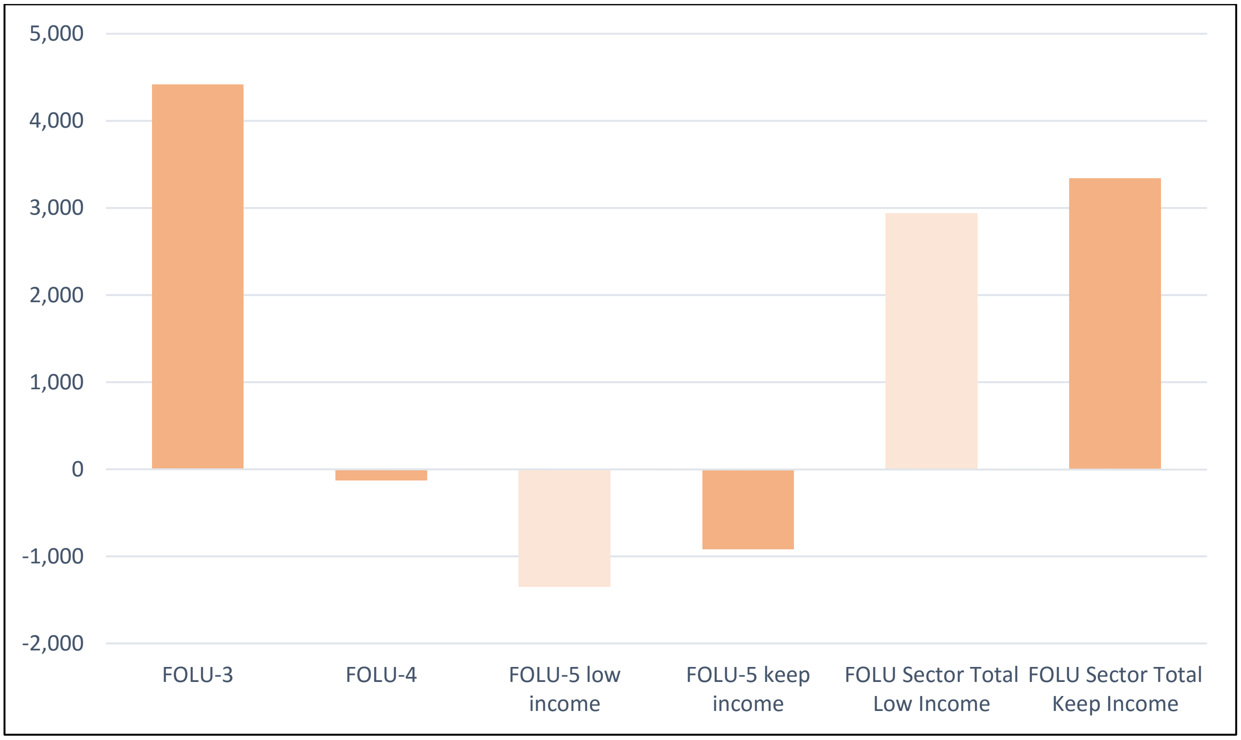


Figure IV-97 FOLU Employment Impacts, 2016-2030 (Job Years)

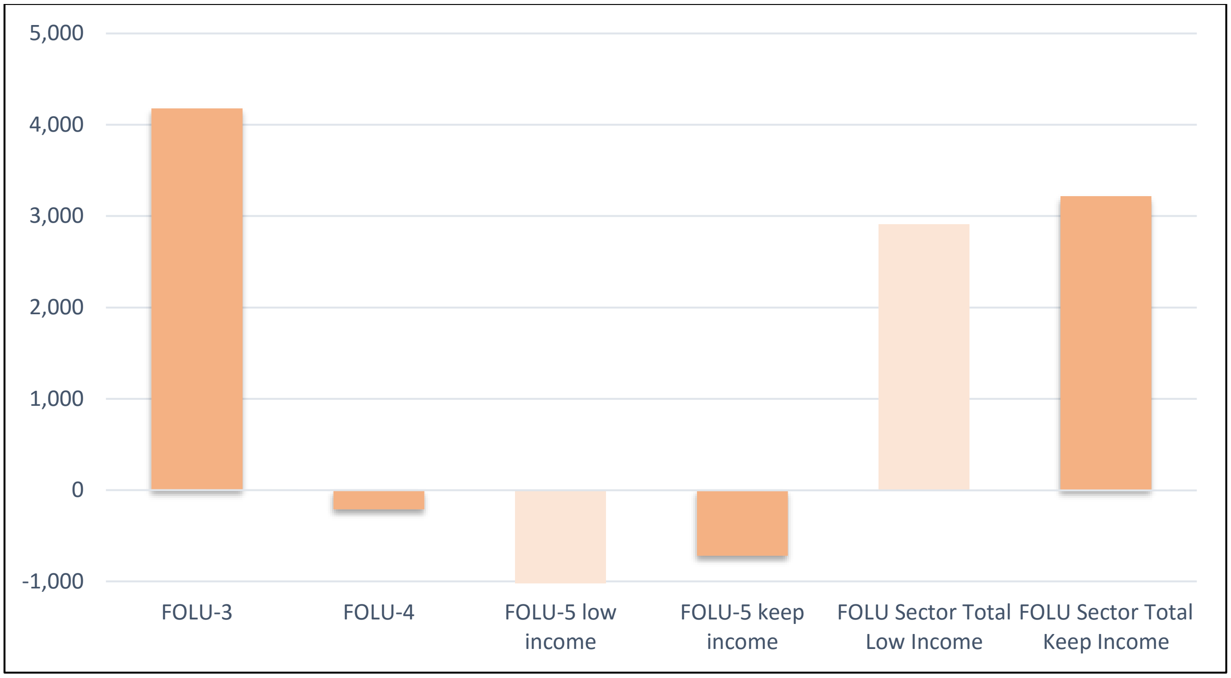


Figure IV-98 FOLU Employment Impacts, Year 2030 (Jobs)

Figure IV-99 FOLU Income Impacts, 2016-2030 Average Annual ($2015 MM)

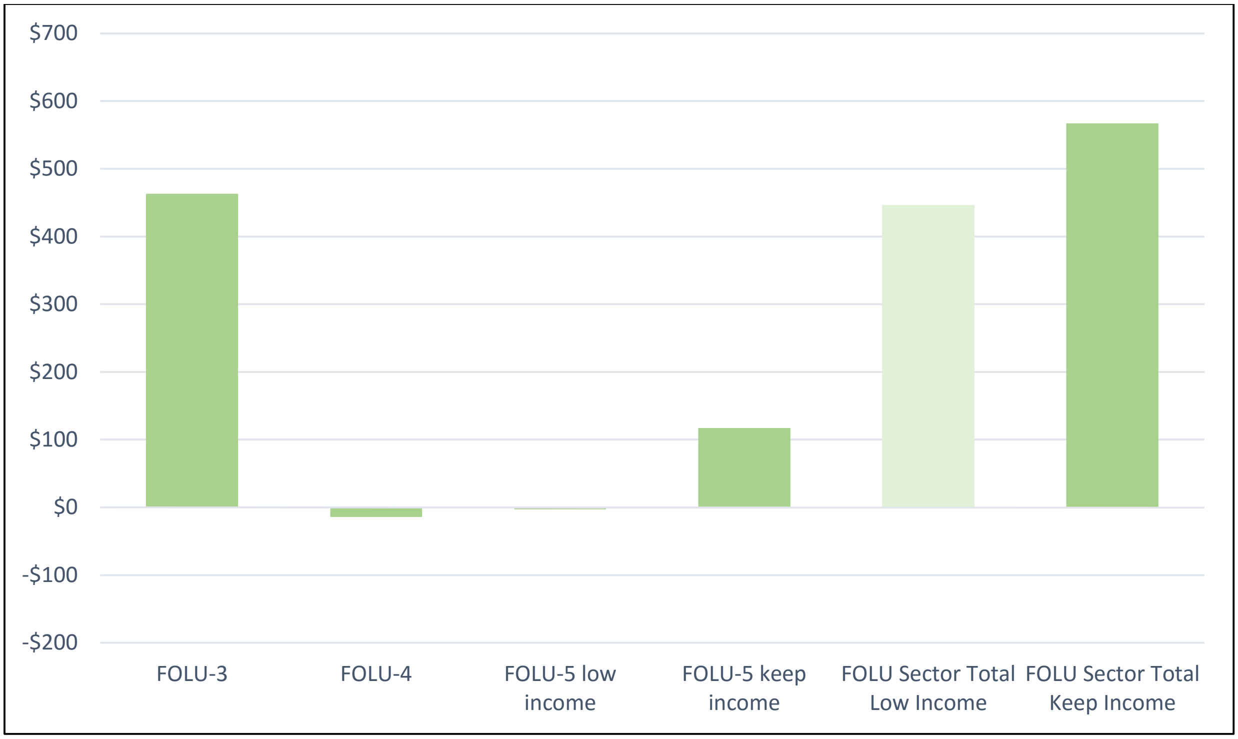
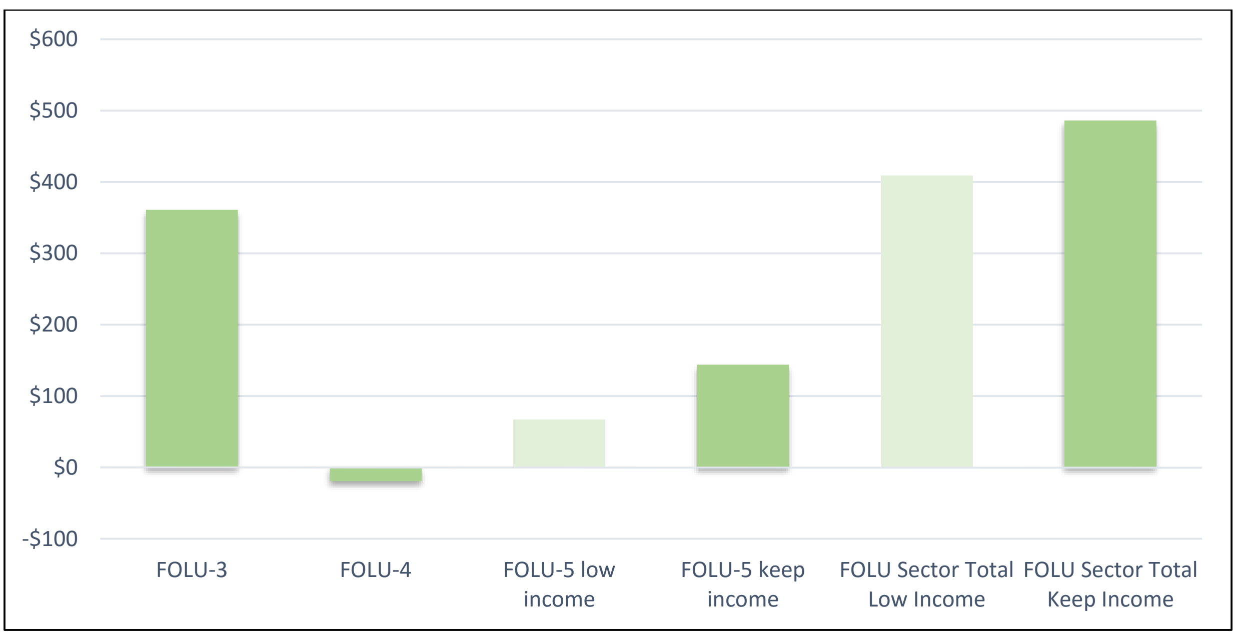


Figure IV-100 FOLU Income Impacts, 2016-2030 ($2015 MM)



6. Waste Management

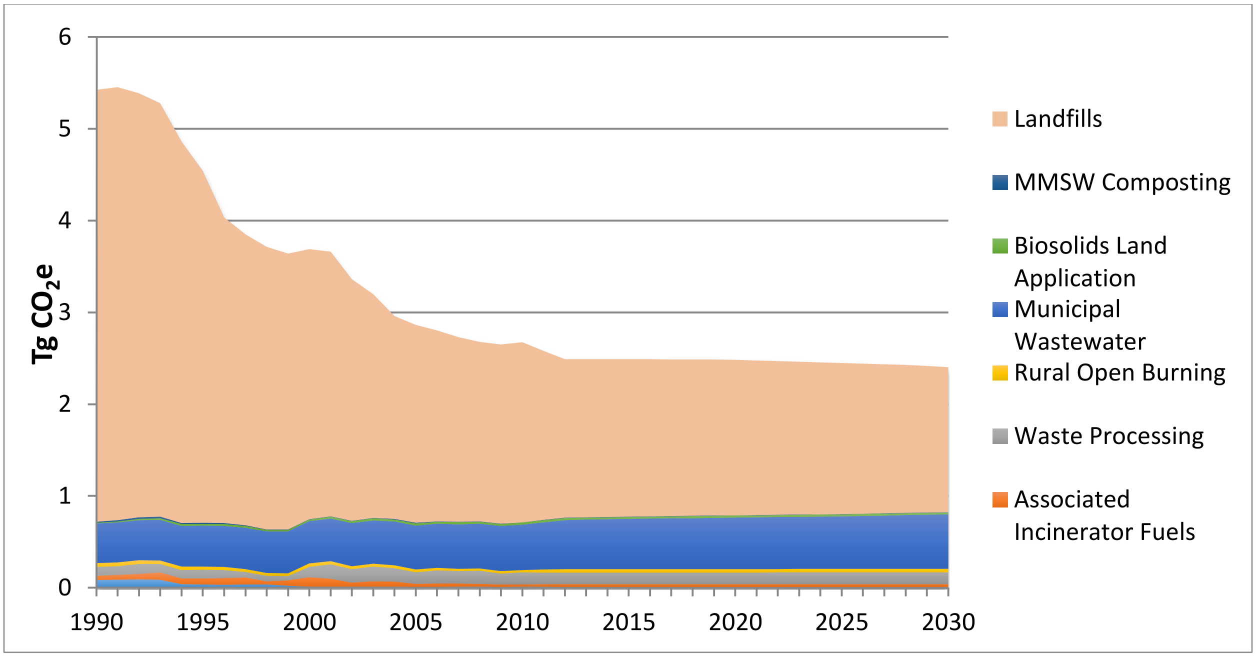
The Waste Management (WM) sector includes two subsectors: solid waste management and wastewater treatment. Key sources include landfills and municipal wastewater treatment. The sector contributed less than two percent of Minnesota's emissions in 2010 and is expected to contribute about 1.5% in 2030. Note that some solid waste is exported from Minnesota for management, and those emissions are not included in these Minnesota totals. Also, it is important to note that the most significant opportunities for greenhouse gas (GHG) reduction from solid waste management involve reducing emissions that occur upstream from the point of waste generation (i.e. during manufacturing and transport of packaging and products that end up in the waste stream). Most of these emissions would occur outside of the state. Also, wastewater treatment plants consume large amounts of energy (mainly electricity); and those emissions are reported under the Energy Supply (ES) sector.

Strategies for GHG reduction and positive economic impacts include: source reduction (reduced waste generation) and re-use; enhanced recycling; composting; landfill gas to energy; and wastewater treatment plant energy efficiency and renewable energy programs.

WM Baseline and Emissions Sources

Figure below provides the WM GHG baseline for Minnesota. It includes landfill methane (CH_4) emissions, CH_4 and nitrous oxide (N_2O) emissions from composting, N_2O emissions from land application of wastewater treatment plant biosolids, CH_4/N_2O from municipal wastewater treatment, CO_2/CH_4/N_2O emissions from rural (open) burning of municipal solid waste (MSW), waste processing, and CO_2/CH_4/N_2O from combustion of auxiliary fuels during waste incineration and the incineration of those wastes. MSW that is used for the purposes of generating electricity (refuse derived fuel) is accounted for in the ES sector.

Figure IV-101 WM Sector GHG Baseline



Notes: This chart excludes ~1TgCO_2 that is sequestered annually in construction and demolition landfills. MMSW = mixed MSW.

Historically, the WM sector emissions were dominated by landfill CH_4, which occurs during the anaerobic decomposition of MSW. However, over time, a combination of factors has lowered these emissions even though levels of waste generation have increased over time. These factors include: more waste being emplaced in modern landfills with landfill gas (LFG) collection and control; some waste being exported for management outside of the state; organic components of the waste stream being diverted to other management methods (e.g., composting); diversion of solid waste for use in waste to energy plants (emissions addressed in the ES sector); and higher levels of recycling and re-use.

As shown in Figure IV-101, even after factoring in expected future diversion of MSW via re-use and recycling, GHG emissions levels are expected to remain relatively constant through the forecast period. Landfill CH_4 is expected to remain the dominant contributor to *direct* in-state GHG emissions, followed by CH_4/N_2O emissions from municipal wastewater treatment. The term *direct* here is emphasized, because from a materials management perspective, there is often much more in the way of GHG emissions embedded in waste materials, than there is in the eventual management of those materials. The current Minnesota baseline does not present these embedded emissions (as most of these likely occur out-of-state or could be double-counted with those from other sectors, like Industry); however, a consumption-based accounting approach would provide estimates for these embedded (or "upstream") emissions. Through policy option interventions such as source reduction and re-use, these often substantial emissions can be reduced, although those reductions may occur outside of the

State's boundaries. This type of thinking has been applied in the selection and design of CSEO solid waste management policy options presented in the next section.

CSEO Policy Options

Three policy options were developed for the WM sector. These are detailed in Appendix F.6 and are summarized as follows:

WM-1. Wastewater Treatment - Energy Efficiency

This policy option addresses opportunities for energy conservation within wastewater treatment plants (WWTPs). The conservation mandate is technology agnostic to allow for flexibility. The policy option design calls for a state-wide reduction in energy usage from WWTPs of 25% by 2025. Most plants that have not already undertaken significant energy efficiency retrofits can find cost savings energy efficiency (EE) measures in the form of more efficient aeration equipment and higher efficiency blowers and pumps.

WM-2. Front-End Waste Management: Source Reduction

Front-end solid waste management (SWM) technologies promote reduction of the volume of waste needing disposal, as well as reduction in consumption through incentives, awareness, and increased efficiency. Four major areas of focus in Minnesota are source reduction, re-use, advanced recycling, and organics diversion. Source reduction, reuse, and recycling provide GHG benefits not only from avoided disposal emissions, but also from reducing product energy-cycle emissions that would otherwise come from the manufacture and transport of new products and packaging. Redirecting organic materials into food-to-people, food-to-livestock, and composting programs cuts GHG emissions compared to disposal in landfills (food-to-people and food-to-livestock programs also reduce upstream energy-cycle emissions).

This policy option along with WM-3 below represent a continuation of the AFW-7 policy option from the 2008 MCCAG report. Following that report in 2008, the 2014 Legislature codified a 75% total recycling goal that combines conventional dry recycling and composting, food-rescue, and food-to-animals for the seven Metro counties. Following the MCCAG report, Minnesota has taken several important steps at the state and local levels to make those goals attainable. As of 2012, the statewide dry recycling rate was 42%, and the organics diversion rate was seven percent, including yard waste, for a combined recycling rate of 49%. The overall goal of WM-2 is to achieve a zero percent per capita increase in waste generation per capita by 2020 and a three percent decrease by 2025.

WM-3. Front-End Waste Management - Re-Use, Composting & Recycling

This policy option represents the second component of the MSW policy option package for improving front-end waste management in MN. The goal of this policy option is to achieve a total recycling rate, including composting of 75% by 2025. This assumes that no additional waste is diverted from current levels of waste to energy (WTE) generation. MN achieved a recycling rate (including organics recycling) of over 49% in 2012.

Direct and Indirect Policy Option Impacts

Overview

The tables above provide a summary of the microeconomic analysis of Climate Solutions & Economic Opportunities (CSEO) policy options in the Waste Management (WM) sector. The first table provides a summary of results on a stand-alone basis, meaning that each policy option was analyzed separately against baseline (business as usual or BAU) conditions. Details on the analysis of each policy option are provided in each of the Policy Option Documents (PODs) that follow within this appendix.

Direct, Stand Alone Economic Impacts

The stand-alone results provide the annual greenhouse gas (GHG) reductions for 2020 and 2030 in teragrams (Tg) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030 (1 Tg is equal to 1 million metric tons). The reductions shown are only those that have been estimated to occur within the state. Additional GHG reductions, typically those associated with upstream emissions in the supply of fuels or materials, have also been estimated and are reported within each of the analyses in each POD.

Also reported in the stand-alone results is the net present value (NPV) of societal costs/savings for each policy option. These are the net costs of implementing each policy option reported in 2014 dollars. The cost effectiveness (CE) estimated for each policy option is also provided. Cost effectiveness is a common metric that denotes the cost/savings for reducing each metric ton (t) of emissions. Note that the CE estimates use the total emission reductions for the policy option (i.e. those occurring both within and outside of the state).

As indicated in the first summary table, WM-2 builds upon and assumes full implementation of WM-3. For both WM-2 and WM-3, the policy options result in net in-state emissions in 2020. However, the total impact of each of these policy options, including out-of-state impacts, is a net reduction in emissions in 2020.

Integrative Adjustments & Overlaps

The second summary table above provides the same values described above after an assessment was made of any policy option interactions or overlaps. In the Waste Management sector there are no overlaps, as removal of any potential overlap between WM-2 and WM-3 was already removed in the analysis. Therefore, the values in the second table are the same as those in the stand-alone table.

Macroeconomic (Indirect) Economic Impacts

Table IV-22 below provides a summary of the expected impacts of WM policies on jobs and economic growth during the CSEO planning period. This table focuses on the impact of policies on Gross State Product (the total amount spent on goods and services produced within the state), Employment (the total number of full-time and part-time positions), and Incomes (the total amount earned by households from all possible sources). These metrics represent three valuable indicators of both the overall size of the economy and that economy's structural orientation toward supporting livelihoods and utilizing productive work.

For the purposes of macro-economic analysis of CSEO policies, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software. This particular REMI model is developed specifically for Minnesota, and is developed consistently with the design of models in use by state agency staff within Minnesota for a range of economic analyses. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

The main inputs for macro-economic analysis are microeconomic estimates of direct costs and savings expected from the implementation of individual policy options. These inputs are supplemented with additional data and assumptions necessary to complete the picture of how these costs and savings (as well as price changes, demand and supply changes, and other factors) influence Minnesota's economy. These additional data and assumptions typically regard how various actors around the state (households, businesses and governments) respond to change by changing their own economic activity. A full articulation of the general and policy-specific assumptions made by the macroeconomic analysis team is provided in the Policy Option Documents, contained as appendices to this report.

Table IV-20 WM Policy Options, Direct Stand-Alone Impacts

Stand-Alone Analysis							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual CO_2e Reductions[a]		2030 Cumulative	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/tCO₂e
WM-1	Waste Water Treatment - Energy Efficiency	0.051	0.068	0.89	0.99	($56)	($56)
WM-2	Front-End Waste Management - Source Reduction	(0.0020)	0.057	0.073	9.4	($277)	($30)

WM-3[e]	Front-End Waste Management - Re-Use, Composting & Recycling	(0.11)	0.15	(0.45)	27	($817)	($30)
Totals		**(0.058)**	**0.28**	**0.52**	**37**	**($1,150)**	**($31)**

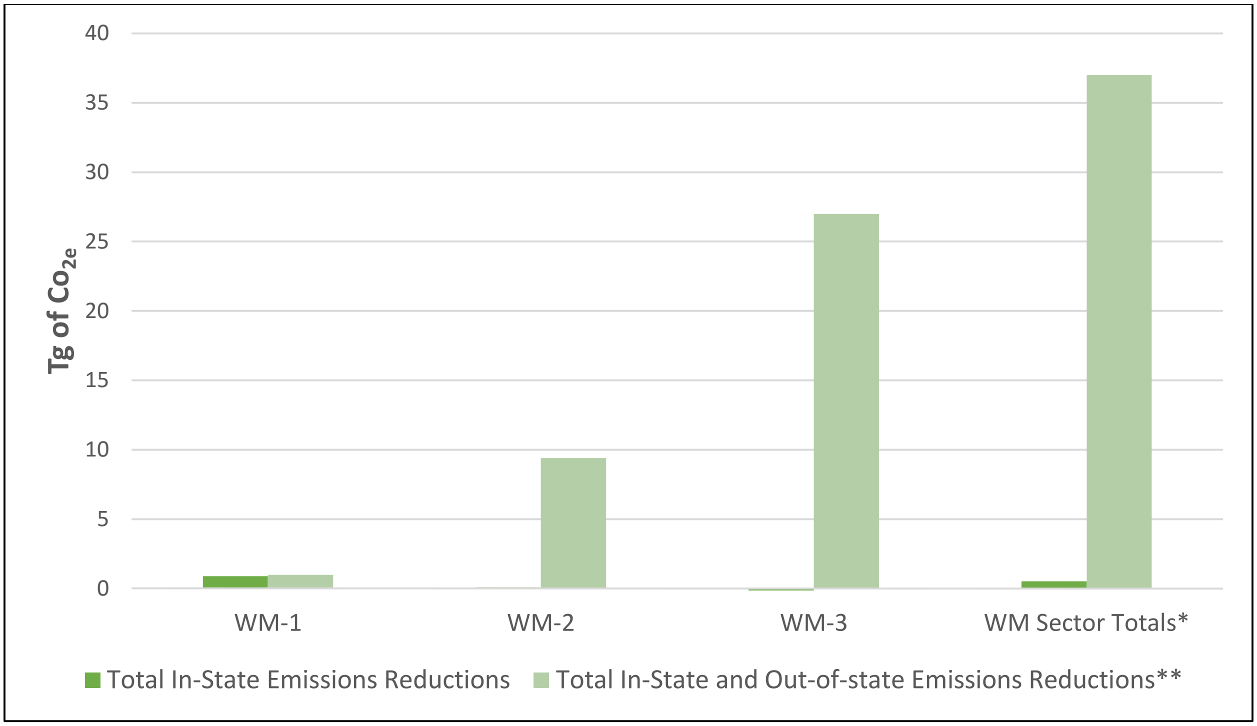
Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] Assumes full implementation of WM-2.

Table IV-21 WM Policy Options, Intra-Sector Interactions & Overlaps

Intra-Sector Interactions & Overlaps Adjusted Results							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Cost[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/tCO₂e
WM-1	Waste Water Treatment - Energy Efficiency	0.051	0.068	0.89	0.99	($56)	($56)
WM-2	Front-End Waste Management - Source Reduction	(0.0020)	0.057	0.073	9.4	($277)	($30)
WM-3	Front-End Waste Management - Re-Use, Composting & Recycling	(0.11)	0.15	(0.45)	27	($817)	($30)
Totals After Intra-Sector Interactions /Overlap		**(0.058)**	**0.28**	**0.52**	**37**	**($1,150)**	**($31)**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] WM-3 builds off of WM-2 and assumes full implementation; so no overlaps.

Figure IV-102 WM Policies GHG Emissions Abatement, 2016-2030



Notes:
* All Policies Total's comprise emissions reductions achieved by WM policies combined.
** Total in and out-of-state emissions reduction are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Table IV-22 Macroeconomic Impacts of WM Policy Options

Macroeconomic (Indirect) Impacts Results									
Scenario	GSP[a] ($2015 MM)			Employment[b] (Individual)			Personal Income[c] ($2015 MM)		
	Year 2030[d]	Average (2016-2030)[e]	Cumulative (2016-2030)[f]	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
WM-1	$2	$2	$31	90	80	1,130	$8	$6	$86
WM-2	$6	$2	$31	150	60	930	$13	$5	$72
WM-3	$240	$203	$3,039	3,290	2,750	41,210	$319	$223	$3,338
WM Sector Total	**$248**	**$207**	**$3,101**	**3,530**	**2,890**	**43,280**	**$340**	**$233**	**$3,496**

Notes:

[a] Gross State Production changes in Minnesota. Dollars expressed in $2015.
[b] Total employment changes in Minnesota.
[c] Personal Income changes in Minnesota. Dollars expressed in $2015.
[d] Single final year value. Year 2030 is the final year of analyses in this project.
[e] Average value from the year 2016 to the year 2030. The average value is calculated from the first year of the policy implementation through the year 2030 if implementation of the policy starts after year 2016.
[f] Cumulative value from 2016-2030 time period.

Figure IV-103 Net Job Creation for WM Policies and WM Sector by Ascending Order, 2016-2030

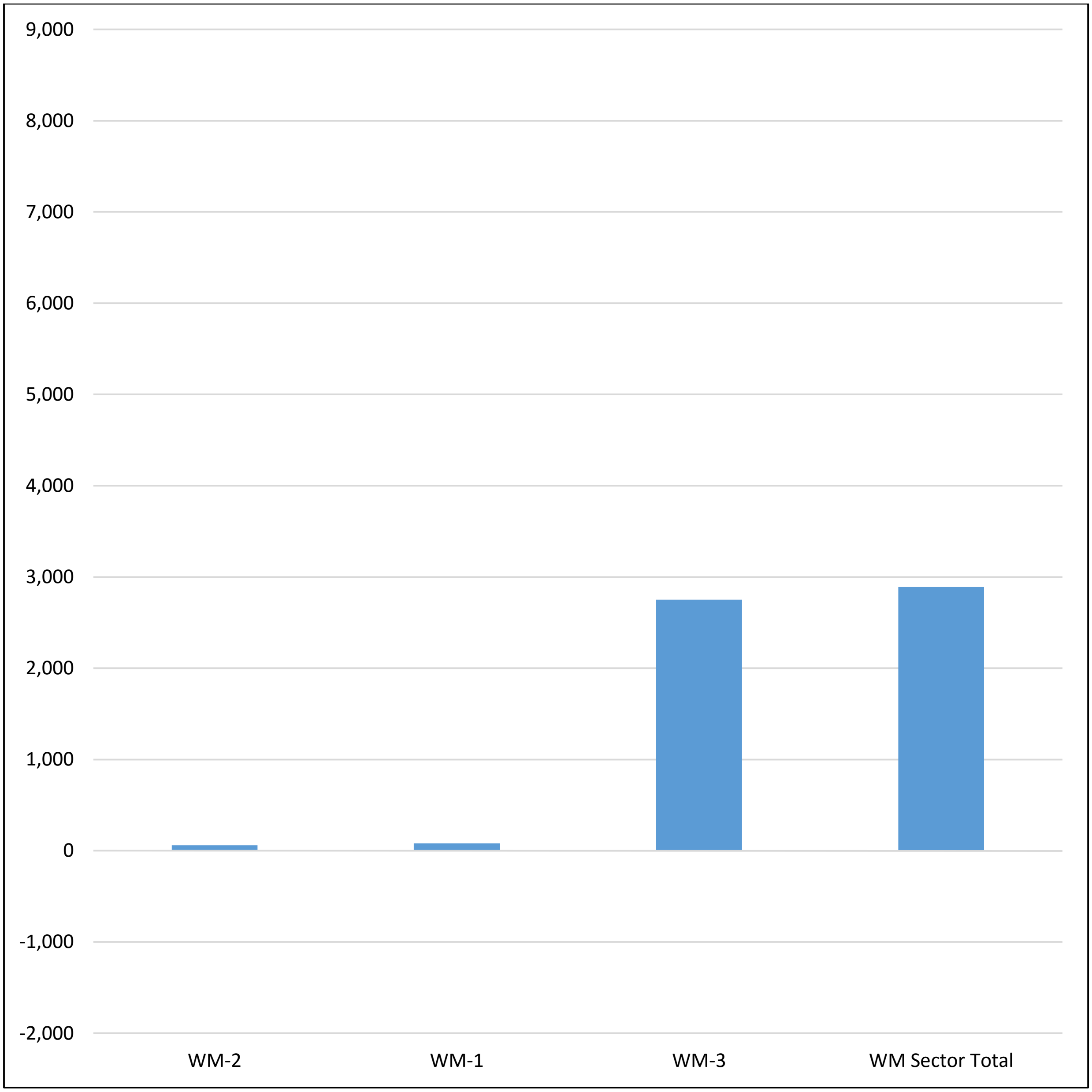
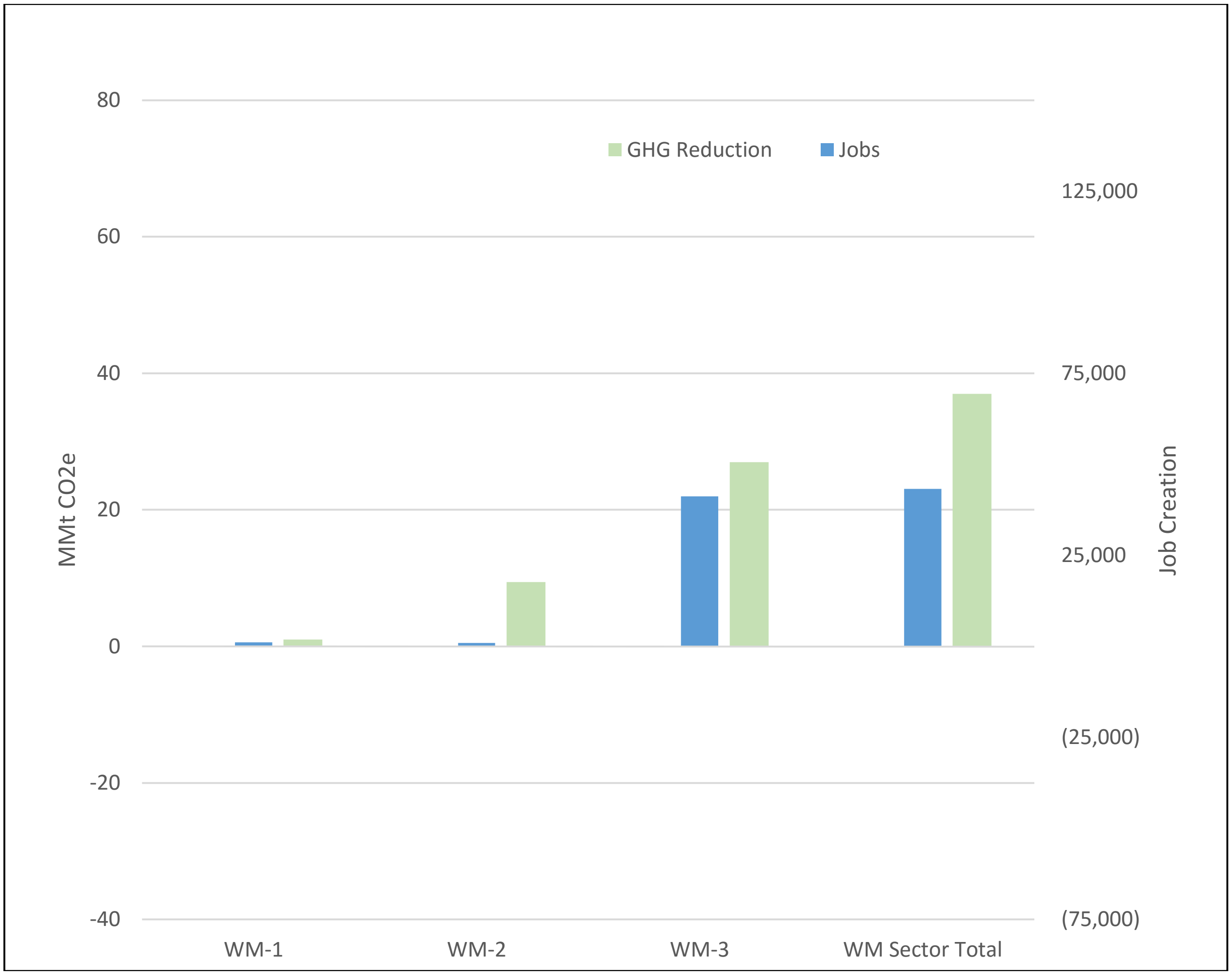


Figure below summarizes a potential for job creation and GHG emissions abatement of WM sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure IV-104 Job Gains and GHG Reduction by WM Policy Recommendations, 2016-2030



Macroeconomic Impacts

Graphs below present the overall macroeconomic impacts of each policy in WM sector, as well as the sector-level impacts, by using the Macroeconomic Impact Index. The index is a blended score indicating overall macroeconomic impact of a policy or a set of policies on GSP, income and employment. In this project, the three variables are weighted equally, and indexed based on the maximum value among all the policies. I_GSP, I_Jobs, and I_Income represent the index score for GSP, Jobs and Income, respectively.

Figure IV-105 WM Macroeconomic Indicators, 2030

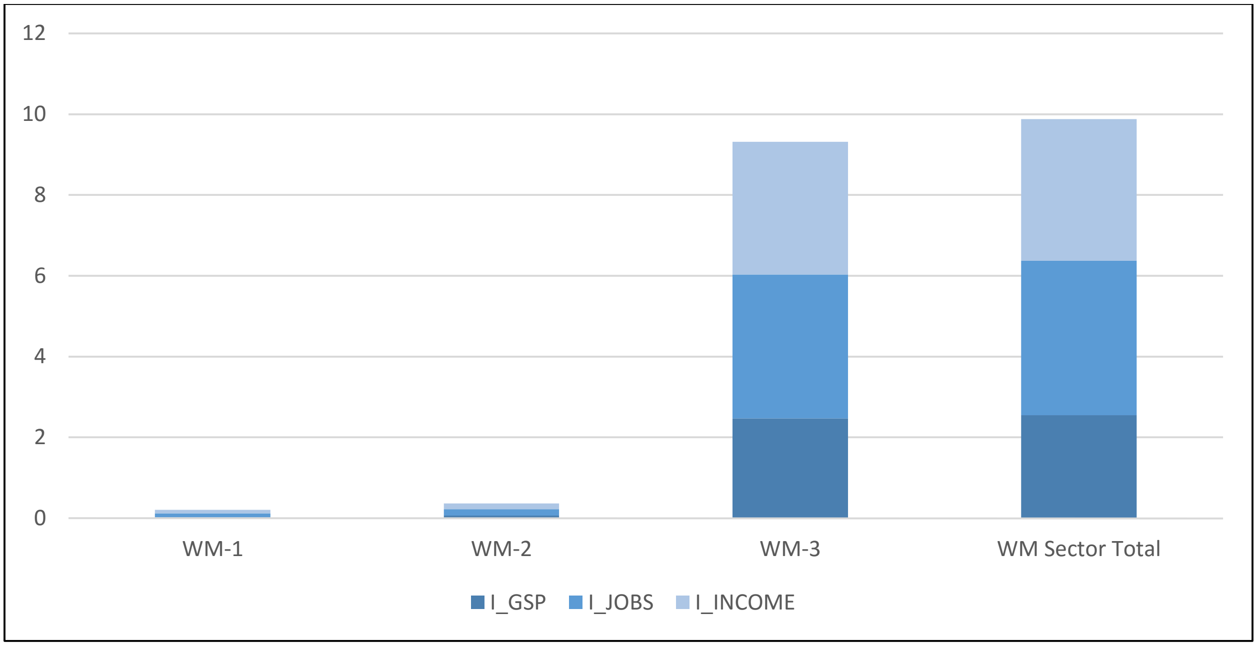


Figure IV-106 WM Macroeconomic Indicators, Average Annual

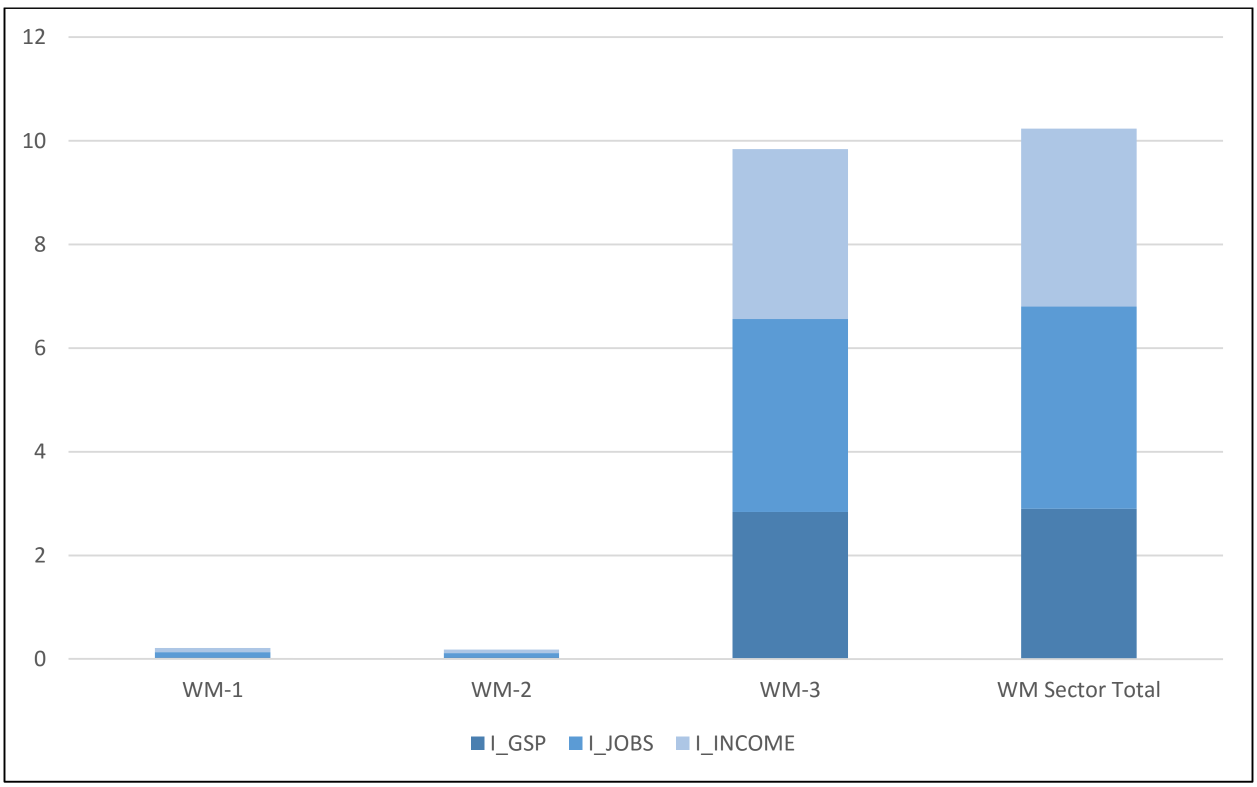
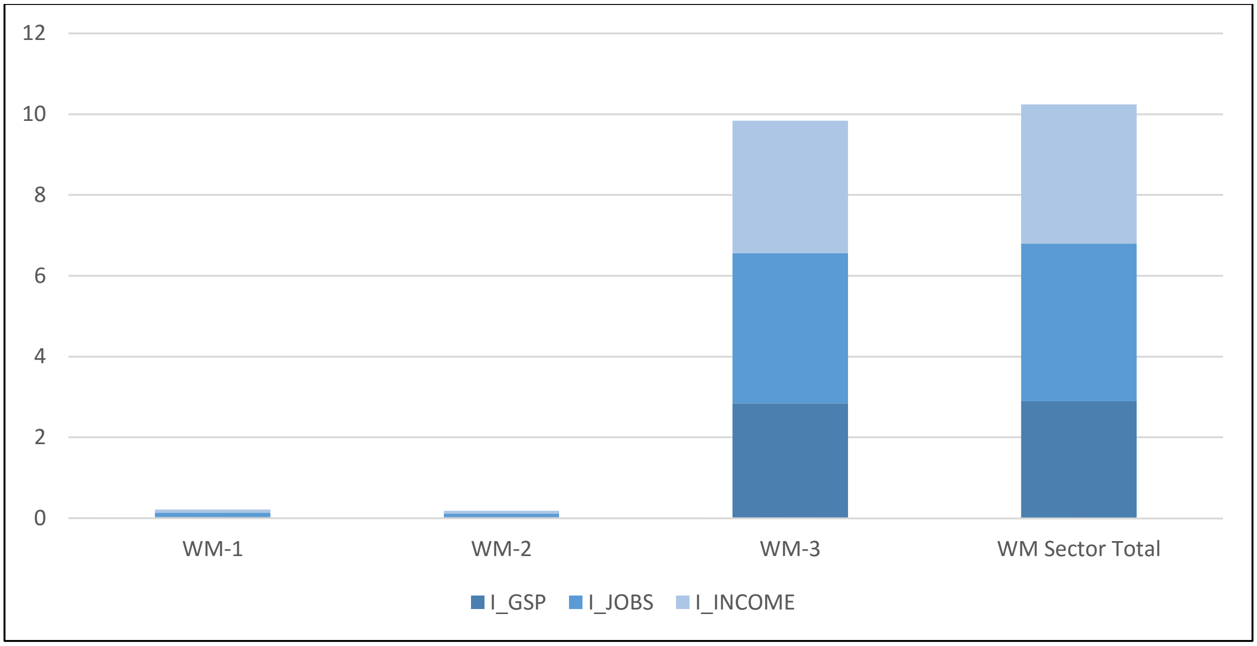


Figure IV-107 WM Macroeconomic Indicators, 2016-2030



Graphs below show the trend of WM policy macroeconomic impacts during the year 2015 to the year 2030.

The Waste sector generates significant positive impacts – around $250 million in GSP and nearly $350 million in income, with 3,500 jobs more than would exist in the state by 2030 than if these policies were not implemented.

The sector impact on Minnesota's economy, according to this analysis, is really the story of the waste reduction policy focused on recycling, re-use and composting waste (WM-3). While the other policies are tiny in their overall impacts, driving very small positive or negative shifts over time, the WM-3 policy is responsible for effectively all of the sector's gains.

Figure IV-108 WM GSP Impacts ($2015 MM)

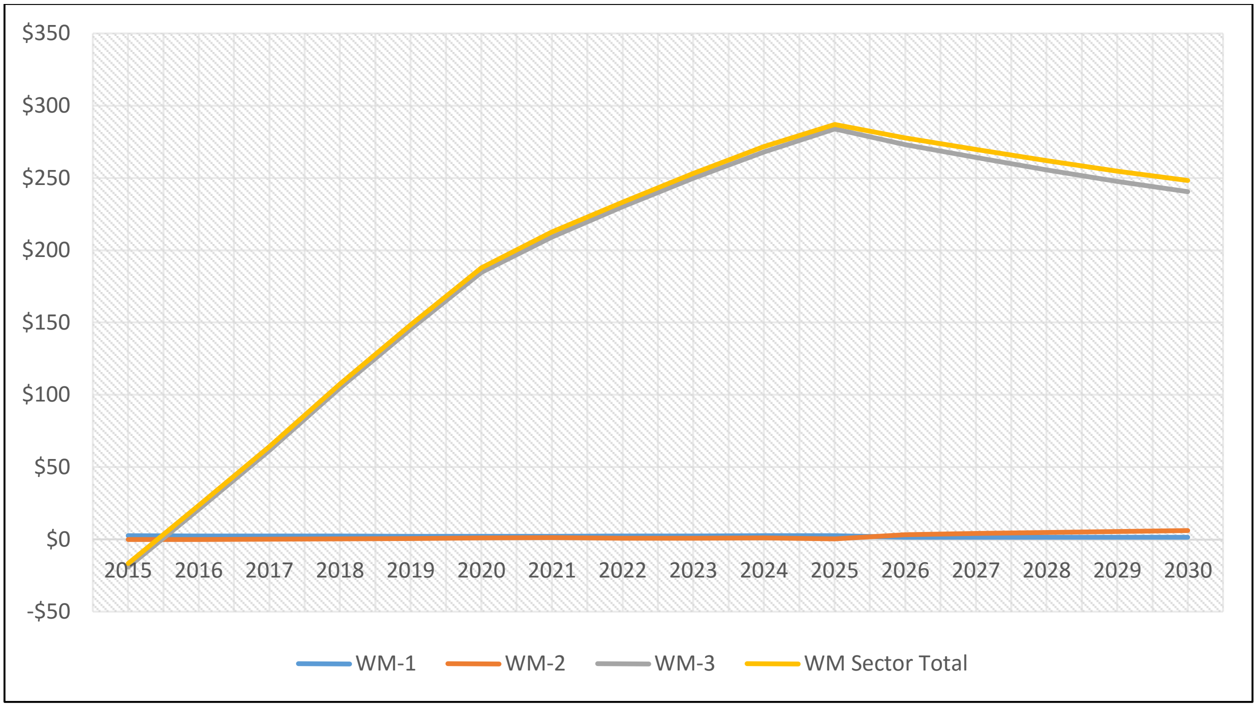


Figure IV-109 WM Employment Impacts (Jobs)

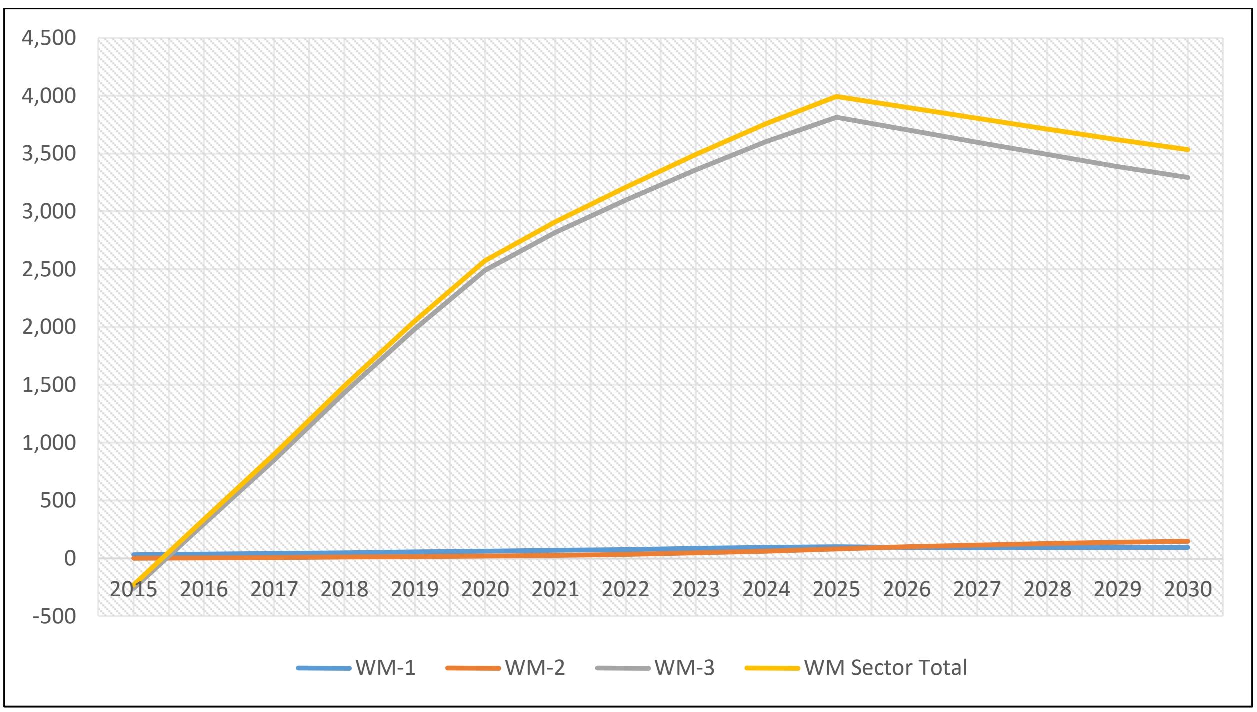
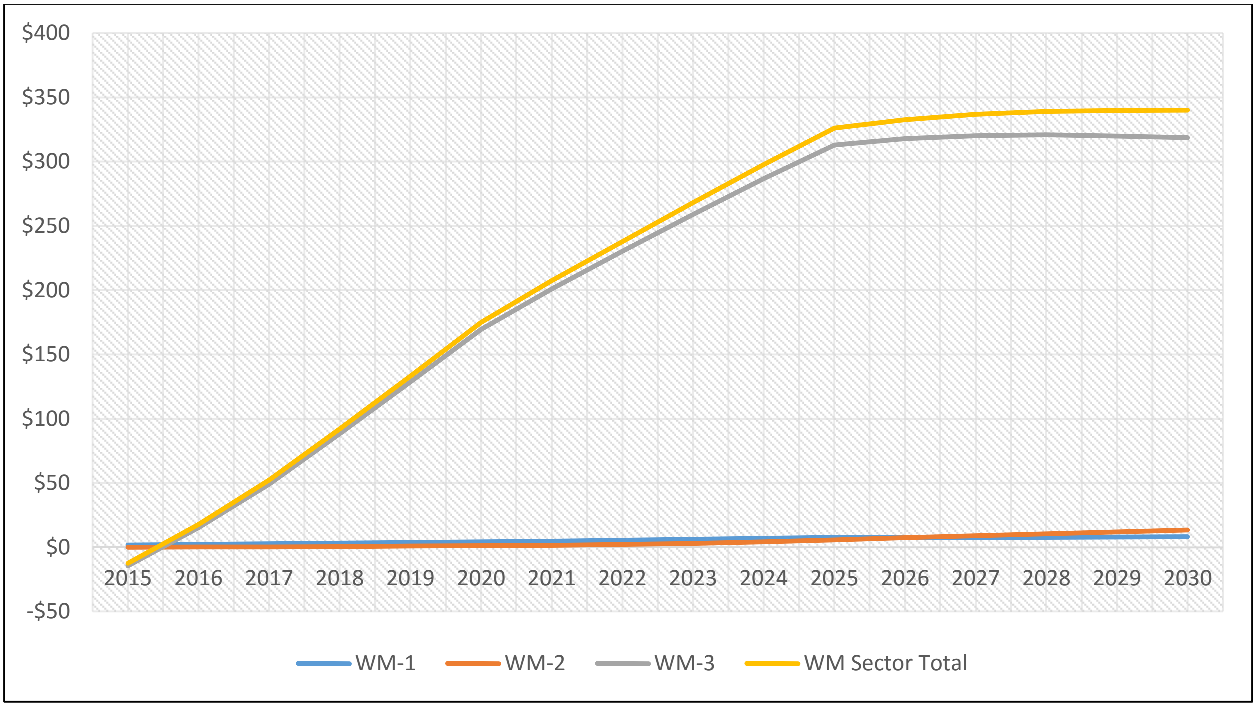


Figure IV-110 WM Income Impacts ($2015 MM)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030).

Figure IV-111 WM GSP Impacts, Average Annual ($2015 MM)

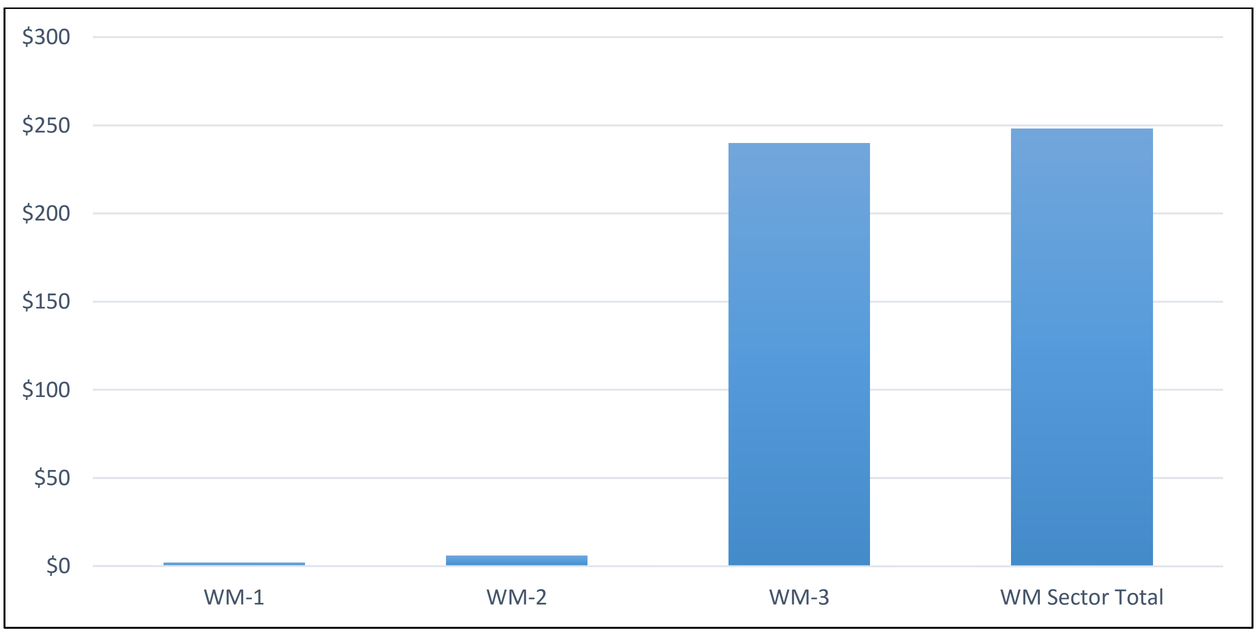


Figure IV-112 WM GSP Impacts, 2016-2030 ($2015 MM)

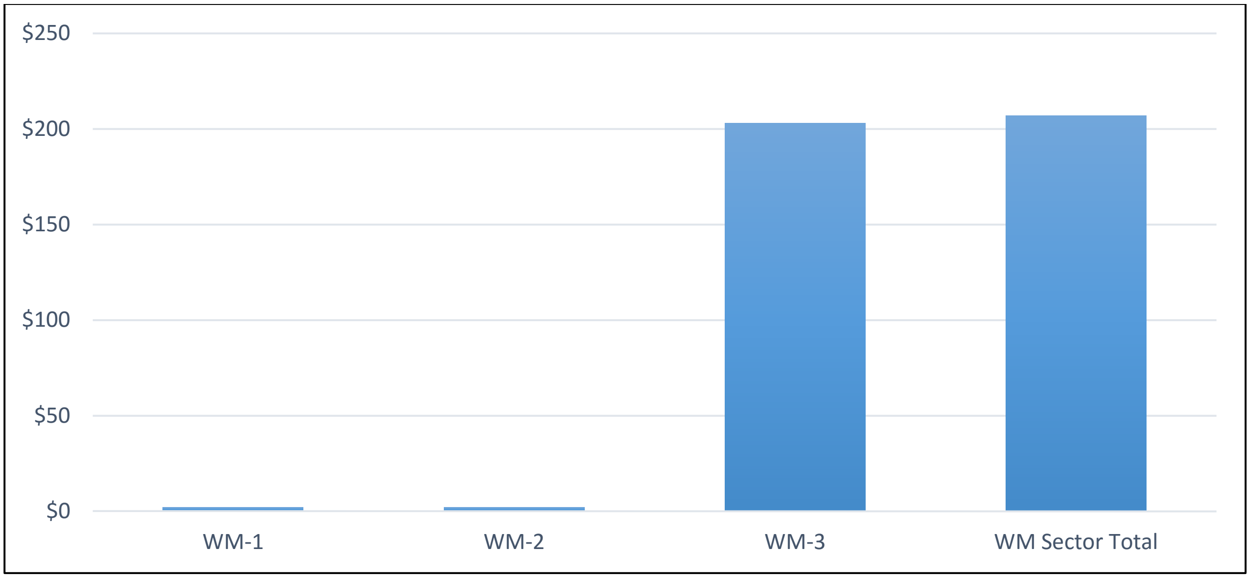


Figure IV-113 WM GSP Impacts, Year 2030 ($2015 MM)

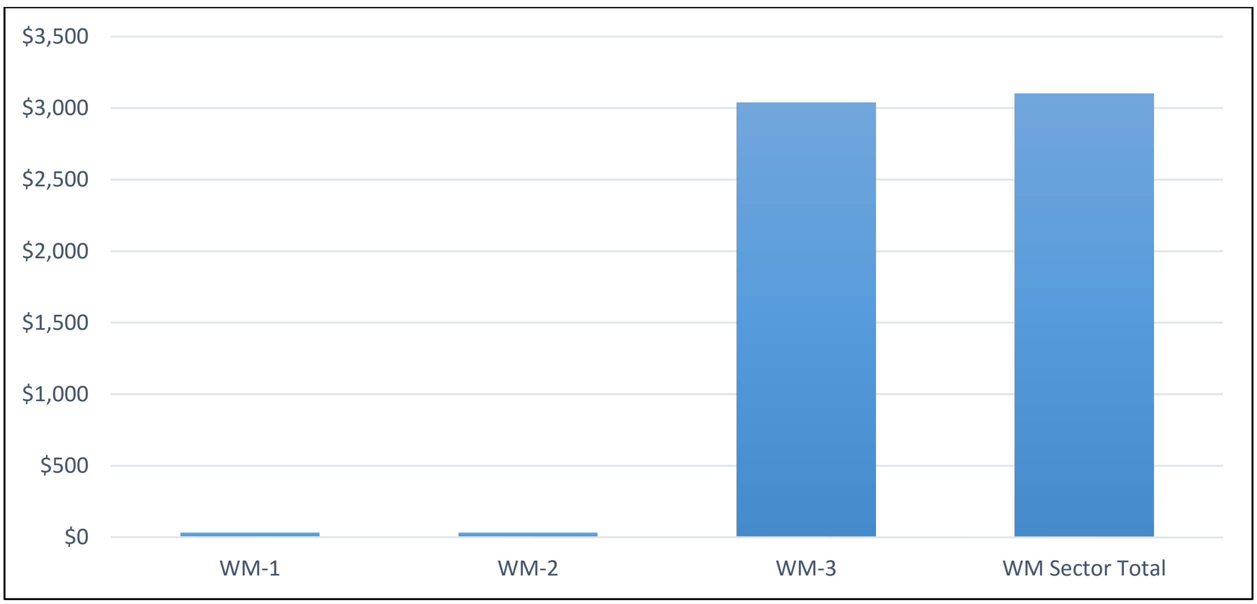


Figure IV-114 WM Employment Impacts, Average Annual (Jobs)

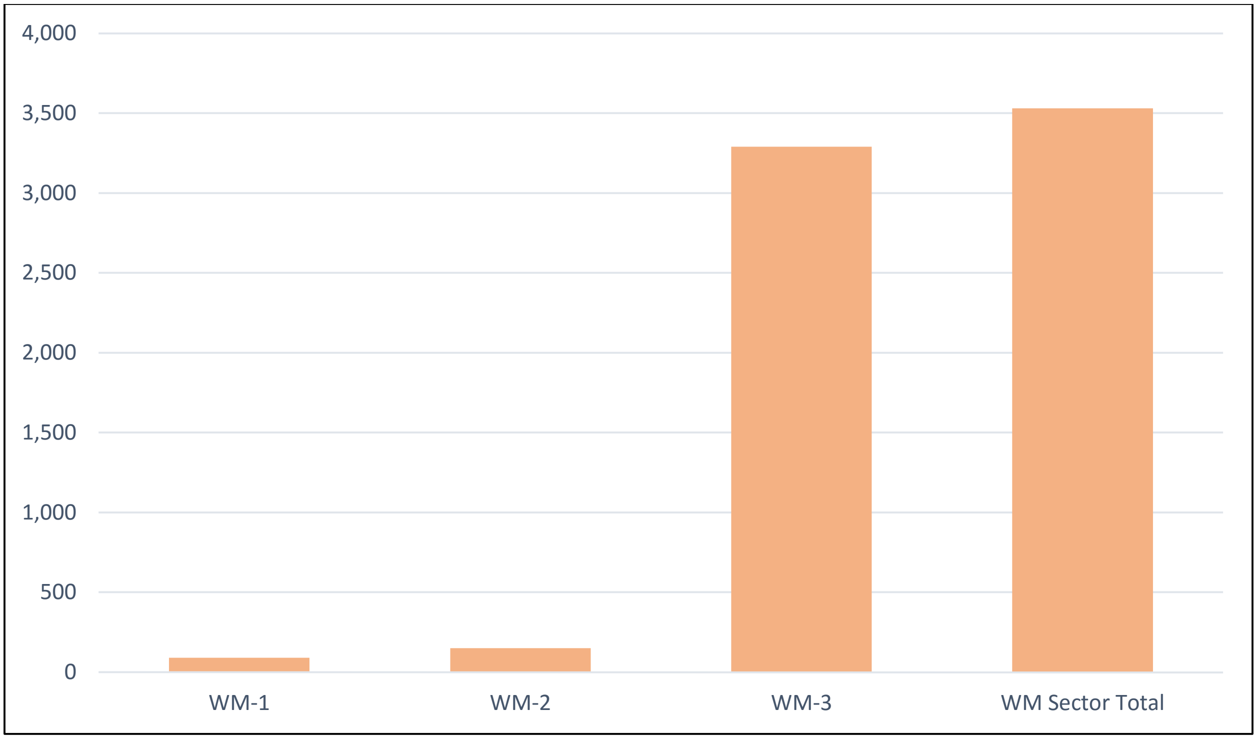


Figure IV-115 WM Employment Impacts, 2016-2030 (Job Years)

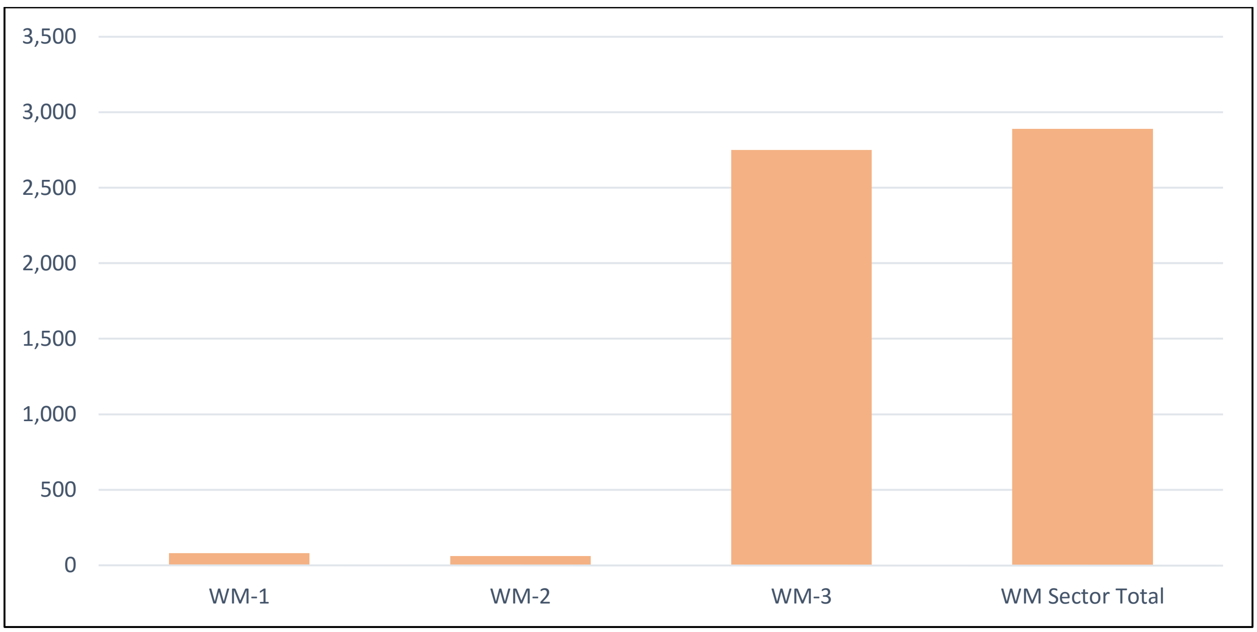


Figure IV-116 WM Employment Impacts, Year 2030 (Jobs)

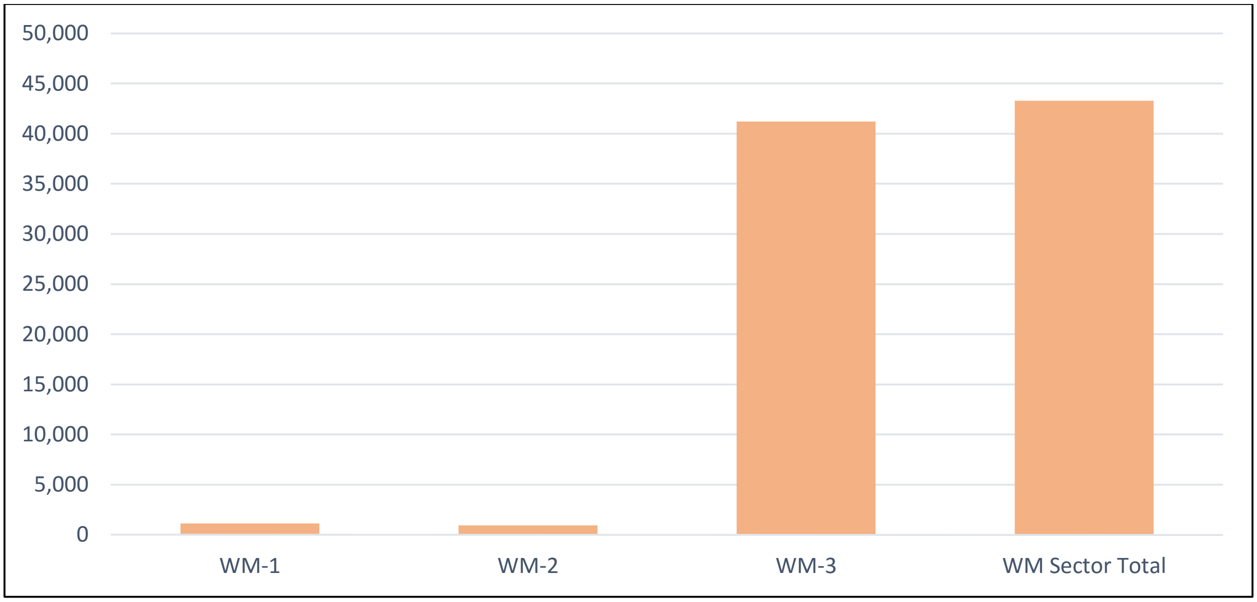


Figure IV-117 WM Income Impacts, Average Annual ($2015 MM)

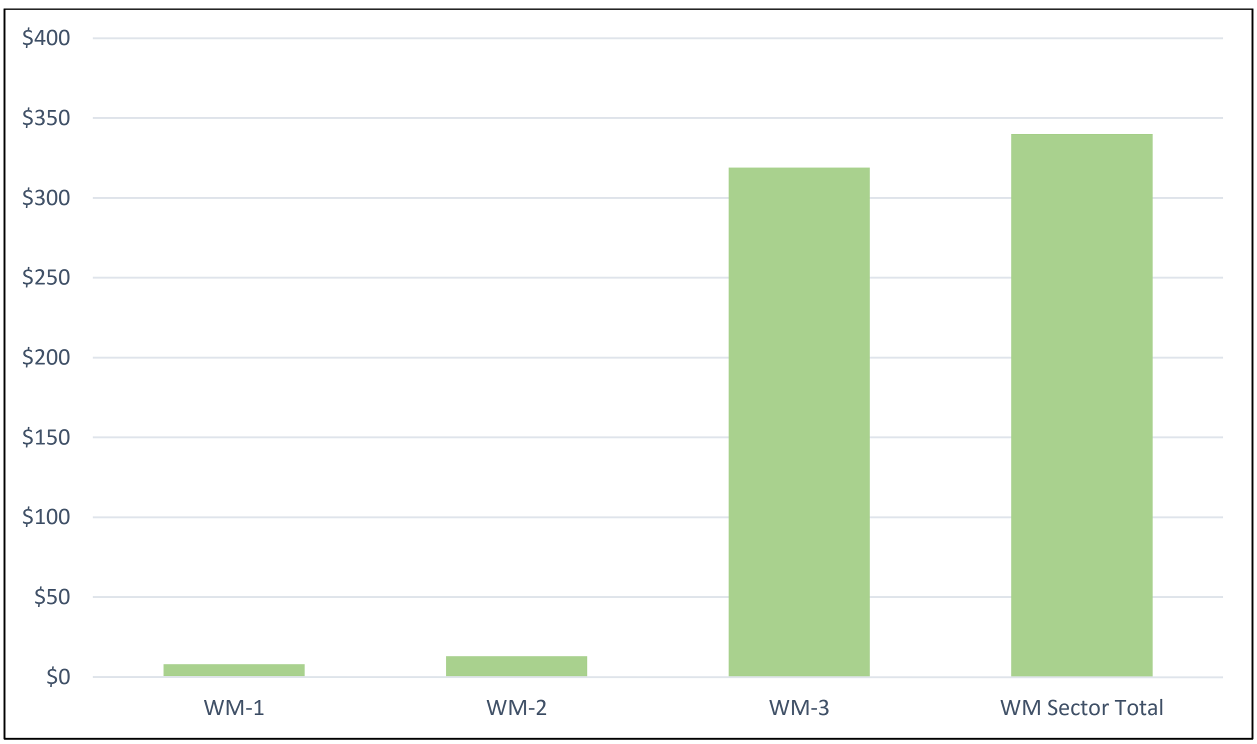


Figure IV-118 WM Income Impacts, 2016-2030 ($2015 MM)

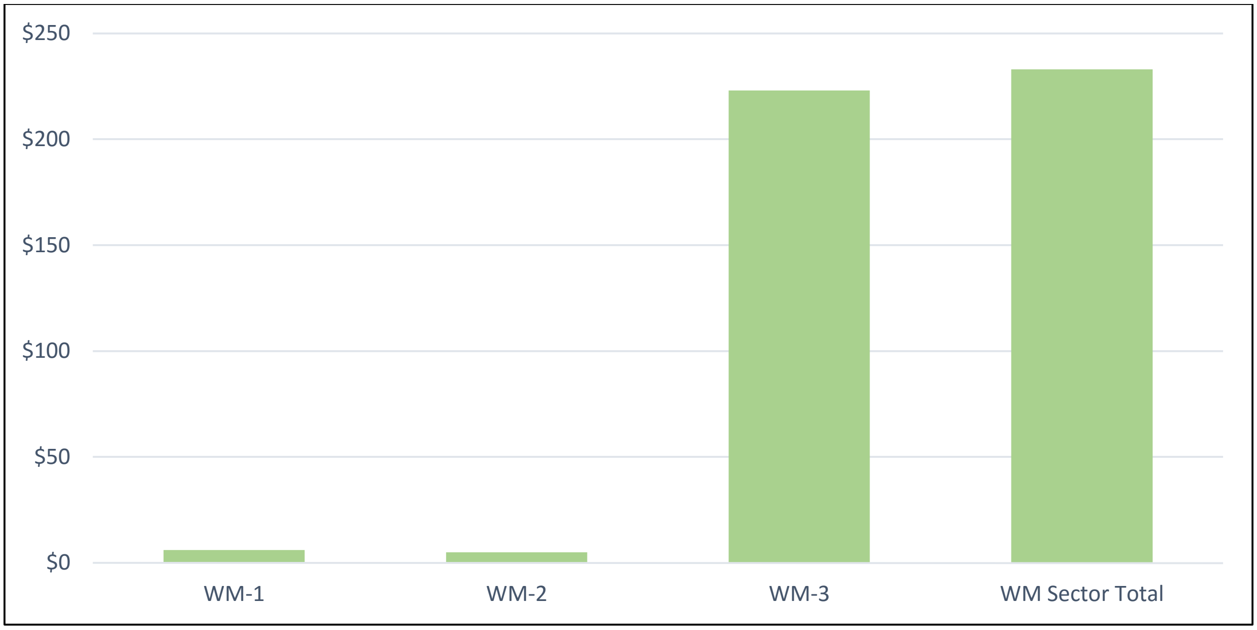
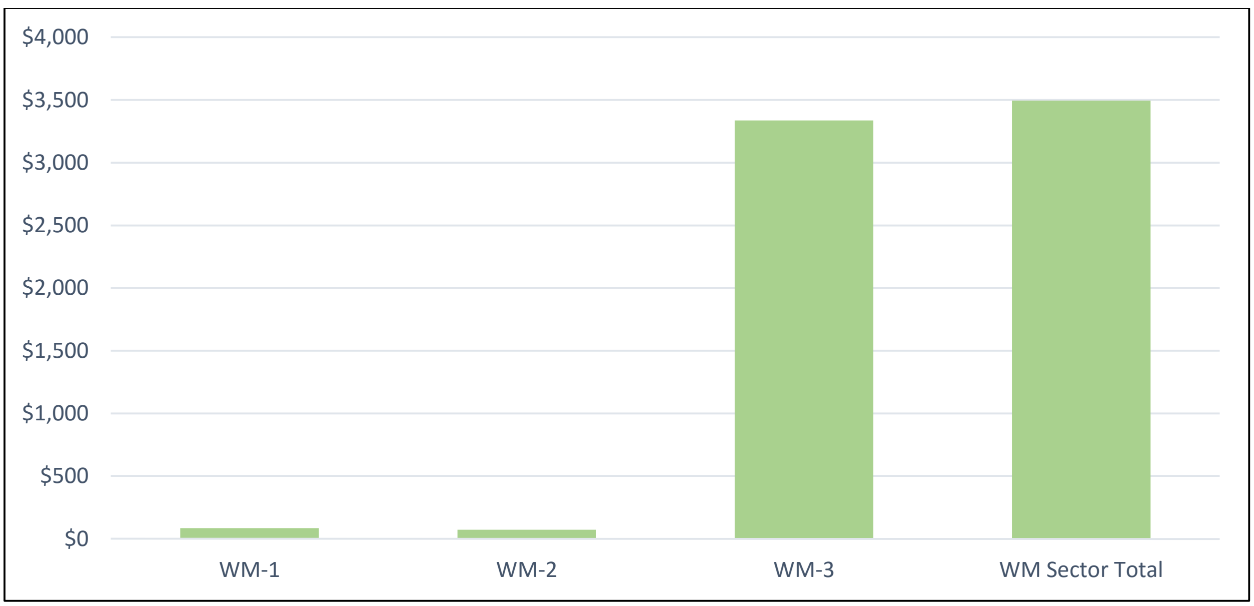


Figure IV-119 WM Income Impacts, Year 2030 ($2015 MM)



Chapter V. Additional Assessments

Policy Option Impacts on EPA Clean Power Plan Compliance

Background

This section analyzes the potential capacity of Minnesota to comply with the EPA Clean Power Plan's emissions limitations under the Clean Air Act Section 111(d) by implementing all the CSEO policies with electricity system impacts. To achieve Clean Power Plan compliance, Minnesota must impose emissions limitations on the affected electricity generation units (EGUs) through standards of performance[6]. CSEO policies that affect electric utility system behavior in Minnesota and neighboring states, either by changing electricity supply fuel composition or by changing the demand for electricity, are: ES 1 and 2, RCII 1,2 and 4, FOLU-3 and WM-1. Additionally, there are polices that cause marginal increase in electricity demand: Agriculture policy 4, WM 2 and WM 3.

An evaluation of how the policies contribute to meeting the Clean Power Plan's target provides an additional perspective on the total value of the proposed policies, and place them more completely in the current national regulatory context.

Policies of greatest interest to Minnesota are Energy Supply (ES) sector and Residential, Commercial, Industrial, and Institutional (RCII) sector policies. ES and RCII policies together account for about 73% of the total GHG reductions achieved by the entire package of CSEO policies against the business as usual scenario (BAU), and thus are considered crucial for the state of Minnesota. As Appendices of this report show, these policies are not only cost effective in terms of greenhouse gas (GHG) emissions abatement but also capable in most cases of resulting in negative net present values (NPVs), which indicates that they save more money than they cost over the projected implementation period (2015-2030).

Results of Policy Options Impacts on 111(d) Compliance

Baseline and GHG Reduction

For the purposes of this analysis, Center for Climate Strategies' (CCS) 3E Planning Synthesis Module tool was used, while utilizing input data both from EPA's Emissions & Generation Resource Integrated Database (eGRID) from 2012[7] and Minnesota Pollution Control Agency (MPCA)[8].

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[6] Environmental Protection Agency. (2015, October 23). Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Final Rule. *80*. 14, Retrieved from https://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22842.pdf

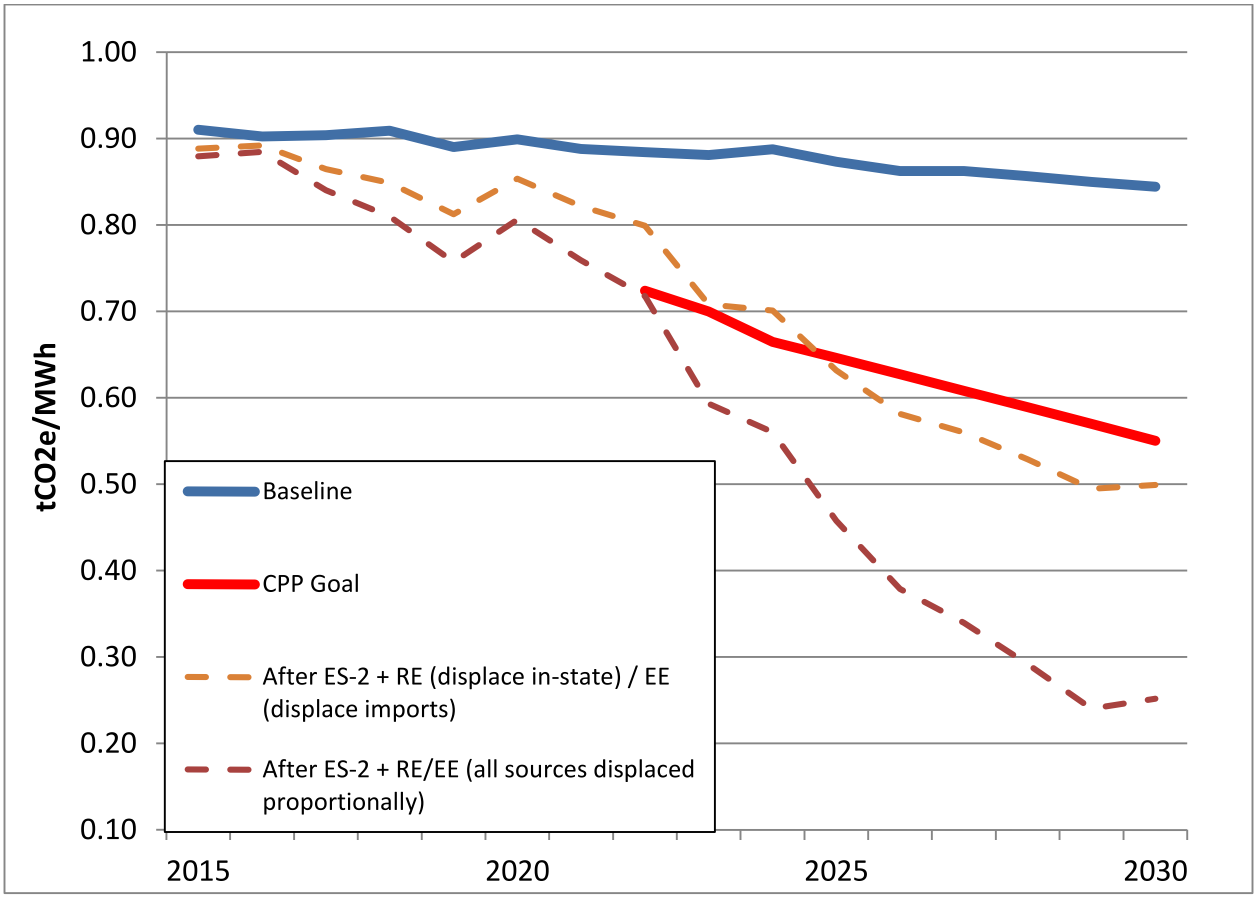
[7] Environmental Protection Agency. (2015, October 29). eGRID. Retrieved from http://www.epa.gov/energy/egrid

[8] More details on this analytical approach are provided in **Quantification Methods** section in Appendix F-7.

Two distinct scenarios for how the CSEO policies will offset MN electricity generation sources were analyzed; these include:

- All source offset proportionally – assumes that 111(d) units will be offset in the same proportion as the proportion of 111(d) unit generation to the total ES baseline (including imports). For example, in 2015 111(d) sources generate 60% of the total electricity consumed in MN, so 60% of emission reductions from RE/EE measures are allocated to 111(d) sources.
- ES-1 (RE) offsets in-state sources; EE policies offset imports - assumes that ES-1 will offset in-state sources (111(d) sources offset proportionally to total in-state generation), and EE will offset imports before offset in-state sources. In other words, no reductions from EE measures will be allocated to 111(d) sources until reductions from those policies exceed electricity imports.

Figure V-1 Emissions for 111(d) Applicable Units Under a Rate-Based Approach



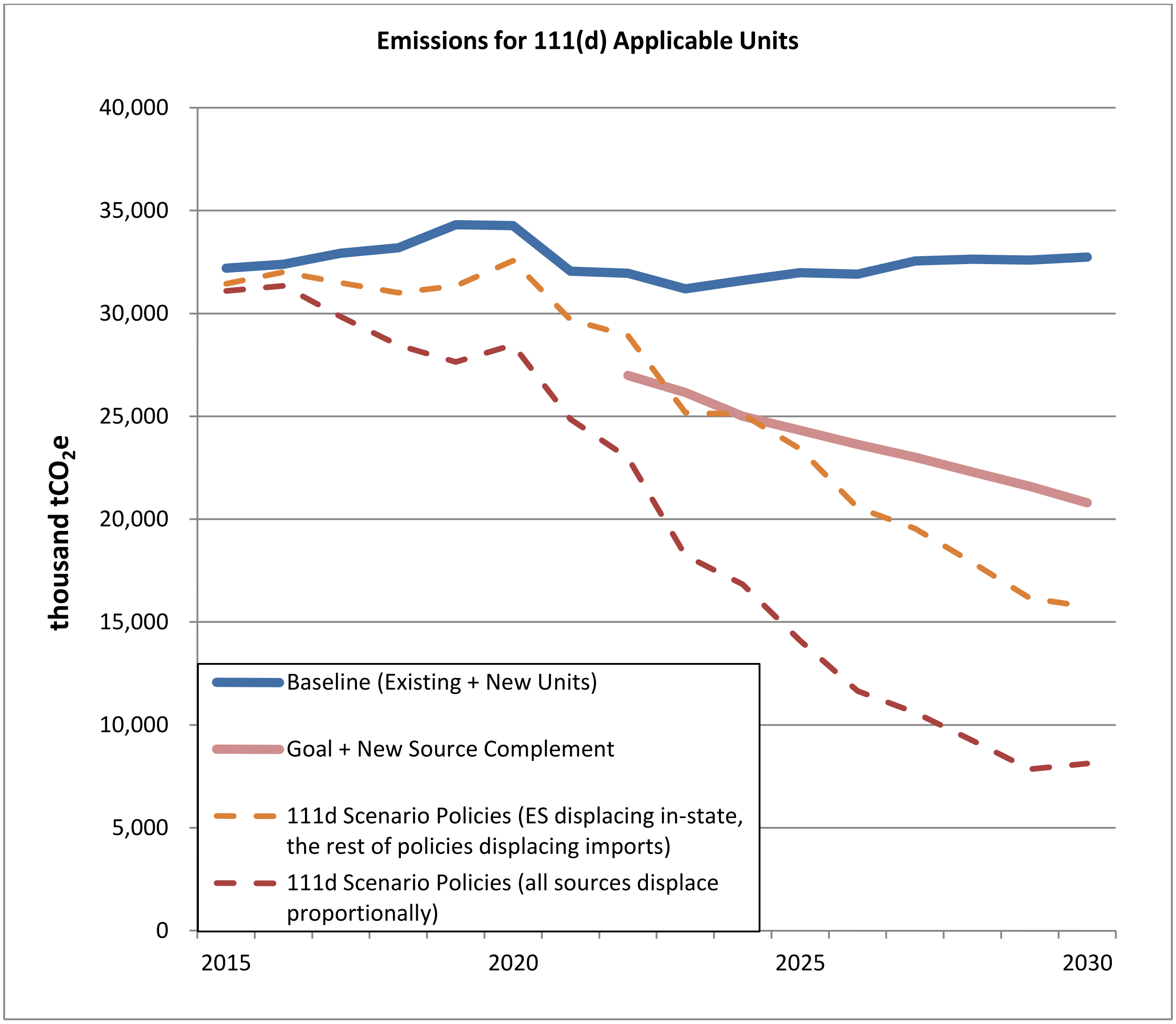
Notes:
Clean Power Plan (referred to as 111d in graph) Scenarios include comprehensive effects of CSEO policy options that affect electricity supply and demand, adjusted as necessary, including: ES-1, ES-2, RCII-1, RCII-2, RCII-4, TLU-2, FOLU-3, WM-1, WM-2, WM-3 and AG-4/AG-5.

The dashed lines present CSEO policy impacts under two geographic displacement scenarios on a mass-basis for the overall MN electricity sector CO_2 emissions. Rate based evaluations are available in the report and appendices.

The blue solid line presents an estimated MN CO_2 and energy baseline, using marginal resource mix assumptions provided by MPCA.

The red solid line presents Clean Power Plan goal calculated for Minnesota, expressed as mass-based CO_2 emissions pathway.

Figure V-2 Emissions for 111(d) Applicable Units Under a Mass-Based Approach



Notes:

Clean Power Plan (referred to as 111d in graph) Scenarios include comprehensive effects of CSEO policy options that affect electricity supply and demand, adjusted as necessary, including: ES-1, ES-2, RCII-1, RCII-2, RCII-4, TLU-2, FOLU-3, WM-1, WM-2, WM-3 and AG-4/AG-5.

The dashed lines present CSEO policy impacts under two geographic displacement scenarios on a mass-basis for the overall MN electricity sector CO_2 emissions. Rate based evaluations are available in the report and appendices.

The blue solid line presents an estimated MN CO_2 and energy baseline, using marginal resource mix assumptions provided by MPCA.

The red solid line presents Clean Power Plan goal calculated for Minnesota, expressed as mass-based CO_2 emissions pathway.

The two graphs above show both compliance and non-compliance pathways modeled under different assumptions pertaining to what electricity will be displaced by implementing CSEO policies: in-state generated electricity, out-of-state electricity imports, or both with different ratios (detailed explanation of these crucial assumptions is provided under "quantification methods" section in the Appendix F-7). The first graph shows the changes in the average state emissions rate of the existing 111(d) applicable electricity generation fleet in Minnesota as a result of introduction of zero emission, renewable sources, and the demand side energy efficiency measures. This is consistent with the EPA's approach to calculating state specific emission rate goals based on averaging of subcategory specific emissions performs rates[9].

The second graph shows changes in the total amount of annual CO_2 emissions from 111(d) applicable MN generation (mass-based approach with the source complement) as a result of implementing CSEO policies that affect electricity supply and demand. EPA establishes equivalency between this mass-based and rate-based targets, and both are derived from the application of best system for emissions reductions (BSER)[10]. As a result of BSER application, the expected emissions limits in each year are quantified for the interim period (2022-2029) and the final period (2030 and beyond). These limits are shown in both graphs as solid red line (for the rate-based approach) and the solid orange line (for the mass-based approach). Solid blue lines represent Minnesota's electricity sector baseline, estimated using marginal electricity resource mix and other relevant assumptions provided by MPCA.

Both graphs indicate that two policy scenarios (light green and brown colors) that combine all the mentioned CSEO policies realized under different displaced electricity assumptions, enable the Minnesota to comply with the goals set by the Clean Power Plan in the final compliance period, while one of them (ES + EE policies-all sources offset proportionally) establishes compliance even during the interim period. This is also true under the mass-based (with new source complement) approach. At the same time, if the state decides not to implement these policies, the compliance gap between Clean Power Plan goal and the baseline remains large (estimated baseline emissions in 2030 are 32,766,605 tCO2e, whereas the estimated Clean Power Plan target for that year is 20,573,680 tCO2e), assuming the state continues with business as usual only.

Table V-1 and Table V-2 below are quantitative translation of the above graphs. Table V-1 represents the rate-based case (this time we express the emission rates in lbs CO2e/MWh the same way EPA does in its final rule) and Table V-2 contains the outcomes for the mass-based

[9] Environmental Protection Agency. (2015, October 23). Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Final Rule. *80*. 161. Retrieved from https://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22842.pdf

[10] Environmental Protection Agency. (2015, October 23). Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Final Rule. *80*. 6. Retrieved from https://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22842.pdf

case. The years chosen are: the assumed beginning of the policy implementation period (2015), the middle of the Clean Power Plan interim period (2025), and the beginning of the Plan's final period (2030). Scenarios ES-2 + RE/EE (all sources offset proportionally) and ES-2 + RE (offset in-state) / EE (offset imports) both individually allow Minnesota to achieve compliance with the EPA's 111(d) rule targets for the state in the final period. This is true whether the state opts for the state rate-based or the mass-based approach.

Table V-1 Forecasted Emission Rates for Baseline, Clean Power Plan Goal Scenario, and Different CSEO Policy Scenarios

Scenarios	Units	Year		
		2015	2025	2030
Baseline (Existing Units)	lbs CO2e/MWh	2,007	1,925	1,861
CPP Goal	lbs CO2e/MWh		1,424	1,213
After ES-2	lbs CO2e/MWh	2,007	1,599	1,547
After ES-2 + ES-1 (RE, all sources offset proportionally)	lbs CO2e/MWh	1,973	1,453	1,337
After ES-2 + RE/EE (all sources offset proportionally)	lbs CO2e/MWh	1,939	1,009	555
After ES-2 + RE (offset in-state) / EE (offset imports)	lbs CO2e/MWh	1,959	1,392	1,100

Notes:

- Acronym "EE" means "energy efficiency" and comprises all the policies that reduce demand for electricity on the grid to various degrees, among other actions and economic impacts they cause. As noted in the first page of this chapter, these are all RCII policies, TLU-2, FOLU-3, AG-4, WM-1, WM-2 and WM-3.
- The cell reserved for CPP scenario emission rate for 2015 is intentionally left empty, since the CCP compliance period starts in 2022.

Table V-2 Forecasted Mass-based Emissions for Baseline, Clean Power Plan Goal Scenario, and Different CSEO Policy Scenarios

Scenarios	Units	Year		
		2015	2025	2030
Baseline (Existing + New Units)	tCO2e	32,208,028	31,981,444	32,746,153
Mass Goal + New Source Complement	tCO2e		24,320,241	20,803,024
After ES-2	tCO2e	32,208,532	26,750,241	27,514,962
After ES-2 + ES-1 (RE, all sources offset proportionally)	tCO2e	31,662,881	24,391,627	24,026,089
After ES-2 + RE/EE (all	tCO2e	31,092,564	14,103,026	

sources offset proportionally)				8,126,943
After ES-2 + RE (offset in-state) / EE (offset imports)	tCO2e	31,441,561	23,424,943	15,746,795

Notes:
tCO2e are metric tons of CO_2 equivalent.
Acronym "EE" means "energy efficiency" and comprises all the policies that reduce demand for electricity on the grid to various degrees, among other actions and economic impacts they cause. As noted in the first page of this chapter, these are all RCII policies, TLU-2, FOLU-3, AG-4, WM-1, WM-2 and WM-3.
The cell reserved for Clean Power Plan scenario emission-based value for 2015 is intentionally left empty, since the Clean Power Plan compliance period starts in 2022.

Cost effectiveness

The aggregate cost effectiveness (CE) value for the scenario "ES-2 + RE/EE (all sources offset proportionally)" was calculated to be -$2.0/ton CO_2 e. This scenario comprises all the CSEO policies that affect electricity generation and emissions (ES-1 and 2, RCII -1,2 and 4, TLU-2, WM-1 ,2 and 3, FOLU-3, and AG-4/AG-5 policies) within the confines of the Section 111(d) rule, Clean Power Plan (CPP). The negative sign indicates that the package of CSEO policies that allow Minnesota to comply with the CPP, when implemented, achieve net cost savings of $2 per ton of CO_2 e they reduce over the modeling period.

As explained in Appendix E, Policy Quantifications Principles Guidelines, the CE metric for each policy is calculated by dividing its NVP values with its cumulative GHG reductions achieved by that policy, which produces values expressed in $/ ton of CO_2 e. For the purposes of CPP compliance, only the electricity system related GHG reductions for each policy achieves are derived, and then those values are used to calculate CPP related cost effectiveness. Individual policy CE values used in this section for the calculation of the aggregate CE related to compliance with CPP are different then the total CEs of each policy, which consider all GHG reductions each policy achieves (not just those related to the electricity system and 111(d) rule limitations).

The contribution of each policy to complying with the CPP (expressed as a percentage of the total contribution) are shown in the table below.

Table V-3 Contribution of Individual Policies to Complying with 111(d) (in %)

ES-2	17.41
ES-1	22.94
RCII-1	23.36
RCII-2	21.13
RCII-4	12.15

TLU-2	2.10
FOLU-3	0.96
WM-1	0.38
AG-4/AG-5	N/A
WM-2	N/A
WM-3	N/A

Table above shows that ES and RCII polices achieve the greatest reduction in GHG emissions related to affected EGUs and have the greatest contribution to Minnesota CPP compliance. Since AG-4/AG-5, WM-2 and WM-3 policies increase the demand for electricity and increase the electricity system emissions (to a small extent), for those policies the contribution calculation is not applicable as a GHG reduction but is included in net effects within the sectors.

Macroeconomic Impacts of CPP Set of Policies

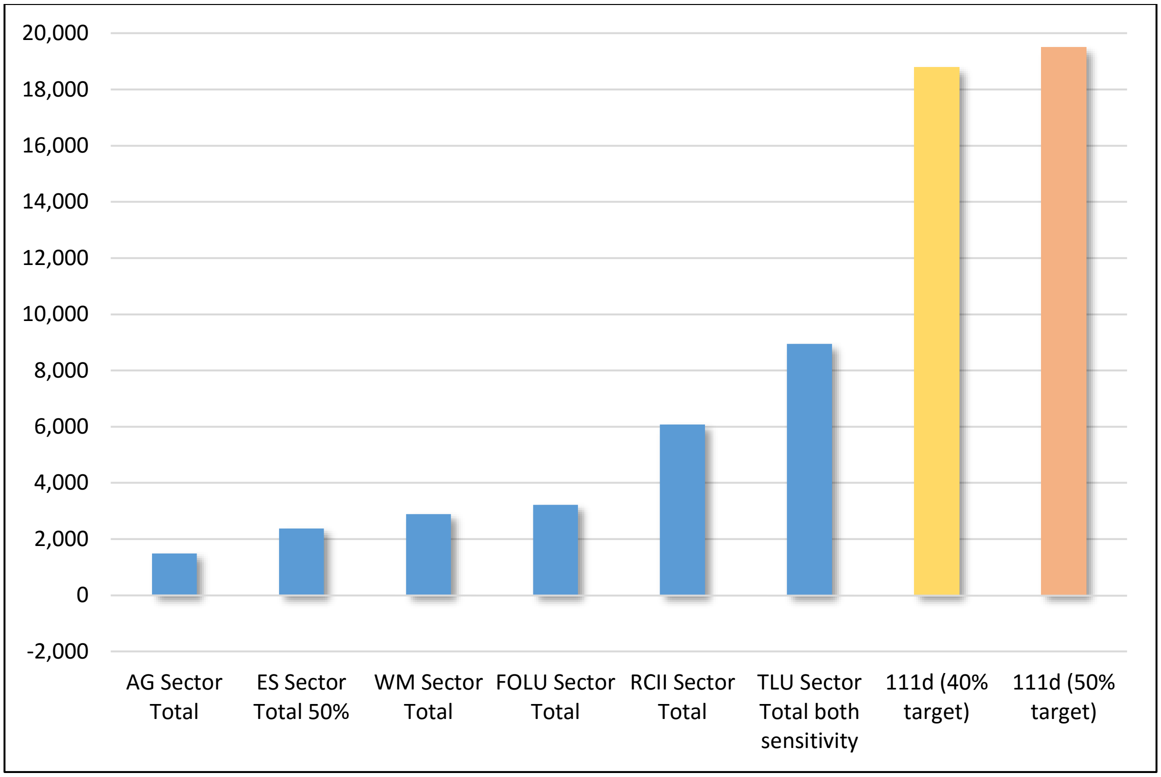
In addition to macroeconomic analyses of individual options, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software to also assess potential macroeconomic impacts of the package of CSEO options relevant to compliance with the CPP. Table below summarizes the results of that analysis. It shows estimated CPP policy package's impact on GSP, employment and total earned income in the state.

Table V-4 Macroeconomic (Indirect) Impacts of Clean Power Plan

Macroeconomic (Indirect) Impacts Results									
Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030[d]	Average (2016-2030)[e]	Cumulative (2016-2030)[f]	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
CPP (ES-1 40%)	$2,669	$ 1,831	$ 27,463	26,480	18,796	281,940	$2,605	$ 1,604	$ 24,063
CPP (ES-1 50%)	$2,894	$ 1,914	$ 28,716	28,140	19,507	292,610	$2,798	$ 1,672	$ 25,078

Notes:
[a] Gross State Production changes in Minnesota. Dollars expressed in $2015.
[b] Total employment changes in Minnesota.
[c] Personal Income changes in Minnesota. Dollars expressed in $2015.
[d] Single final year value. Year 2030 is the final year of analyses in this project.
[e] Average value from the year 2016 to the year 2030. The average value is calculated from the first year of the policy implementation through the year 2030 if implementation of the policy starts after year 2016.
[f] Cumulative value from 2016-2030 time period.

Figure V-3 Average Annual Jobs Impact of 111(d) Scenarios vs. Sector Impacts



Macroeconomic index

Graphs below present the overall macroeconomic impacts of the set of CSEO policies relevant to the compliance with the CPP.

The overall economic impact from each scenario is expressed by a single score, and compares those scores. CCS created this single score (a Macroeconomic Impact Index) in order to encapsulate in one measurement the relative macroeconomic impacts (including jobs, GSP and incomes) of each policy. We have found in our own work and in the literature that indexed scores can be helpful to many readers when comparing options with multiple characteristics.

To produce this score, CCS set the results from the absolute best-case scenario (i.e. the implementation of all CSEO policies with all their optimal sensitivities in place) equal to 100, with that scenario's jobs, GSP and incomes impacts weighted equally at one third of the total score. Each policy's jobs, GSP and income impacts are scaled against that measure, and given a total score. The overall score indicates how significant a policy's impact is projected to be. Negative impacts are scaled the same way, except that those impacts are given negative scores and pull down the total score of the policy.

These scores are calculated separately for the final year of the study (2030), the *average* impact over the 2016-2030 period, and the *cumulative* impact of the policies over that period. While each scenario has one line, the relative importance of jobs, income and GSP remains visible as differently-shaded segments of that line.

Figure V-4 Macroeconomic Indicators, Final Year 2030

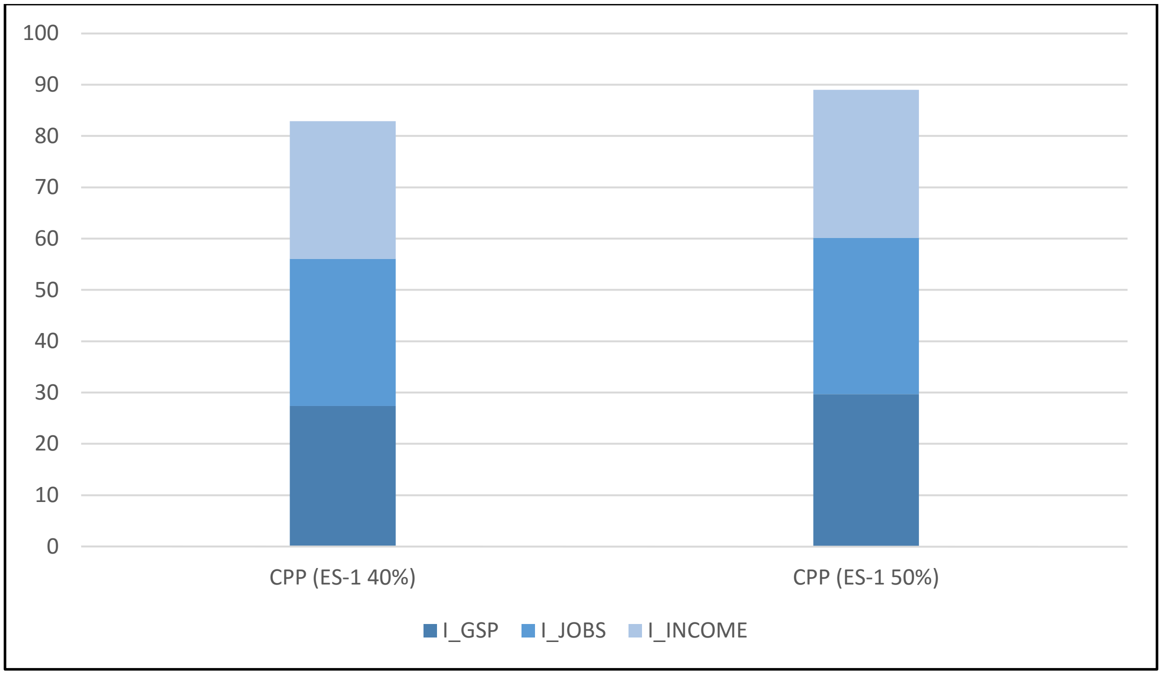


Figure V-5 Macroeconomic Indicators, 2016-2030

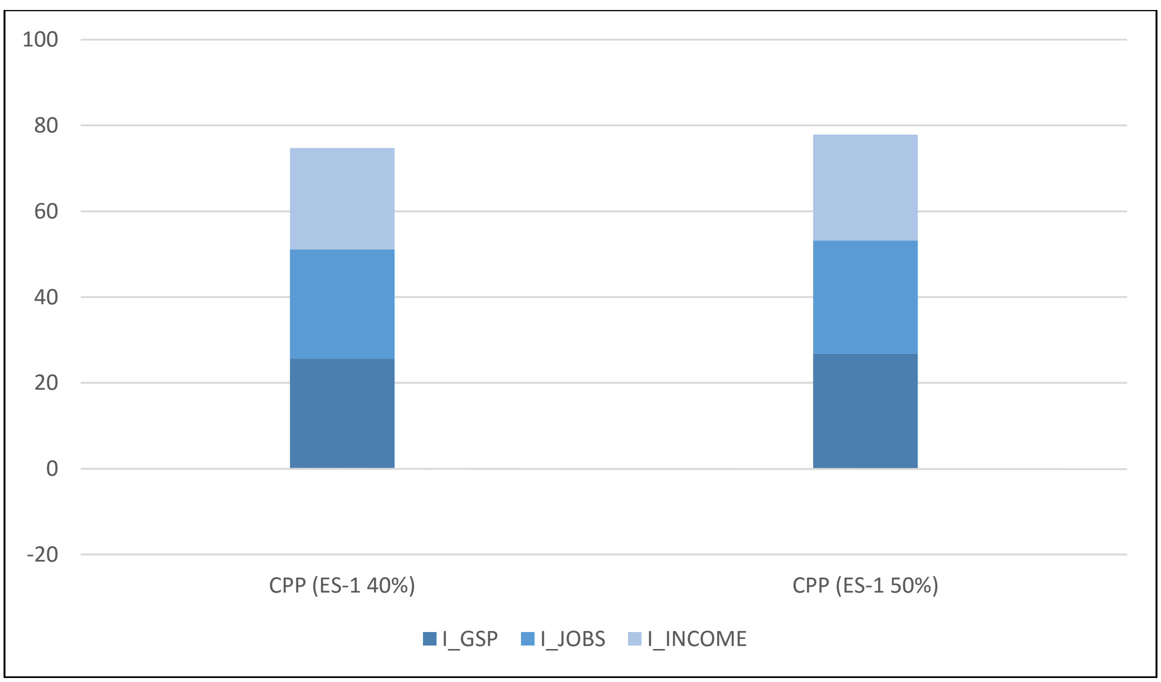
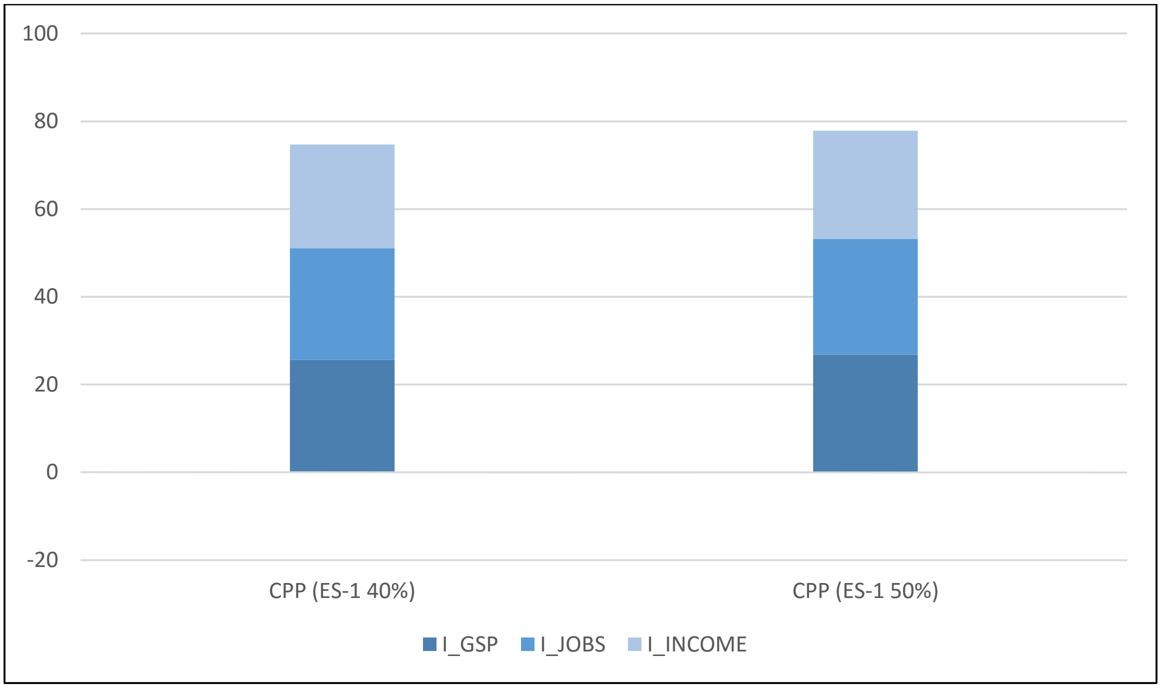


Figure V-6 Macroeconomic Indicators, Average Annual



Graphs below show the trend of CPP policies impacts during the year 2015 to the year 2030.

Figure V-7 CPP GSP Impacts ($2015 MM)

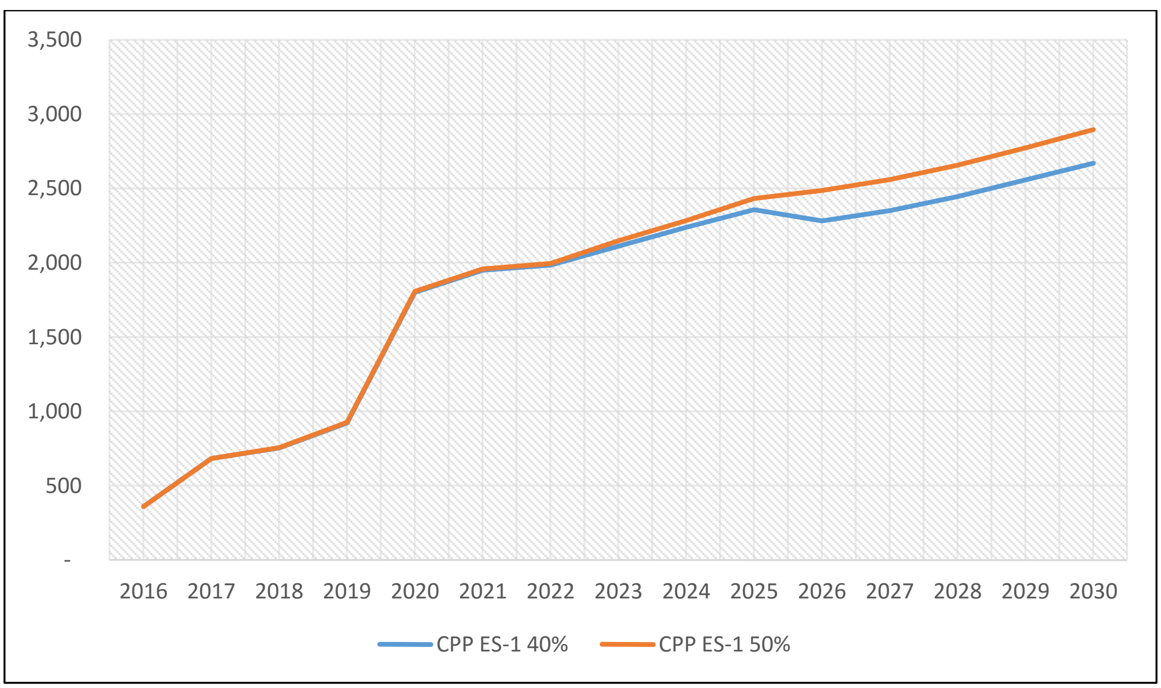


Figure V-8 CPP Employment Impacts 2016-2030 (Jobs)

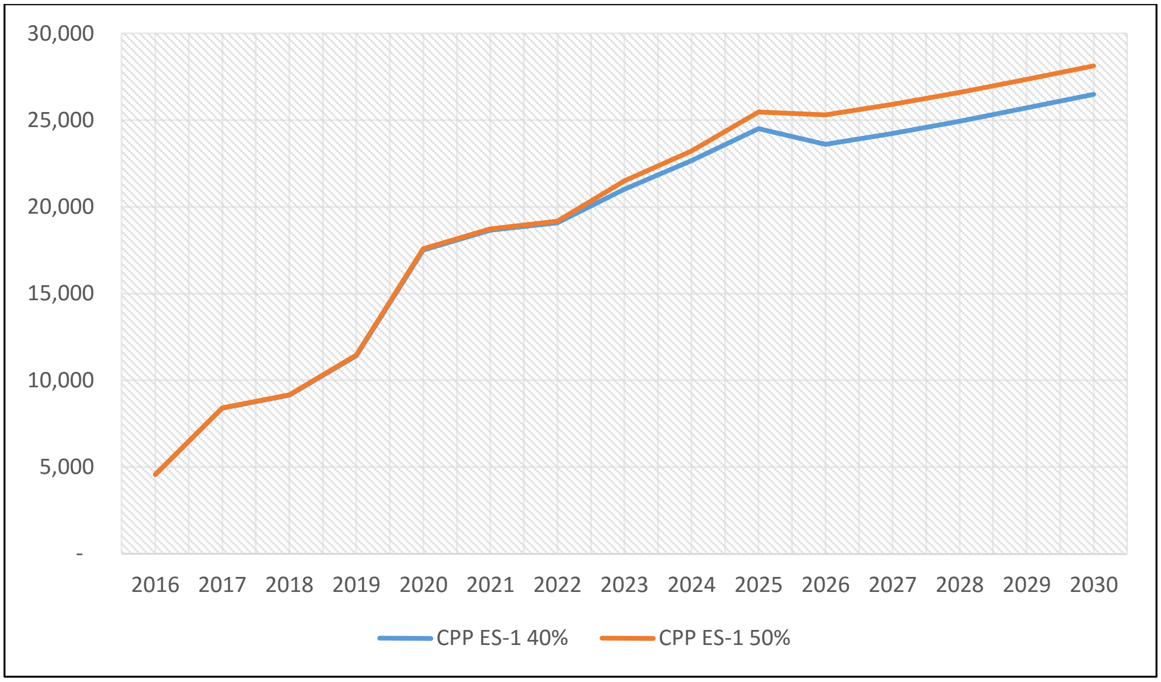
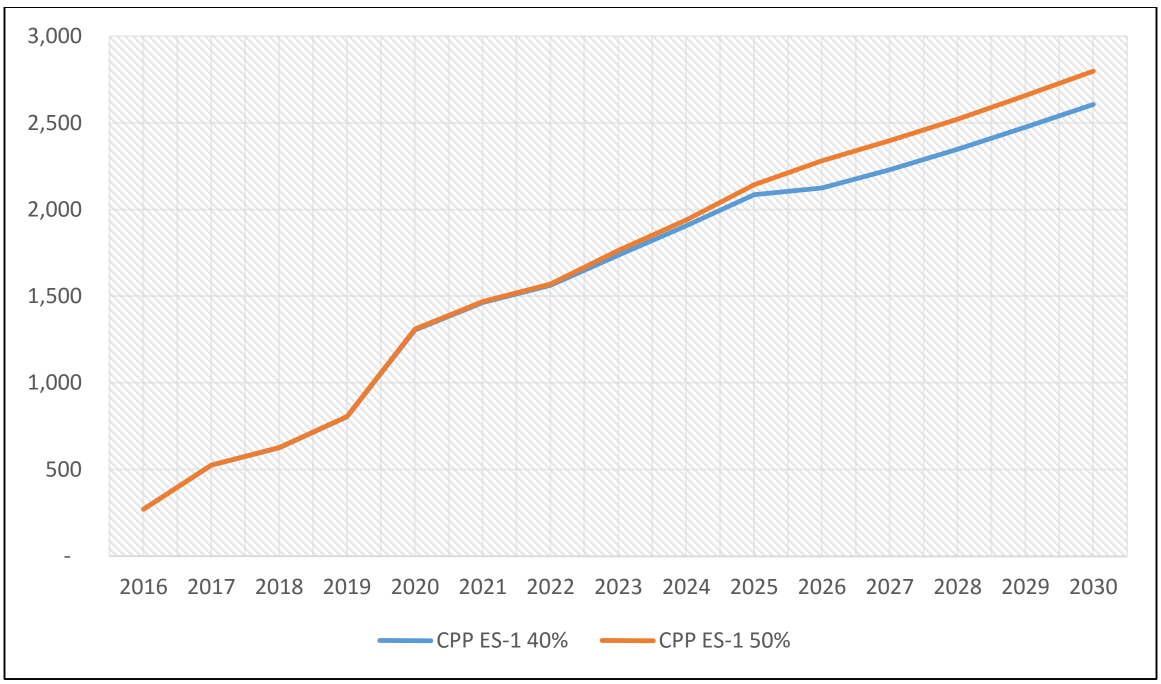


Figure V-9 CPP Income Impacts ($2015 MM)



Bar charts that follow show macroeconomic impacts of CPP policies on GSP, personal income, and employment in the final year (2030), average (2016-2030) and cumulative (2016-2030). Light color indicates sensitivity scenarios.

Figure V-10 CPP GSP Impacts, Year 2030 ($2015 MM)

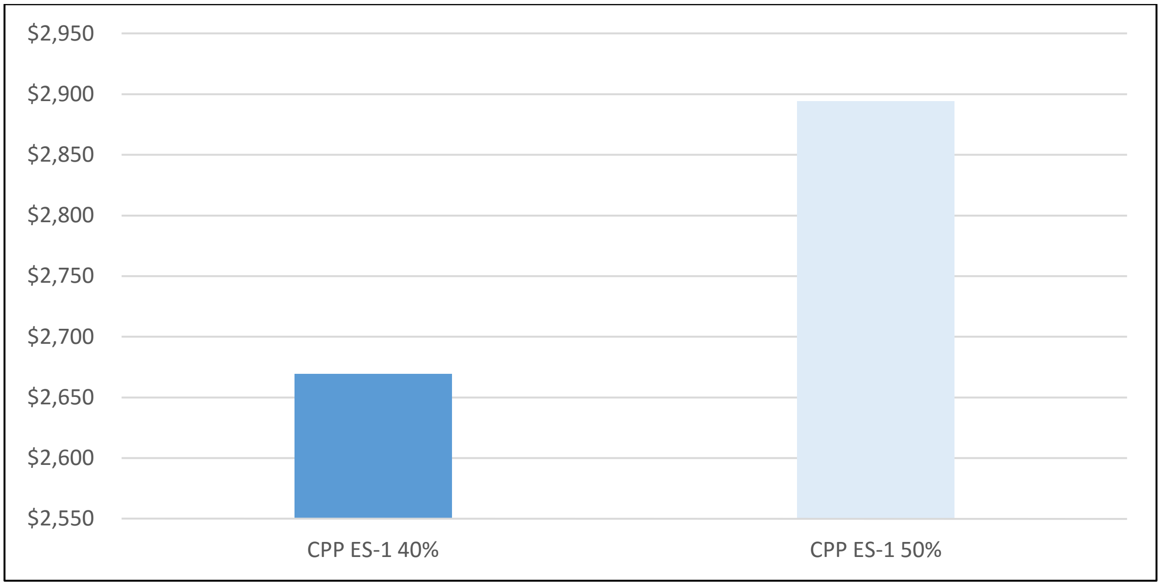


Figure V-11 CPP GSP Impacts, Average Annual ($2015 MM)

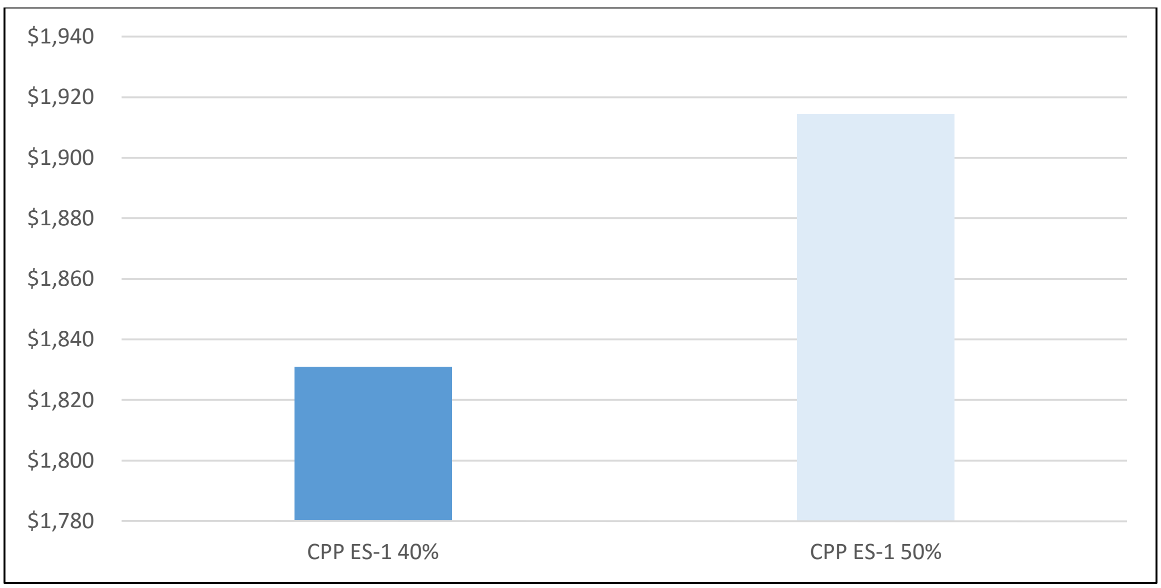


Figure V-12 CPP GSP Impacts, 2016-2030 ($2015 MM)

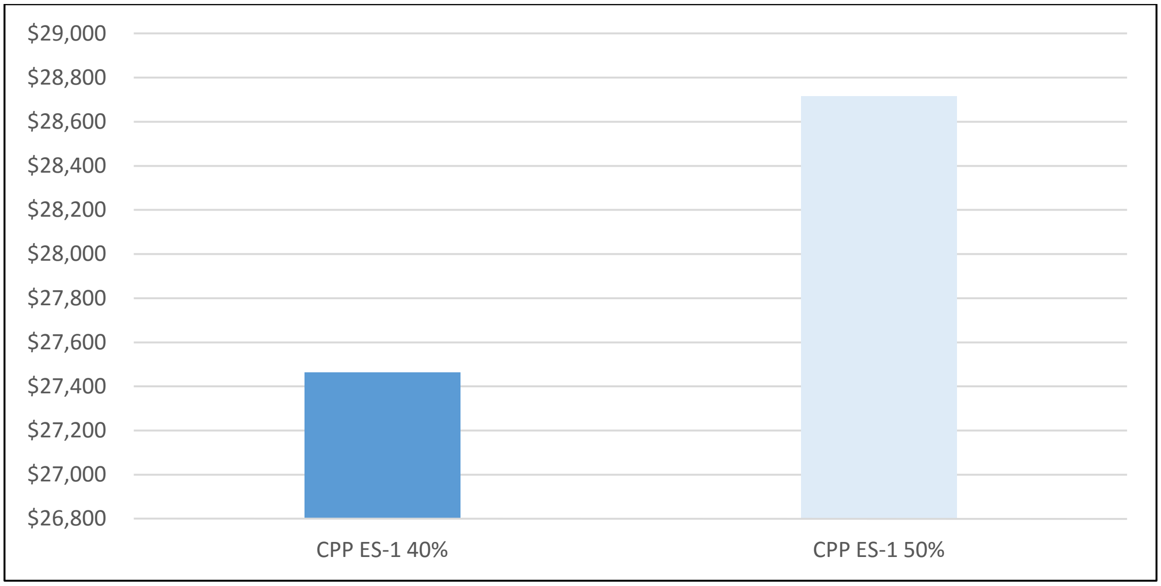


Figure V-13 CPP Employment Impacts, Year 2030 (Jobs)

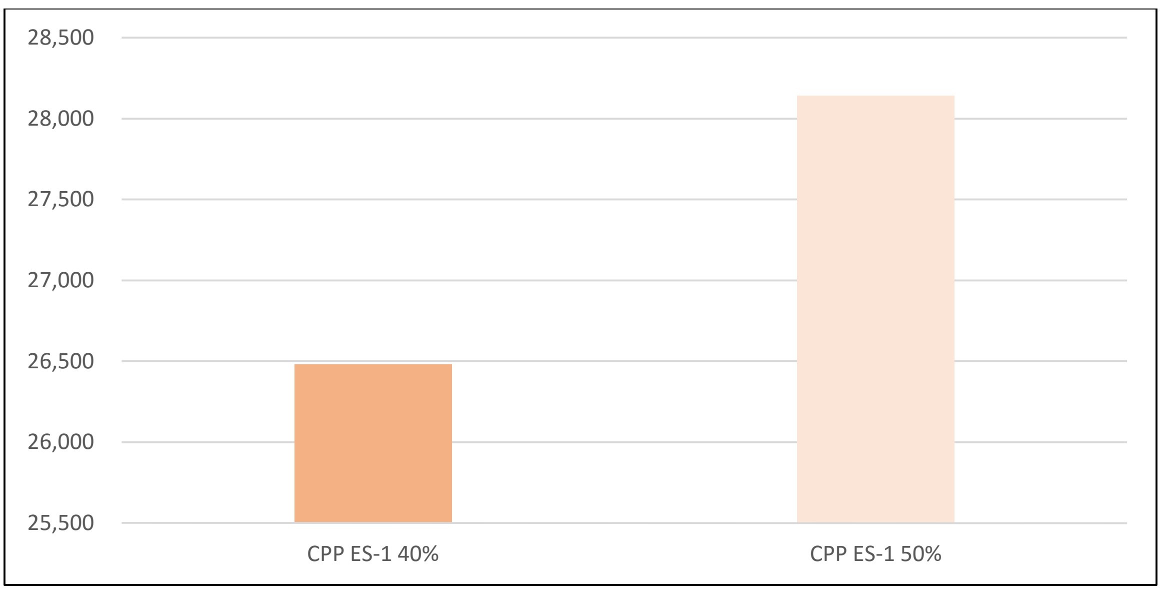


Figure V-14 CPP Employment Impacts, Average Annual (Jobs)

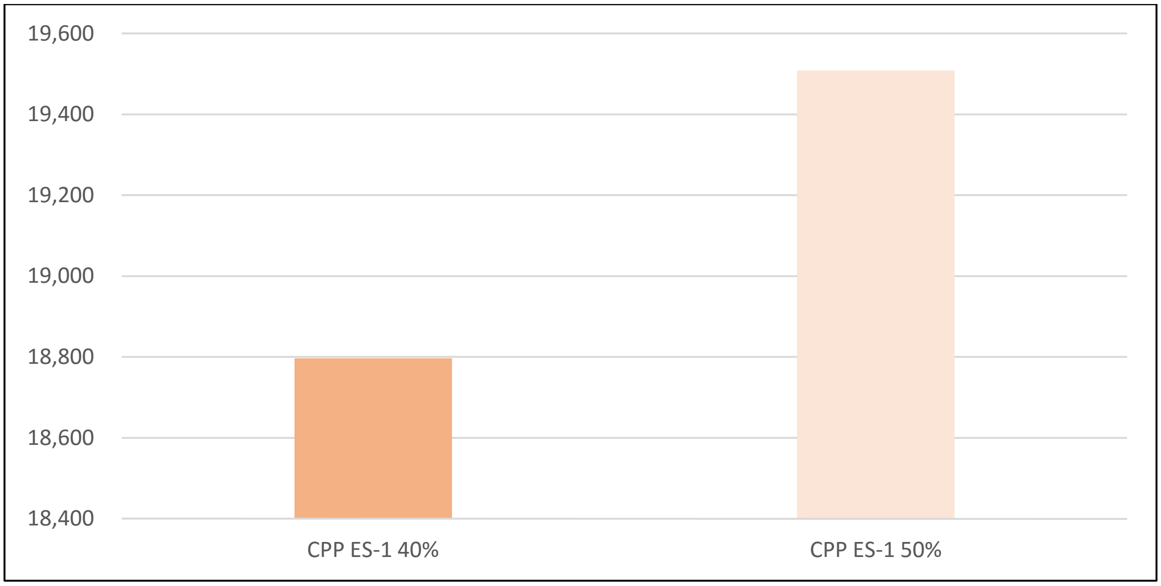


Figure V-15 CPP Employment Impacts, 2016-2030 (Job Years)

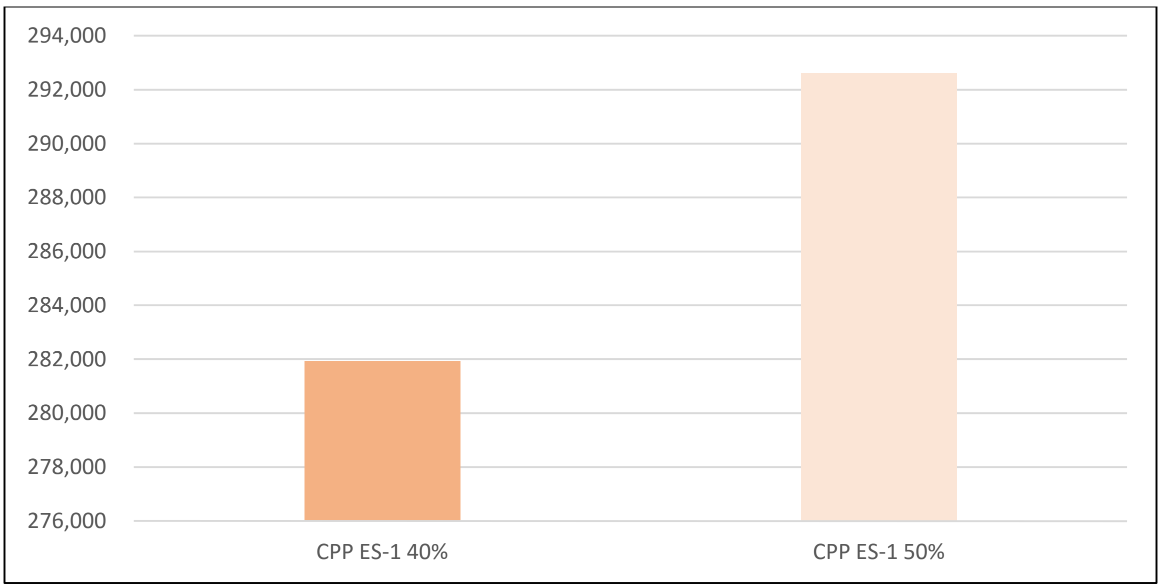


Figure V-16 CPP Income Impacts, Year 2030 ($2015 MM)

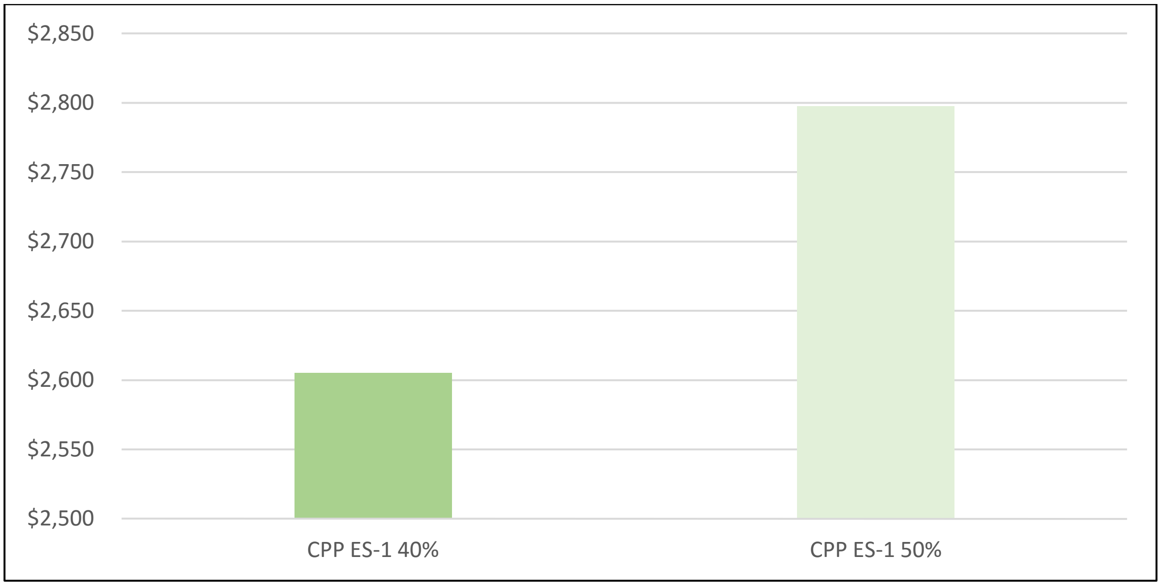


Figure V-17 CPP Income Impacts, Average Annual ($2015 MM)

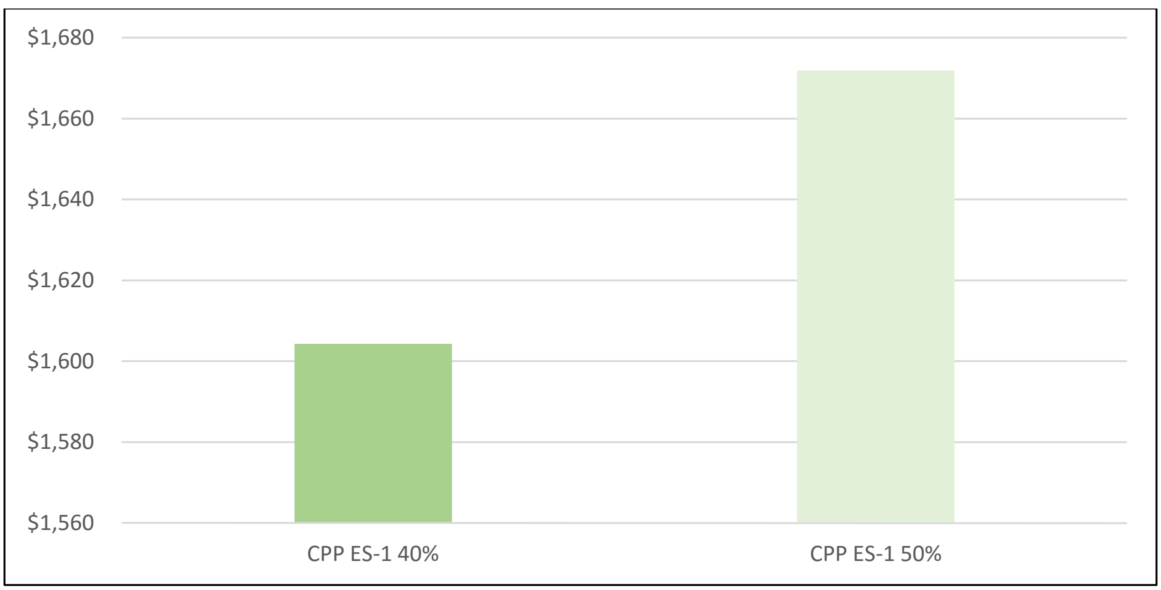
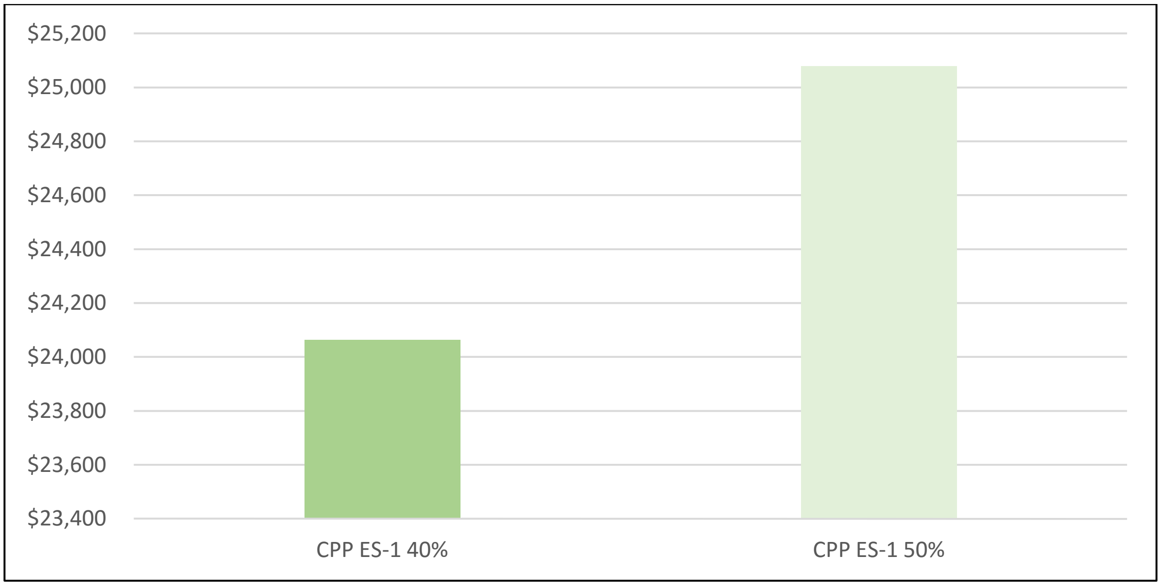


Figure V-18 CPP Income Impacts, 2016-2030 ($2015 MM)



Principal Drivers of Macroeconomic Changes

These Clean Power Plan Scenarios represent combinations of policies described in other chapters and their respective appendices. Policies evaluated under the 111(d) compliance analysis are ES 1 and 2, and EE policies, which comprise RCII 1, RCII-2, RCII-4, FOLU-3, TLU-2, AG-4, WM-1, WM-2 and WM-3. The principal drivers, consequently, are those described within those discussions of macroeconomic impact. Those influences (such as the cost-saving shift involved in ES-1 or the energy-efficiency impacts of the RCII policies) remain in place in the CPP analysis, which simply aggregates into a single scenario (with some integrations to represent the integrative effects identified in the microeconomic analysis) these policies and their major influences on the larger Minnesota economy.

Sectors Most Impacted by This Policy

The direct impacts from the individual policies that we saw before remain present, in general. The construction sector continues to grow rapidly, seeing large gains in size and in the number of people it employees. Chemical manufacturing, which captures the growth in biofuels production, remains a growing sector in the Clean Power Plan scenarios, as that biofuels production is just as present in the combined analysis as it was in the individual analysis.

By contrast, utilities still see smaller scale in demand, and thus require less inputs and labor to carry out their business. The Waste Management policies also bring direct reductions in the scale of the waste disposal sectors, as their goal of reducing and diverting the waste stream reduces the amount to be hauled, tipped and disposed in landfills.

The Clean Power Plan scenarios end up capturing most of the policies that produce significant savings to households and businesses, and a familiar profile of gains – reflecting the availability of more money in pocket and more capacity to spend on the part of households – appears. The greatest indirect gains in employment are in retail sales, health care, clothing and food service, as well as direct hiring by homes; gains in these are all solid indicators that money saved elsewhere has made itself useful in popular consumer-spending destinations. Educational, financial and other services focusing on longer-term returns to consumers also see significant gains, but are less labor-intensive per dollar, and so the job growth there is not as steep.

Businesses, likewise, show signs that their overall costs to operate fall under this scenario rather than rise. Gains in white collar fields, such as management and administrative support, indicate expansion that comes with lower overall costs. The combination of ES-1's reduction in costs to produce electricity along with the lower costs associated with efficiencies from the RCII sector and less demand for waste and other services drives a structural shift toward lower costs that even some less successful policies (such as ES-2, which raises utility costs to produce a bit) do not fully offset.

Policy Option Impacts on Adaptation

Climate adaptation and climate mitigation are closely linked, with many climate mitigation actions having climate adaptation impacts as well as reducing greenhouse gas emissions. The table below outlines some of the key climate adaptation benefits of the CSEO actions, in particular as these relate to Community and Ecosystem Resilience. The footnotes to the table provide some additional clarification about these adaptation benefits.

Table V-5 Community Resilience Co-Benefits of CSEO Policy Options

	Community Resilience Co-Benefits						
CSEO Category	Improve Extreme Weather Resilience	Increase Self-Sufficiency for Energy or Supply Chain Needs	Greater Economic Resilience with More $ Staying in Local Economy	Increase Water Availability/Reduce Drought Impacts	Reduce Need for Infra-structure Investment	Increase Use of Multi-Modal, Non-Motorized Pathways and Healthy Living Behaviors	Reduce Degradation of Air Quality and Other Urban Heat Island Impacts
Agriculture Sector							
AG-1 Nutrient management			X[23]				
AG-2 Healthy soils				X[1]			
AG-5 Biofuels		X	X				X
Forestry Management							

FOLU-1 Protect peat lands							
FOLU-2 Forest thinning		X[3]		X			
FOLU-3 Community forests	X			X	X[5,6]	X	X
FOLU-4 Disturbance response		X[3]		X			
FOLU-5 Conservation		X[8]					
Waste Sector							
WM-1 Water efficiency	X			X	X		
WM-2 Wastewater		X	X				
WM-3 Waste management	X	X	X				
Land Use and Transportation							
TLU-1a Pay as you drive						X	X[12]
TLU-1b Carbon Tax on fuels	X[13]					X	X[12]
TLU-1c Fuel sales tax	X[13]					X	X[12]
TLU-2 Metro densification					X	X	X[12]
TLU-3 Draft 2040 plan					X	X	X[12]
TLU-4 Electric vehicles	X[15]	X	X[16]				X[12]
Energy Supply Sector							
ES-1 Increase RES	X[18]	X[15]	X[15]	X[19]			X
ES-2 Coal plant retirement							X
ES-3 EPA Clean Power Plan	X	X	X		X		X
Demand Side Energy Efficiency							
RCII-1 CHP	X	X	X	X[19]	X[6,20]		X
RCII-2 Zero Energy Ready		X	X	X[21]	X[6]		X
RCII-4 Increase EE		X	X	X[21]	X[6]		X
RCII-5 Thermal renewables	X[15]	X[22]	X		X[6]		

Table V-6 Ecosystem Co-Benefits of CSEO Policy Options

	Ecosystem Co-Benefits					
CSEO Category	Improve Biodiversity/Wildlife Habitat and Resistance to Pests	Improve Surface/ Ground Water Quality	Reduce Soil Erosion	Increase Resilience of Ag and Forestry Production	Reduce Wildfires	Reduce Flooding
Agriculture Sector						

AG-1 Nutrient management	X[24]	X[24]		X[23]		
AG-2 Healthy soils	X[2]	X[1]	X[1]	X[1]		X[1]
AG-5 Biofuels						
Forestry Management						
FOLU-1 Protect peat lands	X	X			X	X
FOLU-2 Forest thinning	X	X	X	X[4]	X	
FOLU-3 Community forests	X	X	X			X
FOLU-4 Disturbance response	X	X	X	X[7]	X	
FOLU-5 Conservation	X	X	X	X[9]		X
Waste Sector						
WM-1 Water efficiency		X		X[10]		
WM-2 Wastewater						
WM-3 Waste management	X	X				
Land Use and Transportation						
TLU-1a Pay as you drive						
TLU-1b Carbon Tax on fuels						
TLU-1c Fuel sales tax						
TLU-2 Metro densification	X[14]	X				
TLU-3 Draft 2040 plan						
TLU-4 Electric vehicles		X[17]				
Energy Supply Sector						
ES-1 Increase RES		X		X	X[11]	
ES-2 Coal plant retirement		X				
ES-3 EPA Clean Power Plan				X		
Demand Side Energy Efficiency						
RCII-1 CHP		X		X	X[11]	
RCII-2 Zero Energy Ready		X				
RCII-4 Increase EE		X				
RCII-5 Thermal renewables					X[11]	

Notes:

1 Healthy soils with high organic carbon content have high infiltration rates and greater water holding capacities. These characteristics reduce runoff and soil erosion. Organic matter improves soil structure and makes it more resilient to erosive effects of wind and water.

2 Cover crops can reduce pest outbreaks by providing enhanced bio-control that promotes the growth and survival of beneficial insects.

3 Makes more woody biomass available for use in home and commercial heating.

4 Favors tree species expected to do better under changed climate conditions and improves overall forest health.

5 Urban forests can reduce stormwater management needs.

6 Reduces the need for expanding utility power generation, transmission and distribution systems due to reduced cooling loads, greater energy efficiency, more distributed generation, and/or increased renewable energy supplies.

7 Focuses on rapid restoration of productive capacity of forests following disturbance.

8 Grassland conservation is part of a cellulosic feed stock supply chain strategy.

9 Forest conservation reduces fragmentation and loss of capacity to manage forests, better enabling effective harvest and adaptation management - providing for sustainable long term fiber supply. Grassland conservation also provides for a forage reserve for livestock producers. Conserved lands can be accessed for emergency haying and grazing as floods and droughts impact other forage supplies.

10 Conserving groundwater resources through more efficient water use will better ensure the sustainability of water resources utilized for agricultural irrigation.

11 Some benefits of woody biomass use could include healthier forests through better, cost-effective forest management practices that mitigate the occurrence/severity of wildfires.

12 Research indicates that stronger urban heat island effects impact both higher density urban areas and lower density sprawling urban areas.

13 Given the many risks to infrastructure condition from extreme weather, more funds could be available to upgrade and maintain infrastructure thus reducing vulnerability.

14 More compact development would prevent or slow growth on the urban edge, thus preserving existing habitat.

15 Diversifying the fuel supply and increasing locally available renewables will result in improved resiliency during extreme weather events, disruption to fossil fuel distribution, or other emergencies.

16 Relying on electricity for a portion of our vehicle fleet will result in some of the fuel production being sourced from local renewable energy like solar and wind.

17 Vehicles with zero emissions will lead to fewer pollutants impacting water quality.

18 Wind or solar power generated as distributed generation on site, versus as electricity from the grid, increases resilience to extreme weather impacting the grid system.

19 Electricity generation at a utility-scale requires significant amounts of water for various parts of the energy production process including extraction, processing and cooling. More renewable energy and/or CHP systems can off-set some of the water requirements for current energy production.

20 Reduces demand on the water distribution system. (Many CHP systems require significantly less water for cooling purposes or are air cooled and can alleviate some of the water demand required for coal-fired generation.)

21 Measures such as low flow faucet aerators, water distribution system efficiency, condensing hot water heaters, industrial process efficiency, etc. can lead to reduced water consumption.

22 Renewable thermal energy can help mitigate volatility in both pricing and fuel supplies by reducing the state's reliance on conventional fuels, and also mitigate risks associated with fuel shortages due to tightened domestic supplies.

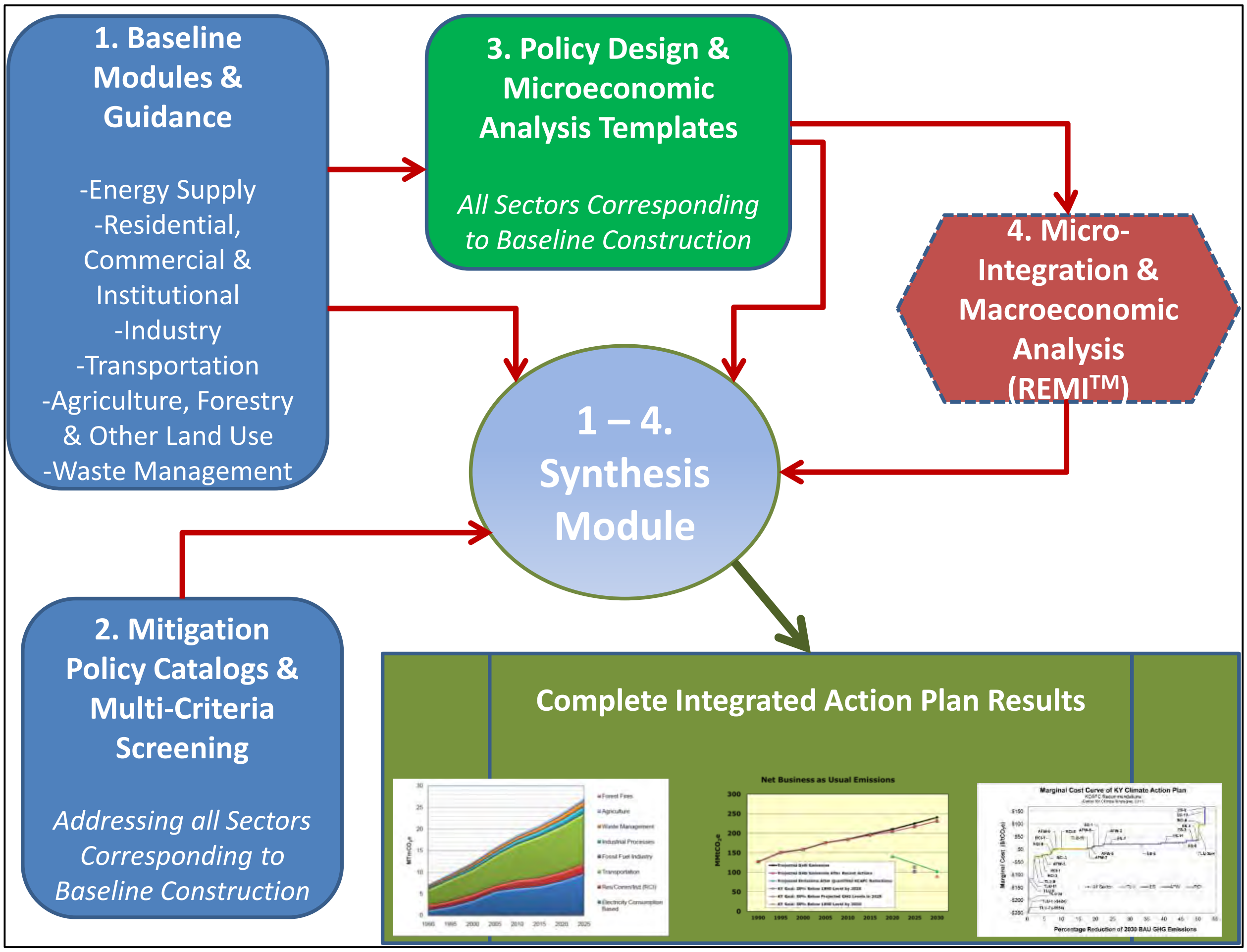
23 Proper nitrogen management through increased nitrogen use efficiency is an important factor in profitability and long term viability of crop production.

24 Increased nitrogen uptake by the crop will reduce nitrogen which would otherwise move into the environment and could have a negative impact on plants, animals, surface waters, and groundwater. Vigorous cropping systems also provide protection from pests.

Chapter XI. Appendix A. CCS Analytical Toolkit

Figure A-1 below provides an overview CCS' Analytical Toolkit used to support multi-objective action planning projects.

Figure A-1 CCS Analytical Toolkit



The function and output of each tool within the Toolkit are described below, as well as their application within the CSEO project:

1. **Baseline Modules & Guidance:** for each sector of the economy, a separate tool is employed to generate a historical and business as usual forecast ("baseline") of emissions, as well as the associated energy, economic, and other drivers of GHG emissions (e.g. land use, demand for housing, transportation activity, etc.). For CSEO, much of the baseline data were provided by MPCA, including sector-level baselines through 2030. Specific enhancements to MPCA's existing baseline data to support the CSEO project were:

a. Forestry & Other Land Use baseline: includes an accompanying land use forecast for the State; net GHG emissions for MN's forests (including urban forests);
b. Agriculture crop production sector forecast: a forecast of MPCA's inventory for the crop production sector;
c. Industrial process forecast: a forecast of emissions for industrial sector fuel combustion and non-fuel process emissions;
d. Power supply sector avoided costs and emissions for the marginal resource mix: as discussed in detail in the report, a set of avoided costs and emissions was developed to support direct impacts analysis of CSEO policies that had an impact to the electrical grid (i.e. either reducing or increasing future project loads).

2. Mitigation Policy Catalogs and Multi-Criteria Screening:

a. Policy Catalogs: for each sector of the economy, a catalog of policies and actions was prepared and reviewed to provide an understanding of the full range of opportunities for consideration in meeting project objectives in emissions reduction and economic growth;
b. A multi-criteria assessment is then built from the full set of policies in the form of a matrix to conduct a screening-level assessment of potential GHG reductions, direct costs/savings, indirect costs/savings, and other objectives (e.g. health, environmental, or natural resources impacts). Policies were then evaluated for their positive or negative contributions to each of these screening metrics. Application of the multi-criteria screening process formed the initial set of CSEO policies for further development and analysis.

3. Policy Design & Microeconomic Analysis Templates:

a. Policy design templates were applied for each of the initial policies to develop and document the details of how each policy would be designed (description, goals, timing), implemented, and analyzed. Results of analysis, including key uncertainties were also documented within each template. The collection of all policy templates for a sector forms each of the sector appendices of the CSEO final report;
b. Policy Impacts Quantification Memo: this technical memorandum was developed to document the methods, boundaries, and key metrics for the direct and indirect policy impacts analyses for CSEO;
c. Sector-Level Micro-Analysis Workbooks: for each sector, a standardized MS Excel workbook was prepared following the guidance laid out in the Quantification Memo above to conduct the direct impacts analysis of each CSEO policy. These workbooks are used to derive policy specific ("stand-alone") results, as well as results that have been adjusted for any intra-sector overlaps among policies;
d. Common Forecast Data Workbook: a separate MS Excel workbook was developed to house common data applied across all sectors during baseline and micro-impacts analysis. These include socio-economic data (e.g. population and

GDP forecasts), carbon intensities and costs of power supply for the marginal resource mix, GHG emission factors for each fuel type (including upstream fuel supply emission factors), fuel price forecasts, and other data.

4. **Micro-Integration and Macroeconomic Analysis:**
    a. Micro-Integration – baseline and direct impacts analysis results are incorporated into the Toolkit's Synthesis Module, where the microeconomic impacts for each policy are further adjusted to account for any overlaps or interactions between sectors. The key interaction present in any similar action planning process occurs between electricity supply and demand policies (see the CSEO report for a full discussion of this process);
    b. Macroeconomic Analysis: for CSEO, the REMI-PI+ model was applied to assess indirect impacts of policy implementation (e.g. employment, GDP). Inputs to REMI-PI+ include the streams of financial flows taken from the direct impacts analysis (sector-level Micro-Analysis Workbooks).

Synthesis Module: Data from each of the tools described above serve as input to the Synthesis Module, where summary tables and charts are produced to document the overall analytical results. Key outputs include a chart showing baseline GHG emissions by sector; baseline GHG emissions and the expected shifts away from this baseline via implementation of the Plan's policies; a marginal abatement cost curve for the Plan; cost effectiveness by policy; emission reductions for key target years, among others.

Chapter VII. Appendix B. MPCA GHG Emissions Baseline Report

"Data from Minnesota Pollution Control Agency (MPCA), which are documented in a separate report entitled “Minnesota Greenhouse Gas Forecast: State-level Results” were used during the Climate Strategies & Economic Opportunities (CSEO) process to provide detailed forecasts of current and projected greenhouse gas (GHG) emissions for all economic sectors (i.e. addressing sources for which all CSEO policies were analyzed). The report was prepared and provided to the Center for Climate Strategies (CCS) by MPCA. The format and page numbering were preserved to reflect the original report."

Minnesota Greenhouse Gas Forecast: State-level Results

By Peter Ciborowski
Minnesota Pollution Control Agency
March 30, 2015

Statewide Emissions

Introduction

To support what has become the Climate Strategies and Economic Opportunities (CSEO) project, between October 2012 and September 2014 the Minnesota Pollution Control Agency (MPCA) developed a 19-year greenhouse gas (GHG) emission forecast, beginning in forecast year 2012 and terminating in forecast year 2030. The intent was and is to provide the analysts at the Center for Climate Strategies (CCS) with an internally consistent, highly detailed energy use and emissions forecast for use in quantifying the costs of policies to reduce statewide GHG emissions. The forecast was developed on a sector-by-sector basis and, given the need of the analysts for highly detailed projection information for energy use, industrial production, waste generation and disposition and other precursor forecast information, generally bottom-up. An effort was made in the forecasting to account for all policies now on the books. In August 2014, the forecast was frozen in place in the form of the forecast then current, based on the work completed at various times over the prior two years.

In the forecast, the economy is segmented into eight emitting sectors: electric power, transportation, industry (mining and manufacturing), commercial buildings, residential buildings, livestock production, crop production, and waste management. Of those, the MPCA developed emission forecasts for all but the crop producing sector. The staff of CCS developed its own forecast for the crop producing sector, the results of which are incorporated in the statewide totals reported below.

The forecast is accompanied by historical reconstructions of past emissions back to 1990. All systems have characteristic time constants which limit the rate at which they might change or be changed. It is reasonable to think that the historic record may shed some light on these rate constants, sector-by-sector.

The forecast begins in 2012 and extends to 2030. At the time the emission forecast was developed, present-day emissions estimates were available only through 2011. With two important exceptions, the boundaries of both the forecast of emissions and historical reconstruction of present-day and past emissions coincide with the geographical boundaries of the state. By statute, the MPCA is required to include in its emission estimates emissions that arise out-of-state as a result of electricity consumed within the borders of Minnesota. Emission totals for aviation include all emissions that result from aircraft departing from airports located in Minnesota regardless of destination.

Specific greenhouse gases (GHGs) that are treated in the forecast include fossil carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6) and two families of GHGs known as perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs). The forecast also accounts for very long-term storage of wood-based biogenic carbon in residential housing and in demolition and construction landfills. Carbon stored in housing or in housing debris in D/C landfills was once atmospheric carbon that, upon plant photosynthesis, was withdrawn from the atmosphere and incorporated into the living biomass of trees. In the forecast, net additions to very long-lived wood storage in the structural parts and sheathing of housing are treated as negative emissions or 'sinks', offsetting a part of emissions from other sources.

In the forecast, GHGs from the residential, commercial, and industrial sectors and waste management are physically emitted on-site, often in association with combustion, but also in association with other non-combustion 'processes'. The emission totals for these sectors do not include emissions associated with the end-use consumption of electricity. It is conventional to treat emissions that are associated with the end-use consumption of electricity as electric power sector emissions. Emissions from feedlots and livestock include emissions from barns, dry lots, manure storage structures and pastures plus emissions from the downstream disposal or land application of livestock manure, but not emissions associated with the generation of electricity used in livestock production or the production of milk and eggs. Most emissions from feedlots and livestock are non-combustion emissions from livestock flatulence and manure storage and disposal.

Emissions from transport include direct emissions, mostly from fuel combustion, from on-road vehicles, rail locomotives, vessels, boats, and aircraft, but not emissions from the generation of electricity used in plug-in electric vehicles or light rail transit. As elsewhere, these emissions are treated as electric power sector emissions.

To maintain internal consistency, the forecast uses the same sector boundaries that are used in the MPCA's biennial legislative reporting on progress toward the GHG emission reduction Goals of the Next Generation Energy Act (NGEA).

Forecast methods are described and documented in detail in the following sector forecast summaries:

- MPCA, Minnesota Electric Power Sector Greenhouse Gas Forecast: Business as Usual GHG Projections, Technical Support Document, 1-20-2015
- MPCA, Minnesota Transportation Sector Greenhouse Gas Forecast: Business as Usual GHG Projections, Technical Support Document, 1-20-2015
- MPCA, Minnesota Industrial Sector Greenhouse Gas Forecast: Business as Usual GHG Projections, Technical Support Document, 1-20-2015
- MPCA, Minnesota Residential Sector Greenhouse Gas Forecast: Business as Usual GHG Projections, Technical Support Document, 1-20-2015
- MPCA, Minnesota Commercial Sector Greenhouse Gas Forecast: Business as Usual GHG Projections, Technical Support Document, 1-20-2015
- MPCA, Minnesota Feedlot/Livestock Sector Greenhouse Gas Forecast: Business as Usual GHG Projections, Technical Support Document, 2-4-2015
- MPCA, Minnesota Waste Management Sector Greenhouse Gas Forecast: Business as Usual GHG Projections, Technical Support Document, 3-17-2015

A number of different forecasting strategies were employed in the development of this forecast. In some sectors of the economy, policy is now the dominant control on future emissions. This seems to hold largely true for the electric power sector and transportation. For these sectors, the forecasting exercise is largely an effort to understand the future effects of policies now on the books on emissions. For other sectors, like the residential sector, a single dominant background trend reaching back decades seems largely to control the long-term trajectory of emissions. For residential buildings, emissions follow trends in energy intensity of on-site space heating intensity with a persistence that, due to the very long life of most residential structures, allows for the extrapolation of observed trends to the distant future.

In some sectors, emissions are sensitive to fuel pricing, such that forecasting strategies necessarily require the use of economic models tuned to specific sectors of the economy. Fuel use in Minnesota's industrial sector is a good example. In this forecast, industry-specific fuel use forecasts taken from the Energy Information Administration's *Annual Energy Outlook 2014* are used to develop a downscaled forecast of emissions for Minnesota's industrial sector.

Extensive analyses of the historic record were conducted to determine the most appropriate forecasting strategy to use for each emitting sector. In instances where the historic record might be understood only in light of policies that have been implemented in Minnesota, these effects were subjected to scrutiny to understand how their continued pursuit might impact future emissions. Where a predominantly empirical approach was taken to derive trends in important forecast parameters, given the wholesale changes of the last decade in the economy, the data used was generally drawn from the last 10 or 15 years. Underlying the forecast is the assumption that the flattening of the statewide emissions trajectory over the last decade is real and provides an important window to the future.

At the time of the drafting of this forecast summary, no written documentation was available for the crop production emissions forecast. As noted above, the crop production forecast was developed by the staff of the Center for Climate Strategies. The results of that forecast are included in the totals shown below.

Regarding present-day and historic emissions, the methods that were used to develop the present-day and historic emissions estimates are discussed in detail in Appendix E of P. Ciborowski and A. Claflin, "Greenhouse Gas Emissions in Minnesota: 1970-2008: Second Biennial Progress Report – Technical Support Document" (2012).

Finally, by definition, all forecasts are wrong or, with the fullness of time, will be shown to be wrong. The purpose of this forecast is less to provide an objectively correct estimate of future emissions levels than an internally consistent framework of future economic activity and emissions within which the effects of different policies and their costs might be evaluated. The forecast should be viewed in that light.

Results

Table S-1 shows historic and forecasted GHGs from Minnesota for selected years in millions of CO_2-equivalent tons. Using 2011, the last historical year for which emission estimates were available, in the forecast, total statewide emissions decline 5.1 million CO_2-equivalent tons or a 3 percent. Most of this occurs between 2011 and 2015, after which forecast emissions are relatively stable at about 150 million CO_2-equivalent tons per year. Over the forecast period, emissions from electric power decline by 2.77 million CO_2-equivalent tons or 6 percent from

Table S-1. Historic and Forecasted Greenhouse Gas Emissions by Sector (Million CO_2-equivalent short tons)

	historical	historical	historical	historical	forecast	forecast	forecast
	1990	**2000**	**2005**	**2011**	**2015**	**2025**	**2030**
Residential	7.79	9.76	8.50	9.23	8.81	8.39	8.07
Commercial	5.74	6.32	6.89	7.01	6.67	7.66	8.25
Industrial	14.58	19.82	18.57	22.06	22.15	22.88	23.04
Electric Power	42.48	54.08	56.72	49.74	47.82	46.99	46.97
Transportation	29.56	37.52	38.32	34.14	33.47	32.02	31.17
Waste Management	5.54	3.17	2.26	1.97	1.71	1.67	1.64
Feedlots/Livestock	9.82	10.44	10.23	10.86	10.91	11.81	12.29
Crop Production	17.16	18.08	19.00	20.05	18.46	18.12	18.54
total	132.67	159.20	160.49	155.07	149.99	149.53	149.97
NGEE goals	-	-	-	-	136.41	112.34	96.29

2011 levels. Emissions from transportation decline by 2.97 million CO_2-equivalent tons or 9 percent from 2011 levels. Emissions from industry increase by 0.98 million CO_2-equivalent tons or 4 percent over the forecast period.

Of the smaller emitting sectors, in the forecast, emissions from the residential sector decline by 1.16 million CO_2-equivalent tons or 13 percent from 2011 levels, while emissions from the commercial sector rise by 18 percent from 2011 levels or 1.24 million CO_2-equivalent tons. Forecast emissions from feedlots and livestock increase by 1.43 million CO_2-equivalent tons or 13 percent. These are more than fully offset by a forecast 1.51 million CO_2-equivalent tons emission reduction from crop production. In the forecast, emissions from waste management decline slightly, by 0.34 million CO_2-equivalent tons.

Between 2011 and forecast year 2030, statewide emissions decline at an average rate of about 0.2 percent per year. In terms of the percentage distribution of emissions, this is largely unchanged between 2011 and forecast year 2030, with electric power sector share of emission declining from 32 to 31 percent, and transportation from 22 to 21 percent. Over this same period, industrial emissions as a percent of total statewide emissions increase from 14 to 15 percent.

In the 2007 The Next Generation Energy Act, the State of Minnesota set statutory emission reductions goals of 15, 30 and 80 percent from 2005 levels by 2015, 2025 and 2050. Forecasted statewide emissions in 2005 were an estimated 160.49 million CO_2-equivalent tons, yielding 2015 and 2025 NGEA target levels of 136.41 and 112.34 million CO_2-

equivalent tons in 2015 and 2025 respectively. In the forecast, 2015 and 2025 estimated statewide GHG emissions come to 149.99 and 149.53 million CO_2-equivalent tons, respectively, short of statutory reduction goals at 2015 and 2025 by a projected 13.58 and 37.19 million CO_2-equivalent tons, respectively.

In the forecast, 2030 emissions statewide come to 149.97 million CO_2-equivalent tons. Drawing a straight line between NGEA 2025 and 2050 percentage goals yields a 2030 NGEA target of 40 percent or, in absolute terms, 96.29 million CO_2-equivalent tons.

Historic emissions also are shown in Table S-1. Over the reported historical period, 1990-2011, total statewide GHG emissions from Minnesota increased by 17 percent or 22.4 million CO_2-equivalent tons. Most of this occurred between 1990 and 2000. Between 2000 and 2011, statewide emissions declined 4.13 million CO_2-equivalent tons or about 3 percent.

The same data that are shown in Table S-1 are shown pictorially in Figure S-1 below. Over the combined historical/forecast period, statewide emissions peak in 2008 at 161.86 million CO_2-equivalent tons, subsequently falling by 2011, the last year for which historical data are available, to 155.07 million CO_2-equivalent tons. Emissions throughout much of the forecast period settle near 150 million tons. By 2030, the gap between forecasted emissions and inferred NGEA target levels is equal to 36 percent of forecasted 2030 emissions or about 54 million tons.

Of the historical and forecast emission reductions, 1990-2030, most occur in the historical period and, of these, most occur in the electric power and transportation sectors.

Historical and forecasted emissions are shown in Figure S-2 by gas. Over the forecast period, fossil CO_2 remains the dominant GHGs emittant in Minnesota, comprising a little more than 80 percent of all statewide emissions. Emissions of PFCs, HFCs and SF_6 increase during the forecast period from about 1 percent of total statewide emissions in 2011 to about 3 percent in 2030. As was discussed in the documentation to the Commercial Sector forecast[1], federal rules are pending that, over the forecast period, might somewhat slow the growth of emissions of HFCs in Minnesota.

[1] MPCA, Minnesota Commercial Sector Greenhouse Gas Forecast: Business as Usual GHG Projections, Technical Support Document, 1-20-2015

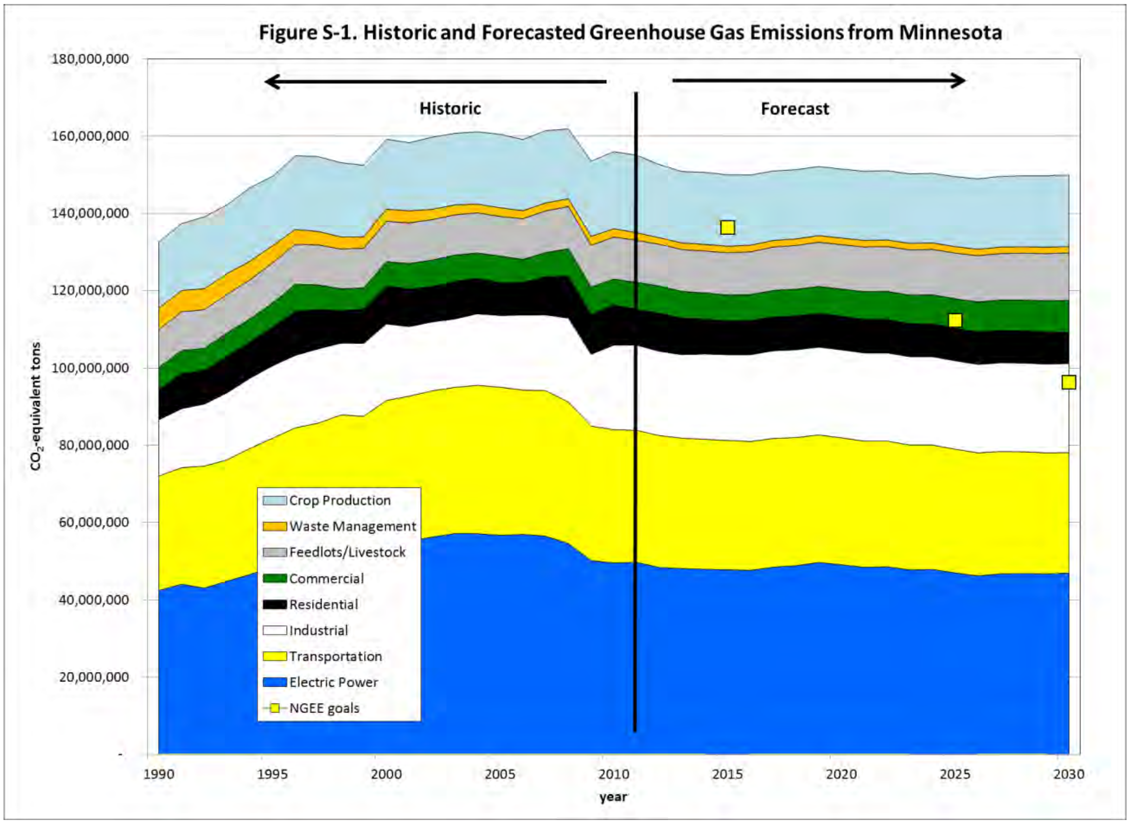


Figure S-1. Historic and Forecasted Greenhouse Gas Emissions from Minnesota
Historic
Forecast
CO2-equivalent tons
180,000,000
160,000,000
140,000,000
120,000,000
100,000,000
80,000,000
60,000,000
40,000,000
20,000,000
-
1990
1995
2000
2005
2010
2015
2020
2025
2030
year
Crop Production
Waste Management
Feedlots/Livestock
Commercial
Residential
Industrial
Transportation
Electric Power
NGEE goals

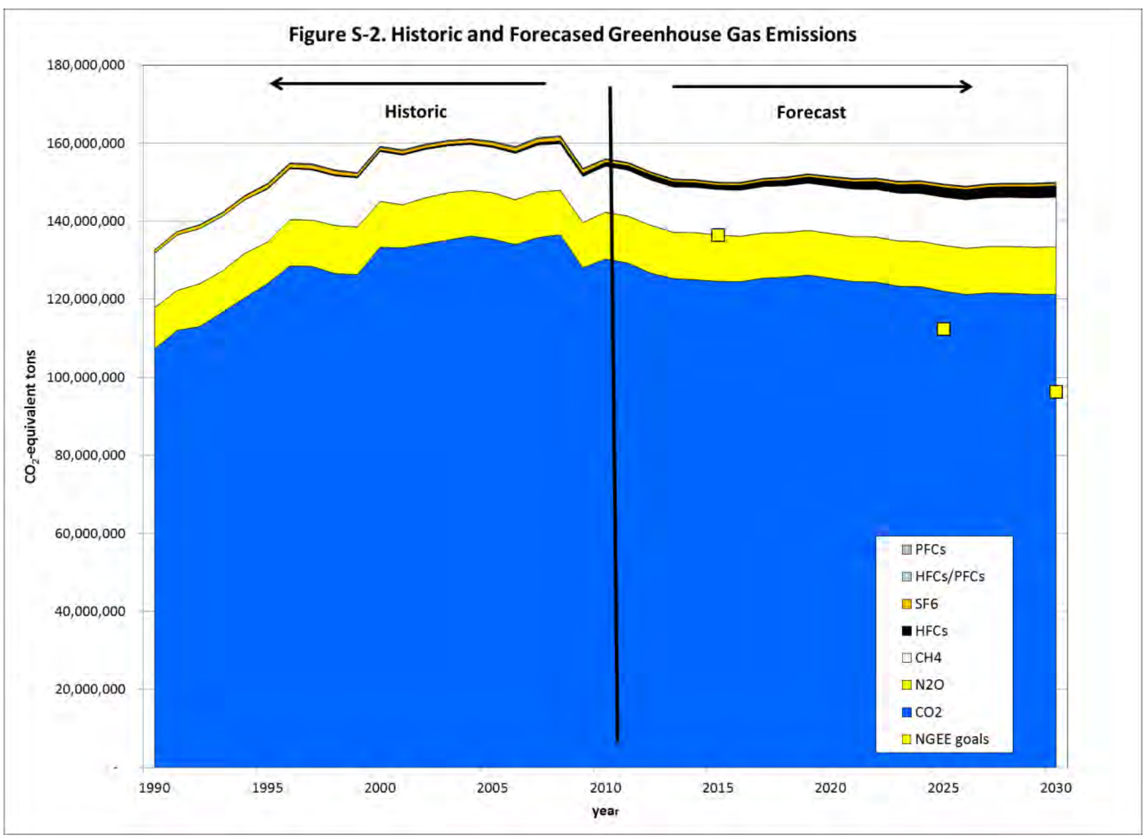


Figure S-2. Historic and Forecased Greenhouse Gas Emissions
Historic
Forecast
CO2-equivalent tons
180,000,000
160,000,000
140,000,000
120,000,000
100,000,000
80,000,000
60,000,000
40,000,000
20,000,000
-
1990
1995
2000
2005
2010
2015
2020
2025
2030
year
PFCs
HFCs/PFCs
SF6
HFCs
CH4
N2O
CO2
NGEE goals

Figure S-3 shows pictorially the trend in historic and forecasted emissions by major activity. Currently, about 80 percent of all GHG emissions from Minnesota are associated with the production or use of energy. Included in this are all emissions associated with combustion for the production of useful energy, plus noncombustion emissions associated with petroleum refining, electric transmission and distribution, air conditioning and refrigeration and nonfuel uses of lubricating oils. Of the remainder, most of this derives from agricultural activities. Waste management and miscellaneous industrial processes contribute a few percent to statewide totals.

In forecast, energy use and production remains the predominant source of emissions, consistently accounting for slightly less than 80 percent of all statewide emissions across all forecast years.

Figure S-3. Historic and Forecasted Emissions by Major Activity

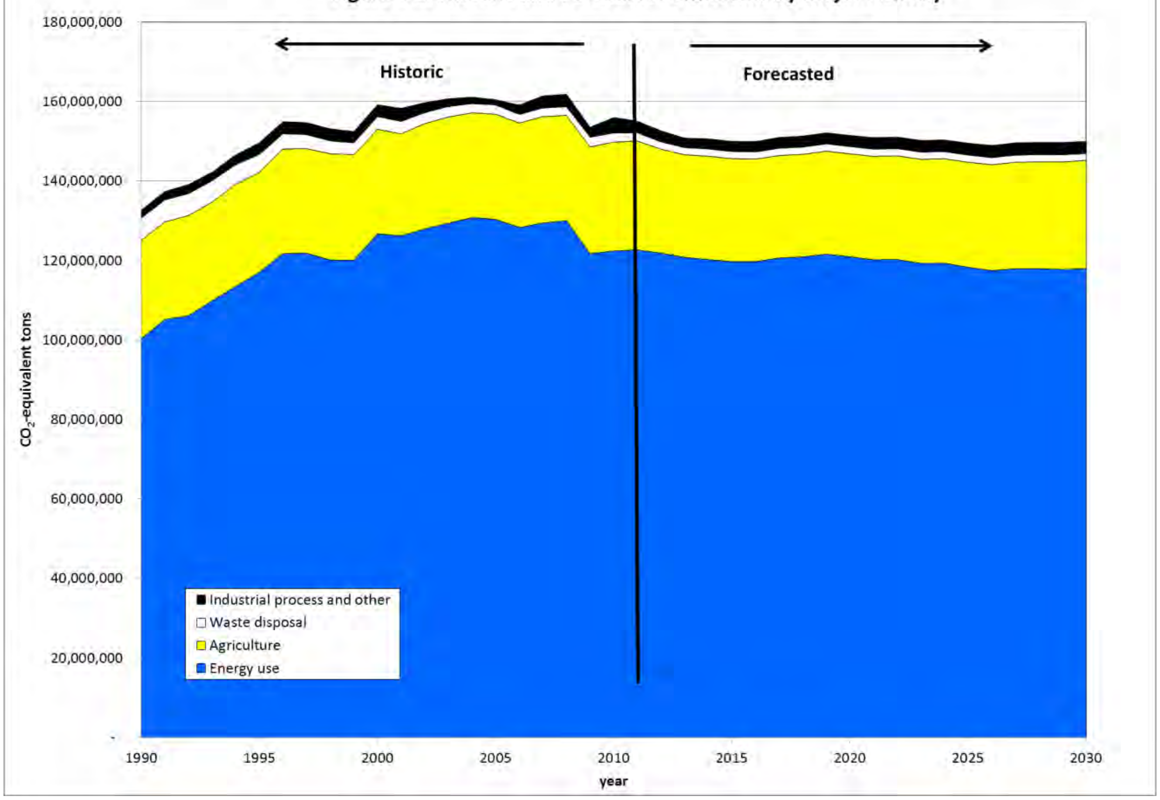


Table S-2 provides a detailed breakdown of historic and forecasted emissions for selected years by emissions source. In Minnesota, about three-quarters of GHG emissions are associated with combustion for the purposeful production of energy, and the rest are noncombustion emissions. This percentage breakdown of emissions persists throughout the forecast period. In the forecast, statewide emissions from combustion decline by 7.03 million CO_2-equivalent tons, 2011-2030, or about 6 percent. Over the forecast period, emissions associated with the combustion of oil decline by 2.6 million CO_2-equivalent tons, while emissions associated with the generation out-of-state of imported power decline by 5.41 million CO_2-equivalent tons, 2011-2030. These are partially offset in the forecast by increased emissions from the combustion of natural gas, some 1.54 million CO_2-equivalent tons. Emissions from the combustion of coal are almost unchanged in the forecast, declining 0.5 million CO_2-equivalent tons by forecast year 2030. Combustion emissions totaled an estimated 118.6 million CO_2-equivalent tons in 2011, declining in the forecast to 111.57 million tons by forecast year 2030.

Statewide noncombustion emissions were in 2011 some 36.46 million CO_2-equivalent tons. In the forecast, emissions from noncombustion sources increase from 36.46 million CO_2-equivalent tons in 2011 to 38.39 million CO_2-equivalent tons in forecast year 2030 or 1.93 million CO_2-equivalent tons. Most of this is from commercial buildings. In the forecast, emissions from commercial buildings increase by 1.75 million CO_2-equivalent tons, principally in the form of HFC emissions from commercial air conditioning and refrigeration. Over the forecast period, emissions from industrial noncombustion processes increase a smaller 0.58 million CO_2-equivalent tons, while agricultural and waste management noncombustion process emissions decline in the forecast by 0.17 and 0.35 million CO_2-equivalent tons, respectively, 2011-2030.

S-2. Historic and Forecasted Greenhouse Gas Emissions by Sector (Million CO_2-equivalent short tons)

	historical	historical	historical	historical	forecast	forecast	forecast
	1990	2000	2005	2011	2015	2025	2030
Combustion Emissions							
Coal	34.11	41.08	41.98	34.82	36.51	34.61	34.38
Oil	39.18	47.98	50.63	44.57	44.00	42.71	41.96
Natural gas	16.34	20.23	20.45	24.00	24.35	24.87	25.54
Other fuel	0.79	0.88	0.95	0.97	1.20	0.93	0.86
Net Electricity imports	8.26	13.78	13.48	14.24	9.26	9.18	8.83
Noncombustion Process Emissions							
Electric Power							
Electric transmission and distribution	0.68	0.43	0.46	0.52	0.51	0.60	0.63
Other electric power sector process	0.06	0.07	0.07	0.07	0.07	0.06	0.06
Industry							
Iron ore processing	2.10	2.29	1.82	2.33	2.37	2.46	2.50
Copper ore processing	-	-	-	-	-	0.10	0.10
Oil refining	0.91	2.12	2.07	2.59	2.93	3.03	2.99
Magnesium die casting	0.15	0.28	0.39	0.15	0.05	0.05	0.05
Semiconductor manufacture	-	0.23	0.25	0.14	0.16	0.16	0.16
Industrial wastewater treatment	0.12	0.15	0.17	0.18	0.18	0.20	0.21
Other industrial sector process	0.53	0.53	0.38	0.40	0.40	0.36	0.36
Transportation							
Tire abrasion	0.01	0.01	0.02	0.01	0.01	0.01	0.02
Agriculture							
Manure management	3.04	3.99	4.18	4.60	4.66	5.30	5.61
Ruminant flatulence	6.01	5.69	5.28	5.45	5.45	5.64	5.80
Soil nutrient management	7.20	8.06	8.30	9.06	8.97	8.83	9.20
Histosols	7.68	7.68	7.68	7.49	6.06	6.06	6.06
Other agricultural processes	0.82	0.91	1.00	0.79	0.73	0.60	0.55
Waste Management							
MMSW landfills	5.12	3.19	2.26	1.86	1.77	1.70	1.64
Industrial landfills	0.07	0.11	0.12	0.13	0.14	0.14	0.14
Solid waste incineration	0.16	0.07	0.06	0.06	0.06	0.06	0.06
Hazardous waste incineration	0.09	0.09	0.11	0.07	0.10	0.10	0.10
Wastewater treatment	0.51	0.54	0.56	0.59	0.60	0.63	0.65
Carbon sequestration in D/C landfills	(0.51)	(1.04)	(0.99)	(0.87)	(1.08)	(1.09)	(1.10)
Other waste management process emissions	0.02	0.05	0.06	0.06	0.06	0.06	0.06
Buildings							
Carbon sequestration in housing	(1.08)	(0.89)	(2.03)	(0.66)	(1.00)	(0.83)	(0.88)
Other housing sector process	0.10	0.34	0.33	0.49	0.61	0.91	0.89
Commercial air conditioning	-	0.15	0.28	0.78	0.67	1.87	2.34
Other Commercial sector process	0.17	0.18	0.15	0.18	0.19	0.19	0.19
Total	**132.67**	**159.20**	**160.49**	**155.07**	**149.99**	**149.53**	**149.97**

other agriculture processes: agricultural burning, atmospheric nitrogen deposition, wild rice cultivation, wind erosion of soils

As discussed with respect to Figure S-2, it is possible that, with pending federal rules on the allowable use of HFCs in commercial refrigeration, some of the forecasted increase in noncombustion emissions, 2011-203, may be avoided.

Regarding the distribution of emissions among sources, this remains largely unchanged over the forecast period. With regard to combustion emissions, at present about 29 percent derive from the combustion of coal, 38 percent from the combustion refined petroleum products and 20 percent from the combustion of natural gas. As of 2011, about 12 percent of combustion-based emissions derived from out-of-state combustion leading to the generation of electricity that eventually is consumed in Minnesota by Minnesotans. In the forecast, by forecast year 2030, a projected 31 percent of combustion emissions are associated with coal combustion, 38 percent with the combustion of oil and 23 percent with the combustion of natural gas. The percent of total combustion emissions that are associated with net imported electricity declines to about 8 percent in the forecast by forecast year 2030.

About 75 percent of noncombustion emissions now are agricultural in origin and another roughly 16 percent are of an industrial provenance. Waste management accounts for an additional 5 percent and buildings 2 percent. In the forecast, by forecast year 2030, these distributions are only slightly different, with agricultural contribution at 71 percent, industry at 17 percent, buildings 6 percent and waste management 4 percent.

In developing the sector forecasts, substantial efforts were made to understand the impacts of policies that are already in-place on emissions over the historic period and forecast emissions. Figure S-4 shows the results of those efforts pictorially. The figure was assembled from the results shown in:

- Figure E-6. Minnesota Electric Power Sector Greenhouse Gas Forecast, Technical Support Document
- Figure T-8. Minnesota Transportation Sector Greenhouse Gas Forecast, Technical Support Document
- Figure I-5. Minnesota Industrial Sector Greenhouse Gas Forecast, Technical Support Document
- Figure R-6. Minnesota Residential Sector Greenhouse Gas Forecast, Technical Support Document
- Figure C-4. Minnesota Commercial Sector Greenhouse Gas Forecast, Technical Support Document
- Figure W-3. Minnesota Waste Management Sector Greenhouse Gas Forecast, Technical Support Document

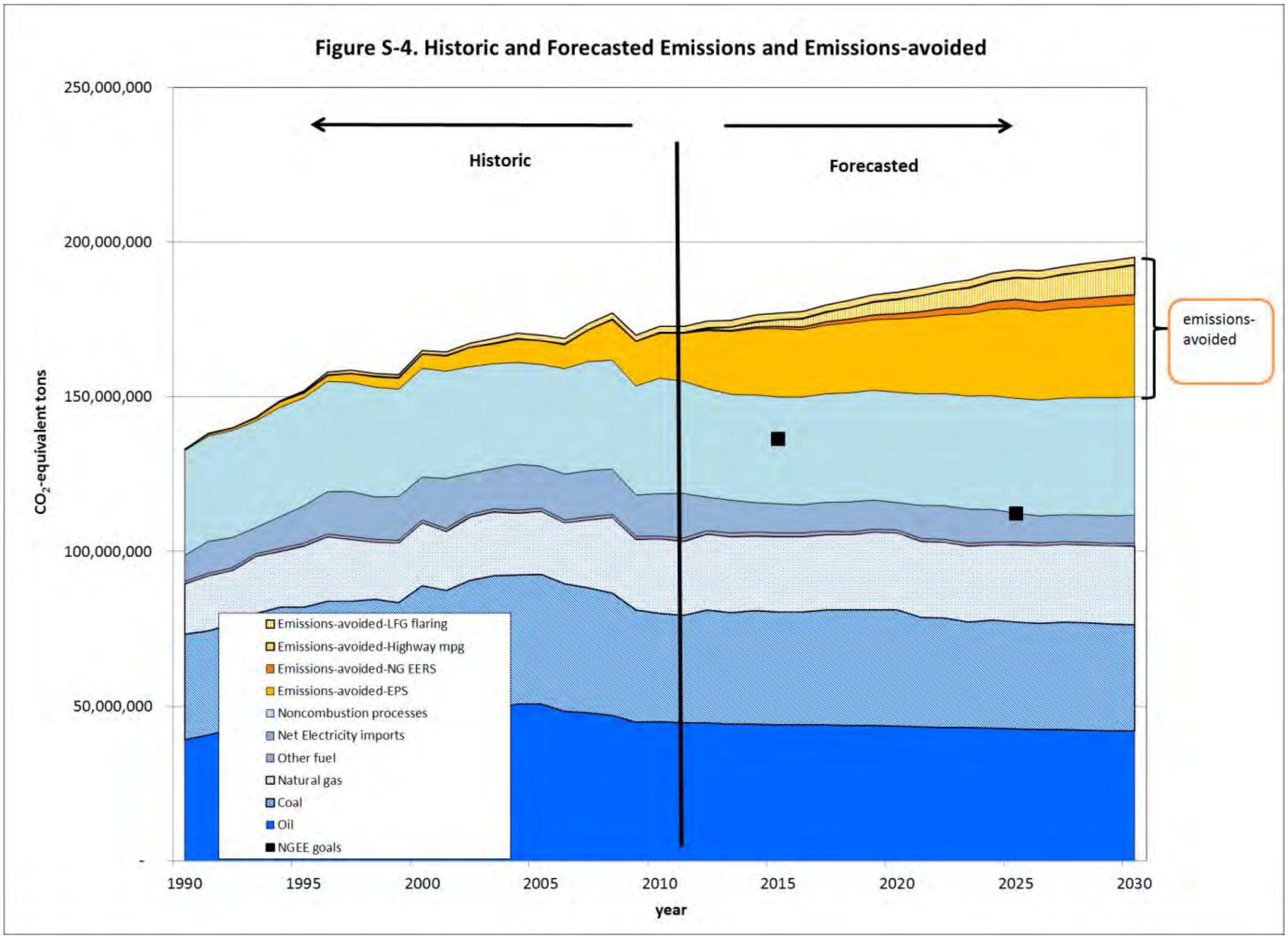


Figure S-4. Historic and Forecasted Emissions and Emissions-avoided

The questions asked were:

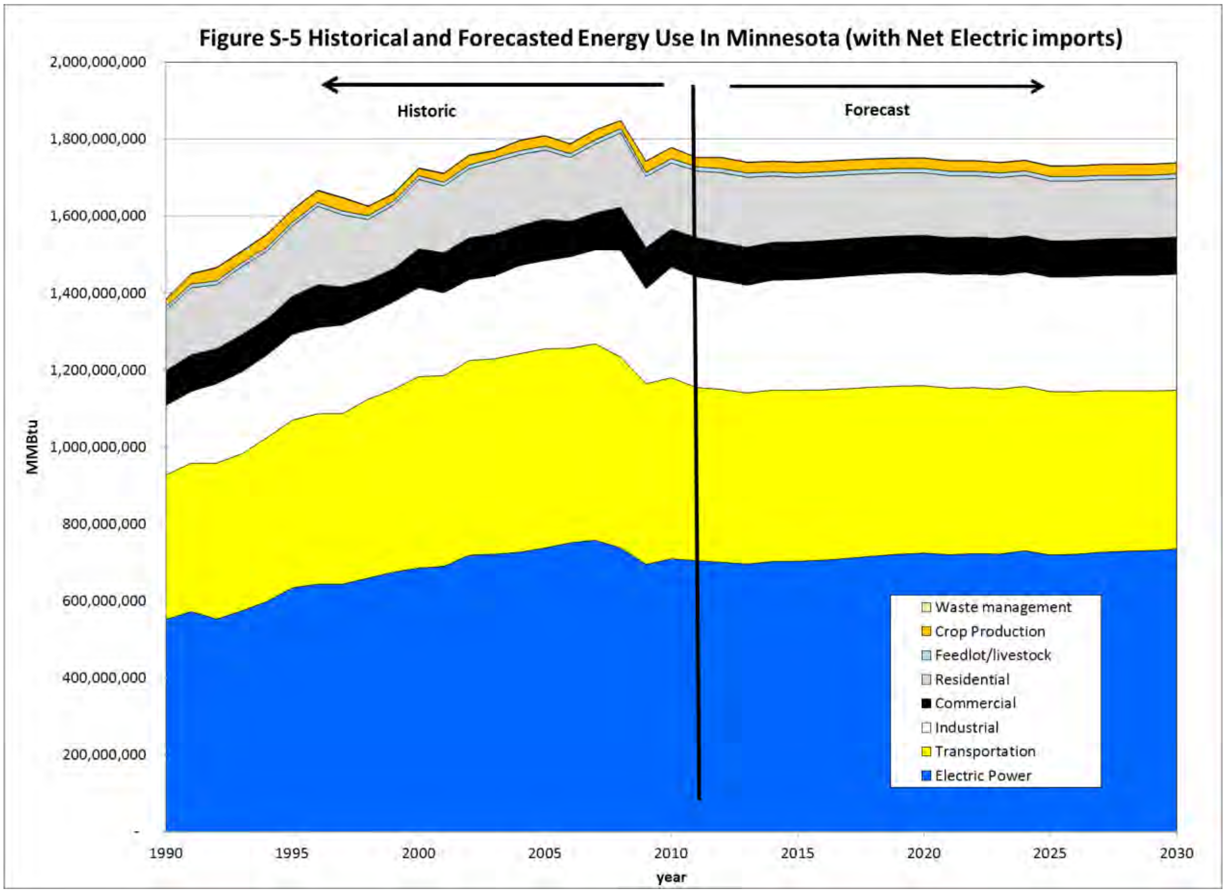
- in the case of forecast emissions, if emissions were modeled with no consideration given to the effects of policies now in-place and expected to continue in-place throughout the forecast period, how would the forecast trend in emissions differ from what otherwise is projected out to 2030?
- in the case of emissions during the historical period, how would have the known trajectory of emissions otherwise been different had the policies that in fact were implemented over that period not been implemented?

If modeled without consideration given to the effects of policies now in-place and expected to continue in-place throughout the forecast period, projected state-level GHG emissions would be roughly 45 million CO_2-equivalent tons higher in 2030 than are now projected. Based on the modeling, in absence of the policies that are now in place, historical emissions would have been higher in 2000 and 2011 than the historic data record by an estimated 5.6 and 17.6 million CO_2-equivalent tons, respectively or 4 and 11 percent. In the historical record, emissions peak in 2008 and decline about 4 percent through 2011. Forecast emissions are largely flat at levels only slightly lower than 2011 levels. Absent the policies that are now in place, emissions over the combined historical period and forecast period would have grown, 1995-2011, and otherwise would grow in the forecast, 2011-2030, at a sustained 30-year rate of about 0.6 percent per year out to 2025.

As noted above, the NGEA targets at 2025 are some 112.3 million CO_2-equivalent tons, while forecasted emissions in 2025 are 149.5 million CO_2 equivalent tons. Forecasted emissions-plus-emissions-avoided are some 192.5 million CO_2-equivalent tons. This suggests that, with the emissions reductions already baked into the forecast, the state is roughly halfway to its NGEA statutory goals. This is shown in Figure S-4 as the difference between total forecasted emissions plus emissions-avoided and the NGEA targets, on the one hand, and total forecasted emissions and the NGEA targets, on the other hand.

Figure S-5 shows the trend and breakdown of historic and forecasted future energy use in Minnesota. This includes the energy associated with the generation out-of-state of electricity that is consumed in Minnesota. Total energy use in Minnesota increased at an average annual rate of 1.1 percent over the historical period (1990-2011), peaking in 2008 and declining by about 5 percent to 2011. Of the 2008-2011 decline, about half of this occurred in transportation and one-third in the electric power sector. The rate of growth in energy use was rapid early in the historical period, 2 percent per year, 1990-2000, declining to 0.3 percent per year, 2000-2010.

In the forecast, total energy use in Minnesota declines by 14 million MMBtu from 2011 levels by forecast year 2030 or by 1 percent. In the forecast, total energy use in transportation and housing declines 37 and 21 million MMBtu, respectively, 2011-2030, partially offset by increased energy use in electric power and industry (mining and manufacturing), some 30 and 14 million MMBtu, respectively. Over the forecast period, total energy use declines at an average annual rate of 0.04 percent per year, continuing the flattening of growth in energy use evident in the historical record back to the early 2000s. Energy use in transportation declines in the forecast principally in response to federal fuel economy standards, and energy use in residential housing due to declining space heating energy intensity, the state's natural gas energy efficiency resource standard (EERS), and continued projected climatic warming. Energy use in electric power generation increases in the forecast principally in response to forecasted increased future electric demand.



Forecast energy use in mining and manufacturing increases mainly due to rising industrial production, particularly in oil refining, food processing, mining, and miscellaneous light manufacturing. By sector, total forecasted energy use in Minnesota increases by 0.2, 0.2 and 0.8 percent per year in the electric power sector, industry and agriculture, respectively. Energy use in transportation, residential housing, and the commercial sector declines in the forecast at an average annual rate of 0.5, 0.7 and 0.3 percent per year, respectively, 2011-2030.

By percent, the distribution of total Minnesota energy use by sector remains relatively unchanged over the forecast period, with electric power sector share of total energy use increasing from 40 to 42 percent, and transportation's share falling slightly from 26 to 24 percent of the total, 2011-2030. By forecast year 2030, total forecasted energy use in Minnesota is 6 percent below peak 2008 energy use levels.

Table S-3 shows historic and forecasted energy use in Minnesota by fuel type and energy carrier. Also shown is the energy consumed out-of-state to generate electricity that is imported into Minnesota. In the forecast, the in-state use of natural gas, nuclear energy, and renewable energy increases 26, 11 and 45 million MMBtu, respectively, offset by a reduction in the in-state use of refined petroleum products of 33 million MMBtu and a reduction of an estimated 64 million MMBtu in out-of-state energy used to generate electricity imported into Minnesota. In percentage terms, in-state use of natural gas increases 6 percent over the forecast period, 2011-2030, while the use of refined petroleum products decreases by 6 percent. In-state use of renewable energy increases in the forecast by about 36 percent, while out-of-state energy used to generate electricity imported into Minnesota declines a forecast 34 percent, 2011-2030. Energy inputs to nuclear power increase in the forecast about 9 percent from 2011 levels.

In-state coal use, the third largest source of energy for the Minnesota economy, declines in the forecast, but only slightly, by 4 million MMBtu or 1 percent, 2011-2030.

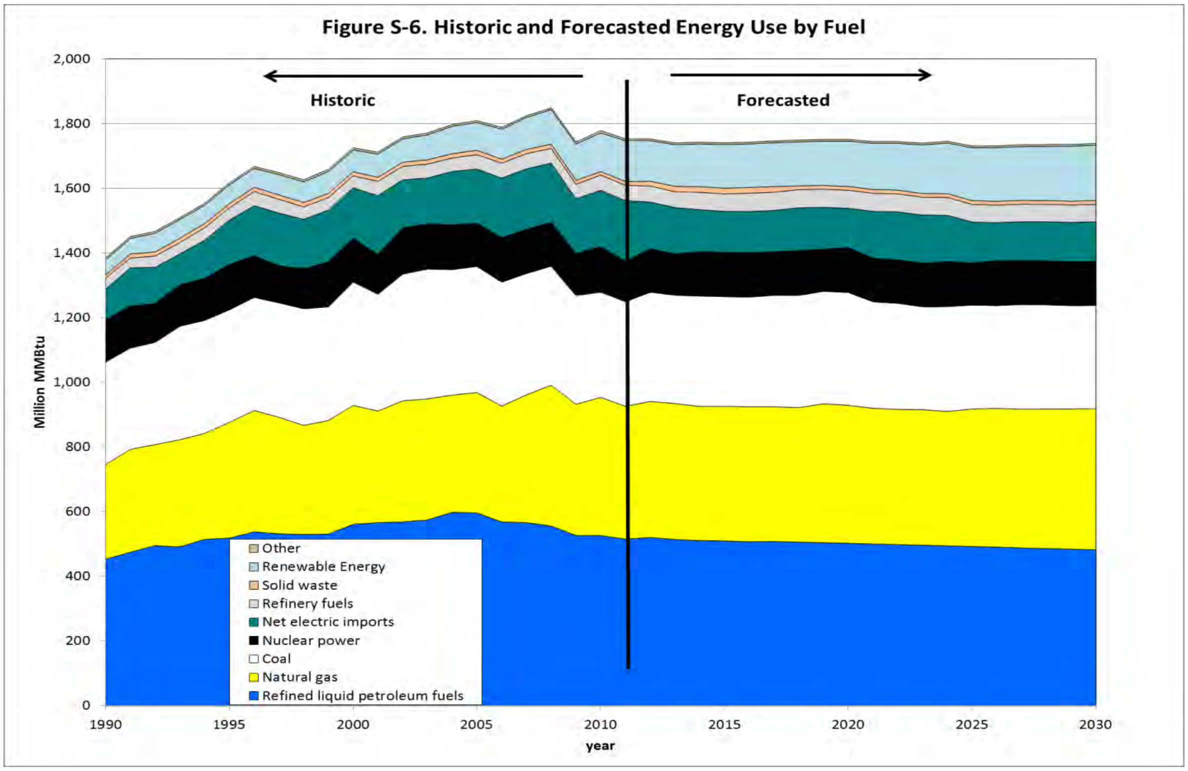
The percentage distribution of energy use by fuel changes slightly in the forecast. In the forecast, by forecast year 2030, natural gas and renewable energy account for a combined 35 percent of total energy use in Minnesota, up from a combined 30 percent in 2011. The forecasted share of net electric imports and refined petroleum products of total state energy use declines in the forecast from a combined 40 percent in 2011 to 35 percent in forecast year 2030.

Table S3. Historic and Forecasted Total State Energy Use by Fuel (Million MMBtu)

	1990	**2000**	**2011**	**2020**	**2030**
Refined liquid petroleum fuels	453	561	515	502	482
Natural gas	292	367	410	426	436
Coal	317	382	323	349	319
Nuclear power	131	135	125	139	136
Net electric imports	95	156	187	121	123
Renewable Energy	46	68	126	140	171
Refinery fuels	33	37	47	56	54
Solid waste	11	13	12	12	12
Other	6	6	6	6	6
total	**1,385**	**1,725**	**1,752**	**1,751**	**1,739**

Figure S-6 shows the same data pictorially. As noted above, the forecast largely continues trends in energy use that are evident in the historic data since the mid-2000s. Striking is the decline in the use of refined petroleum products between 2005 and 2011 and continuing throughout the forecast period. In-state coal use, which declined 17 percent between 2005 and 2011, continues near those reduced levels throughout the forecast period. In-state production of energy from renewable energy sources, mostly in the form of electricity, increases in the forecast, as does natural gas use, again mostly in electricity generation. Forecast energy inputs to net imported electricity decline about one-third over the forecast period. In the forecast, net electricity imports decline 31 percent between 2011 and forecast year 2030.

Finally, Figure S-7 shows the changing distribution of statewide energy use using the following categories: fossil fuels, nuclear power, renewable energy, and net electricity imports. In the forecast, in forecast year 2030, 75 percent of total energy use in Minnesota IS from fossil fuels, unchanged from 2011 levels. In forecast year 2030, 10 percent of statewide energy use is from renewable energy sources, up from 8 percent in 2011, while the energy associated with the generation of power for import declines in the forecast from 11 percent in 2011 to 7 percent by forecast year 2030. Energy inputs to nuclear power generation increase over the forecast period from 7 to 8 percent, 2011-2030.



Using 1990 as a starting point, in he forecast, the system is decarbonizing, but at a slow long-term rate of 0.2 percent per year. Adding in the effects of increased out-of-state use of renewables in imported power would only slightly change this conclusion.[2]

[2] Assuming in the extreme case that 50% of forecasted net imports in 2030 are fossil-based, and 100% of 1990 net imports were fossil based, the system would remain 78 percent fossil dependent as late as forecast year 2030, declining at a rate of 0.3 percent per year, 1990-2030.

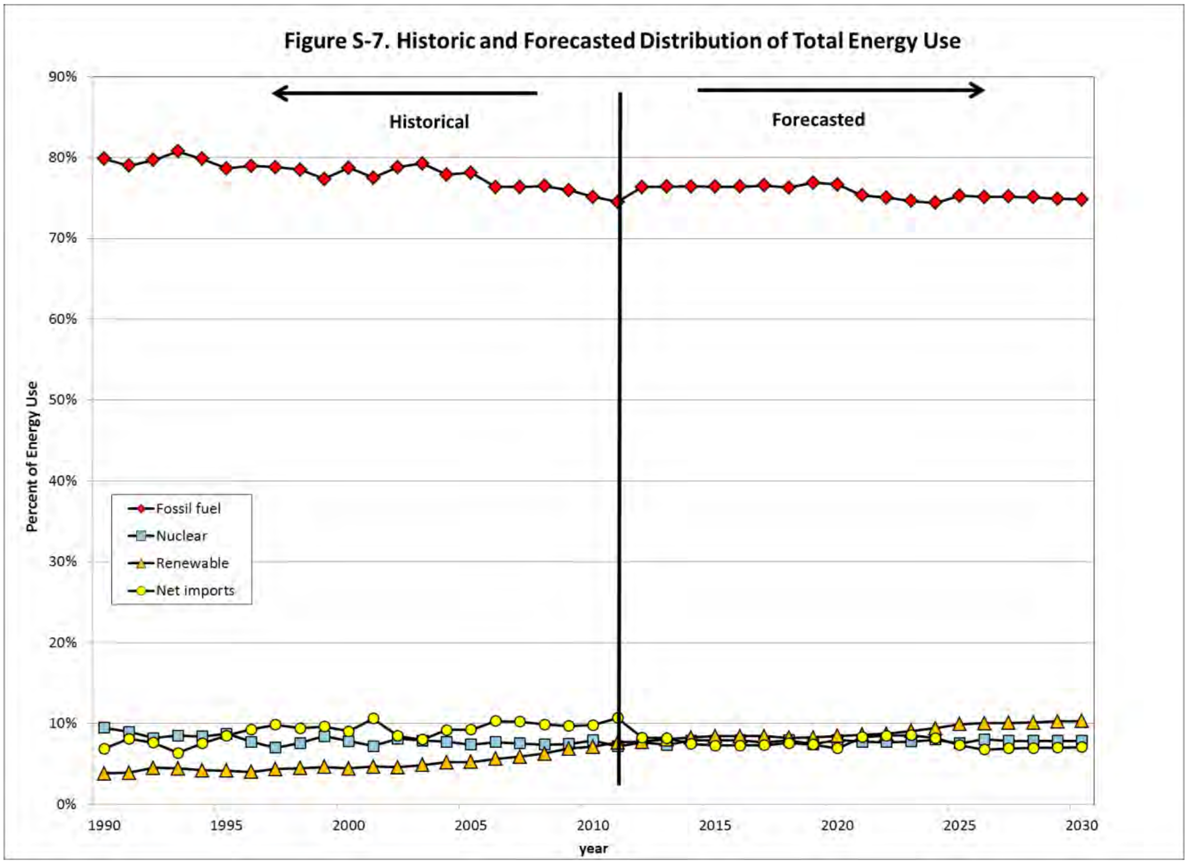


Figure S-7. Historic and Forecasted Distribution of Total Energy Use
Historical
Forecasted
Percent of Energy Use
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Fossil fuel
Nuclear
Renewable
Net imports
1990
1995
2000
2005
2010
2015
2020
2025
2030
year

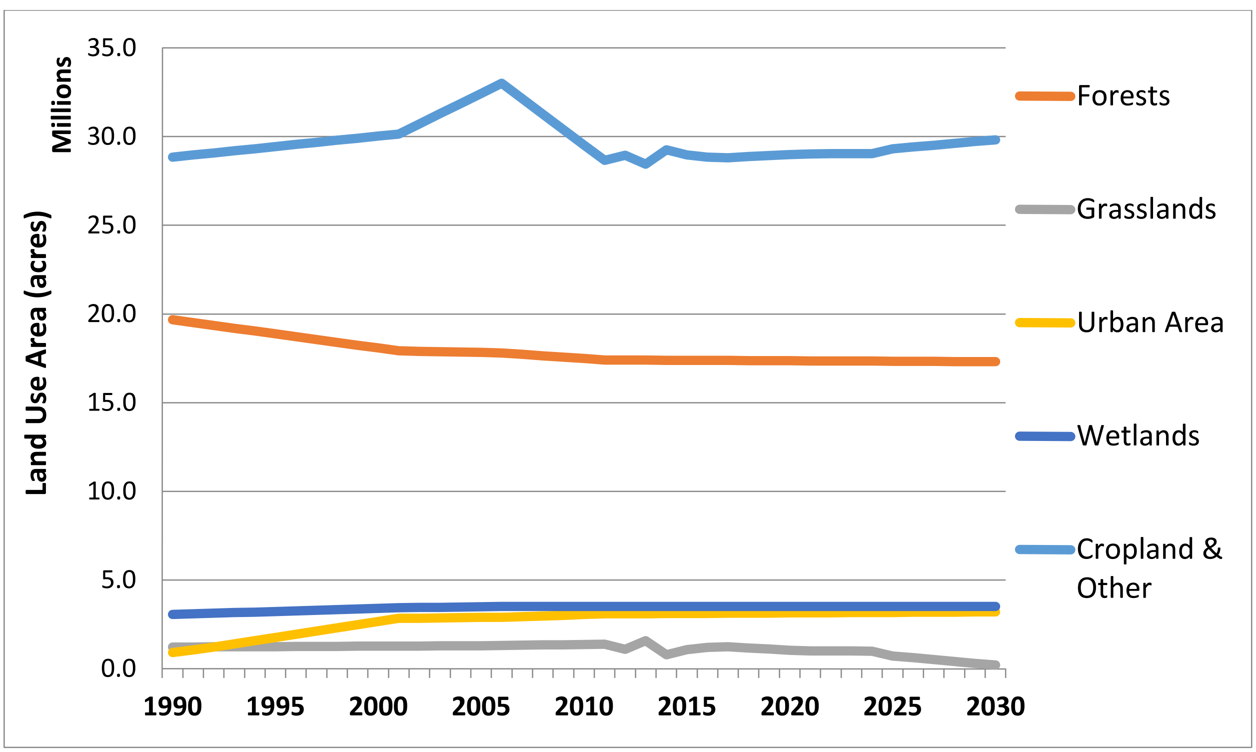
Chapter VIII. Appendix C. Forestry and Other Land Use Baseline

Sector Overview

The Forestry and Other Land Use (FOLU) sector focuses on net carbon sequestration across the different land uses in the state. Energy use and the associated greenhouse gas (GHG) emissions within the FOLU sector (e.g. forest industries) are captured within the Residential, Commercial, Institutional, and Industrial (RCII) sector. There are also a small number of other non-energy related GHG sources addressed. These include methane (CH_4) releases from wetlands, CH_4 and nitrous oxide (N_2O) emissions from wildfires, and N_2O emissions from "settlement soils" (deriving from non-farm fertilizer application to urban soils).

For the overall FOLU sector, a key starting point is the construction of a state-wide land use/land cover (LULC) data set that covers the entire baseline period (1990-2030 or beyond). The US Geological Service's (USGS) National Land Cover Database (NLCD) was used to construct historic estimates of land use for the state. These are shown in Figure C-1 below. Data were available for the years 1992, 2001, 2006, and 2011.[1]

Figure C-1. Minnesota Land Use Baseline



[1] National Land Cover Database; NLCD 1992: http://landcover.usgs.gov/states_regions_2.php?rec=22; 2001, 2006, and 2011; http://www.mrlc.gov/eva/viewer.html.

Historic NLCD data are shown in Figure C-1 as provided, even though the total land areas varied among the years available. Total land area was reported as 54.0 million acres in 1992 and up to 58.5 million acres in 2006. The data for 2011 totaled 54.0 million acres and all forecasted land use areas were normalized to this total. Forecasted area for each land use was developed as follows:

- *Forests*: developed based on expected conversion rates of forest to developed use. Based on a study by Nowak and Walton, the expected rates of loss are 0.03%/yr through 2050.[2] Note that this land area includes woody wetlands. Some land use or forest carbon assessments assign woody wetlands into a wetlands or other non-forest category.
- *Grasslands:* these were estimated based on the cultivated crop acreage from the Climate Solutions & Economic Opportunities (CSEO) crop production forecast (assumes all gains and losses of grasslands are driven by the expansion/contraction of crop area).
- *Urban Areas:* the estimate of expansion in urban area was also taken from Nowak and Walton. Annual urbanized growth through 2050 was estimated to be 0.19%/yr.
- *Wetlands*: as noted above, these include emergent herbaceous wetlands (woody wetlands are included within the totals for Forests). The forecasted area for these wetlands was held constant at 3.5 million acres through 2030. This assumption derives from recent historical data showing slight gains in emergent herbaceous wetlands from 2001-2006 of 0.37%/yr, but that from 2006-2011 those gains had slowed to 0.04%/yr.[3] This means that any shifts in future land area occurs between the other land use categories.
- *Cropland & Other*: most of this area is cultivated crops with the next most dominant subcategory being pasture/hay. Very small amounts of barren land are also included (<0.5% of the area for this category). The growth in cultivated cropland was taken from the CSEO crop production forecast. The growth in cultivated crops ranged from 15.7 million acres in 2012 to 16.6 million acres in 2030. The primary source of data underlying the crop cultivation forecast was the USDA long-term forecasts.[4] Annual growth rates (2012-2030) derived for the major crops are:
    - Grain corn: -0.6%
    - Soybeans rotated with corn: -1.2%
    - Soybeans other rotation: 4.8%
    - Wheat: -0.1%

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[2] Nowak & Walton, 2005; http://www.sfrc.ufl.edu/urbanforestry/Resources/pdf%20downloads/nowak_2005.pdf. Based on total forest area losses of over 277,000 acres from 2000 – 2050.

[3] National Land Cover Database [(NLCD); 2001-2006]; NLCD on-line GIS data for 2011: http://www.mrlc.gov/eva/viewer.html

[4] USDA Long-Term Forecasts: http://usda.mannlib.cornell.edu/MannUsda/viewStaticPage.do?url=http://usda.mannlib.cornell.edu/usda/ers/94005/./2014/index.html.

- Other crops: -0.6%
- Total cultivated crops: 0.3%

Other sources of land use data that were considered include the Natural Resources Conservation Service's (NRCS) Natural Resources Inventory (NRI) which provides historic data through 2010.[5] The NLCD data were favored based on a better break-out of land use categories needed for this project. For forest area, the USFS Forest Inventory & Analysis (FIA) was another potential source of data;[6] however, to maintain consistency with all other land use categories, the NLCD data were selected as the historical basis of the CSEO land use baseline. Forecasts of land category loss or growth derive from the data sources described above.

Carbon Sequestration Estimates

Forested Areas. Historic (pre-2014) forest carbon dioxide (CO_2) flux was based on FIA data and NLCD land use data. Carbon stock data for multiple carbon pools (standing dead trees, down dead trees, understory, litter, soil carbon, and live trees) for 1990 and 2003-2013 are available from the Forest Inventory and Analysis database (FIADB version 5.1). The forest carbon density was calculated for each year by dividing the total carbon stock, excluding soil carbon, by the FIA forest area. Carbon density values ranged from 23.8 metric tons (t) of carbon (C) per acre in 1990 to 25.9 tC/acre in 2012. Exclusion of soil carbon from these calculations follows from previous guidance suggested by USFS contacts that these should be excluded due to the large uncertainties in the size of this carbon pool and the subsequent impacts it has on net carbon flux estimates (this treatment of forest soil carbon is consistent with the approach used in the 2008 MCCAG work). The total carbon density was then applied to NLCD forest area to estimate the forest carbon stock for each year.

Future carbon density was forecasted based on the growth in historic density (0.18%/yr based on 1990-2013 FIA data). Based on an USFS RPA assessment which predicts that northern forests carbon density will peak between 2020 and 2040, carbon density was held constant after 2020.[7]

CO_2 flux was calculated from the change in carbon stocks for the total of all forest carbon pools (excluding soil carbon) between consecutive years. The total forest carbon flux estimates (forest carbon sequestration) are shown in Figure C-2 along with net emissions from the rest of the FOLU sector (dotted line). Large changes prior to the early 2000's could be the result of changes in FIA survey practices that began around the year 2000, rather than real increases in carbon sequestration rates. The large increase in sequestration shown for 2013 should also not be taken as a likely large change in overall forest carbon (C) sequestration. This year represents the first year of the forest carbon forecast, including the initial forecasted carbon density estimate which is constructed based on FIA-based forest disturbance data.

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[5] 2010 NRI Summary Report: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1167354.pdf.

[6] FIA website: http://www.fia.fs.fed.us/.

[7] Future of America's Forests and Rangelands: Forest Service, 2010 Resources Planning Act Assessment, http://www.fs.fed.us/research/publications/gtr/gtr_wo87.pdf.

For forest carbon sequestration, it is much more important to focus on the total post-2015 sequestration rates. These range from –910,000 tCO_2/yr in 2015 to 350,000 tCO_2/yr in 2030. Net emissions in the post-2020 time-frame result from a combination of slight declines in forest area and declining carbon densities due to disturbances. Figure C-3 provides a summary of the carbon density and forest land area estimates used to construct the forest land CO_2 sequestration baseline.

Urbanized Areas. The area of urban forest was estimated by multiplying the total urban area, obtained from the NLCD land use data, by an estimate of state-wide urban tree canopy cover percentage. The 1990-2000 urban canopy cover percentage (18.4%) came from USFS urban forest data for 2000.[8] The 2011 urban canopy estimate (20.0%) was provided by Minnesota DNR.[9] Canopy percentage values for intervening years were interpolated. The urban forest area was then applied to the urban forest carbon sequestration rate developed for Minneapolis (0.081 kg C m^{-2} yr^{-1}) in a recent study.[10] Beginning in 2012, losses to urban forest canopy were factored into the baseline as a result of expected state-wide losses of ash trees. An estimate of about 6,200 acres/yr of canopy cover was derived from an estimate that 20% of all urban forest cover is contributed by ash trees[11] and that a complete loss of all ash trees is expected in 20 years.

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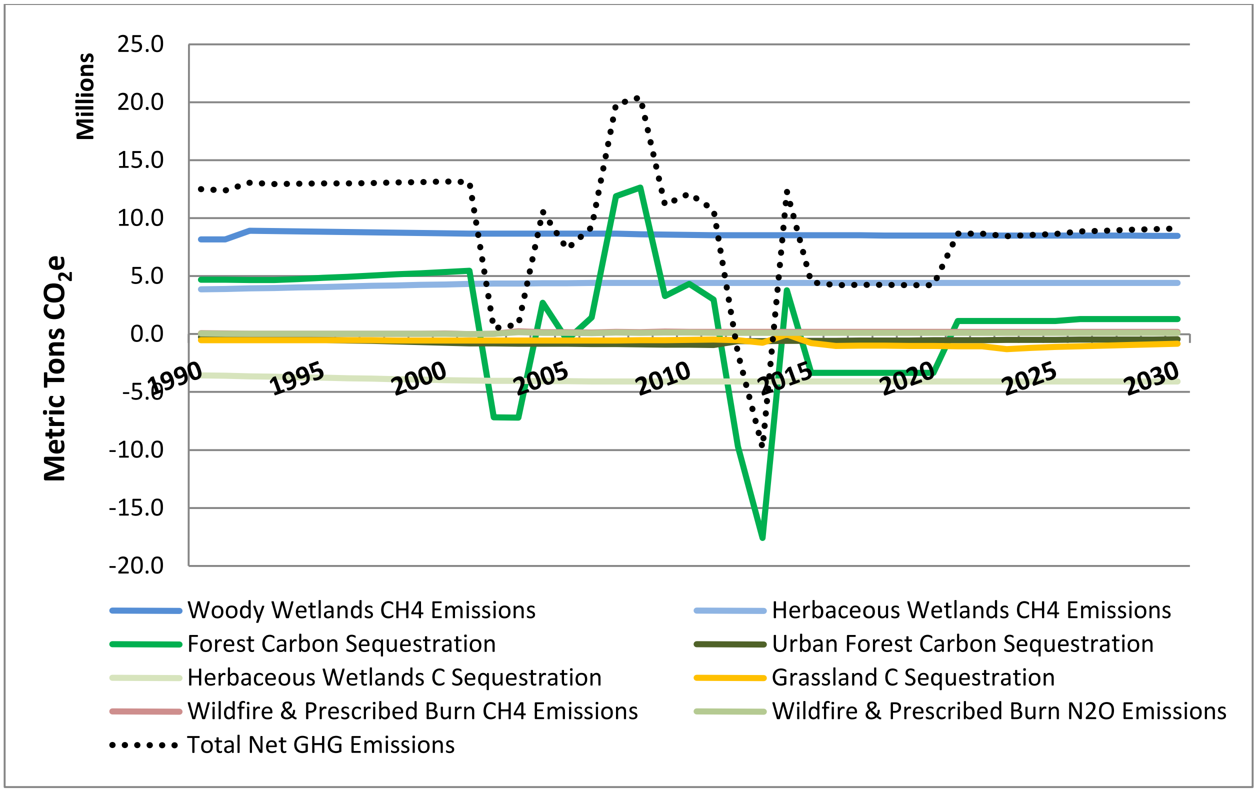
[8] Urban Forest Data for Minnesota, US Forest Service, Northern Research Station, http://www.nrs.fs.fed.us/data/urban/state/?state=MN.

[9] Gary Johnson, Extension Professor, Urban & Community Forestry, University of Minnesota Department of Forestry Resources, Coordinator of Minnesota Tree Care Advisor Program.

[10] Nowak, D., et al. "Carbon storage and sequestration by trees in urban and community areas of the United States". *Environmental Pollution* 178 (2013) 229-236. http://www.fs.fed.us/nrs/pubs/jrnl/2013/nrs_2013_nowak_001.pdf.

[11] Minnesota DNR Community Tree Survey, http://archive.leg.state.mn.us/docs/2012/other/120339.pdf.

Figure C-2. GHG Baseline for the FOLU Sector

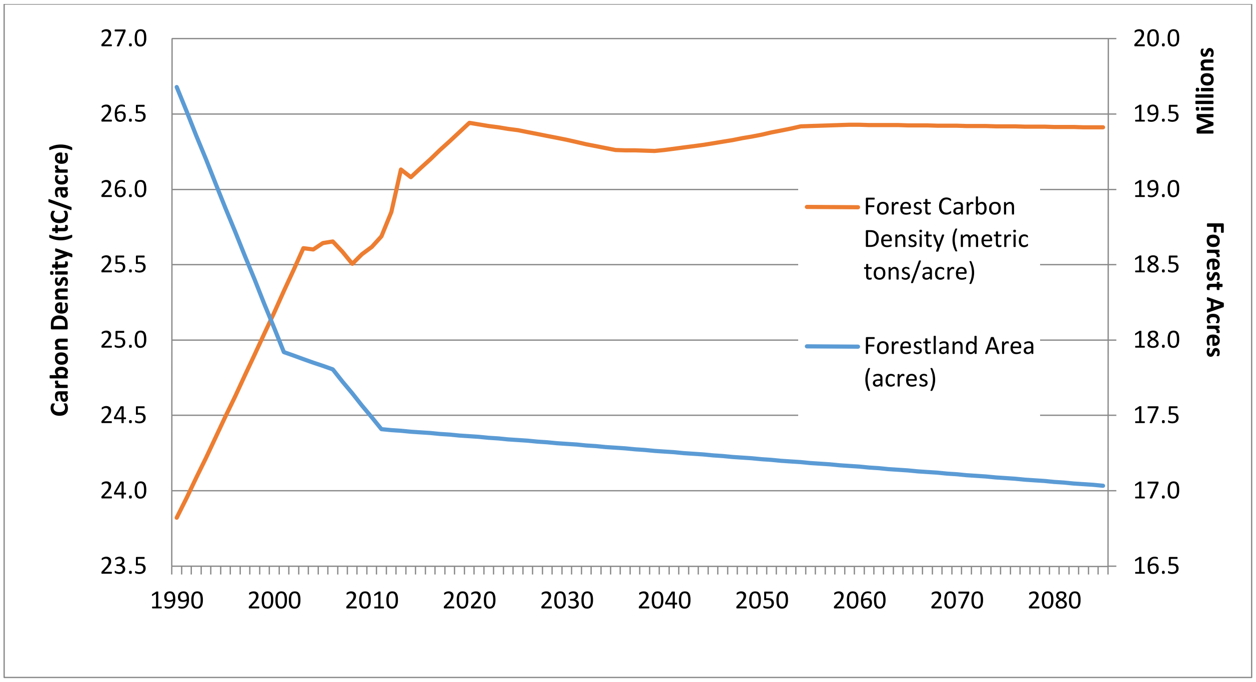


Forest Disturbances. For some additional understanding of total forest carbon flux, Center for Climate Strategies (CCS) and Minnesota Department of Natural Resources (MDNR) developed estimates of the apparent losses of forest C from disturbances (e.g. fires, pests/disease, weather, and other[12]). The historic estimates were also based on FIA data (disturbance area and carbon pools). To forecast future losses, studies from the literature on expected fire incidence and extreme weather events were used.[13] MDNR provided information on the expected spread of emerald ash borer which was used to forecast acreage impacted by pests/disease. The area for "other" disturbed forest was held constant at 2013 FIA levels. Figure C-4 below summarizes the average (2003 – 2013) carbon densities for forest areas with no disturbances as compared to those that were disturbed. Figure C-5 provides the historic and forecasted forest disturbance areas.

[12] Other disturbances include animal damage, human-caused damage, vegetation (suppression, competition, vines), and disturbances of unknown causes.

[13] Wotton et al, 2010. "Forest fire occurrence and climate change in Canada". *International Journal of Wildland Fire* 2010, 19, 253-271. Trapp et al., 2007. "Changes in severe thunderstorm environment frequency during the 21st century caused by anthropogenically enhanced global forcing", *Proceeding of the National Academy of Sciences*.

Figure C-3. Forested Land and Carbon Density Baselines

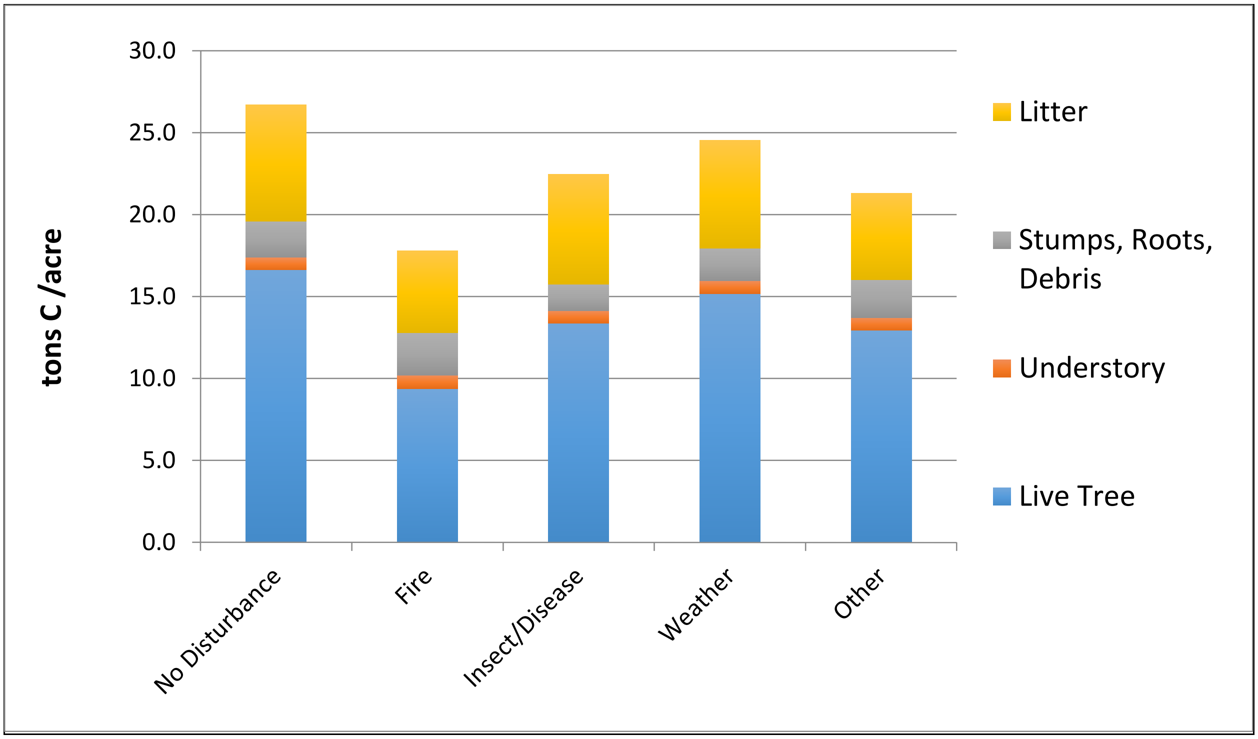


From the difference in carbon densities between average undisturbed forests and those with disturbances and the estimated future disturbance area, estimates of total carbon losses due to disturbances were made and then used to adjust forecasted carbon densities. Figure C-6 provides a summary of these estimates. Note that these sizable losses are already captured in the net sequestration estimates provided in Figure C-2 above. As indicated in Figure C-6, in the post-planning period (after 2030), increases in the rate of carbon loss due to disturbances is expected (especially from pests).

Wetlands. Carbon sequestration on woody wetlands was included in the state-wide forest carbon sequestration estimates described above. For herbaceous wetlands, a CO_2 sequestration factor of -1.17 tCO_2/acre-yr was derived as the mean value of nine values addressing undisturbed ecosystems.[14] Note that there is a large range around this factor (with reported values ranging from -0.000077 to -2.9 tCO_2/acre-yr; although most values range from -0.50 and -2.0 tCO_2/acre-yr). The ecosystem types addressed included: Minnesota Bog, Minnesota Transitional Peatland, MI Bog, MI Cedar Swamp, MI Fen, Temperate Bog (Europe), Temperate Fen (Europe), Wetland (cold, temperate, wet), and Bog Forest (Europe). The area of herbaceous wetlands was held constant at the 2012 level through the forecast period (3.51 MM acres).

[14] Craft, 2008; http://www.indiana.edu/~craftlab/publications/Vymazal_Ch03%20Final.pdf; Olson, 2013; http://www.srs.fs.fed.us/pubs/ja/2013/ja_2013_olson_001.pdf; Byrne, 2004; https://www.bgc-jena.mpg.de/bgp/uploads/Teaching/Peatreport_final.pdf; IPCC *Good Practice Guidance for LULUCF*, Chapter 3.

Figure C-4. Average Carbon Density by Disturbance Type



Grasslands. Carbon sequestration from grasslands was based on NLCD land use data and an annual grassland sequestration of -0.43 tC/acre from a 2008 study of carbon sequestration in Minnesota.[15]

Peatlands. For farmed peatlands (histosols cultivation), the GHG emissions are represented within the agricultural crop production sector. Carbon dioxide and N_2O emissions from this category are significant (~6 $TgCO_2e$/yr) based on information from the U.S. EPA's national GHG inventory.

[15] The Potential for Terrestrial Carbon Sequestration in Minnesota: Appendix II, 2008, http://www.wrc.umn.edu/prod/groups/cfans/@pub/@cfans/@wrc/documents/asset/cfans_asset_119302.pdf.

Figure C-5. Area of Forest Land Affected by Disturbances

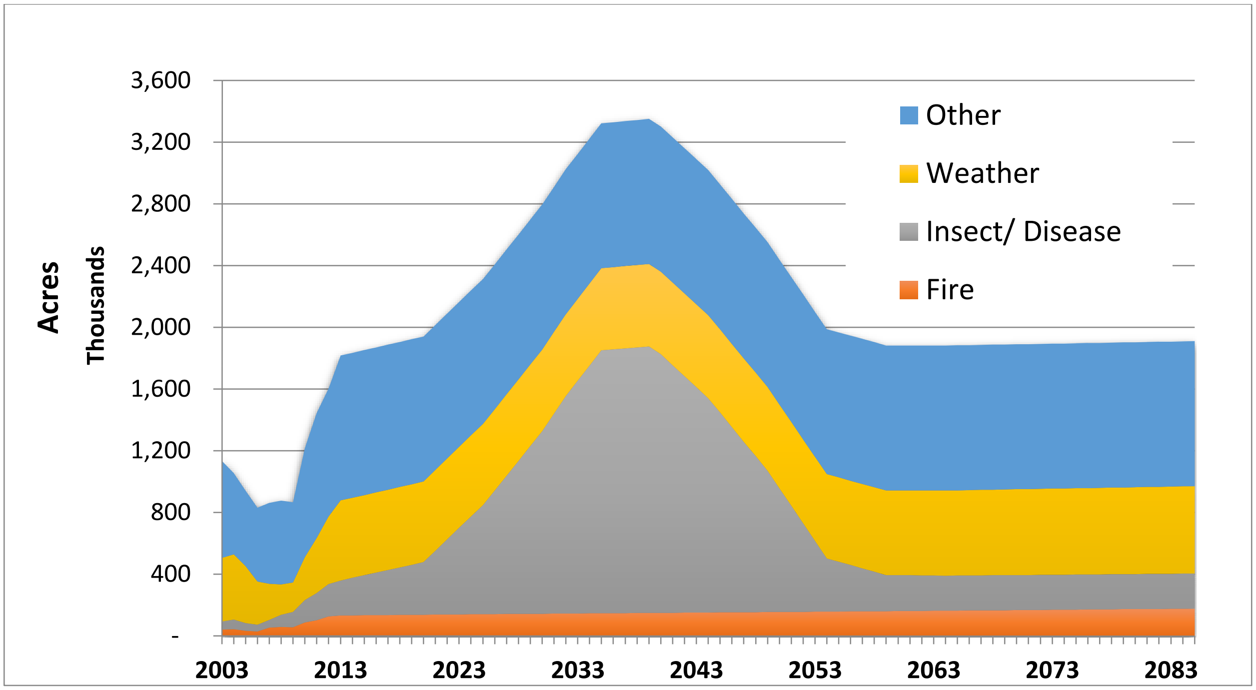
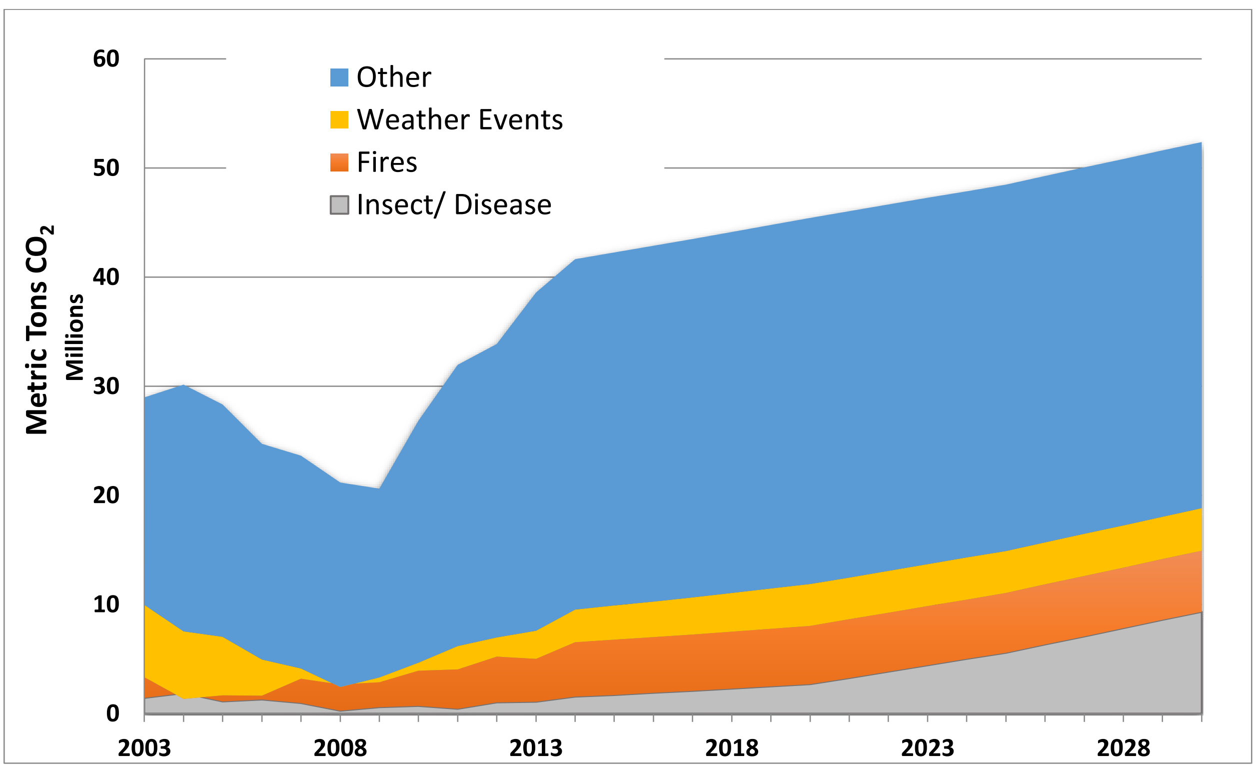


Figure C-6. Apparent Forest Carbon Losses from Disturbances



Methane Emissions

Methane emissions from wetlands were estimated using an emission factor of 0.050 tCH_4/acre-yr. This value is an average of several studies for undisturbed wetlands (range is 0.009 - 0.094 tCH_4/acre).[16] This emission factor was applied to both forested and emergent herbaceous wetlands areas based on NLCD land use data.

Wildfires and Prescribed Burns. These emissions cover CH_4 and N_2O emissions from wildfires and prescribed burns. For forest wildfires, net CO_2 emissions are addressed within the accounting of carbon densities based on USFS FIA survey data. For forest wildfire CH_4 and N_2O, the historical estimates were taken from Minnesota Pollution Control Agency's (MPCA) agriculture inventory. MPCA's historical emissions estimates were available through 2010. Beginning in 2011, the emissions were forecasted using the 2011-2030 annual growth factor (1.85%/yr) for expected increases in wildfire activity taken from the assessment of forest disturbances described above.

Since prescribed burns are presumed to be just those associated with crop residue burning, they are excluded from the FOLU sector here (and included with the Agriculture baseline).

Other Land Uses or GHG Sources.[17] Other sources include CH_4 from: sediments of rivers, estuaries, and lakes; geologic sources; terrestrial arthropods (e.g. termites); wild animals; and plants (highly uncertain, but with most global emissions occurring in the tropics). Other sources of N_2O are from: upland soils and riparian zones (here forested soils would be addressed in the Forests LULC subsector, but pasturelands would be an area that is potentially not addressed in the Agriculture inventory).

Given the relatively high level of uncertainty associated with most of the above sources and the likely lack of mitigation responses, additional effort was not taken to characterize the emissions for the CSEO project.

[16] Byrne, 2004; https://www.bgc-jena.mpg.de/bgp/uploads/Teaching/Peatreport_final.pdf;
Carter, 2012; http://www.creaf.uab.cat/global-ecology/Pdfs_UEG/2012%20Biogeosciences.pdf;
Couwenberg et al 2012, http://pixelrauschen.de/wbmp/media/map10/map_10_03.pdf;
IPCC Good Practice Guidance for LULUCF, Chapter 3; Olson, 2013;
http://www.srs.fs.fed.us/pubs/ja/2013/ja_2013_olson_001.pdf;
Turestsky, 2014; http://onlinelibrary.wiley.com/doi/10.1111/gcb.12580/abstract;
Juottonen, 2012, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3416597/.

[17] US EPA report on natural source emissions: http://www.epa.gov/outreach/pdfs/Methane-and-Nitrous-Oxide-Emissions-From-Natural-Sources.pdf.

Chapter IX. Appendix D. Crop Production Forecast and Associated GHG Emissions

Sector Overview

Center for Climate Strategies (CCS) prepared a forecast of crop production activity and associated greenhouse gas (GHG) emissions to supplement the Minnesota Pollution Control Agency (MPCA) GHG inventory [1] and derive a complete baseline for use in the CSEO project. MPCA separately addressed the other agricultural subsector: livestock management. Emissions from crop production include both energy and non-energy sources. Energy consumption sources are mainly diesel combustion by crop cultivation and harvesting equipment. Non-energy sources are quite varied and include:

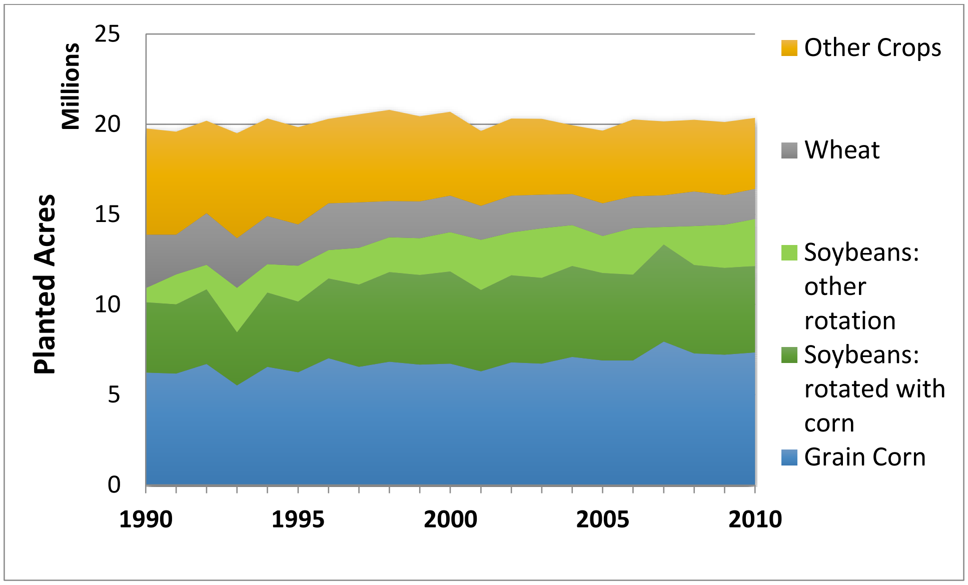
- Agricultural burning: burning of crop residues, such as wheat straw; it includes both methane (CH_4) and nitrous oxide (N_2O) emissions; carbon dioxide (CO_2) is considered to be carbon neutral;
- Wildfires and prescribed burns: burning of biomass on other agricultural lands that are not considered crop lands, e.g. rangelands - both N_2O and CH_4 are included;
- Nitrogen inputs to crop soils which produce N_2O emissions directly from these soils or indirectly in another location following run-off and transport;
- Crop residues: decomposition of crop residues which are left in the field to decompose;
- Nitrogen deposition: deposition of nitrogen (e.g. ammonium) from sources of nitrogen that have been emitted elsewhere;
- Legumes: add nitrogen to soils through nitrogen fixation;
- Conventional nitrogen fertilizer application;
- Manure application: both to crops and as deposited in feedlots;
- Cultivation of histosols (soils with high levels of organic carbon): exposure of these soils to air results in emissions of both CO_2 and N_2O;
- Urea application: in addition to being a soil nitrogen (N) input, decomposition of urea results in CO_2 emissions; and
- Soil liming: results in CO_2 emissions.

Modeling Approach. Due to their contributions to the historic emissions estimates and the selected CSEO policy options, CCS' concentration on this crop production forecast was to assess the expected growth in emissions from the cultivation of three primary crops: grain corn,

[1] MPCA provided historic baseline data and GHG emissions for crop production to CCS in June 2014.

soybeans, and wheat. As shown in Figure D-1, these are by far the dominant crops grown in the State, and as a result, they drive future nitrogen requirements and fuel consumption, which are the primary drivers in GHG emissions. Most of the historical data for crop production were available through 2013; however, in some cases (e.g. yields) data were only available through 2010. The MPCA baseline data were supplemented with information from the Minnesota Department of Agriculture.[2]

Figure D-1. Minnesota Historic Planted Acres



To forecast energy use and nitrogen inputs, estimates of the growth in harvested acres, nitrogen use/acre, and crop yield were developed. The initial key forecast assumption for primary crop production was that Minnesota's growth in harvested acres will follow the long-term forecast for crop production for the nation developed by the US Department of Agriculture.[3] For grain corn, this resulted in a 2010 – 2030 annual growth rate of 0.09%.

Regarding yields, it was assumed that Minnesota yields would reach the values in the United States Department of Agriculture's (USDA) long-term forecast for 2022/2023. Beyond 2023, it was assumed that: for grain corn, growth would continue at the same growth rate through 2030; for soybeans, no growth in yield; and for wheat, no growth in yield.

For grain corn, commercial N additions were trended from recent historical data (2000 to 2010) to 2020 and then held constant at 103.5 lb N/acre. For soybeans, the fraction of acres receiving commercial N additions was held constant at an average of the most recent 10 years (0.16). The

[2] USDA data as provided by E. Jerve, MN Department of Agriculture to S. Roe, CCS, August 2014.

[3] USDA Long-Term Forecasts: http://usda.mannlib.cornell.edu/MannUsda/viewStaticPage.do?url=http://usda.mannlib.cornell.edu/usda/ers/94005/./2014/index.html.

application rate on these acres was held constant using an average of the previous 10 years (after correcting for an outlier, the value used was 18.7 lb N/acre). For wheat, the application rate was trended through 2030 based on historic data from 2000 – 2009.

Crop residue N inputs were forecasted from the MPCA historical data based on the growth in harvested acres. Soybean N fixing inputs were forecasted using MPCA baseline rate of 95.9 lb N/acre. Manure N applied to grain corn was forecast using the average of historic data in the MPCA inventory for the fraction of acres receiving these additions (0.23) and the application rate (8.9 tons manure/acre). Key forecasting input variables derived to estimate future production, acreage and input levels are summarized in Table D-1 below.

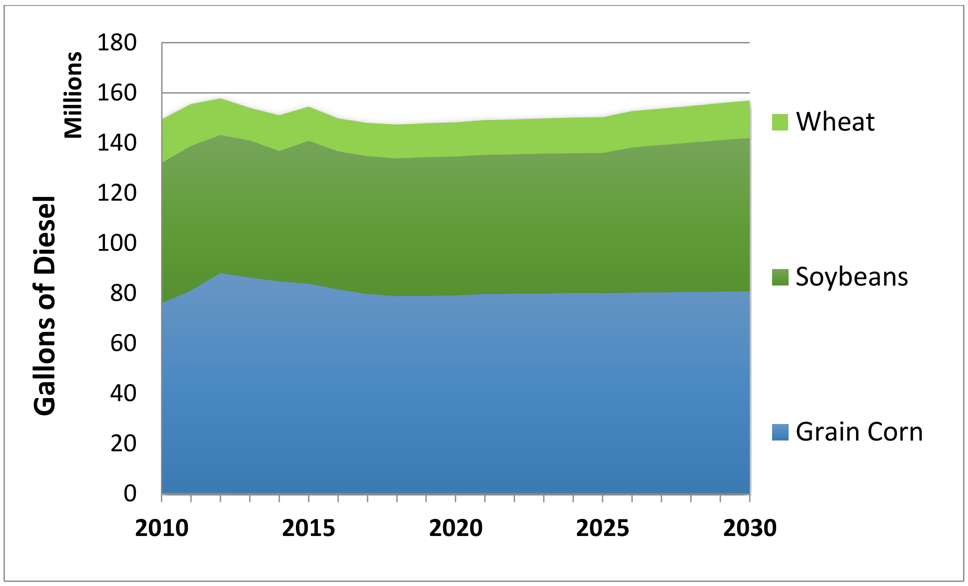
Table D-1. Key Crop Forecast Input Parameters

Parameter	Grain Corn	Soybeans	Wheat
	(%/yr)		
2010 – 2030 Growth in Harvested Acres	0.09	0.50	-0.97
2010 – 2030 Growth in Commercial N Additions	-0.94	0.00	-0.79
2010 – 2030 Growth in Yield	0.50	0.45	-0.59
2010 – 2030 Growth in Residue N Input	0.78	0.50	-0.97
2010 – 2030 Fraction of Corn Rotated with Soybeans	-0.55	n/a	n/a
2010 – 2030 N Fixation per acre Soybeans	n/a	1.9	n/a
2010 – 2030 Manure N Inputs per bushel	-4.2	n/a	n/a
2010 – 2030 Total N Additions per bushel	-0.99	1.4	-0.02
2010 – 2030 Diesel Gallons per acre	0.21	0.38	-0.76

The growth factors in Table D-1 were used along with information in the GHG baseline (e.g. emission factors) to estimate GHG emissions during each year of the forecast for each primary crop type. All other (non-primary) crops were grouped together for forecasting purposes. Total commercial N additions for all other crops were estimated by first assessing the historical fraction of total commercial N additions for the 3 primary crops as a total of all commercial N sold in the State. Prior to 2000, roughly 40-45% of commercial N was applied to non-primary crops. This fraction has slid to the range of 27-33% in the mid- to late 2000's. A near term average of 27% of total commercial N was applied to all years of the forecast in order to estimate commercial N additions for non-primary crops. The 27% average for non-primary crops was used along with the total modeled primary commercial N additions in order to estimate the commercial N additions for all non-primary crops.[4]

To estimate growth in diesel fuel combustion, it was assumed that the modeled diesel consumption for primary crops would drive the overall crop production sector growth (in 2010, diesel fuel use for primary crops was estimated to represent about 80% of all crop production diesel consumption). Annual growth factors were derived for each year of the planning period from the total diesel consumption for all primary crops and applied beginning with the last year of historic estimates (2010). The diesel consumption forecast for primary crops is shown in Figure D-2 below.

Figure D-2. Primary Crop Diesel Consumption Forecast



Results. Figure D-3 provides the primary crop cultivation baseline (harvested acres per year). From these estimates of future year crop production activity, the forecasted estimates for N application shown in App. D-4 were derived. The additional commercial N inputs for all other crops were then added to those for primary crops. These are summarized in Figure D-5 below.

[4] Future improvements to the crop forecasting could include similar modeling of manure N inputs for primary versus non-primary crops.

Figure D-3. Primary Crop Cultivation Baseline

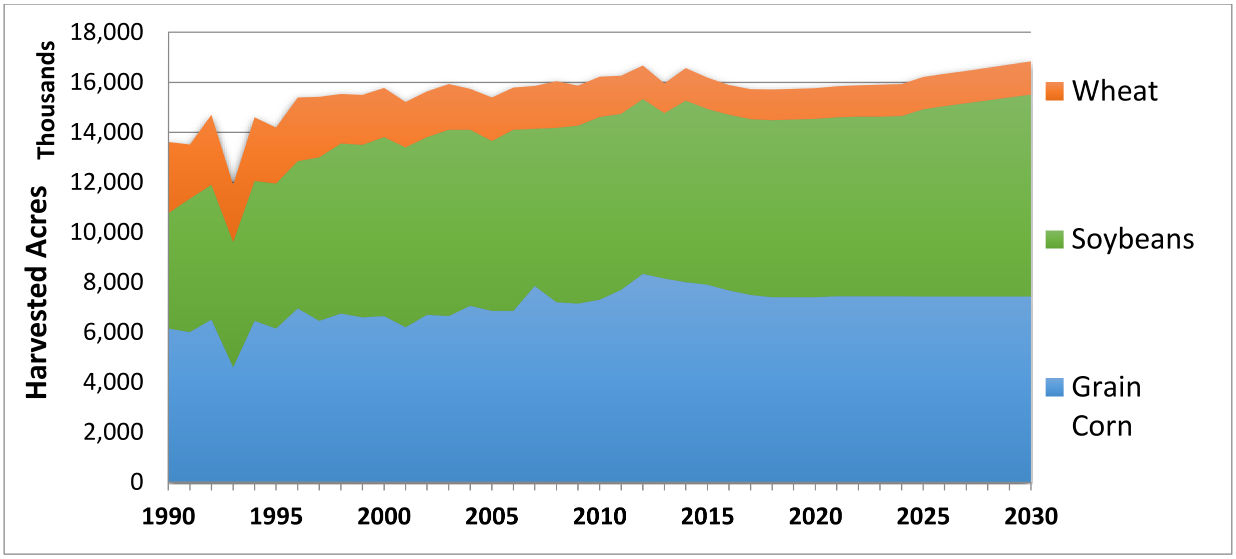


Figure D-4. N Application Baseline for Primary Crops

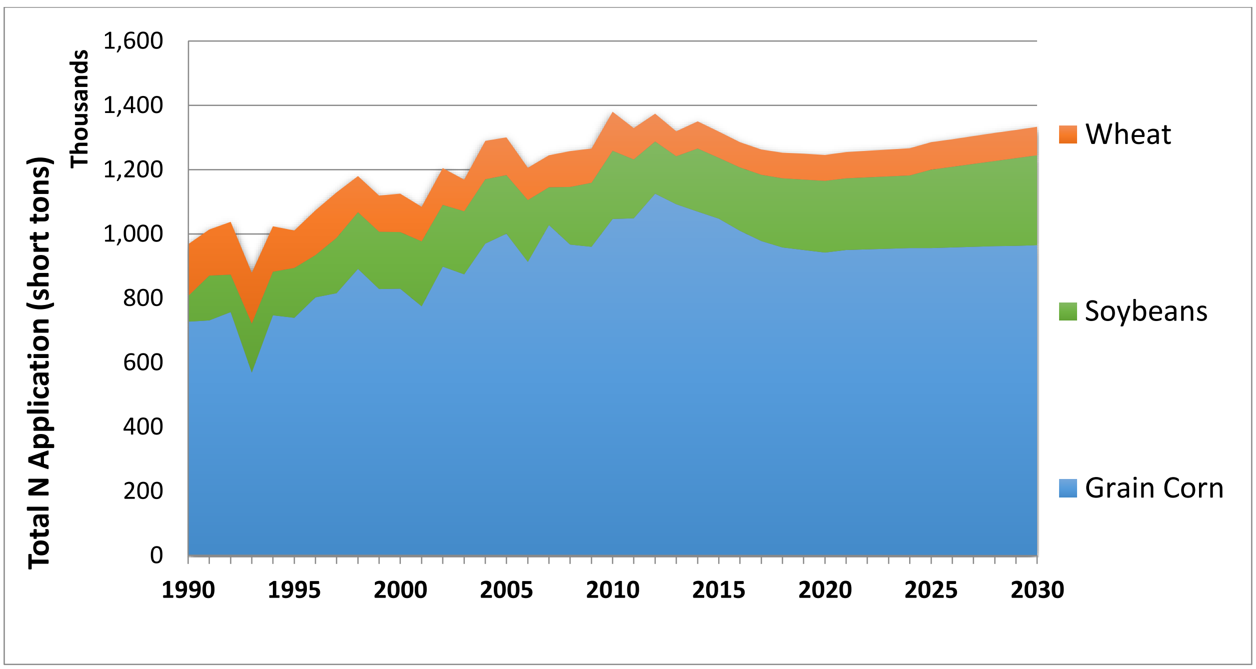
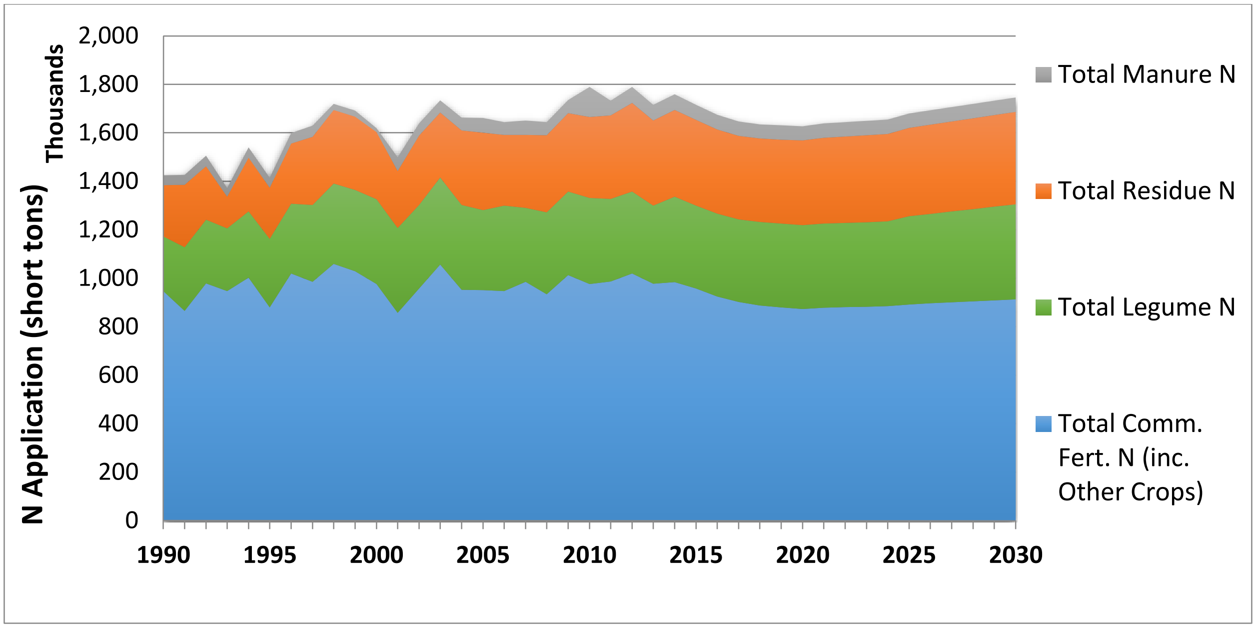
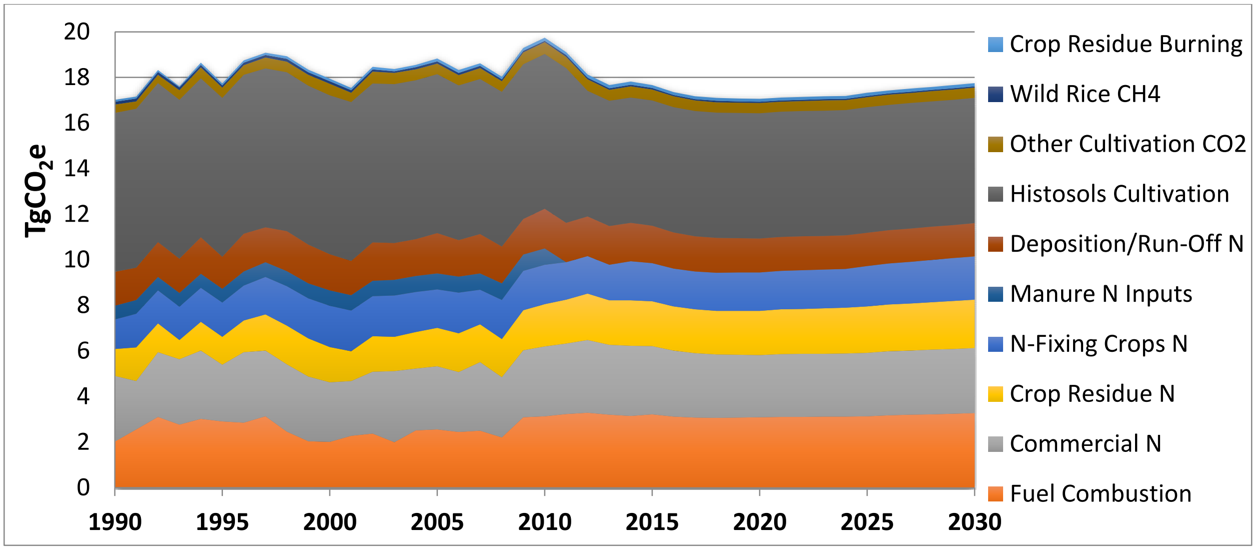


Figure D-5. Total N Inputs Forecast



Since the emission factors for estimating GHG emissions are not varied by year, the overall approach to estimating future emissions was to apply growth factors to the historic inventory estimates from MPCA. The most recent of those were available for 2010. Figure D-6 provides a summary of the historic and forecasted crop production GHG emissions. For sources that were not a focus of this crop production forecast (e.g. wild rice CH4, histosols cultivation), the emissions were forecasted based on simple trend analysis or were held constant at recent levels.

Figure D-5. GHG Baseline for the Crop Production Sector



Notes: Deposition/Run-off N refers to N_2O emissions that result from nitrogen that was applied to soils then either: leached into groundwater; run-off into surface waters; or volatilized into the atmosphere and subsequently deposited elsewhere. "Other Cultivation CO_2" refers to emissions resulting from soil liming, urea application, and soil organic carbon erosion.

Chapter X. Appendix E. Principles and Guidelines for Quantification Memo

This appendix is the Technical Memorandum from the Center for Climate Strategies that sets forth the methods used for quantifying the socio-economic impacts for the recommended mitigation policies. This includes both the greenhouse gas (GHG) emission reductions and direct costs/cost savings (on a net societal basis) associated with the policy recommendations (also referred to as "microeconomic analysis"). Data exports for use in subsequent macroeconomic modeling of indirect economic impacts using the REMI-PI+ model are also discussed. Macroeconomic impacts include net employment and gross state product impacts.
In addition, an introduction to the combined impacts of all of the policy recommendations within (intra-) and between (inter-) each sector is provided here to reflect expected impacts of all CSEO policy recommendations being implemented together. This involves eliminating any overlaps in coverage of affected entities that would occur to avoid double counting of impacts. This memorandum was initially submitted to Minnesota Climate Solutions and Economic Opportunities team members on June 3, 2014 and subsequently revised on August 18, 2015 to address team member review comments.

Memo

To: Minnesota Climate Solutions and Economic Opportunities Members

From: Stephen M. Roe and
Thomas D. Peterson, President and CEO, *The Center for Climate Strategies*

CC: Technical Team, CCS

Re: Principles and Guidelines for Quantification of Policy Options

Date: June 3, 2014; rev. August 18, 2015

The purpose of this "Quantification Memo" is to propose and explain the principles, guidelines and general methods needed for quantifying the socio-economic impacts for the recommended Minnesota Climate Solutions & Economic Opportunities (CSEO) mitigation policies.

I. General Guidelines

Selection and Design of Policy Options by Technical Workgroups

The policies to be designed and analyzed for Minnesota CSEO will be selected during the initial phase of the project. These policies will be listed in Table E-1 below. The policies are shown by sector and will be supported by technical workgroups (TWGs) that will design and analyze each mitigation policy. A total of five TWGs will address policies for each of the following sectors: Energy Supply (ES); Residential/Commercial/Institutional/ Industrial (RCII); Transportation & Land Use (TLU); Agriculture, Forestry & Other Land Use (AFOLU); and Waste Management (WM). A final TWG will be formed, if needed, to develop the Cross-Cutting (CC) policies (commonly, these CC policies are not analyzed for mitigation impacts and costs as in the sector-based TWGs).

Through facilitative and technical support of CCS, each TWG will identify, design and guide analysis of the socio-economic impacts of each policy and an aggregate scenario of all policies combined. Co-benefits will be described and or analyzed where possible and applicable. The analytical work on each policy will be led by CCS; however, TWG members, including Minnesota Pollution Control Agency (MPCA) staff and other agency staff will make substantive contributions to this work (e.g. determining net benefits and/or costs for specified policies). That division of labor will be determined during the initial phase of the project.

Table E-1. Mitigation Policies for the Minnesota CSEO

Sectors:	AG	FOLU	WM	ES	RCII	TLU	CC
AG-1. Nutrient Management in Agriculture							
AG-2. Soil Carbon Management in Agriculture: Increased Use of Cover Crops							
AG-3. Soil Carbon Management in Agriculture: Increased Use Conversion of Row Crops to Perennial Crops							
AG-4. Advanced Biofuels Production							
AG-5. Biofuels Consumption (Existing Biofuels Statute)							
FOLU-3. Urban Forests: Maintenance and Expansion							
FOLU-4. Tree Planting: Forest Ecosystems							
FOLU-5. Conservation on Private Lands							
WM-1. Wastewater Treatment: Energy Efficiency							
WM-2. Front-End Waste Management: Source Reduction							
WM-3. Front-End Waste Management: Re-Use, Composting & Recycling							
ES-1. Increase the Renewable Energy Standard							
ES-2. Efficiency Improvements, Repowering, Retirement, and Upgrades to Existing Plants							
RCII-1. Incentives and Resources to Promote Combined Heat and Power (CHP) for Biomass and Natural Gas							
RCII-2. Zero Energy Transition/Codes (SB2030)							
RCII-4. Increase Energy Efficiency Requirements							
RCII-5. Incentives and Resources to Promote Thermal Renewables							
TLU-1. Transportation Pricing							
TLU-2. Improve Land Development and Urban Form							
TLU-3. Met Council Draft 2040 Plan							
TLU-4. Zero Emissions Vehicle Standard							
CC-1. No Cross-Cutting policy options are being addressed.							

Planning Period for Minnesota CSEO

- The planning period will begin with implementation in 2015 and run through 2030.

Specification of Policy Option Design Parameters

For each policy, a series of design parameters must be defined to support detailed quantification of impacts. These include:

- *Timing* (start and stop dates for the proposed policy options, as well, as any phase in or ramp up/down schedules).
- *Level of effort* (or quantitative goals for the proposed action).

Coverage of implementing or affected parties (including geographic boundaries and the specific types of entities or groups that will be required to implement the policy)

- *Other definitional issues* or eligibility provisions (such as renewable fuel definitions, small business definitions, hydro power size classes, etc.).

Specification of Policy Implementation Mechanisms

In addition, the instruments or mechanisms used to implement each policy option must be defined, at least in general terms, to capture potential variations in effectiveness. This is particularly true for differences in price and non-price incentives and mandatory versus voluntary approaches). A variety of instruments or mechanisms exist, including:

- Voluntary agreements
- Technical assistance
- Targeted financial assistance
- Taxes or fees
- Cap and trade
- Codes and standards
- Disclosure and reporting
- Information and education
- Others

The impacts of each are policy specific and will vary by circumstance. For instance, price instruments, such as taxes and cap and trade, may perform better for policy options that are price responsive in comparison to those that are relatively unresponsive to price. Similarly, non-price instruments, such as codes and standards, may perform better where significant market barriers exist and require barrier removal. Mandatory actions may have higher compliance or market penetration rates.

Coverage and Metrics of Policy Impacts[1]

Quantitative estimates will be developed for the following types of impacts where applicable based on priorities set by the advisory members of Minnesota CSEO, and within the analytical capacity of the contract and process:

- *Net GHG reduction potential*, expressed as teragrams (Tg; million metric tons) carbon dioxide equivalent (CO_2e) removed, including net effects of carbon sequestration or sinks, measured as an incremental change against a forecasted baseline; where very small denominations of GHGs are involved use of metric tons (tCO_2e) may be used with notation.
- *Non GHG physical impacts* (such as on air quality or energy use), as appropriate and possible based on the availability of data, applied on a case-by-case basis.
- *Individual or "stand alone" impacts* of policies, as well as *aggregate or interactive effects* of policy sets and scenarios ("system-wide" impacts); these will be measured as an incremental change against a forecasted baseline.
- *Direct economic impacts*, also known as *microeconomic analysis;* two key analytical endpoints will be: *cost effectiveness* (expressed as $/$tCO_2e$ removed); and *net societal costs/savings*, presented as the net present value (NPV) of the stream of costs/savings incurred to implement the policy over the planning period; these analyses will include avoided costs of policy implementation, such as the avoided cost of investment in infrastructure or services from efficiency measures.
- *Indirect or secondary economic impacts* on jobs, income, economic growth, and prices, also known as *macroeconomic impacts,* that arise from or in association with direct costs and savings. Also *distributional impacts,* including differential impacts related to size, location, and socio-economic character of affected households, entities, and communities; often framed as *fairness and equity.* For instance, this would include disparate effects on small versus big business or wealthy versus low income households.
- *Full energy-cycle impacts,* including net energy effects that include all inputs and outputs of projects, as possible based on the availability of data and relevance.
- *Discounting* or time value of costs, typically using standard rates of five percent/yr real and seven percent/yr nominal, applied to net flows of costs or savings over the Minnesota CSEO planning horizon (2015 – 2030). CCS requests input from TWG members on the selection of a real discount rate (real rate of interest) for this project.
- *Annualized impacts,* typically real net costs are estimated for each year of the planning period and are also shown on a net present value (NPV) basis in order to provide both cumulative and year-specific snapshots.

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[1] For additional reference see the economic analysis guidelines developed by the Science Advisory Board of the US EPA available at: http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html.

- *Impacts beyond the end of the planning period*; where important additional GHG reductions or costs occur beyond the project period as a direct result of actions taken during the project period, these will be shown for illustration.

Direct versus Indirect Effects and Linkages

Socio-economic impacts of policy options and scenarios will include direct, indirect, and distributional effects. Direct effects are those borne or created by the specific entities, households or populations subject to the policy or implementing the new policies. Indirect effects are other than those specifically involved in implementing the policy recommendation. For instance, new vehicle standards may directly affect manufacturers and consumers of cars (e.g. due to initial higher vehicle costs). Indirectly, their sales may increase or decrease local taxes and spending on goods and services that benefit from or are hurt by increased disposable income of the manufacturing workforce and consumers. These direct and indirect economic analyses are sequentially linked, with overlap. Direct effects must be calculated first in order for indirect effects and distributional impacts to be calculated.

Direct physical effects (net energy and GHG impacts) will be estimated to support cost-effectiveness and GHG reduction target evaluations. Indirect GHG effects will be conducted only as needed to address energy-cycle and boundary issues, based on availability of data, acceptability of methods, and priority. Examples of direct and indirect net costs and benefits metrics are included in Attachment I of this memo by sector for purposes of illustration:

- Energy Supply (ES)
- Residential, Commercial, Institutional & Industrial (RCII)
- Transportation and Land Use (TLU)
- Agriculture, Forestry and Other Land Use (AFOLU)
- Waste Management (WM)

Transparency of Analysis

All key elements of policy development and analysis will be explicitly provided for review and consideration by the State of Minnesota. The TWGs will work directly with CCS technical leads to develop each of the individual policy designs. This includes policy design and implementation mechanism choices (above) as well as the technical specification of analysis for options and scenarios. These technical specifications for analysis include:

- *Data sources*, based on best available data and TWG determinations;
- *Methods and models,* determined with input from TWG members following review of proposed methods/models by CCS;
- *Key assumptions,* based on TWG determinations; and
- *Key uncertainties*, to be identified and discussed either qualitatively, or addressed through sensitivity analysis or other analytical approaches, as appropriate and possible.

Decisions on each of these variables will be made through open facilitated decisions of the TWGs. Analysis by CCS and TWG members will follow these guidelines and specifications. For the micro-economic analysis of policies, each TWG will work from an MS Excel workbook for their sector(s) ("Micro-Analysis Workbook"). Each of these will have a common structure to produce analyses that allow for a reviewer to follow through the construction of each stream of energy, GHG reduction, and cost elements to produce estimates of cost effectiveness and net societal costs (on an NPV-basis). Standard outputs from these sector micro-analysis workbooks will be used for integration analysis across sectors ("inter-sector integration") and for input to macro-economic modeling.

Documentation of Policy-Specific Results

Documentation of the work completed for each policy will be provided in a standard Policy Option Template format that addresses the following topics (among others) to ensure consistency for comparison of information and also assist with identifying data gaps that will be addressed.

- Policy Area (Sector)
- Name of Policy Option
- Plain English Policy Description
- Causal Chain for GHG Effects
- Technical Policy Design Specifications (described above)
- Policy Implementation Mechanisms: described in general terms above but will be defined more specifically for each policy option and program through which it is implemented
- Related Policies and Programs in Place or Anticipated: for baseline definition (including existing and planned actions)
- Quantification Results, including:
    - Estimated Net GHG Savings in target years,
    - Cumulative net GHG reduction potential and net costs/savings (NPV),
    - Net Cost/savings per cumulative tCO_2e saved,
    - Energy impacts (net production/consumption or shift in supply/demand mix and timing),
    - Specified data sources, quantification methods, and key assumptions
- Key Uncertainties and Sensitivity analyses (where applicable)
- Co-Benefits Assessments or Characterization, as appropriate

The completed Policy Option Templates will be assembled into a separate appendix of the final report. Additional printouts of worksheets and reference materials may be provided where needed.

Accounting for Policy Interactions & Overlaps

The initial micro-economic analysis of each policy will be done on a "stand-alone" basis. This assumes that the policy is being implemented all by itself, and the results are calculated against business as usual (BAU) conditions as addressed in the GHG inventory and forecast. The stand-alone GHG reductions and net societal costs will be calculated first within each sector micro-workbook.

Policies will often have overlapping or interacting effects with others that are being implemented at the same time. These interactions/overlaps can occur between policies within the same sector (intra-sector) or between policies in separate sectors (inter-sector). An example of an *intra-sector* overlap would be a policy that reduces waste emplacement in landfills and another that addresses landfill gas capture. By implementing the first policy, there will be less waste being emplaced in landfills (as compared to BAU), which will reduce the amount of methane generated in the future and the possible GHG reductions. As well, with implementation of the second policy, there will be less methane being emitted (as compared to BAU). This will reduce the potential reductions that could be achieved by reducing landfill waste emplacement (assuming no landfill gas collection and control under BAU conditions).

A common example of *inter-sector* interactions/overlaps occurs between electricity energy efficiency policies in the RCII sector and clean electricity generation policies in the ES sector. This occurs due to the difference in electrical grid carbon intensity between the BAU forecast and the intensity that results from the implementation of all ES supply-side policies. Another common area for inter-sector interaction/overlap is biofuels supply and demand policies. If both biofuel demand and supply policies are selected for this project, in order to avoid the need to address overlaps due to biofuels consumption, CCS will work with the TWG members to focus the AFOLU/WM policy analyses on volumes that can be produced in-state and the associated production costs. Those results will serve as inputs to the demand-side policies in TLU. TLU policy analysts will then compute the full GHG reductions achieved and costs incurred for consuming these biofuels (e.g. including blending, distribution and other costs).

The next step after stand-alone policy analysis will be an assessment of *intra-sector* interactions and overlaps that occur within sectors. In each sector micro-workbook, adjustments will be made to the stand-alone GHG reduction and cost estimates to account for the overlapping policy effects. The methods to be used to quantify these interactions/overlaps will vary depending on the suite of policies within each sector, as well as the details of their design. For complex situations involving multiple policies, a separate technical memo might be needed to document the methods developed within the micro-workbook to quantify the level of interaction/overlap. In other simpler cases, the documentation and methods will be provided directly within the sector micro-workbook.

The next step after *intra*-sector policy analysis will be the *inter*-sector interactions and overlaps that occur between sectors. For inter-sector overlaps, a separate technical memo will be prepared by CCS to document where these occur and the methods used to quantify them, so that the final Minnesota CSEO results represent the best estimates of GHG reductions and net societal costs that are net of all interactions/overlaps. The design of each sector micro-workbook will include data export features that capture the information needed from each policy analysis in order to assess inter-sector overlaps. The overall Minnesota CSEO results will be developed within a separate MS Excel workbook referred to as the "Synthesis Module".

Micro-Macro Data Bridge

In addition to the inter-sector integration data exports noted in the previous section, the microeconomic analysis work will also need to provide relevant data to the macroeconomic modeling team for use in the REMI Policy Insights+ (REMI-PI+) model. The results from the microeconomic analysis of each policy are the direct net activity, energy, GHG, and cost/savings effects of the policies on the parties responsible for or affected by their implementation (utility companies, industrial enterprises, building developers/owners/ operators/residents, car owners, farmers, government agencies, etc.). Macroeconomic modeling analysis estimates the indirect effects of these changes in energy expenditures, investment costs/savings, and operation and administrative costs on the regional economy as a whole, as well as for different economic sectors, demographic/income groups, and occupancy types, with results for changes in employment, gross state product (GSP), personal income, personal consumption expenditures (PCE)-price index, and population, as well as implications for regional competitiveness from each individual policy and for the Minnesota CSEO project as a whole.

Two categories of information are necessary for the microeconomic analysis sector leads to prepare and provide for the linkage/export to REMI-PI+: 1) detailed cost/savings information from the microeconomic analysis of each policy option; some of the assumptions of how they were calculated; and how the initial investments required for policy implementation will be financed; and 2) the sectors from the REMI-PI+ input-output (I-O) table that will bear the costs, receive the savings, and stimulate from the investment.

Each sector micro-economic workbook will have separate data export features to capture these needed outputs for the Macro Team. A separate technical memorandum will be prepared by CCS to document the data bridging between the micro- and macro-analyses.

II. Additional Background

Pollutant Coverage and Global Warming Potentials

The analysis will cover the following six GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of these gases will be presented using a common metric, carbon dioxide equivalent (CO_2e), which indicates the relative contribution of each gas to global average radiative forcing on a Global Warming Potential- (GWP-) weighted basis. Table E-2 shows the 100-year GWPs published by the Intergovernmental Panel on Climate Change (IPCC) in its Second, Third, and Fourth Assessment Report. The 100-year GWP's published in the IPCC's Fourth Assessment Report (AR4) will be used to convert mass emissions to a 100-year GWP basis. Use of the AR4 100-year GWP's will retain consistency with those used in other Minnesota baseline and policy analysis work.

Table E-2. 100-Year Global Warming Potentials from the 2nd, 3rd, and 4th IPCC Assessment Reports

Gas	100-year GWP (2nd Assessment)[b]	100-year GWP (3rd Assessment)[c]	100-year GWP (4th Assessment)[d]
CO_2	1	1	1
CH_4[a]	21	23	25
N_2O	310	296	298
HFC-23	11,700	12,000	14,800
HFC-125	2,800	3,400	3,500
HFC-134a	1,300	1,300	1,430
HFC-143a	3,800	4,300	4,470
HFC-152a	140	120	124
HFC-227ea	2,900	3,500	3,220
HFC-236fa	6,300	9,400	794
HFC-4310mee	1,300	1,500	1,640
CF_4	6,500	5,700	7,390
C_2F_6	9,200	11,900	12,200
C_4F_{10}	7,000	8,600	8,860
C_6F_{14}	7,400	9,000	9,300
SF_6	23,900	22,200	22,800

[a] The methane GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor.

[b] Second Assessment: http://www.epa.gov/climatechange/emissions/downloads/ghg_gwp.pdf 1995. Because only a summary of the Second Assessment Report is available online, an EPA document is cited which has the table from the IPCC report.

[c] Third Assessment: http://www.ipcc.ch/ipccreports/tar/wg1/248.htm, 2001.

[d] Fourth Assessment: http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf, 2007.

Black carbon is another pollutant with positive climate-forcing properties. Black carbon is an aerosol (particulate) species (component of particulate matter) that has not yet had a GWP assigned to it by the IPCC. If the set of Minnesota CSEO policies includes one that is meant to address sources of black carbon specifically, then CCS will provide to TWG members, a technical memorandum from one of the US states that CCS supported in the development of their black carbon emissions inventory. In that work, CCS developed estimates of both mass emissions and emissions on a climate-forcing basis.

If approved for use, the CCS methods will be used to generate black carbon emission reductions on a CO_2e basis, so that the benefits can be compared to other policies that target the IPCC GHGs. In order to count any estimated emission reductions against a future BC target, an inventory and forecast of black carbon emissions should be prepared and added into the current GHG inventory and forecast for Minnesota, at least for the sources addressed by the policy.

Emission Reductions

Emission reductions for individual policies will be estimated incremental to baseline emissions based on the change (reduction) in emissions activity (e.g., physical energy or activity units), or as a percentage reduction in emissions activity (e.g., physical energy or activity units or emissions) depending on the availability of data. This information will be needed to support the cost-effectiveness calculation for each policy option.

Fuel- and pollutant-specific emission factors will be used to convert physical units of emissions activity to emissions. Activity-based emissions factors may also be used where applicable. The emission factors will be based, preferentially, on those used within the baseline GHG inventory and forecast for Minnesota, or on other established and accepted factors, as a back-up (such as those of the EPA or IPCC).

Net Costs and Savings

Net financial (initial investment) outlays and receipts and other fixed costs/savings, and variable financial costs/savings, such as operation and maintenance (O&M) costs or savings, energy/fuel costs or savings, and other direct financial costs and savings, will be estimated for each of the policies that are determined quantifiable. Costs and savings will be discounted as a multi-year stream of net costs/savings to arrive at the NPV cost associated with implementing the new technologies and best practices called for in the policy design. CCS suggests that costs be discounted in constant 2014 dollars using a five percent annual real discount rate (seven percent nominal) based on standard rates used for regulatory impact analysis in the United States at the federal and state levels.

Financial (initial) investments will be represented in terms of both actual annual and annualized or amortized costs over the planning period, although simplified amortized benchmarks may be used where appropriate. Total financial costs or savings represent the combined fixed and variable costs/savings associated with the implementation of a policy relative to the baseline or BAU technology or practice.

Total annual direct costs are the sum cost of financing (equals the cost of debt plus the cost of equity), taxes, depreciation, and direct variable costs (operations, maintenance, fuels). Financing costs are determined based on the specific implementation assumptions for the policy based on the lifetime of the investment, finance rates, and the fraction of initial investment costs that are financed. Total direct costs each year are then discounted using the discount rate selected for the project. Total annual discounted costs can then be used to calculate a "levelized" costs/savings for large, long term investments (see Attachment II for an example calculation of levelized costs for the Energy Supply sector). For initial investments that address smaller projects/equipment with shorter lifetimes (e.g. <15-20 years), the cost of initial investment financing will be determined using a simpler method, referred to as a capital recovery factor (CRF). The essential difference here is that taxes and depreciation are not factored in.

O&M costs or savings refer to labor, equipment, and fuel costs related to annual operation and maintenance of facilities and equipment, and can be categorized as either variable O&M costs or fixed O&M costs. Variable O&M cost estimates are provided as a function of activity units (e.g. $/MWh of power generated). Fixed O&M costs don't vary based on the output of a facility and are estimated on the basis of plant capacity. In the micro-economic cost analyses conducted for this project, net energy costs will be kept separate from the other variable O&M costs.

Savings calculations include avoided costs associated with policy implementation as compared to BAU conditions. For instance, location efficiency measures may reduce the required infrastructure or services associated with new communities, depending on design and other circumstances. Similarly, electricity end use efficiency may reduce the need for new power generation facilities, and fuel efficiency measures may reduce the need for new fuel production and distribution facilities. Whenever an element of the overall societal cost analysis cannot be estimated, it will be referenced qualitatively and documented within the policy option template. In addition to cost savings, revenues and other positive cash flows from implementation of the policy are included in the discounted cash flow analysis.

Cost Effectiveness

Because the monetized dollar value of the impacts of GHG emissions reduction is not available (i.e. the total social cost of carbon), physical avoided emissions benefits are used instead as an input to cost effectiveness calculations, measured as dollars per tCO_2e (cost or savings per ton), and referred to as "cost effectiveness." Both positive costs and cost savings (negative costs) are estimated as a part of the calculation of emissions mitigation costs. When combined with GHG impact assessments, the results of these cost estimates will be aggregated into a stepwise marginal cost curve that can be broken down by sector or subsector, as needed. Cost effectiveness calculations may also be made for other benefits, such as energy savings, health gains, etc.

The cost effectiveness of a proposed policy is calculated by dividing the NPV (cumulative future streams of incremental costs or savings over the appropriate policy option time period, discounted back to the present time), by the cumulative undiscounted net CO_2e reductions achieved by the technological or best practice change brought about by implementation of the policy. Mathematically, the equation to be used is as follows (note that discounting of GHG reductions may also be done but is not a standard practice for multiple reasons):

$$CE = \frac{\sum_{t=0}^{n} \left\{ \frac{((LC_m - LC_r) * A_t)}{(1 + D_r)^t} \right\}}{\sum_{t=0}^{n} (CO_2e_r - CO_2e_m)}$$

Where:

CE	=	Cost effectiveness of a technology or best practice, $/t$CO_2$e avoided
LCm	=	Levelized cost of a mitigation technology or best practice, $/activity unit
LCr	=	Levelized cost of the reference (BAU) technology/practice, $/activity unit
A_t	=	Amount of activity affected by the technology or best practice in year t, activity unit
D_r	=	Real discount rate, dimensionless
CO_2er	=	CO_2e emissions associated with the reference (BAU) technology in year t, metric tons CO_2e
CO_2em	=	CO_2e emissions associated with a mitigation technology or best practice in year t, metric tons CO_2e
t	=	year in the evaluation period ($0 \leq t \leq 20$)

Activity units refer to a unit indicator of GHG emissions activity for a policy. The activity units will vary depending on the sector and within each sector by the individual policy design. The activity units are used to normalize data for comparison of the policy option to the baseline. For example, for the Power Supply sector, megawatt-hours (MWh) of gross electricity generation could be used as the activity unit such that dollars per megawatt-hour ($/MWh) would be used as the activity unit for the "LCm" and "LCr" terms, and MWh would be used as the activity unit for the cost terms in the equation.

The results of the analyses will be used to develop a GHG abatement cost curve, which will rank each technology or best practice in the order of its cost effectiveness for reducing one tCO_2e of emissions. This ranking will be represented in the form of a curve. Each point on this curve represents the cost-effectiveness of a given policy option relative to its contribution to reductions from the baseline, expressed as a percentage of baseline emissions. The points on the curve appear sequentially, from most cost-effective in the lower left area of the curve, to the least cost-effective options located higher in the cost curve in the upper right area. Figure E-1 below provides an example from the Kentucky (KY) Climate Action Plan.

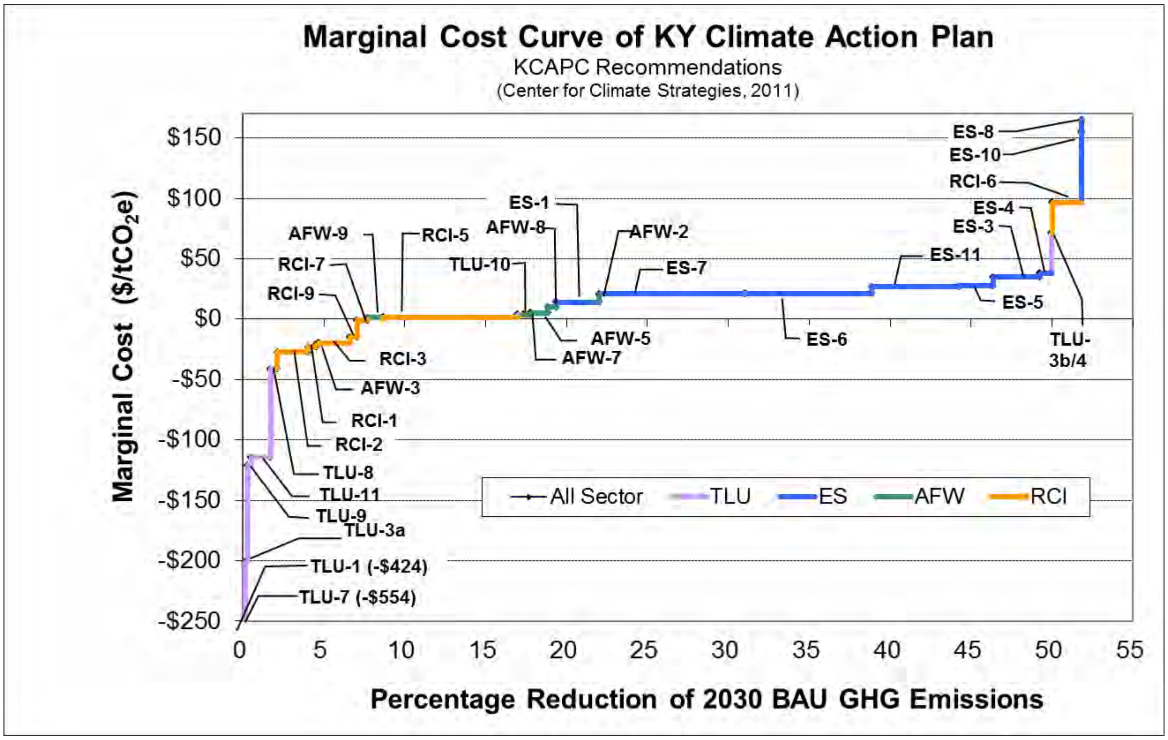
Levelized Costs, Common Forecast Data and NPV Calculations

As noted earlier, the costs of each policy with large long-term investment requirements are often levelized and converted into dollars per activity unit. The cost components to be considered include relevant fixed and variable costs and savings. Sector-specific direct costs and savings (e.g., savings from avoided losses in transmission of electricity) will be included as applicable to each sector or policy option. An example calculation of levelized costs for power generation technology is included as Attachment II to this memo.

Similar data inputs are often required for conducting GHG reduction and net societal cost analyses across all sectors (future energy prices, population, economic forecasts). Examples of these inputs are provided in Attachment III to this memo.

An example calculation of the net present value of a policy micro-economic analysis is provided in Attachment IV to this memo.

Figure E-1. Example GHG Abatement Cost Curve



Time Period of Analysis

For each policy, incremental emission reductions and incremental costs and savings will be calculated relative to the characteristics of the baseline that would otherwise prevail in Minnesota up through the end of the 2015-2035 planning period. The NPV of the cumulative net costs of each option, and the cumulative emission reductions of each option, will be reported for the entire Minnesota CSEO planning period of 2015 – 2035. Annual GHG reductions will also be reported for an interim year of 2020.

Geographic Inclusion

GHG impacts of activities that occur within Minnesota will be estimated, regardless of the actual location of emission reductions. For instance, when electrical energy efficiency measures are implemented in Minnesota buildings, GHG reductions occur as a result of lowering the demand for electricity from power plants both within and outside of the state (i.e. due to power imports). CCS recommends that the GHG reductions be calculated to capture reductions for power production regardless of the location of the generation plants. This concept ties back to the GHG inventory & forecast accounting of electricity emissions on a consumption-basis.

There will be other policies where the GHG effects occur both within and outside the state. For example, if renewable fuels are planned for use in the transportation sector (e.g. ethanol or biodiesel), and these fuels are being sourced from outside of the state, then an accounting of full energy-cycle GHG emissions benefits is needed. For example, this accounting would capture the full net benefits of offsetting gasoline (including petroleum extraction, transport, refining, distribution, and combustion) with ethanol (including feedstock production, transport, processing, distribution, and combustion). The issue of energy-cycle coverage is further explored in the next section of this memo.

Where significant emission impacts are likely to occur outside Minnesota, this will be clearly indicated. Emission reductions that can't be determined to occur solely within the state's boundaries will be provided as a separate stream of reductions. Cost effectiveness, however, will always be based on the full energy-cycle impacts.

Energy-Cycle Coverage

GHG reductions for each policy will be based on an energy-cycle and net energy impact analysis wherever possible, based on best available data and priority need. Tracking the full range of fuel use inputs is preferred, and in some cases essential, for accurately tracking full energy-cycle carbon emissions for technology options and best practices displaying very different performance characteristics from the standard practices they are replacing. The approach involves identifying all the possible stages of the energy-cycle, for instance, and quantifying the fuel input per unit of energy produced (electricity or fossil fuel). The focus, however, will be on those energy-cycle elements where there are significant differences in GHG emissions between the BAU case (standard practice) and the policy case.

Energy-cycle impacts will be reported for each source for which information is available to support an energy-cycle analysis. Where net energy-cycle emission reductions are captured, there can often be two sets of emission reductions estimated: the total energy-cycle reductions and those estimated on just a direct basis (e.g., tailpipe emissions). In many cases, it is difficult to determine how much of the upstream component of the energy-cycle emissions actually occur within the state (e.g. how much of the gasoline consumed in Minnesota is produced from petroleum extracted, transported, refined, and distributed in Minnesota). Therefore, by default, the in-region reductions will often be those just associated with fuel combustion; the remaining upstream component will be identified separately to make it clear that these could be reductions that occur out of state.

Similar to the treatment of fuel combustion emission reductions above, GHG reductions from in-state non-combustion sources will be reported separately for those processes that are known to occur within Minnesota (e.g., landfill emission reductions); and, the upstream GHG emissions (e.g. emissions embedded in each waste component). For example, a policy directed at reducing municipal solid waste generation will reduce future in-state landfill emissions and also emissions occurring either inside or outside of the state, including those associated with the extraction/processing/packaging of virgin materials into usable products that were avoided as a result of the policy. Because it is often not possible to determine the amount of upstream GHG emissions that occur in-state, any reduction of these will be reported separately from those known to occur within Minnesota.

Macroeconomic Impacts

The principles and guidelines and key decisions on methods (i.e. use of the REMI-PI+ model), data sources and assumptions for macroeconomic analysis will be provided separately from this advisory memo.

Co-benefits and Costs Assessments

To the extent needed, the principles and guidelines and key decisions on methods, data sources and assumptions for co-benefits/costs analysis will be provided in a separate and linked advisory memo by CCS.

Acronyms and Glossary

Table E-3. Quantification Memo Acronyms & Abbreviations

Acronym	Definition
AFOLU	Agriculture, Forestry & Other Land Use
BAU	Business as usual
CAP	Climate Action Plan
CC	Cross-Cutting
CCS	The Center for Climate Strategies
CD	Central Desktop
CE	Cost effectiveness
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CRF	Capital recovery factor
ES	Energy Supply
FCR	Fixed charge rate (factor)
GHG	Greenhouse gas
GSP	Gross State product
GWP	Global warming potential
HFC	Hydrofluorocarbon
IPCC	Intergovernmental Panel on Climate Change
KY	Kentucky
CSEO	[Minnesota] Climate Solutions & Economic Opportunities
MN	Minnesota
MWh	Megawatt-hours
N_2O	Nitrous oxide
NPV	Net present value
O&M	Operations and Maintenance
PFC	Perfluorocarbon
RCII	Residential, Commercial, Institutional & Industrial

SAR	Second Assessment Report (of the IPCC)
SF_6	Sulfur hexafluoride
t	Metric ton
Tg	Teragram
TLU	Transportation & Land Use
TWG	Technical workgroup
US EPA	United States Environmental Protection Agency
WM	Waste Management

Table E-4. Quantification Memo Glossary

Term	Meaning
Business as usual (BAU)	Inaction planning, refers to the normal operation of society over time in terms of economic growth, energy use, GHG emissions, and other related factors in the absence of any intervention.
Consumption-based accounting	Considers all the emissions that result from energy consumed, waste generated, and transportation trips generated in an area, even if the emissions occur outside of the boundaries of the geographic area considered. In many cases, consumption-based accounting is useful to policy makers wishing to assess the emissions impacts of actions that address activities that they have control over (e.g. energy and materials consumption; trip generation).
Direct emissions	Emissions occurring at the emission source, for example exhaust from the vehicle tailpipe or power plant stack.
Energy-cycle emissions	These emissions include those from fuel combustion as well as the upstream emissions associated with the extraction, processing, transport, refining, and distribution of the fuel. This applies to fuels used directly in stationary and mobile sources, as well as those used to produce power. So, for example, if power is derived from fossil fuels, the upstream emissions associated with coal/petroleum/natural gas extraction, processing and transportation/distribution are captured. Unlike life-cycle emissions, the emissions associated with constructing facilities or equipment associated with upstream activities (e.g. steel in a pipeline; equipment at a refinery) are not included; just the emissions associated with operating the upstream activity itself (e.g. process gas used at a refinery).
Fixed operations and maintenance (O&M) costs	Consist primarily of labor costs, but could also include taxes and other fixed costs. Fixed O&M costs are incurred regardless of the energy produced by a process, and are usually assessed per unit of capacity. [shouldn't we cover all fixed costs here?]
Levelization	The process of developing a lump sum that has been divided into equal amounts over a specified period of time.
Life-cycle emissions	Involves a cradle-to-grave view of GHG emissions associated with an activity (e.g., driving) or use of product (e.g., plastic bottle). Such an assessment includes the extraction and transport of raw materials, manufacture, packaging, freight, usage and final disposal. It also generally includes the emissions from construction of all facilities within the value chain.
Macro-economic assessment	Addresses the indirect or secondary economic impacts on jobs, income, economic growth, productivity, and prices that arise from or in association with the microeconomic direct costs and savings. Such an analysis is also useful to address *distributional impacts,* including differential impacts related to size, location, and socio-economic character of affected households, entities, and communities (often framed as *fairness and equity).*
Net present value (NPV)	Under the net present value method, the present value of a project's cash inflows is compared to the present value of the project's cash outflows. The difference between the present value of these cash flows is called "the net present value". This net present value determines whether or not the project is an acceptable investment. The same concept can be applied to the analysis of policy alternatives.

Term	Meaning
Nominal discount rate	Based on rates of interest observed by financial institutions.
Real discount rate	Removes the rate of inflation from the nominal discount rate. For example, when the nominal discount rate is 6% and there is a 2% rate of inflation, then the real discount rate is 1.06/1.02 = 1.0392 or 3.92%.
Renewable energy	Energy from sources that are perpetual or that are replenished as quickly as they are used up. Renewable energy includes solar, wind, wave, tidal, geothermal, landfill gas, anaerobic digestion of biomass, and other forms of sustainably-sourced biomass, and hydro power.
Renewable Portfolio Standard (RPS)	A policy that requires electricity providers to obtain a minimum percentage of their power from renewable energy resources by a certain date. As an example, the State of New Jersey's RPS goal is 22.5 percent power from renewable resources by 2021.
Upstream emissions	Emissions that occur before a product is used for its intended purpose; for example drilling, refining, and transportation of oil to be used as vehicle fuel; emissions during manufacturing of a product (metal can, glass bottle, steel beam, etc), as well as extraction, processing and transportation of the raw materials.
Variable O&M costs	Include periodic inspection, replacement and repair of system components and consumables, such as water and pollution control materials. Variable O&M costs vary depending on the amount of power (or other product) generated.

Attachment I. Examples of Direct and Indirect Net Cost and Benefit Metrics

Note: These examples are meant to be illustrative and are not necessarily comprehensive or the focus of the Minnesota CSEO Process.

1. **Transportation and Land Use (TLU) Sector**
    - **a.** Direct Costs and/or Savings
        - i. Incremental financial and operating cost of more efficient vehicles, net of fuel savings.
        - ii. Incremental costs of implementing Smart Growth programs, net of saved infrastructure and service costs.
        - iii. Incremental cost of mass transit investment and operating expenses, net of any saved infrastructure and service costs (e.g., roads, road maintenance, vehicles)
        - iv. Incremental cost of alternative fuel, net of any change in maintenance costs
        - v. Net effects of carbon sequestration from land use measures
    - **b.** Indirect Costs and/or Savings
        - i. Net value of employment and income impacts, including differential impacts by socio economic category
        - ii. Re-spending effects on the economy from financial savings
        - iii. Net changes in the prices of goods and services in the region
        - iv. Health benefits of reduced air and water pollution
        - v. Ecosystem benefits of reduced air and water pollution
        - vi. Value of quality-of-life improvements
        - vii. Value of improved road and community safety
        - viii. Energy security
2. **Residential, Commercial, Institutional and Industrial (RCII) Sectors**
    - **a.** Direct Costs and/or Savings

i. Net capital costs or savings (or incremental costs or savings relative to standard practice) of improved buildings, appliances, equipment (for example, cost of higher-efficiency refrigerator versus refrigerator of similar size and with similar features that meets standards)

ii. Net operation and maintenance (O&M) costs or savings (relative to standard practice) of improved buildings, appliances, equipment, including avoided/extra labor costs for maintenance (for example, maintenance cost savings from less changing of longer-lived compact fluorescent light (CFL) or light-emitting diode (LED) bulbs in lamps relative to incandescent bulbs)

iii. Net fuel (gas, electricity, biomass, etc.) costs (typically expressed as avoided costs from a societal perspective, that is, based on the net cost to society of producing an additional unit of fuel, as opposed to the retail cost of fuel)

iv. Cost/value of net water use/savings

v. Cost/value of net materials use/savings (for example, raw materials savings via recycling, or lower/higher cost of low-global warming potential (GWP) refrigerants)

vi. Direct improved productivity as a result of industrial measures (measured as change in cost per unit output, for example, for an energy/GHG-saving improvement that also speeds up a production line or results in higher product yield)

b. Indirect Costs and/or Savings

i. Net value of employment and income impacts, including differential impacts by socio economic category

ii. Re-spending effect on economy

iii. Net value of health benefits/impacts

iv. Value of net environmental benefits/impacts (value of damage by air pollutants on structures, crops, etc.)

v. Net embodied energy of materials used in buildings, appliances, equipment, relative to standard practice

vi. Improved productivity as a result of an improved working environment, such as improved office productivity through improved lighting (though the inclusion of this as indirect might be argued in some cases)

3. Energy Supply (ES) Sector

a. Direct Costs and/or Savings

i. Net financial costs or savings (or incremental costs or savings relative to reference case technologies) of renewables or other advanced technologies implemented as a result of policies

ii. Net O&M costs or savings (relative to reference case technologies) of renewables or other advanced technologies implemented as a result of policies

iii. Avoided or net fuel savings (gas, coal, biomass, etc.) of renewables or other advanced technologies implemented as a result of policies relative to reference case technologies

iv. Total system costs (net capital + net O&M + avoided/net fuel savings + net imports/exports + net transmission and distribution (T&D) costs) relative to reference case total system costs

b. Indirect Costs and/or Savings

i. Net value of employment and income impacts, including differential impacts by socio economic category
ii. Re-spending effect on economy
iii. Higher cost of electricity in the region
iv. Energy security
v. Net value of health benefits/impacts
vi. Value of net environmental benefits/impacts (value of damage by air pollutants on structures, crops, etc.)

4. Agriculture, Forestry, and Other Land Use (AFOLU) Sectors

a. Direct Costs and/or Savings

i. Net financial costs or savings (or incremental costs relative to standard practice) of facilities or equipment (e.g., manure digesters, biogas-fired generators, and associated infrastructure; ethanol production facilities)
ii. Net O&M costs or savings (relative to standard practice) of equipment or facilities
iii. Net fuel (gas, electricity, biomass, etc.) costs or avoided costs
iv. Cost/value of net water use/savings
v. Cost/value of carbon sequestration from land use measures
vi. Reduced vehicle miles traveled (VMT) and fuel consumption associated with land use conversions (e.g., as a result of forest/rangeland/cropland protection policies)

b. Indirect Costs and/or Savings

i. Net value of employment and income impacts, including differential impacts by socio-economic category
ii. Net value of human health benefits/impacts
iii. Net value of ecosystem health benefits/impacts (wildlife habitat; reduction in wildfire potential; etc.)
iv. Value of net environmental benefits/impacts (value of damage by air or water pollutants on structures, crops, etc.)

5. Waste Management (WM) Sector

a. Direct Costs and/or Savings

i. Net financial costs or savings (or incremental costs relative to standard practice) of facilities or equipment (e.g., composting facilities; landfill gas collection and utilization equipment; anaerobic digesters and methane utilization equipment; associated electricity transmission/distribution infrastructure; other waste to energy facilities; waste collection and processing equipment; material recovery facilities; recycling facilities; upgrades to wastewater treatment plants)

ii. Net O&M costs or savings (relative to standard practice) of equipment or facilities

iii. Net fuel (gas, electricity, biomass, etc.) costs or avoided costs

iv. Cost/value of net change in waste management practice (e.g. avoided cost of landfilling)

v. Cost/value of recycled commodities; reclaimed water

b. Indirect Costs and/or Savings

i. Net value of employment and income impacts, including differential impacts by socio-economic category

ii. Net value of human health benefits/impacts

iii. Net value of ecosystem health benefits/impacts (reduction in surface and groundwater contamination)

iv. Net embodied energy of water use in equipment or facilities relative to standard practice

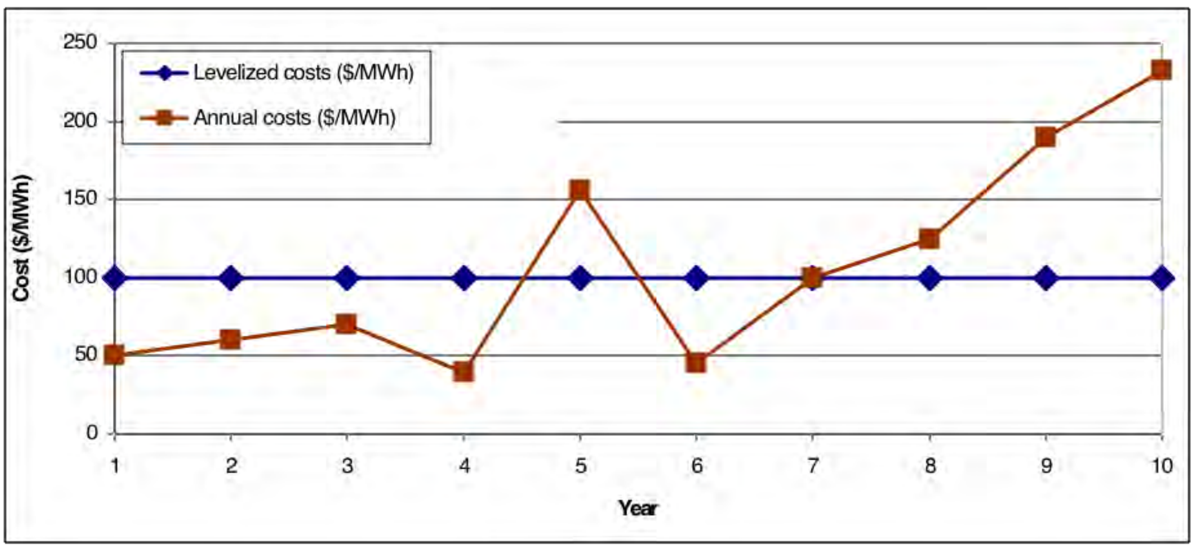
Attachment II. Example Calculation of Levelized Costs

This attachment provides a brief conceptual overview as well as an annotated example regarding the calculation of levelized costs associated with power generation technology. Levelized costs are useful in evaluating financial feasibility and for directly comparing the cost of one technology against another.

Conceptual Overview of Levelized Costs for Power Generation Technology

Levelized cost can be defined as a constant annual cost that is equivalent on a present value basis to the actual annual costs. That is, if one calculates the present value of levelized costs over a certain period, its value would be equal to the present value of the actual costs of the same period. Using levelized costs, often reported in $/MWh, allows for a ready comparison of technologies in any year, something that would be more difficult to do with differing annual costs. This can be illustrated in Figure E-1 below. The present value of the levelized cost as shown is exactly equal to the present value of the annual costs.

Figure E-2. Illustrative Comparison of Levelized and Actual Annual Costs



Components of Levelized Costs

For power generation technologies, there are several components that typically make up the levelized cost, as briefly described in the bullets below.

- *Initial investment (financial) costs (IIC):* Typically reported in units of $/kW, these costs include the total costs of construction, including land purchase, land development, permitting, interconnections, equipment, materials and all other components. Construction financing costs are also included
- *Fixed operations & maintenance (O&M):* Typically reported in units of $/kW-yr, these costs are for those that occur on an annual basis regardless of how much the plant

operates. They typically include staffing, overhead, regulatory filings, and miscellaneous direct costs.

- *Variable O&M:* Typically reported in units of $/MWh, these costs are for those that occur on an annual basis based on how much the plant operates. They typically include costs associated with maintenance and overhauls, including repairs for forced outages, consumables such as chemicals for pollution control equipment or boiler maintenance, water use, and other environmental compliance costs.
- *Fuel:* Typically reported in units of dollars per million British Thermal Units of fuel heat content ($/MMBtu), these costs are for start-up fuel use as well as on-line fuel use.

Information Needed to Calculate Levelized Costs for Power Generation Technologies

There are several other bits of information that is needed in order to calculate levelized costs, as briefly described in the bullets below.

- *Plant size:* This refers to the size of the plant, expressed in units of MW.
- *Capacity factor:* This refers to the share of the year that the plant is in operation, expressed as a percentage.
- *Fixed charge factor:* This factor is calculated based on assumptions regarding the plant lifetime, the effective interest rate or discount rate used to amortize capital costs, and various other factors specific to the power industry. Expressed as a decimal, typical fixed charge factors are typically between 0.10 and 0.20, meaning that the annual cost of ownership of a power generation technology is typically between ten and twenty percent of the capital cost. Fixed charge factors decrease with longer plant lifetimes, and increase with higher discount or interest rates.
- *Fuel price projection:* This refers to the projected price of the fuel used to produce electricity over the lifetime of the plant, expressed in units of $/MMBtu in each year of the fuel price forecast. Price projections from the U.S. Department of Energy’s Energy Information Administration are often used. In some cases, fuel price projections are expressed as levelized values for use in calculating the overall levelized costs of generation.
- *Heat rate:* This refers to the efficiency by which fuel is consumed for the production of electricity, expressed in units of Btu/kWh.

Formulas used to Calculate Levelized Costs

There are several formulas needed to convert the various units into the $/MWh units used to express levelized costs. These are briefly described below.

- *Initial Investment Costs (IIC):* These costs are converted to $/MWh units as per the formula below:

Levelized IIC = IIC * FCF * conversion factor / (HPY * CF)

Where: IIC = initial investment costs ($/kW)

CF = capacity factor (%)

HPY = hours per year = 8,760

FCF = fixed charge factor

conversion factor = 1,000 (convert from $/kW to $/MW)

- *Fixed O&M (FOM):* These costs are converted to $/MWh units as per the formula below:

Levelized fixed O&M cost = FOM * conversion factor / (HPY * CF)

Where: FOM = fixed O&M ($/kW-yr)

CF = capacity factor (%)

HPY = hours per year = 8,760

conversion factor = 1,000 (convert from $/kW to $/MW)

- *Variable O&M (VOM):* These costs are already provided in units of $/MWh so no conversion is needed.
- *Fuel costs (FC):* Each year's fuel price is converted to units of $/MWh as follows:

Fuel price = FPt * HR / conversion factor

Where: FPt = fuel price in year t ($/MMBtu)

HR = heat rate (Btu/kWh)

Conversion factor = 1,000 (convert from kWh to MWh)

t = year in the plant lifetime

These annual fuel costs are then levelized as follows:

Levelized fuel cost = [PV * DR * (1+DR)t] / [(1 + DR)t – 1]

Where: PV = present value of discounted fuel cost stream

DR = discount rate

Example Calculation of Levelized Costs for Power Generation Technologies

The above information can be combined to develop the levelized cost for any technology. As an example, the case of a conventional natural gas-fired combined cycle plant is considered.

Table E-5 summarizes the starting assumptions. Levelized cost calculations are offered in the bullets that follow the table. Note that cost parameters are specified on a per-unit basis, the calculation is independent of the size of the generator.

Table E-5. Power Generation Cost and Performance Assumptions

Parameter	Value	Annual Fuel Price (constant $/MMBtu)					
Size (MW)	540	Year	Price	Year	Price	Year	Price
Online year	2014	1	7.57	11	6.09	21	6.57
Fuel type	Natural gas	2	7.12	12	6.14	22	6.61
Heat rate (btu/kWh)	7,064	3	7.54	13	6.20	23	6.83
Capacity factor (%)	65%	4	7.77	14	6.25	24	6.96
Discount rate (%)	5.0%	5	7.30	15	6.16	25	7.09
Operating life (years)	30	6	7.01	16	6.06	26	7.20
Fixed charge factor (%)	12%	7	6.77	17	6.18	27	7.25
Capital cost ($/kW)	703	8	6.47	18	6.25	28	7.30
Fixed O&M cost ($/kW-yr)	12.14	9	6.26	19	6.36	29	7.35
Variable O&M cost ($/MWh)	2.01	10	6.14	20	6.46	30	7.4

- *Initial investment costs:* the levelized initial investment cost is equal to:

  Levelized (IIC) = 703 * 0.12 * 1,000 / (8,760 *0.65) = $14.82/MWh

- *Fixed O&M:* The levelized fixed O&M cost is equal to:

  Levelized fixed O&M cost = 12.14 * 1,000 / (8,760 * 0.65) = $2.13/MWh

- *Variable O&M:* The levelized variable O&M cost is equal to $2.01/MWh

- *Fuel costs:* The present value of the discounted fuel cost stream is equal to $104.35/MMBtu. The levelized fuel cost is equal to:

[104.35 * 0.05 * (1+0.05)30] / [(1 + 0.05)30 – 1] = $6.79/MMBtu

This levelized value is then converted to units of $/MWh as follows:

Levelized FC = 6.79 * 7,064 / 1,000 = $47.97/MWh

- *Total levelized cost:* The total levelized cost is equal to the sum of the above components, as follows:

Total levelized cost = levelized IIC + levelized FOM + VOM + levelized FC

= 14.82 + 2.13 + 2.01 + 47.97

= $66.93/MWh

Attachment III. List of Common Factors for Policy Quantification

These are examples of data needed across sectors. Each sector has its own sector-specific data needs. CCS will work with the TWG members to identify recommended data sources. These will be entered into a common MS Excel file called "Common Baseline Forecast and Microeconomic Analysis Data.xls". This file will be located in the following Central Desktop (CD) folder along with this Quantification Memo: 02 Microeconomic Analysis:

- Energy price forecasts: covering electricity, as well as each fuel type;
- Forecasts for electricity and gas sales in Minnesota during the planning period;
- Information on current (most recent year) utility sales of gas and electricity in Minnesota, preferably by utility, especially if different goals are to apply to different utilities;
- Carbon intensity of grid electricity: should be taken from Minnesota's GHG I&F or derived from data supporting these baseline estimates (i.e. net generation and the associated CO_2e emissions in each year; also net annual imports and estimates of their carbon intensity). This value may change over the modeling period, and will be needed for many ES options and demand-side policies in the other sectors;
- Estimates of the average current and projected gas and electricity avoided costs (in $/MMBtu and $/MWh) in Minnesota. If these data are not readily-available, they can probably be estimated from the results of statewide cost modeling exercises;
- Energy-cycle emission factors: for electricity, as well as each fuel type; sources could be the ANL GREET model (http://greet.es.anl.gov/) or specific studies done for Minnesota;
- State-wide population forecast;
- Forecasts for the number of new residential buildings to be constructed over the planning period (by year), and of the commercial floor space to be constructed annually (or, for example, forecasts for these parameters in five-year increments);
- Estimates of current total water use, preferably by sector, for the most current year available (and, preferably, for recent years) in Minnesota. If water use data are unavailable, water production (volume of water treated for domestic, commercial, and industrial uses) in Minnesota would be a good proxy; also, the embedded energy/carbon content of water deliveries to different regions (cities) in Minnesota; the need for this TBD depending on Minnesota CSEO policy section and design;
- Estimates of future water use in Minnesota. These may be available from water treatment/distribution authorities, or may need to be created by extrapolating trends in use per person and applying them to demographic projections; the need for this TBD depending on Minnesota CSEO policy section and design;
- Estimates of current and future volumes of wastewater treated by municipality or plant; the need for this TBD depending on Minnesota CSEO policy section and design;

- Regional economic forecast (employment, gross state product (GSP); and
- Biomass supply and demand assessment: a common need for energy and GHG planning where strategies target in-state fuel supplies; the need for this TBD depending on Minnesota CSEO policy section and design.

Attachment IV. Example Calculation of Net Present Value in Micro-Economic Policy Analysis

This attachment provides an example calculation of the net present value (NPV) of costs for implementation of a policy addressing the application of straw mulching technology in the agricultural sector. This policy has a goal of reducing crop residue (straw) burning as a management method by assisting farmers to transition to mulching crop straw for re-application to crop fields. Benefits include reduced GHG emissions from crop straw burning, an increase in crop yields, lower irrigation requirements, and reduced nutrient requirements. Results here are shown in Chinese currency (RMB or ¥).

The cost elements for the policy include the following:

- *Initial investment costs:* capital costs for crop residue harvesting and application equipment;
- *Annualized investment costs:* this example assumes 100% financing of initial investments over the lifetime of the equipment (15 years at 5.0% interest produces a capital recovery factor of 0.096);
- *Transport costs:* for application to local area crop land (¥/t biomass);
- *Operations costs:* additional labor for mulch harvest and application (¥/hectare);
- *Fuel costs:* for harvest and application equipment (¥/hectare);
- *Irrigation savings:* electricity savings for reduced irrigation pumping. Calculated as a function of reduced water needs, reduced power requirements, and value of electricity savings (¥/MWh avoided);
- *Fertilizer savings:* calculated as a function of reduced nitrogen requirements and value of avoided commercial fertilizer use (¥/t avoided); and
- *Yield increase value:* value of higher yields produced through mulch application (¥/hectare).

The costs of applying this new management practice (straw mulching) need to be netted against those for baseline management. In this example, baseline management is crop residue burning with costs that are low enough to be considered zero.

Table E-6 summarizes the stream of costs associated with each of these cost elements during the planning period (2010-2035). Costs for each element in each year are shown in nominal (real) million (MM) RMB (¥). For each of these cost elements, the details of how each one is escalated through the planning period will be spelled out in the Quantification Results section of the Policy Option Template introduced earlier in this memorandum. For example, future increases in energy costs will be determined from the energy price forecasts assembled for use by all sector analysts in this project. Other escalation procedures will be specific to the sector and policy being analyzed. For example, the future expected costs of commercial nitrogen fertilizers or future value of crop commodities will need to be determined for an agricultural sector policy that requires those inputs.

The column in Table E-6 showing net costs shows the sum of all costs and savings (net costs) for each year of the planning period. The final column shows the net discounted costs, which have been discounted to a financial base year of 2010. The overall calculation of the net present value (NPV) of costs is shown in the following equation.

$$\textbf{NPV} = \sum_{t=0}^{n} \left\{ \frac{((LC_m - LC_r) * A_t)}{(1 + D_r)^t} \right\}$$

Where:

LCm = Levelized cost of a technology or best practice, $/activity unit

LCr = Levelized cost of the reference (BAU) technology or best practice, $/activity unit

A_t = Amount of activity affected by the technology or best practice in year t, activity unit

Dr = Real discount rate, dimensionless

For this example policy, the net societal costs are ¥MM 1,296 (1.30 billion RMB) in real currency which is equal to ¥MM 913 (0.91 billion RMB) when discounted to 2010 dollars using a 5.0% discount rate.

Table E-6. Example NPV Calculation: Agricultural Crop Residue Mulching

Year	Harvest & Application Capital Costs (MM¥)	Annualized Capital Costs (MM¥)	Transport Costs (MM¥)	Operations Costs (MM¥)	Yield Increase (MM¥)	Irrigation Savings (MM¥)	Fertilizer Savings (MM¥)	Diesel Costs (MM¥)	Net Costs (MM¥)	Discounted Net Costs (2010MM¥)
2010	¥67	¥6.4	¥9	¥22	¥-7	¥-22	¥-1	¥20	¥27	¥27
2011	¥67	¥12.8	¥17	¥45	¥-14	¥-44	¥-3	¥40	¥54	¥51
2012	¥67	¥19.2	¥26	¥67	¥-21	¥-66	¥-8	¥59	¥77	¥70
2013	¥67	¥25.6	¥35	¥90	¥-28	¥-88	¥-15	¥79	¥98	¥84
2014	¥67	¥32.0	¥43	¥112	¥-35	¥-109	¥-25	¥99	¥116	¥95
2015	¥0	¥32.0	¥43	¥112	¥-35	¥-109	¥-32	¥99	¥109	¥86
2016	¥0	¥32.0	¥43	¥112	¥-35	¥-109	¥-38	¥99	¥103	¥77
2017	¥0	¥32.0	¥43	¥112	¥-35	¥-109	¥-45	¥99	¥97	¥69
2018	¥0	¥32.0	¥43	¥112	¥-35	¥-109	¥-51	¥99	¥90	¥61
2019	¥0	¥32.0	¥43	¥112	¥-35	¥-109	¥-57	¥99	¥84	¥54
2020	¥0	¥32.0	¥43	¥112	¥-35	¥-109	¥-64	¥99	¥77	¥48
2021	¥0	¥32.0	¥43	¥112	¥-35	¥-109	¥-70	¥99	¥71	¥42
2022	¥0	¥32.0	¥43	¥112	¥-35	¥-109	¥-76	¥99	¥65	¥36
2023	¥0	¥32.0	¥43	¥112	¥-35	¥-109	¥-83	¥99	¥58	¥31
2024	¥0	¥32.0	¥43	¥112	¥-35	¥-109	¥-89	¥99	¥52	¥26
2025	¥0	¥25.6	¥43	¥112	¥-35	¥-109	¥-96	¥99	¥39	¥19
2026	¥67	¥25.6	¥43	¥112	¥-35	¥-109	¥-102	¥99	¥33	¥15
2027	¥67	¥25.6	¥43	¥112	¥-35	¥-109	¥-108	¥99	¥26	¥12
2028	¥67	¥25.6	¥43	¥112	¥-35	¥-109	¥-115	¥99	¥20	¥8.3
2029	¥67	¥25.6	¥43	¥112	¥-35	¥-109	¥-121	¥99	¥14	¥5.4
2030	¥67	¥32.0	¥43	¥112	¥-35	¥-109	¥-127	¥99	¥14	¥5.2
2031	¥0	¥32.0	¥43	¥112	¥-35	¥-109	¥-134	¥99	¥7	¥2.6
2032	¥0	¥32.0	¥43	¥112	¥-35	¥-109	¥-140	¥99	¥1	¥0.3
2033	¥0	¥32.0	¥43	¥112	¥-35	¥-109	¥-147	¥99	¥-5	¥-1.8
2034	¥0	¥32.0	¥43	¥112	¥-35	¥-109	¥-153	¥99	¥-12	¥-3.7
2035	¥0	¥32.0	¥43	¥112	¥-35	¥-109	¥-159	¥99	¥-18	¥-5.4
								Totals=	**¥1,296**	**¥913**

Chapter XI. Appendix F. CSEO Policy Option Documentation

This appendix provides the detailed documentation of Climate Solutions & Economic Opportunities (CSEO) policy option development and direct impacts analysis. The appendix is divided into six subsections that address each sector:

1. Energy Supply
2. Residential, Commercial, Institutional and Industrial
3. Transportation and Land Use
4. Agriculture
5. Forestry and Other Land Use
6. Waste Management
7. Clean Power Plan

Each subsection opens with two summary charts of the direct impacts expected for each CSEO policy option that was taken through full development and direct impacts and microeconomic analysis as well as indirect and macroeconomic analysis (with the exception of the Clean Power Plan analysis subsection). The first chart summarizes the "stand-alone" policy option impacts (results assume that this policy option is implemented without any overlaps or interactions with other CSEO policies). Impacts include: the expected in-State GHG reductions for the years 2020 and 2030; cumulative in-State reductions through 2030; total cumulative GHG reductions through 2030 (these include the expected upstream GHG emission reductions that may occur out of State); the net present value (NPV) of direct societal costs or savings of policy option implementation; and the cost effectiveness (CE) for each policy option (total cumulative reductions divided by the NPV of direct societal costs).

The second summary chart provides results that have been adjusted to account for any intra-sector interactions and overlaps (those occurring within the sector). A summary is also provided that describes the intra-sector policy option overlaps/interactions identified and what was done to adjust the results for each policy option. Inter-sector overlaps/interactions (those occurring among policies in other sectors are described and summarized in Chapter III of the final report).

The third summary chart provides results for macroeconomic analysis of policy options and combined option scenarios using results of fully integrated direct impact analysis as inputs to macroeconomic analysis using the REMI PI+ model.

Following the direct impacts assessment summary tables, the detailed policy option development and analysis documents are presented. Each policy option development and analysis document used the same template for policy option development. The sections in the template include:

- Policy Option Description
- Causal Chain for GHG Reductions
- Policy Option Design, including timing, level of effort or goals, coverage of parties, eligibility and definitions
- Implementation Mechanisms, such as codes and standards, incentives, technical and financial assistance, credits and trading, pricing, voluntary agreements, information and education, disclosure, and others
- Related Policies/Programs in Place and Recent Baseline Actions
- Estimated Net GHG Reductions and Net Costs or Savings, including choices of data sources, analysis methods, and key assumptions
- Estimated Macroeconomic Impacts, including jobs, growth, and income
- Key Uncertainties
- Additional Benefits and Costs
- Key Feasibility Issues

Each policy option has been custom selected by Minnesota with Center for Climate Strategies (CCS) assistance, and designed, and analyzed by CCS based on Minnesota agency conferrals and concurrence. Results of each of these specific decisions are documented for each individual CSEO policy option in the following policy option document sections.

Chapter XII. Appendix F-1. Energy Supply Policy Option Recommendations

Overview

The tables below provide a summary of the direct impacts and microeconomic analysis of Climate Solutions & Economic Opportunities (CSEO) policies in the Energy Supply sector. The first table provides a summary of results on a stand-alone basis, meaning that each policy option was analyzed separately against baseline (business as usual or BAU) conditions. Details on the analysis of each policy option are provided in each of the Policy Option Documents (PODs) that follow within this appendix.

Direct, Stand Alone Economic Impacts

The stand-alone results provide the annual greenhouse gas (GHG) reductions for 2020 and 2030 in teragrams (Tg) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030 (1 Tg is equal to 1 million metric tons). The reductions shown are only those that have been estimated to occur within the state, that is, the net emissions reduction from fuels combustion plus the estimated emissions reduction from the decrease in demand for electricity generation. Additional GHG reductions, typically those associated with upstream emissions in the supply of fuels or materials, have also been estimated, and upstream emissions results are reported within each of the analyses in each POD.

CCS did not utilize any generalized co-benefit estimate (such as a social cost of carbon) or estimate a consistent suite of co-benefit impacts across all policies. In some policies, however, aspects of specific co-benefits were isolated and quantified. For the transit policy, as one example, a small improvement in access to employment was applied to the macroeconomic modeling. The larger economic benefit of any savings to either businesses, households or the government is captured in the macroeconomic impact analysis (as is, by the same token, the economic burden of any increases in prices or costs of living/doing business).

Also reported in the stand-alone results is the net present value (NPV) of societal costs/savings for each policy option. These are the net costs of implementing each policy option reported in 2014 dollars. The cost effectiveness (CE) estimated for each policy option is also provided. Cost effectiveness is a common metric that denotes the cost/savings for reducing each metric ton (t) of emissions. Note that the CE estimates use the total emission reductions for the policy option (that is, cumulative emissions reductions counting reductions occurring both within and outside of the state).

The summary tables show the results for selected scenarios for the ES policies, ES-1 (40% goal) and ES-2. Results for a second policy option scenario for ES-1 (50%) is reported within the POD for that policy option.

Integrative Adjustments & Overlaps

The second summary table below provides net GHG emissions reductions and net costs for each option after an assessment was made of any policy option interactions or overlaps between ES options.

Macroeconomic (Indirect) Economic Impacts

Table F-1.3 below provides a summary of the expected impacts of ES policies on jobs and economic growth during the CSEO planning period. This table focuses on the impact of policies on Gross State Product (the total amount spent on goods and services produced within the state), Employment (the total number of full-time and part-time positions), and Incomes (the total amount earned by households from all possible sources). These metrics represent three valuable indicators of both the overall size of the economy and that economy's structural orientation toward supporting livelihoods and utilizing productive work.

For the purposes of macro-economic analysis of CSEO policies, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software. This particular REMI model is developed specifically for Minnesota, and is developed consistently with the design of models in use by state agency staff within Minnesota for a range of economic analyses. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

The main inputs for macro-economic analysis are microeconomic estimates of direct costs and savings expected from the implementation of individual policy options. These inputs are supplemented with additional data and assumptions necessary to complete the picture of how these costs and savings (as well as price changes, demand and supply changes, and other factors) influence Minnesota's economy. These additional data and assumptions typically regard how various actors around the state (households, businesses and governments) respond to change by changing their own economic activity. A full articulation of the general and policy-specific assumptions made by the macroeconomic analysis team is provided in the Policy Option Documents, contained as appendices to this report.

Table F-1.1 Energy Supply Policy Options, Direct Stand-Alone Impacts

Stand-Alone Analysis							
		GHG Reductions				Costs	
Policy Option ID	Policy Option Title	Annual CO_2e Reductions[a] 2020 Tg	Annual CO_2e Reductions[a] 2030 Tg	2030 Cumulative[a] $TgCO_2e$	2030 Cumulative[b] $TgCO_2e$	Net Costs[c] 2015-2030 $Million	Cost Effectiveness[d] $/tCO_2e
ES-1	Increase Renewable Energy Standards	1.9	7.5	67	75	-$620	-$8.2

	(40% goal)						
ES-2	Efficiency Improvements, Repowering, Retirement, and Up Grades to Existing Plants	0.00	6.3	44	39[e]	$752	$19
Totals		**1.9**	**14**	**111**	**114**	**$132**	**$1.16**

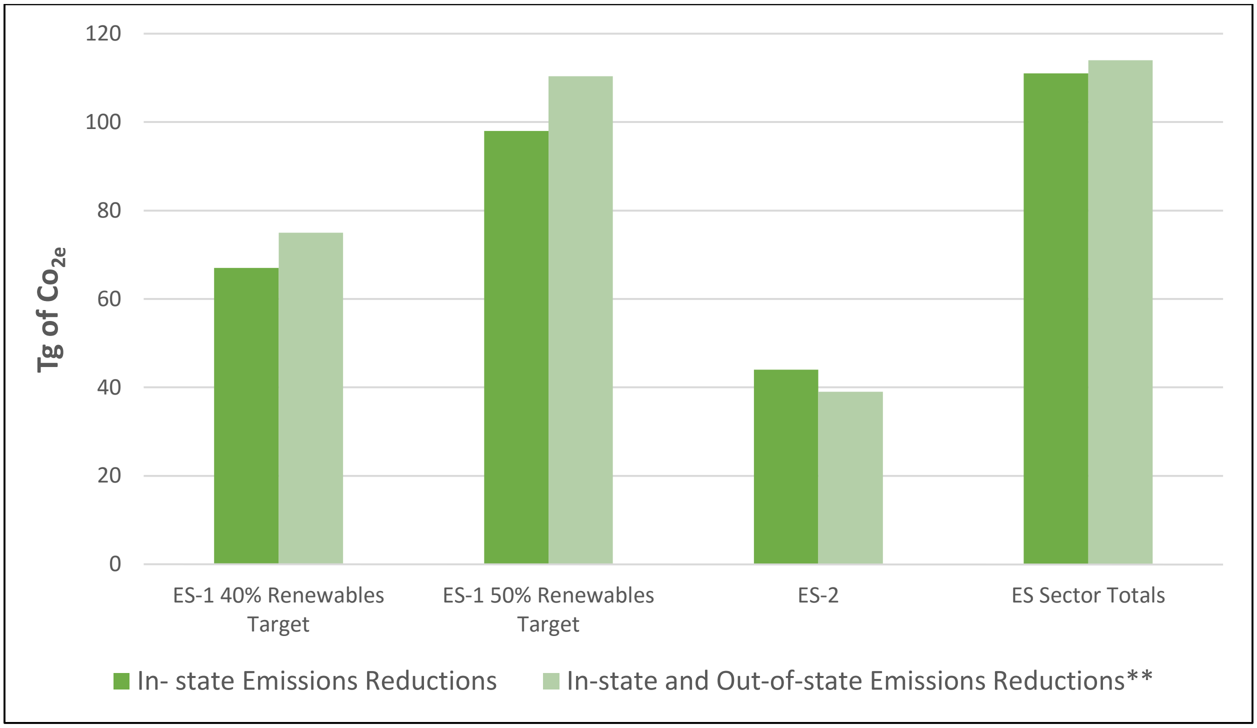
Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] Total GHG reductions are lower than in-state GHG reductions for ES-2 because upstream emissions for natural gas are higher than for coal; therefore, switching from coal to natural gas results in lower in-state emissions but higher out-of-state emissions.
Note: Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-1.2 Energy Supply Policy Options, Intra-Sector Interactions & Overlaps

Intra-Sector Interactions & Overlaps Adjusted Results							
Policy Option ID	**Policy Option Title**	**GHG Reductions**				**Costs**	
		Annual[a]		**2030 Cumulative[a]**	**2030 Cumulative[b]**	**Net Cost[c] 2015-2030**	**Cost Effectiveness[d]**
		2020 Tg	**2030 Tg**	**$TgCO_2e$**	**$TgCO_2e$**	**$Million**	**$/tCO₂e**
ES-1	Increase Renewable Energy Standards (40% goal)	1.9	6.9	63	74	-$430	-$5.8
ES-2	Efficiency Improvements, Repowering, Retirement, and Up Grades to Existing Plants	0.00	5.8	41	38	$854	$22
Total After Intra-Sector Interactions/Overlap		**1.9**	**13**	**104**	**112**	**$424**	**$3.8**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.

Figure F-1.1 ES Policies GHG Emissions Abatement, 2016-2030



Notes:
* All Policies Total's comprise emissions reductions achieved by ES-1 40% (default) policy and ES-2 policy.
** Total in and out-of-state emissions reduction are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Table F-1. 3 Macroeconomic (Indirect) Impacts of ES Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	**Gross State Product** (GSP, $2015 Millions)			**Employment** (Full & Part-Time Jobs)			**Income Earned** ($2015 Millions)		
	Year 2030[d]	**Average (2016-30)**[e]	**Cumulative (2016-2030)**[f]	**Year 2030**	**Average (2016-2030)**	**Cumulative (2016-2030)**	**Year 2030**	**Average (2016-2030)**	**Cumulative (2016-2030)**
ES-1 40% Renewables Target (Default)	$394	$177	$2,652	2,900	1,510	22,580	$311	$138	$2,075
ES-1 50% Renewables Target	$538	$228	$3,416	3,690	1,820	27,290	$434	$180	$2,695

ES-2	-$73	-$39	-$309	170	310	2,470	-$16	-$3	-$22
ES Sector (ES-1 40%) (Default)	**$319**	**$156**	**$2,336**	**3,070**	**1,670**	**25,020**	**$294**	**$137**	**$2,050**
ES Sector (ES-1 50%)	**$542**	**$239**	**$3,579**	**4,720**	**2,380**	**35,650**	**$485**	**$204**	**$3,058**

Notes:
[a] Gross State Production changes in Minnesota. Dollars expressed in $2015.
[b] Total employment changes in Minnesota.
[c] Personal Income changes in Minnesota. Dollars expressed in $2015.
[d] Single final year value. Year 2030 is the final year of analyses in this project.
[e] Average value from the year 2016 to the year 2030. The average value is calculated from the first year of the policy implementation through the year 2030 if implementation of the policy starts after year 2016.
[f] Cumulative value from 2016-2030 time period.
Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Figure AP F-1.2 – Average Annual Jobs Impact of ES Policies, Individually and in Concert

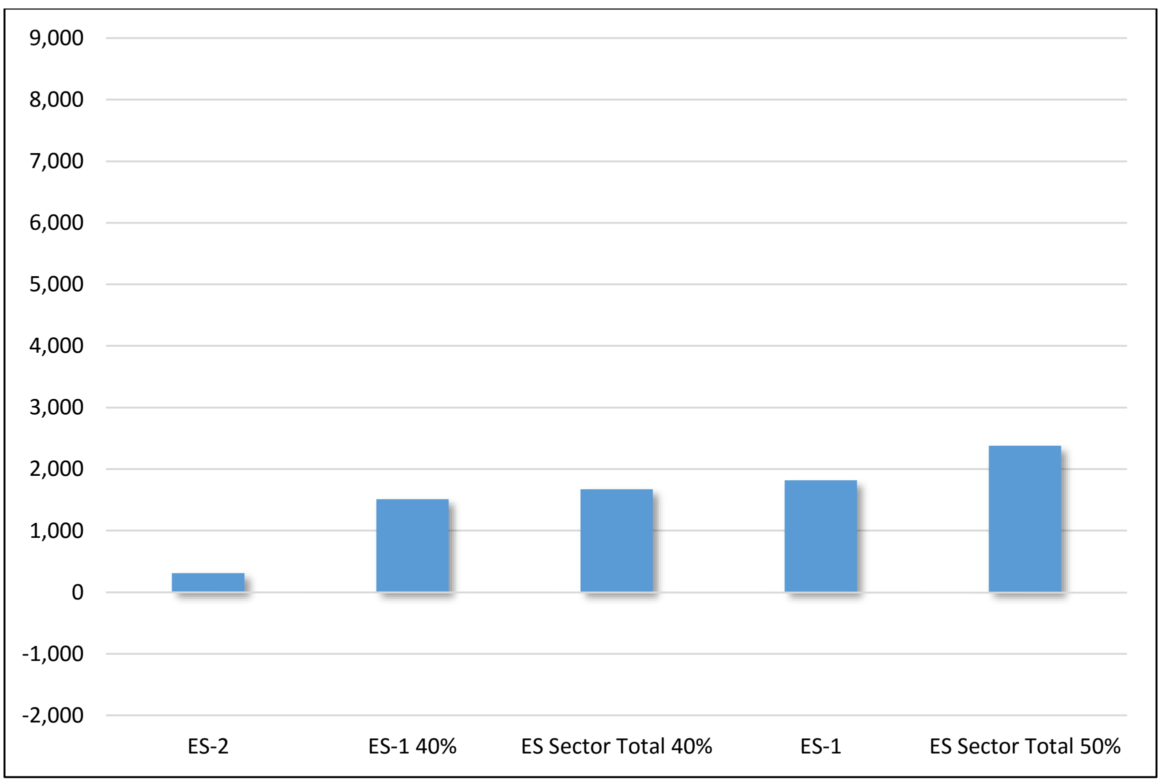
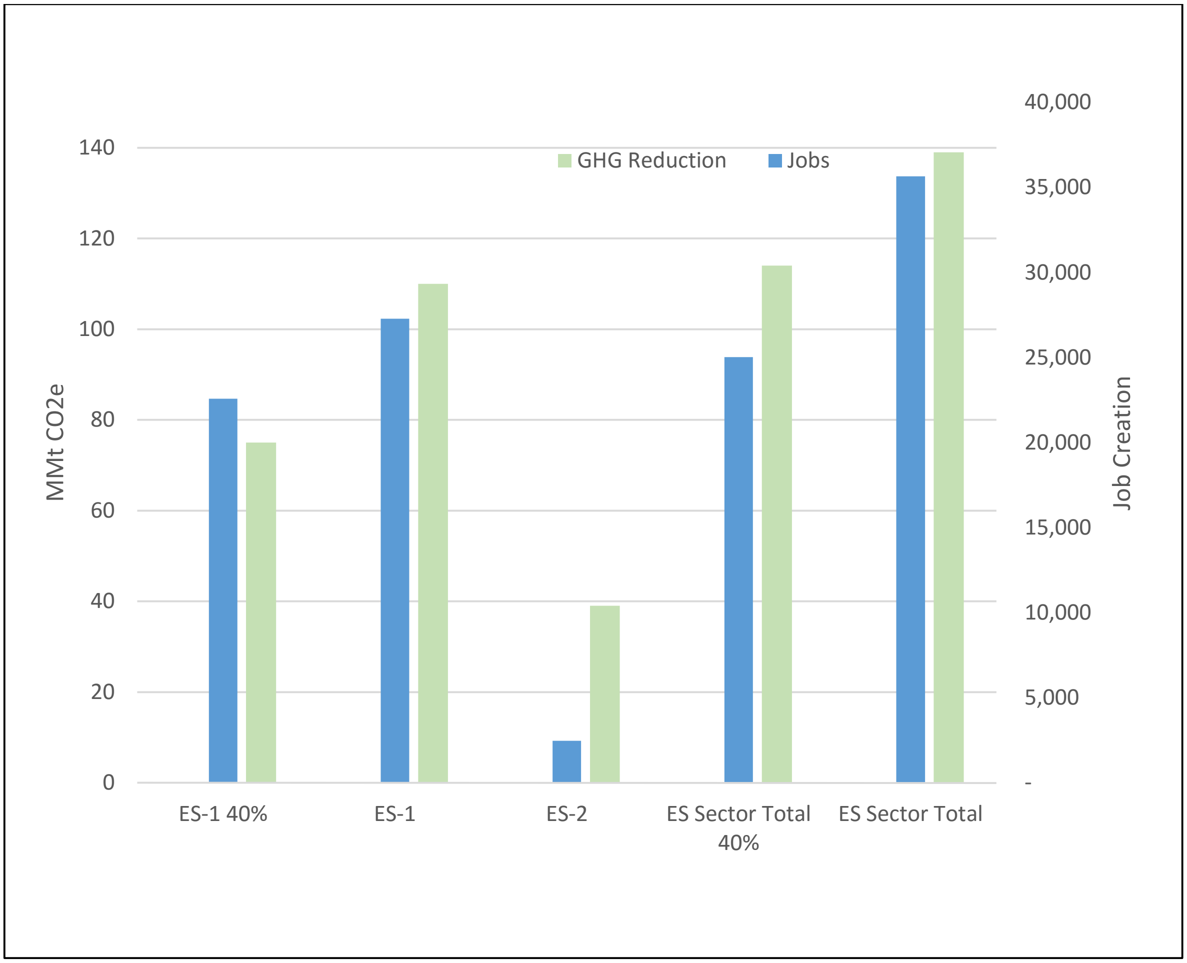


Figure F-1.3 below summarizes a potential for job creation and GHG emissions abatement of ES sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure F-1.3 ES Policies Jobs and GHG Reduction, 2016-2030



Macroeconomic index

The graph below expresses the overall economic impact from each scenario in a single score, and compares those scores. CCS created this single score (a Macroeconomic Impact Index) in order to encapsulate in one measurement the relative macroeconomic impacts (including jobs, GSP and incomes) of each policy. We have found in our own work and in the literature that indexed scores can be helpful to many readers when comparing options with multiple characteristics.

To produce this score, CCS set the results from the absolute best-case scenario (i.e. the implementation of all CSEO policies with all their optimal sensitivities in place) equal to 100, with that scenario's jobs, GSP and incomes impacts weighted equally at one third of the total score. Each policy's jobs, GSP and income impacts are scaled against that measure, and given a total score. The overall score indicates how significant a policy's impact is projected to be. Negative impacts are scaled the same way, except that those impacts are given negative scores and pull down the total score of the policy.

These scores are calculated separately for the final year of the study (2030), the *average* impact over the 2016-2030 period, and the *cumulative* impact of the policies over that period. While each scenario has one line, the relative importance of jobs, income and GSP remain visible as differently-shaded segments of that line.

Figure F-1.4 ES Macroeconomic Impacts, Final Year 2030

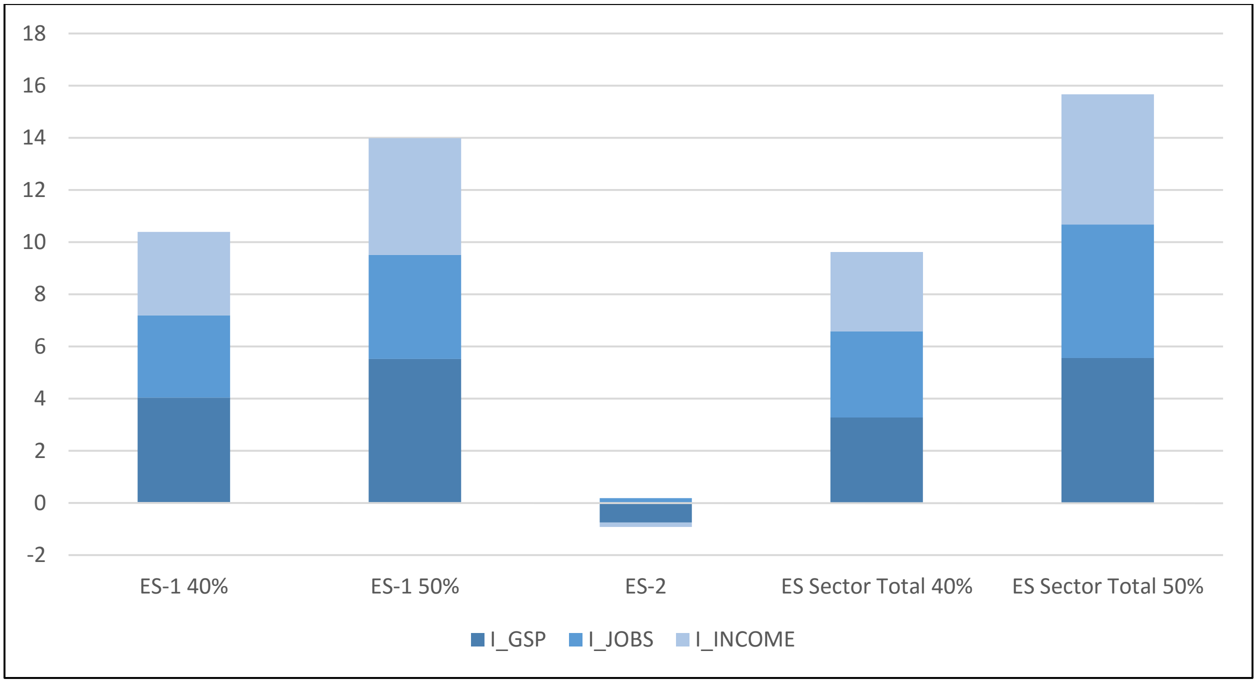


Figure F-1.5 ES Macroeconomic Impacts, 2016-2030, Yearly Average

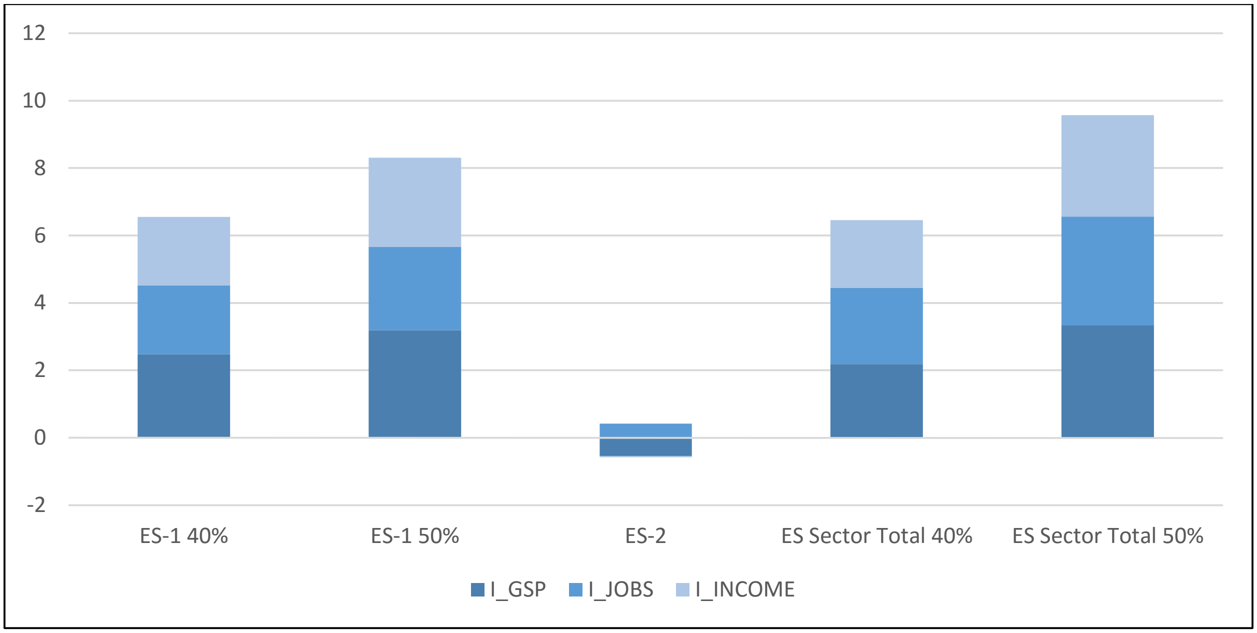
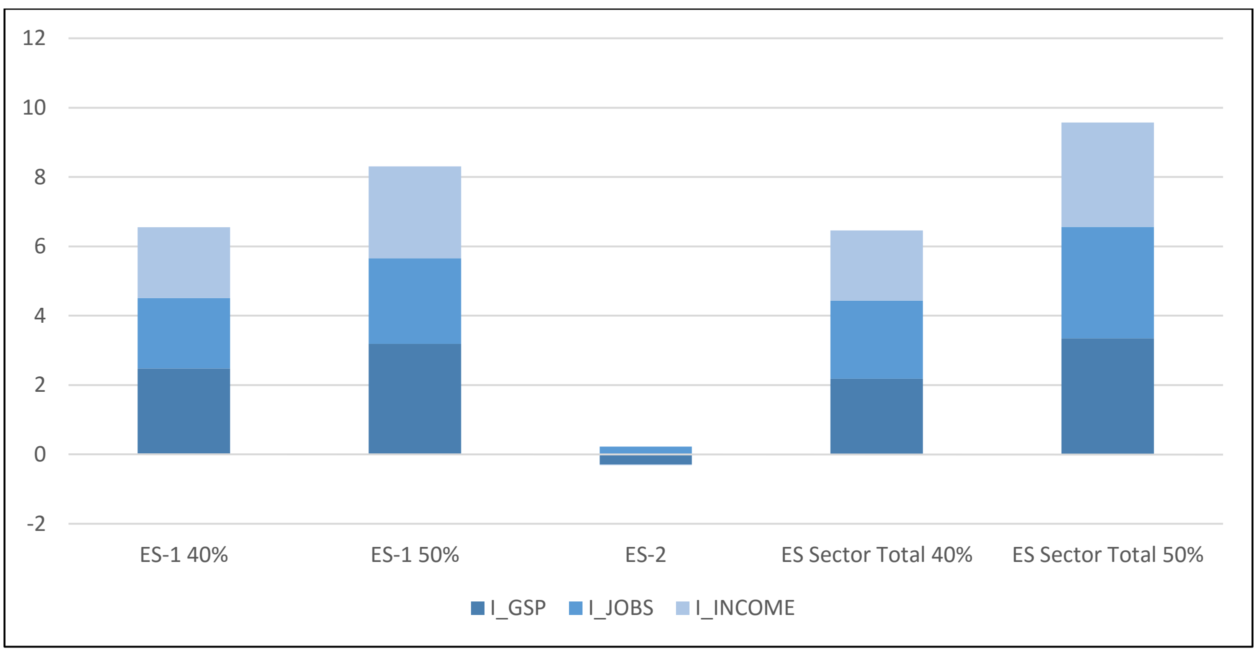


Figure F-1.6 ES Macroeconomic Impact Index, 2016-2030 Cumulative



From the line and bar graphs that follow, it is evident that the renewable energy standard (ES-1) has by far the larger impacts than the partial shut-down and partial repowering of the Sherburne County facility (ES-2). Its impact on the broader economy, driven by a cost-effective shift to renewables, generates progressively more and more economic activity (measured by

GSP) over time. New jobs appear, at a rate of between 100 and 200 per year, as a result of this growth.

The more aggressive version of ES-1, which targets the higher 50% of total energy supply from renewables, outperforms its 40% alternative as well. The fundamentals of the policy are magnified by scaling up the spending shifts involved in this policy.

ES-2, by contrast, produces a small number of new employment positions, but drives slightly negative changes to overall GSP, and to total incomes. The relative savings involved with shutting down and the cost of developing new resources balance out somewhat differently in this policy, and it does not produce the same upward pressure on the total size of the economy.

In the line graphs below, dashed lines represent chosen sensitivity scenarios. In bar graphs following, those sensitivity scenarios are presented in light colors.

Figure F-1.7 ES GSP Impacts ($2015 MM)

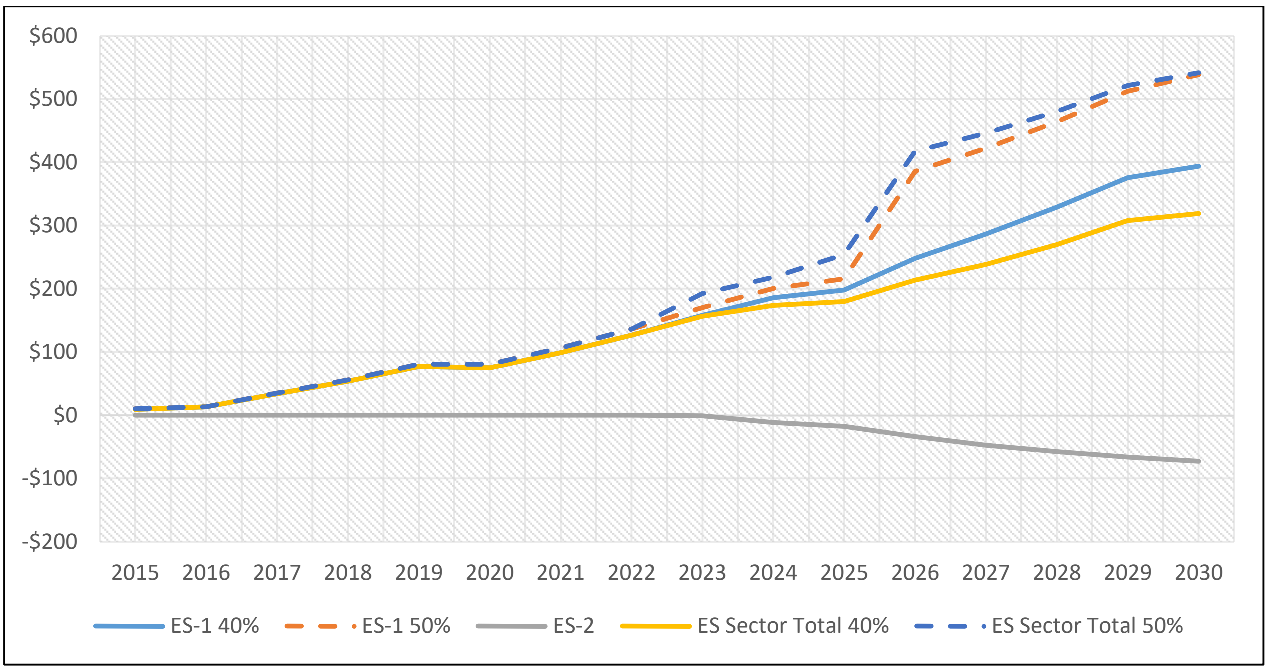


Figure F-1.8 ES Employment Impacts (Individual Jobs)

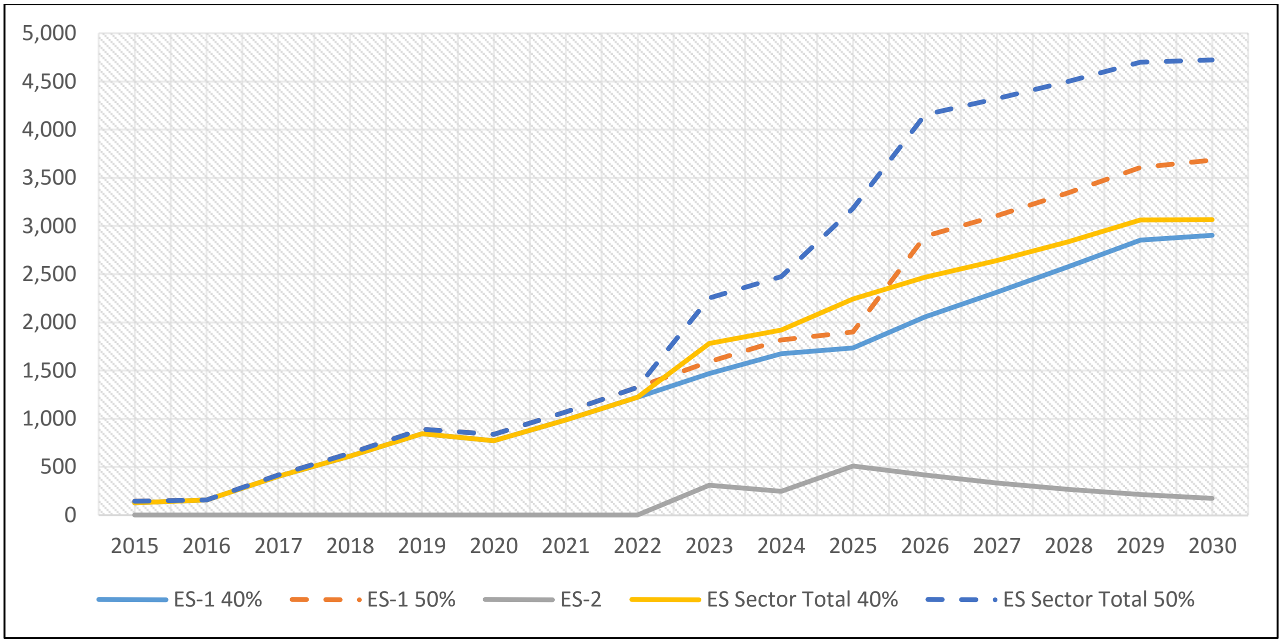


Figure F-1.9 ES Income Impacts ($2015 MM)

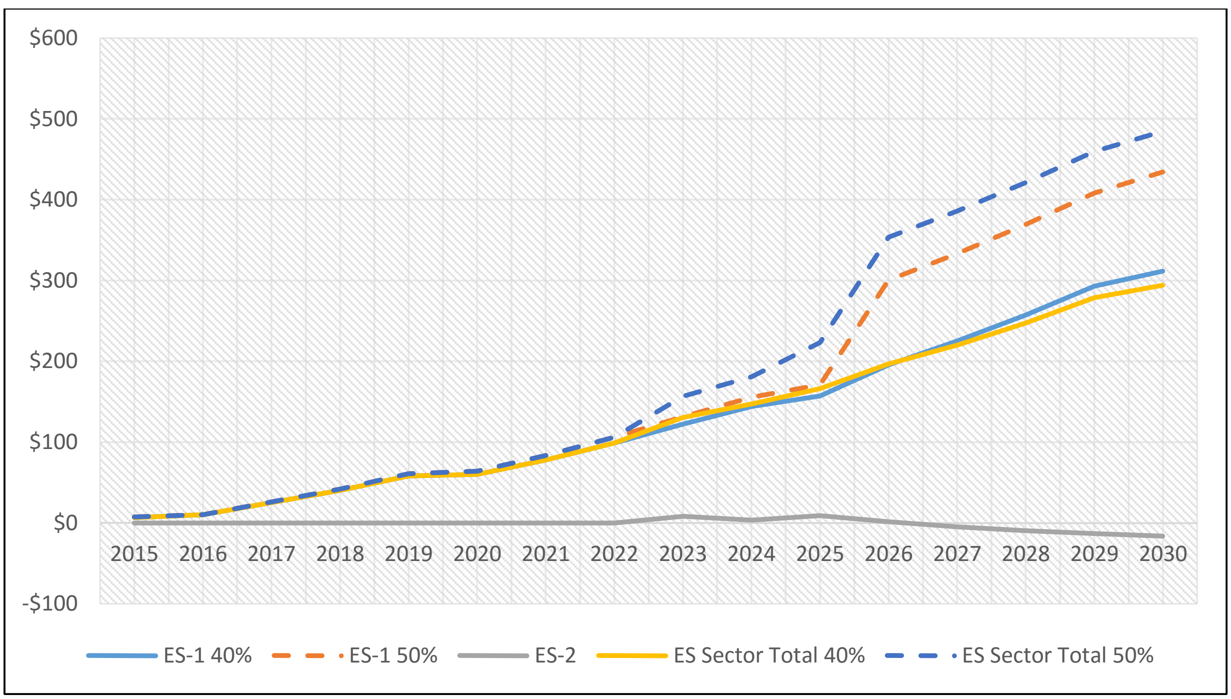


Figure F-1.10 ES GSP Impacts, 2016-2030 Average ($2015 MM)

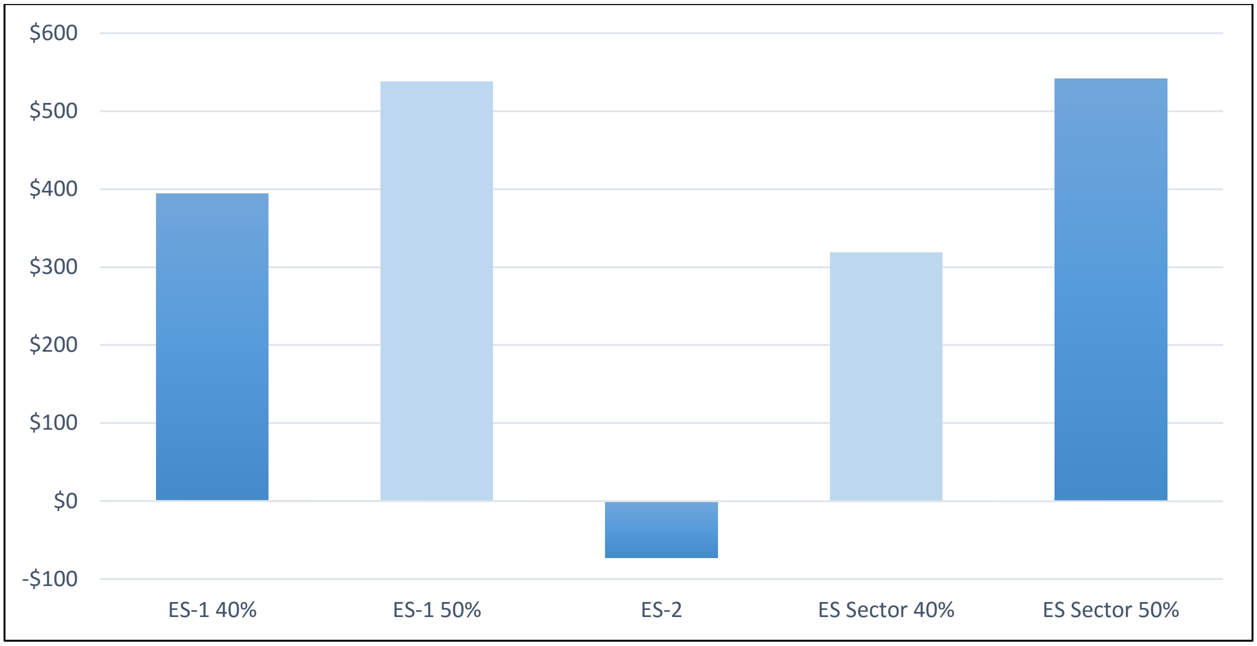


Figure F-1.11 ES GSP Impacts, 2016-2030 Cumulative ($2015 MM)

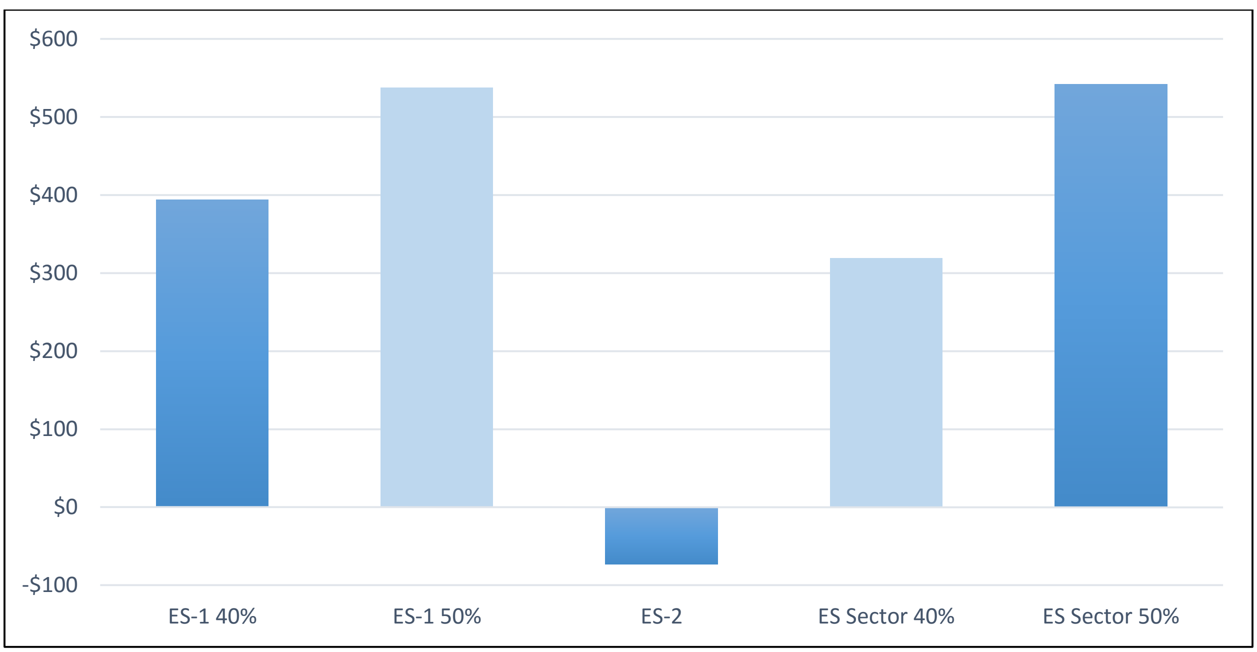
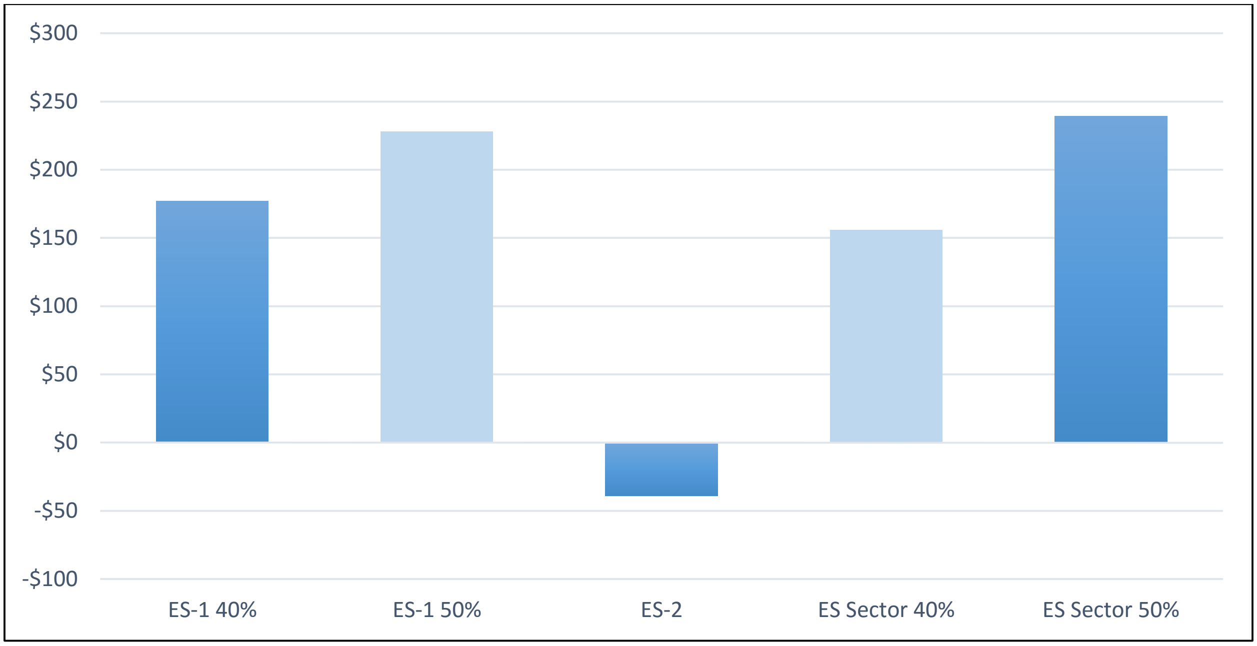
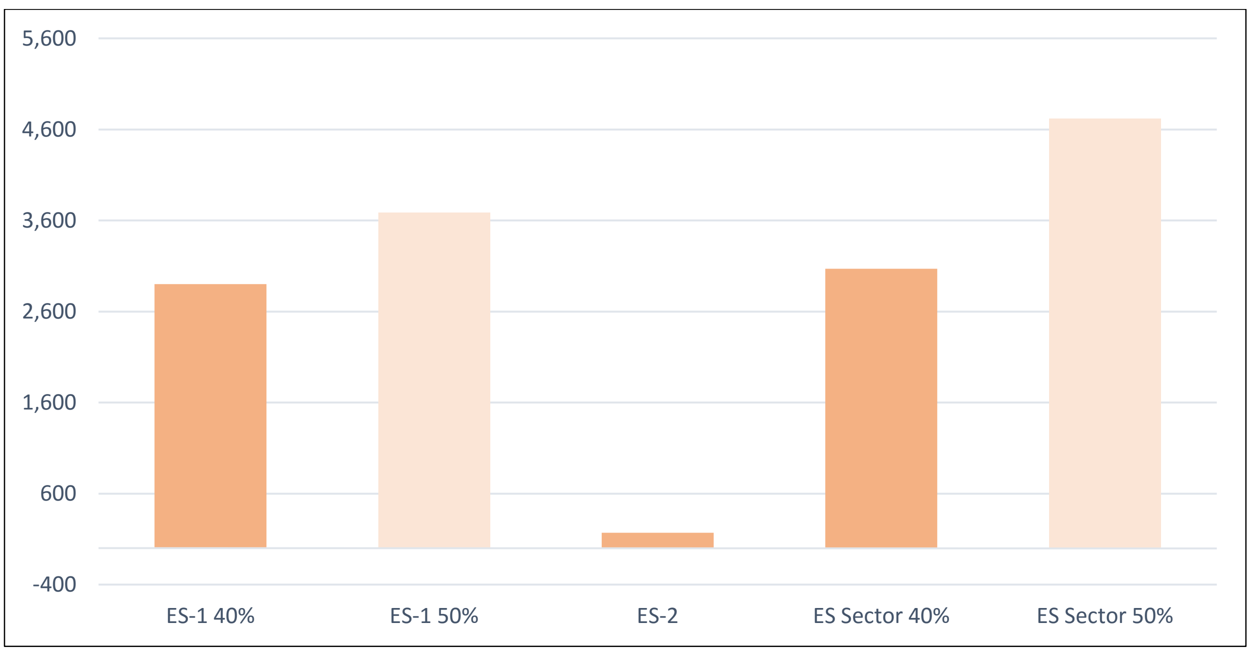


Figure F-1.12 ES GSP Impacts, Year 2030 ($2015 MM)



F-1.13 ES Employment Impacts, 2016-2030 Average (Jobs)



F-1.14 ES Employment Impacts, 2016-2030 Cumulative (Jobs)

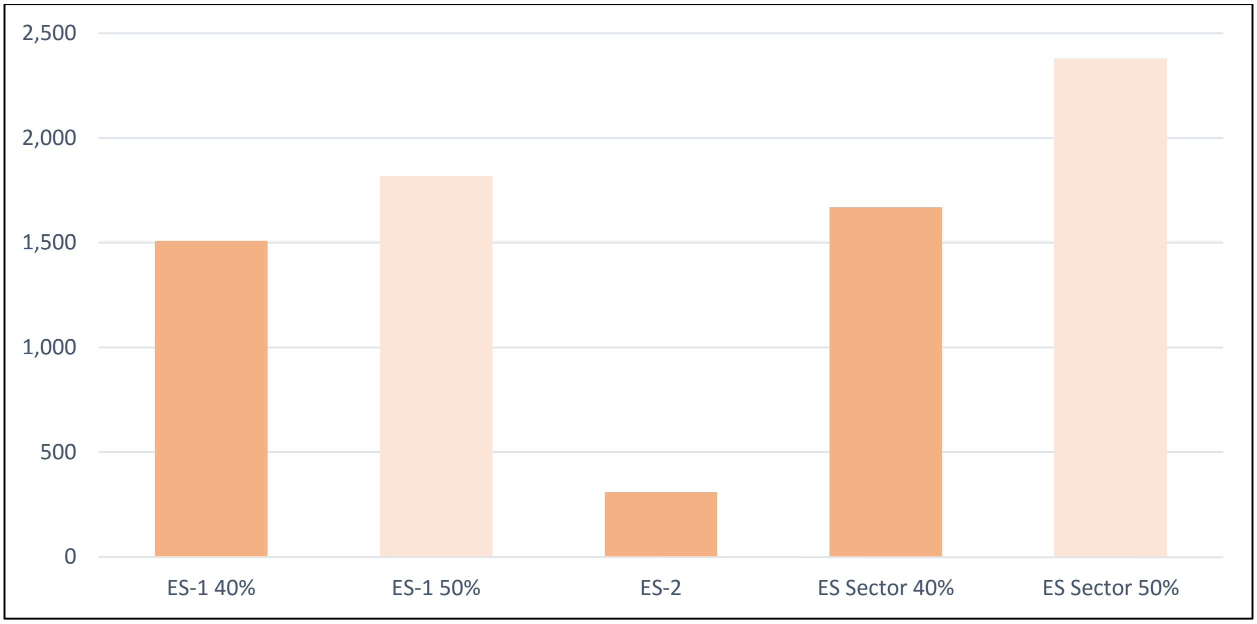


Figure F-1.15 ES Employment Impacts, Year 2030 (Jobs)

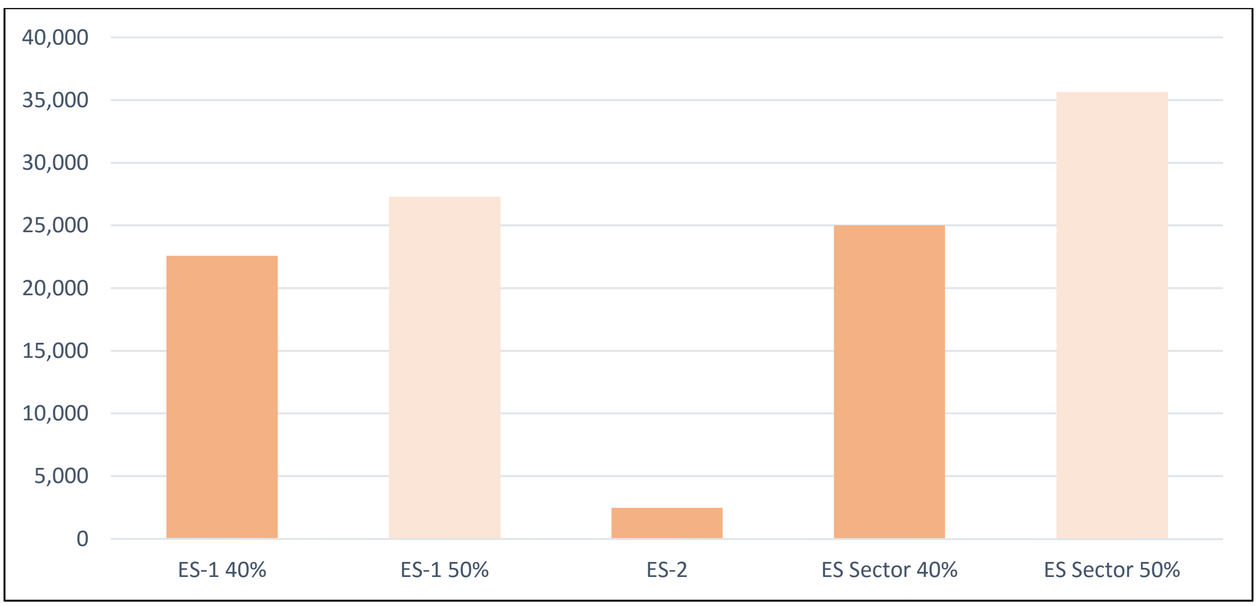


Figure F-1.16 ES Income Impacts, 2016-2030 Average ($2015 MM)

Figure F-1.17 ES Income Impacts, 2016-2030 Cumulative ($2015 MM)

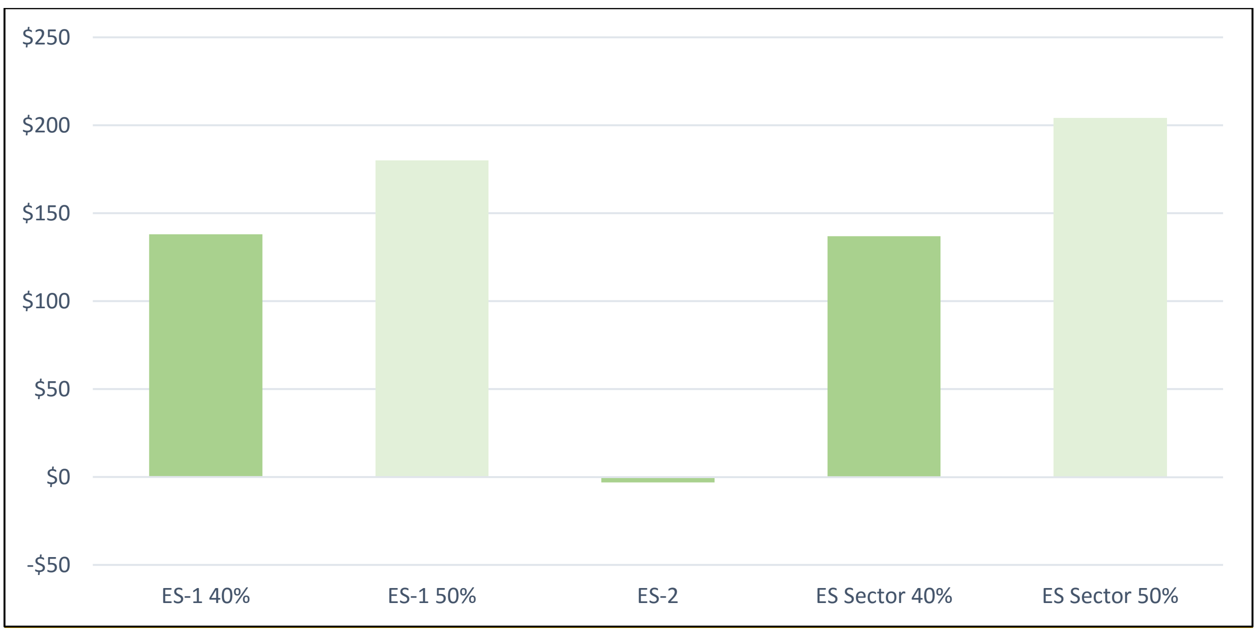
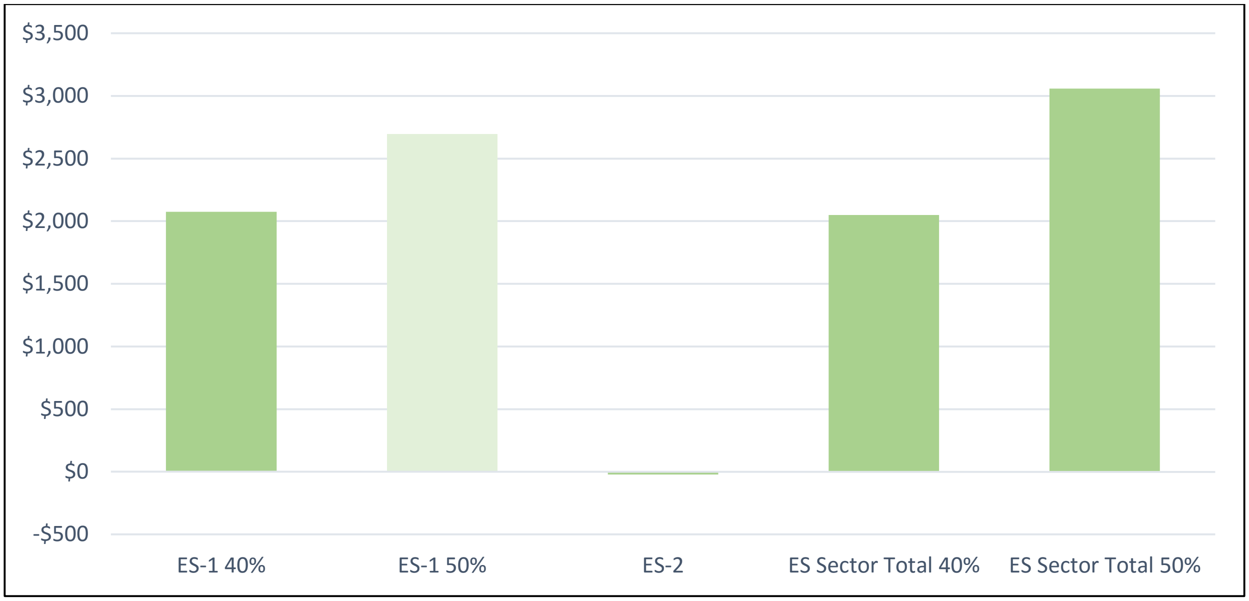


Figure F-1.18 ES Income Impacts, Year 2030 ($2015 MM)



ES-1. Increase Renewable Energy Standards

Policy Option Description

Renewable Energy Standard is a state mandate that requires different categories of electricity providers (investor-owned utilities, publically owned municipal utilities and cooperatives) to source certain amount of electricity they produce, or purchase, from eligible renewable energy technologies. Legislation passed in 2013 supports the investigation of higher levels of renewable energy use in Minnesota, starting with increasing the Renewable Electricity Standard to 40% by 2030, and to higher proportions thereafter (Minnesota Laws 2013, Chapter 85 HF 729, Article 12, Sections 1, 4, and 7). State legislation also sets the goal that by 2030, 10% of the retail electric sales in Minnesota be generated by solar energy (Minnesota Stat. §216B.1691). This policy option aims to expand RES to 40% by 2030. A 50% RES was also evaluated.

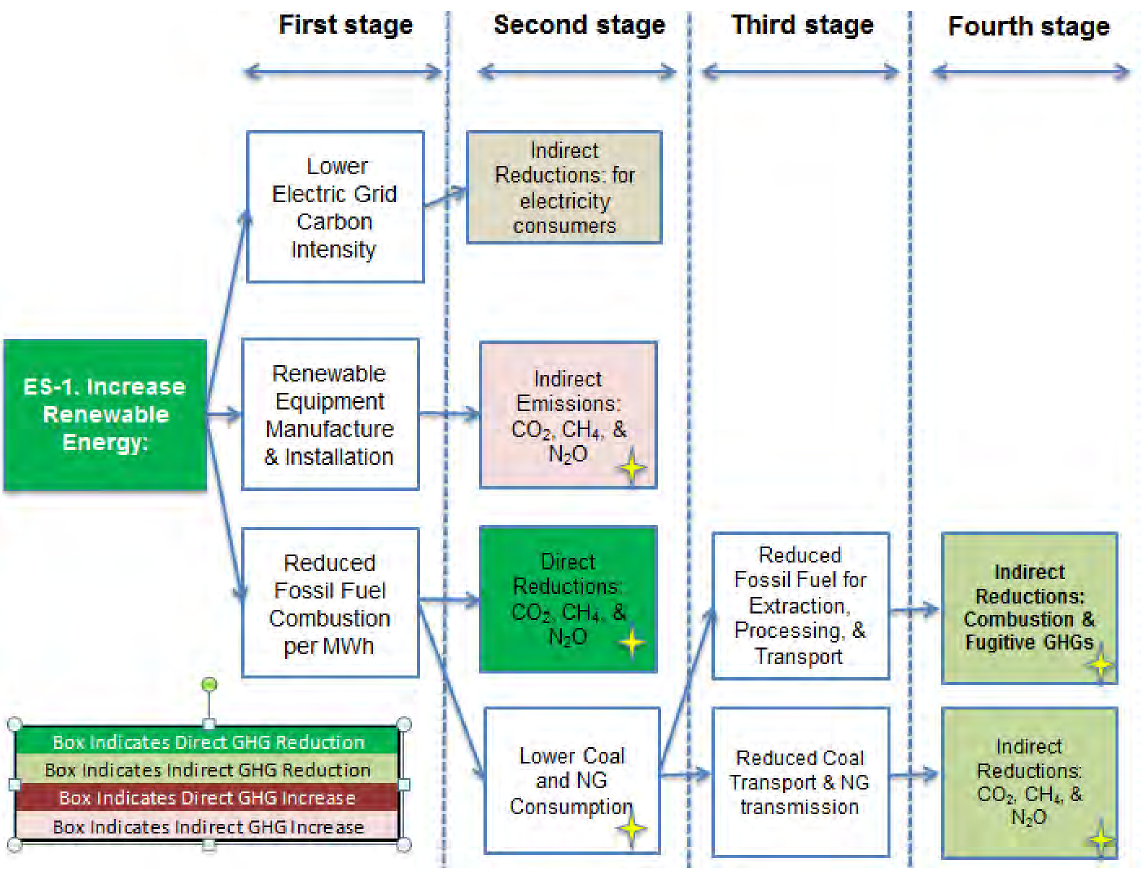
Causal Chain for GHG Reductions

The diagram below illustrates how the policy option leads to GHG reductions.

- "First Stage" refers to the direct physical impacts of the policy option, namely a lower CO_2e intensity of the electric system, increased manufacture of renewable systems, and lower fossil fuel use for every MWh of electricity produced;

- "Second Stage" refers to indirect physical impacts of the policy option, namely GHG reductions allocated to consumers, GHG increases associated with increased renewable manufacturer activity, and lower absolute levels of GHGs and primary energy;
- "Third Stage" refers to reductions in direct upstream GHGs and fossil fuel use; and
- "Fourth Stage" refers to indirect upstream GHGs and fossil fuel use.

Figure F-1.19 Causal Chain for ES-1 GHG Reductions



Policy Option Design

Goals: Model the GHG impacts of increasing the Renewable electricity standard to:

- Forty percent by 2030 – (modeling assumptions: 31% wind + 3% hydro + 3% biomass combined heat and power (CHP) + 3% solar)
- Fifty percent by 2030 – (modeling assumptions: 34% wind + 3% hydro + 3% biomass CHP + 10% solar)
- Goals are stated as a percent of annual Minnesota retail electricity sales (representing total contribution and not 'new' or 'incremental').

Note: Large industrial ratepayers are exempted from the current Solar Electricity Standard (216B.1691, Subd 2f. (d)), but as the specifics of the exemption were in progress at the time this policy option was developed, for the purpose of modeling the proposed goals these ratepayers were included in calculations of retail sales.

Timing: Current standards are ~28.5% by 2025:

- Thirty percent by 2020 for Xcel,
- Twenty-five percent x 2025 for all other utilities, and
- 1.5% additional Solar Electricity standard for Investor Owned Utilities (this works out to ~1% of Minnesota total retail sales)

Parties Involved: This requirement would apply to all retail electricity sales in Minnesota. Implementation of this policy option would require the enactment of enabling legislation and subsequent regulation by the Public Utility Commission (PUC). Affected parties include ratepayers, utilities, transmission owners, power producers, renewable energy providers (in Minnesota and neighboring states), and the Midwest Independent Transmission System Operator (MISO).

Entities subject to RES Statute[1]:

- Basin Electric Power Cooperative
- Central Minnesota Municipal Power Agency (CMMPA)
- Dairyland Power Cooperative
- East River Electric Cooperative
- Great River Energy (GRE)
- Heartland Consumer Power District
- Interstate Power and Light
- L&O Power Cooperative
- Minnkota Power Cooperative
- Minnesota Municipal Power Agency (MMPA)
- Minnesota Power
- Missouri River Energy Services
- Northwestern Wisconsin Electric Company
- Ottertail Power Company
- Southern Minnesota Municipal Power Agency (SMMPA)

1 In the Matter of Detailing Criteria and Standards for Measuring an Electric Utility's Good Faith Efforts in Meeting the Renewable Energy Objectives Under Minn. Stat. §216B.1691, Docket No. E999/CI-03-869, Order Setting Filing Requirements and Clarifying Procedures, (November 12, 2008).

- Xcel Energy

Note: Large industrial ratepayers are exempted from the current solar electricity standard (216B.1691, Subd 2f. (d)), but as the specifics of the exemption were in progress at the time this policy option was developed, for the purpose of modeling the proposed goals, these ratepayers were included in calculations of retail sales.

Other: Renewable Energy Credits used for compliance have a four year shelf life.

Implementation Mechanisms

Regulatory Framework: Regulatory framework for wind, solar and hydro based on existing statute (Minnesota Statute 216B.1691) and PUC orders

Relevant PUC dockets/orders:

- Docket No. E-999/M-08-1163, In the Matter of Commission Consideration and Determination on Compliance with Renewable Energy Obligations and Renewable Energy Standards,
- E-999/CI-04-1616, In the Matter of a Commission Investigation into a Multi-State Tracking and Trading Systems for Renewable Energy Credits
- Docket No. 14-12 / E999/PR-14-237, In the Matter of Commission Consideration and Determination on Compliance with Renewable Energy Standards
- Docket No. 13-542 – In the Matter of the Implementation of Solar Energy Standards Pursuit to 2013 Amendments to Minnesota Statutes, Section. 216B.2691
- Docket No. 11-852 - In the Matter of Utility Renewable Energy Cost Impact Reports Required by Minnesota Statutes Section 216B.1691, Subd. 2e

Table F-1.4 RES Milestones

	Minnesota Utilities Milestone	Xcel Milestone
2010	7.0%	15.0%
2012	12.0%	18.0%
2016	17.0%	25.0%
2020	20.5%	31.5%
2025	25.5%	31.5%

Related Policies/Programs in Place and Recent Actions

Minnesota Renewable Energy Integration and Transmission Study (MRITS) - Legislation passed in 2013 required an engineering study of increasing the state's Renewable Energy Standards

(RES) to 40% by 2030, and to higher proportions thereafter, while maintaining system reliability. The study must incorporate and build upon prior study work.

The study was conducted by Minnesota utilities and transmission companies in coordination with MISO and directed by the Minnesota Department of Commerce. Review and input was provided by a Technical Review Committee (TRC) comprised of engineers with expertise in electric transmission system engineering, electric power system operations, and renewable energy generation technology.

The study was Minnesota centric with a study area focused on Minnesota within the MISO footprint and adjoining neighboring regions of the Integrated System (IS – Basin & WAPA) and Manitoba Hydro (MH).

The engineers conducted three analyses:

- The development of a conceptual transmission plan.
- The evaluation of the power system over one year, hour-by-hour to understand operational impacts.
- The overall system strength and stability of the region power system.

Study scenarios for MRITS:

- Baseline: 28.5% of Minnesota Retail sales in 2028 from wind/solar (current Minnesota RES & SES) with 13% MISO in 2028 from wind/solar (current MISO state RESs)
- S1: 40% of Minnesota retail sales in 2028 from wind/solar; with 15% MISO in 2028 from wind/solar (current non-Minnesota RESs + Minnesota @40%)
- S2: 50% of Minnesota retail sales in 2028 from wind/solar; with 25% MISO in 2028 from wind/solar

The final study completed November 1, 2014 included: 1) A conceptual plan for transmission for generation interconnection and delivery and for access to regional geographic diversity and regional supply and demand side flexibility, and 2) Identification and development of potential solutions to any critical issues encountered.

The results from the study show that the addition of wind and solar generation to supply 40% of Minnesota's annual electric retail sales can be reliably accommodated by the electric power system.

Additional analysis would need to be done for adding renewables at levels significantly higher than 40%.

Note: Modeling assumptions for the Minnesota Renewable Energy Integration and Transmission Study differ from those assumptions used in the CSEO modeling (e.g. total load, energy consumption, siting, and percent wind and PV)

Estimated Policy Impacts

Direct Policy Impacts

Table F-1.5 ES-1 Estimated Net GHG Reductions and Net Costs or Savings

Scenario	2030 In-State GHG Reductions (Tg CO_2e)	2015 – 2030 Cumulative In-State Reductions (Tg CO_2e)	Net present Value of Societal Costs, 2015 – 2030 (MM $2014)	Cost Effectiveness ($2014/ ton CO_2e)	Net Discounted Incremental Cost $2014/kWh
40% Scenario	7.5	67	-$620	-$8.2	-$0.00052
50% Scenario	13	98	-$404	-$3.7	-$0.00034

Data Sources

- Common Forecast assumptions spreadsheet developed for the Minnesota CSEO project by Steve Roe
- Electric system assumptions: final version of the power sector forecast prepared by the Pollution Control Agency.
- Utility RES compliance reporting data in docket 14-12
- Generator data from the Midwest Renewable Energy Tracking System.
- Siler-Evans et al "Marginal Emissions Factors for the U.S. Electricity System," 2012
- Final Report - 2006 Minnesota Wind Integration Study Volume I[2]
- Wind, solar PV and NGCC cost and performance assumptions from Lazard's Levelized Cost of Energy Analysis – Version 8.0[3] (*Note: levelized costs in Lazard v. 8.0 did not assume extension of the PTC or ITC).*
- For Biomass CHP, cost and performance assumptions are for commercial and industrial facilities as per the RCII-1 analysis, i.e., RCII-1_for_review_3-19-2015.xlsx. Note that heat rate for biomass CHP plants are in reference to electric generation efficiency only
- Sensitivities: there were several sensitivities that were run for the 40% and 50% scenarios. These are as follows:
    - CO_2e emission intensity of resources on the margin: these were considered for a) point-of-generation (i.e., in-state), b) upstream (i.e., out-of-state), and c) total (i.e., point-of-generation plus upstream. The default assumption was total.

[2] http://www.uwig.org/windrpt_vol%201.pdf
[3] https://www.lazard.com/media/1777/levelized_cost_of_energy_-_version_80.pdf

  - Retail electricity sales: these were considered as a) benchmarked to the statute in 2020 and 2025 and b) relative to a 2% reduction in projected retail electricity sales. The default assumption was benchmarked to the statute in 2020 and 2025.
  - Costs of resources on the margin: these were considered as a) energy and capacity and b) energy only. The default assumption was energy and capacity.
  - Cost & performance options for new units: these were considered as from a) Lazard (low end of range), b) EIA's AEO2014, and c) user-defined. The default assumption was Lazard (low end of range)

Quantification Methods

Using the assumptions below regarding resources on the electric margin, a spreadsheet analysis was undertaken using the methods summarized in the bullets below:

- Incremental renewable energy generation over and above the levels in the BAU were developed over the period 2015-2030 and costed using real levelized assumptions.
- Annual decreases in marginal generation levels due to the penetration of renewable generation was calculated on the basis of the margin assumptions below.
- The avoided CO_2e emissions associated with process heat from biomass CHP facilities was calculated on the basis of the same estimates that were developed for industrial and commercial facilities analyzed in the RCII-1 policy option.
- The annual net amounts of CO_2e emissions and costs for each of the above categories was calculated and discounted using a 5% real discount rate.
- Avoided emissions costs were not calculated due to uncertainty in the valuation method for proposed regulation.
- Cost of new transmission to deliver increased levels of renewable energy were not calculated in the CSEO model due to uncertainty in assigning such costs to renewables, which vary considerably from project to project.[4]
- Indirect costs and emissions of ancillary services were not calculated due to uncertainty in assessing the portion on ancillary services attributable to renewable energy

[4] While renewable energy can be a driver for new transmission investment, transmission improvements are long-term investments that are made for a variety of reasons with multiple benefits from reduced congestion, improved reliability, and economics. Allocation of a specific percentage of the cost of transmission investments to a general increment of renewable generation can be contentious without adequate documentation. Note: in the recent MRITS study, costs of a conceptual transmission plan for similar levels of renewables were identified (the modeling assumptions used in MRITS differ from those assumptions used in the CSEO modeling (e.g. total load, energy consumption, siting, and % wind and PV). MRITS modeled higher levels of variable renewables with 40 and 50% from wind and solar only. CSEO includes biomass and hydro in the 40 and 50% modeling.

compared to the ancillary services needed to support conventional generation that that would be offset by additional renewable generation.[5]

Key Assumptions

- *Marginal resource ratios for energy and emissions:* A key assumption concerned the resources on the electric margin that would be displaced by incremental renewable generation. These assumptions are outlined in the following bullet.
    - Siler-Evans et al "Marginal Emissions Factors for the U.S. Electricity System," April 2012 and "Regional variations in the health, environmental, and climate benefits of wind and solar generation," July 2013 were two sources used to estimate marginal resources. The Siler-Evens et al analyses provide regional estimates of the share of generation resource on the margin based on hourly gross power output data over the 2006-2011 time period from the Continuous Emissions Monitoring System (CEMS).
    - With increasing coal retirements and natural gas plant installations, the coal fraction is expected to decrease as the marginal resource over the CSEO modeling period from 2014 – 2030. Marginal resource fractions in 2014 are based on estimates from Siler-Evans et al and then extrapolated linearly out to 2030 using an assumed marginal resource blend displaced by incremental renewable generation.
    - The marginal resource being displaced by wind energy was assumed to be 80%Coal/20%Gas in 2011 and trending linearly to 50%Coal/50%Gas in 2030. The 2011 ratio is supported by a marginal emissions factor of 830 kg CO2/MWh from Siler-Evans et al 2013 estimation[6]and comparison with the Marginal resource mix from Siler-Evans et al 2012 work[7].
    - The marginal resource being displaced by solar photovoltaic energy was assumed to be 60%Coal/40%Gas in 2011 trending linearly to 40%Coal/60%Gas in 2030. The 2011 ratio is supported by a marginal emissions factor of 780 kg CO2/MWh from Siler-Evans et al 2013 estimation and comparison with the Marginal resource mix during daylight hours from Siler-Evans et al 2012 work.
    - The marginal resource being displaced by biomass CHP energy was assumed to be 80%Coal/20%Gas in 2011 and trending linearly to 50%Coal/50%Gas in 2030.

[5] If ancillary service cost is calculated for renewables, then it will also need to be calculated for other technologies displaced by renewable energy. Furthermore, large coal plants are a driver of contingency reserves on the bulk electric grid, but MISO has confirmed that dispersed generation such as wind does not require contingency reserves.

[6] Siler-Evans et al, Regional variations in the health, environmental, and climate benefits of wind and solar generation, July 2013. The data for this work is on the Carnegie Mellon website: http://cedmcenter.org/tools-for-cedm/marginal-emissions-factors-repository/)

[7] Siler-Evans et al, Marginal Emissions Factors for the U.S. Electricity System, April 2012. The data for this work is on the Carnegie Mellon website: http://cedmcenter.org/tools-for-cedm/marginal-emissions-factors-repository/)

The 2011 ratio is supported by the average (across all hours) over the 2006 – 2011 period of the marginal emissions fractions for the MRO region provided by Siler-Evans et. al. (2012).

- *Capacity factor for natural gas combined cycle units:* The CSEO modeling assumes a capacity factor of 40% for new and existing natural gas combined cycle (NGCC) units for the modeling period (2015-2030). The 40% assumption is based on the upper range of capacity factors observed in state Strategist modeling and is considerably lower than the EPA's expectations set in the final version of the Clean Power Plan. Under EPA's performance rate-setting methodology, building block 2 gradually shifts, over the entire interim period, fossil steam generation from coal-fired to the existing NGCC units until their proposed maximum capacity factor reaches 75% in all the regions. The reason for these differences lies in the fact that Midwestern states, with significant coal and renewable generation, use their NGCC units primarily to balance load during peak daytime hours, especially in the summer. Wind turbines have no fuel cost and no emissions so they are more economical to operate compared natural gas or coal. As a result, NGCC units in the Midwest are dispatched to a much lesser degree than in states with high penetration of natural gas generation. Minnesota ranks seventh in the nation for both wind energy capacity installed and wind electricity generation, and over 15% of its net electricity generation in 2013 was supplied by wind turbines. Therefore, Minnesota authorities are expecting to meet federal requirements relying more on renewable energy than on generation shift among existing affected energy generation units. Flexibility to do so is corroborated by EPA's note that the proposed 75% capacity factor for NGCC is subject to regional limits informed by historical growth rates.
- *Avoided cost of energy:* The avoided cost of energy from coal, natural gas combustion turbine (NGCT), NGCC, and oil-fired units accounted for real escalation in fuel prices as well as fixed and variable O&M costs. For avoided energy costs and emissions, the CSEO analysis assumes a capacity *value* of 45% for wind and 20% for solar.[8]
- *Avoided cost of capacity:* This analysis used the low-end range of levelized cost of energy (LCOE) numbers published in Lazard's Levelized Cost of Energy Analysis – Version 8.0.[9] Lazard's analysis breaks down the LCOE numbers by region for resource dependent variable generation like wind and solar instead of just giving a wide national range and the low end of the range is closer to the prices observed in the Midwest. In calculating the avoided cost, efficiency measures, new wind, and solar will displace/delay the need for new natural gas CC & CT units. For the avoided cost of new capacity, the analysis

[8] Capacity factor is a simple measure of the total annual energy production relative to nameplate. =(Annual energy production in MWh/yr) / (nameplate capacity in MW) / (8760 hours/yr)
[9] https://www.lazard.com/media/1777/levelized_cost_of_energy_-_version_80.pdf

uses a capacity *credit* of 14% for wind and 45% for solar[10]. *Note: levelized costs in Lazard v. 8.0 did not assume extension of the PTC or ITC.*

- *Generation siting in-state vs out-of-state:* Under the statute governing Minnesota's RES, renewable generation at eligible renewable capacity located in any of the MRETs states may be used to generate RECs for compliance purposes. For the modeling here to simulate the RES, for both the business as usual case and the increased RES scenarios, we are including generation that counts toward the Minnesota RES even if it is sited out-of-state. [Note: Under the MPCA's reporting framework for Next Generation Energy Act goals, renewable energy generation that occurs outside of Minnesota, whether earning Minnesota RECs or not, does not figure in emissions (or emissions-avoided) calculations.]
- *Policy option model interactions:* Increased efficiency on the demand-side will amplify the effect of existing renewable generation resources but it will also reduce the need for new capacity from renewable or fossil resources. Additional CHP capacity may have the effect of reducing electric demand if it is in must-run mode. Although it is a supply-side resource, its effect on the operation and dispatch of other resources in the region may be similar to demand-side efficiency.
- *Out-of-state renewable generation:* The assumed BAU out-of-state renewable generation shares of retail sales was 8.8% in 2020, 5.6% in 2025, and 5.2% in 2030.

Macroeconomic (Indirect) Policy Impacts

Table F-1.6 below provides a summary of the expected impacts on jobs and economic growth during the CSEO planning period.

Table F-1.6 ES-1 Macroeconomic Summary Impacts on GSP, Employment and Income

Scenario	**Gross State Product** (GSP, $2015 Millions)			**Employment** (Full & Part-Time Jobs)			**Income Earned** ($2015 Millions)		
	Year 2030	**Average (2016-2030)**	**Cumulative (2016-2030)**	**Year 2030**	**Average (2016-2030)**	**Cumulative (2016-2030)**	**Year 2030**	**Average (2016-2030)**	**Cumulative (2016-2030)**
ES-1 40% Renewables Target (Default)	$390	$180	$2,650	2,900	1,510	22,580	$310	$140	$2,080

[10] Capacity value (a.k.a capacity credit or Effective Load Carrying Capability (ELCC)) is a statistical measure of the ability of a generation resource to maintain a reliable system and meet demand. Essentially this is the amount of capacity output, relative to nameplate, that is coincident with peak system load.

Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	**Average (2016-2030)**	**Cumulative (2016-2030)**	**Year 2030**	**Average (2016-2030)**	**Cumulative (2016-2030)**	**Year 2030**	**Average (2016-2030)**	**Cumulative (2016-2030)**
ES-1 50% Renewables Target	$540	$230	$3,420	3,690	1,820	27,290	$430	$180	$2,700

The following three graphs illustrate a trend in annual impacts of ES-1 policy (both default and 50% sensitivity scenario, which is presented by dashed line) on GSP, total personal income and employment in the state of Minnesota. Annual fluctuations can be seen. It is evident from those illustrations that ES-1 50% sensitivity scenario has a superior performance against all three macroeconomic parameters then the default, ES-1 40% policy.

Figure F-1.20 ES-1 GSP Impacts ($2015 MM)

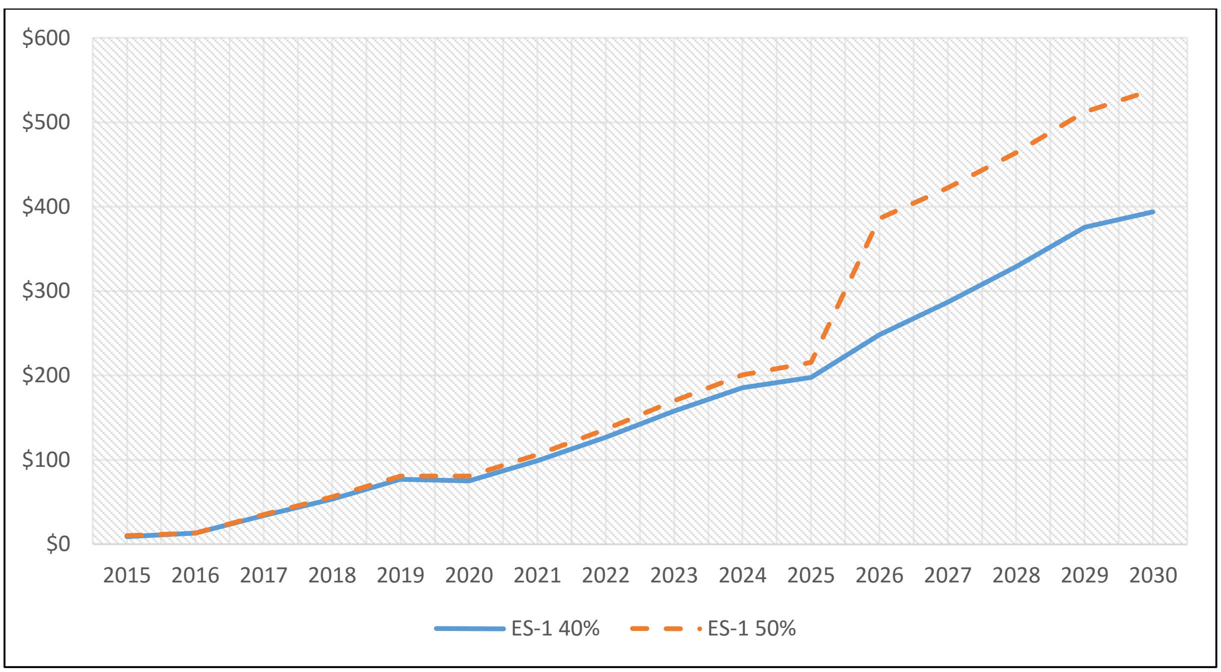


Figure F-1. 21 ES-1 Employment Impacts (Individual Jobs)

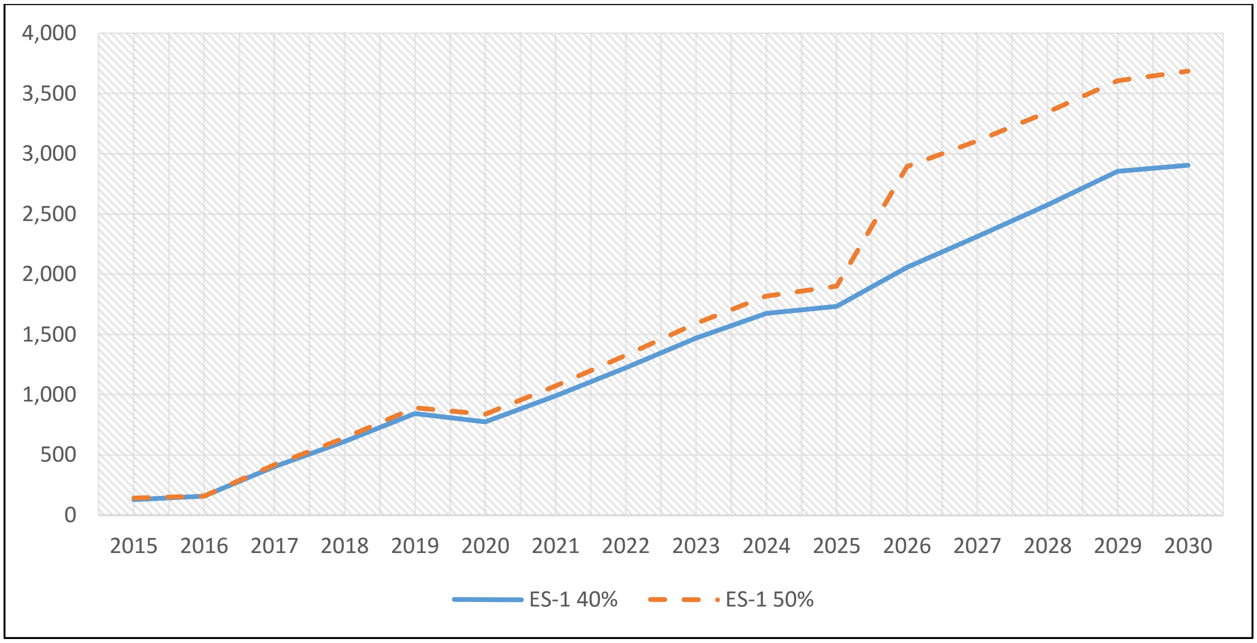
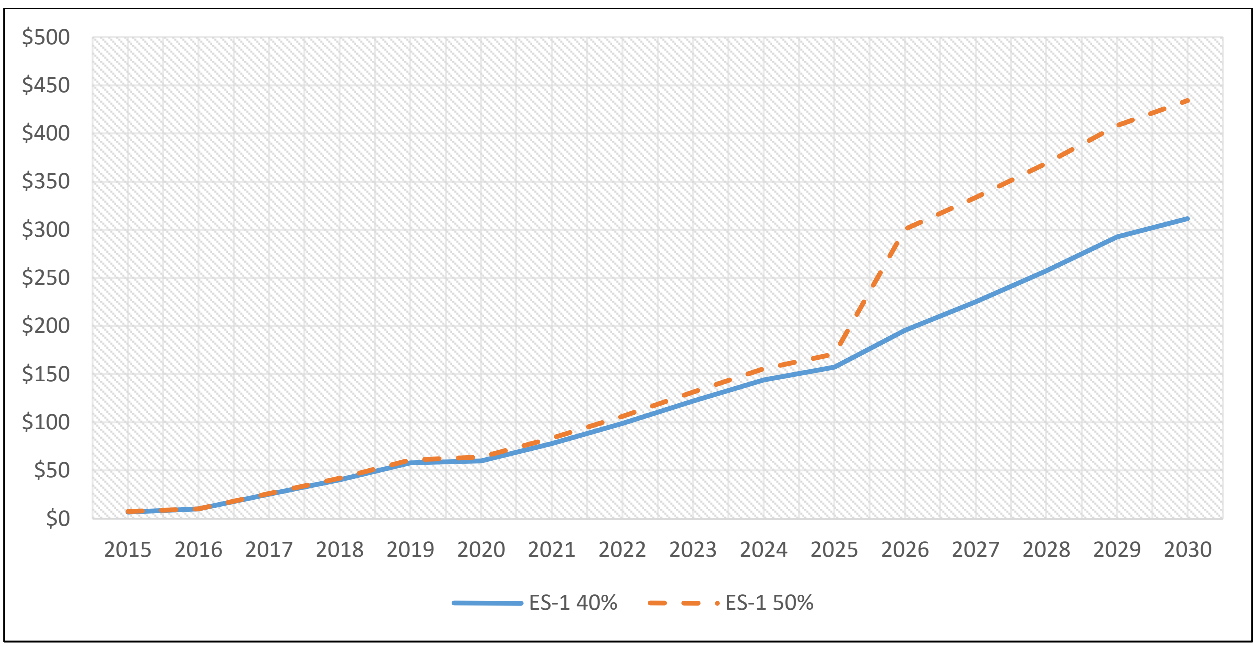
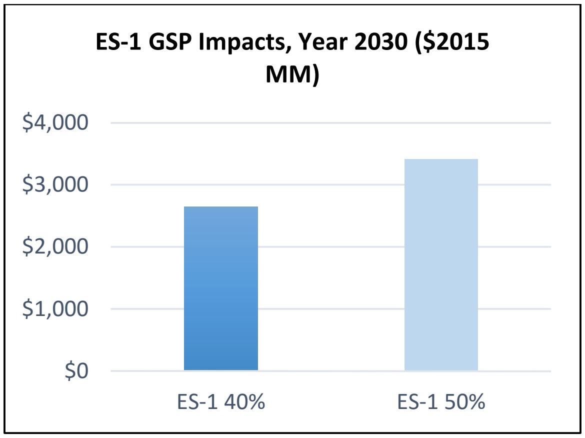
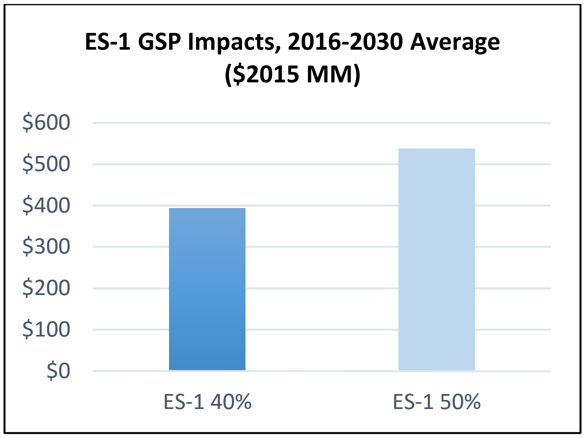


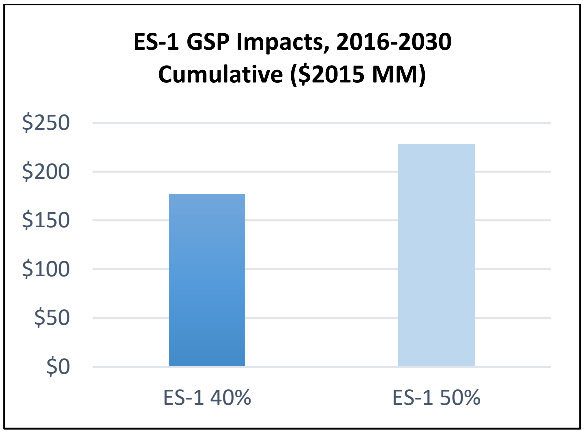
Figure F-22. 21 ES-1 Income Impacts ($2015 MM)

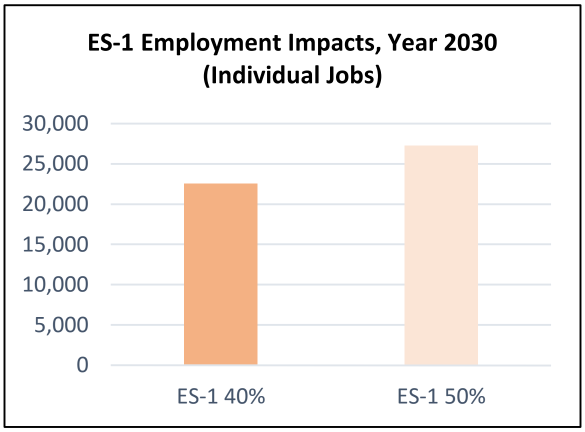


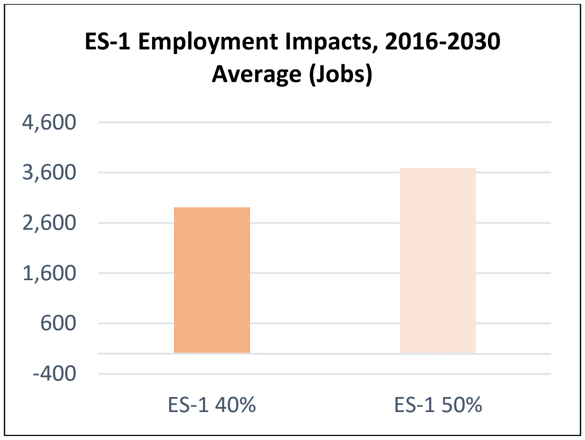
The following nine bar charts show the average, final year and cumulative impacts of ES-1 policy against the same macroeconomic indicators (annual fluctuations cannot be seen here).

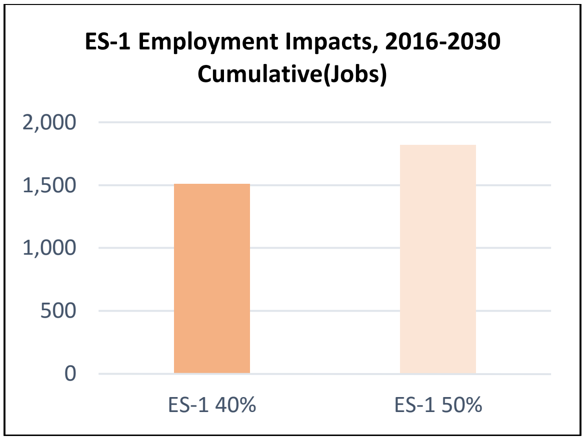

ES-1 GSP Impacts, Year 2030 ($2015 MM)
$4,000
$3,000
$2,000
$1,000
$0
ES-1 40%
ES-1 50%

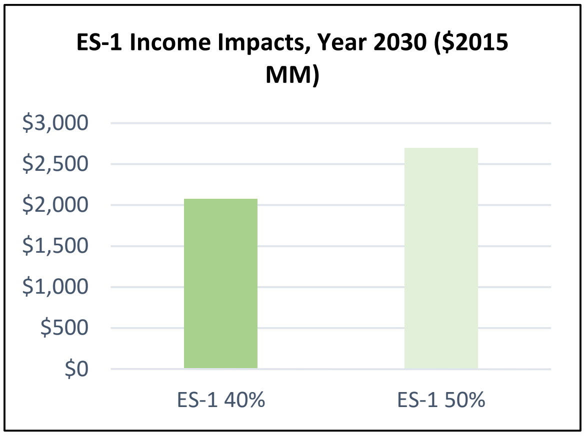

ES-1 GSP Impacts, 2016-2030 Average ($2015 MM)
$600
$500
$400
$300
$200
$100
$0
ES-1 40%
ES-1 50%

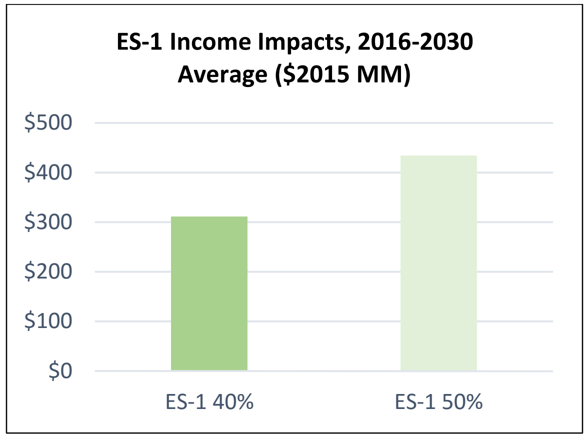

ES-1 GSP Impacts, 2016-2030 Cumulative ($2015 MM)
$250
$200
$150
$100
$50
$0
ES-1 40%
ES-1 50%

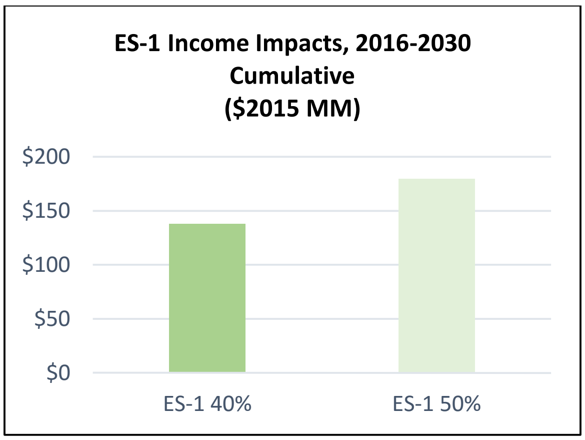

ES-1 Employment Impacts, Year 2030 (Individual Jobs)
30,000
25,000
20,000
15,000
10,000
5,000
0
ES-1 40%
ES-1 50%


ES-1 Employment Impacts, 2016-2030 Average (Jobs)
4,600
3,600
2,600
1,600
600
-400
ES-1 40%
ES-1 50%


ES-1 Employment Impacts, 2016-2030 Cumulative(Jobs)
2,000
1,500
1,000
500
0
ES-1 40%
ES-1 50%

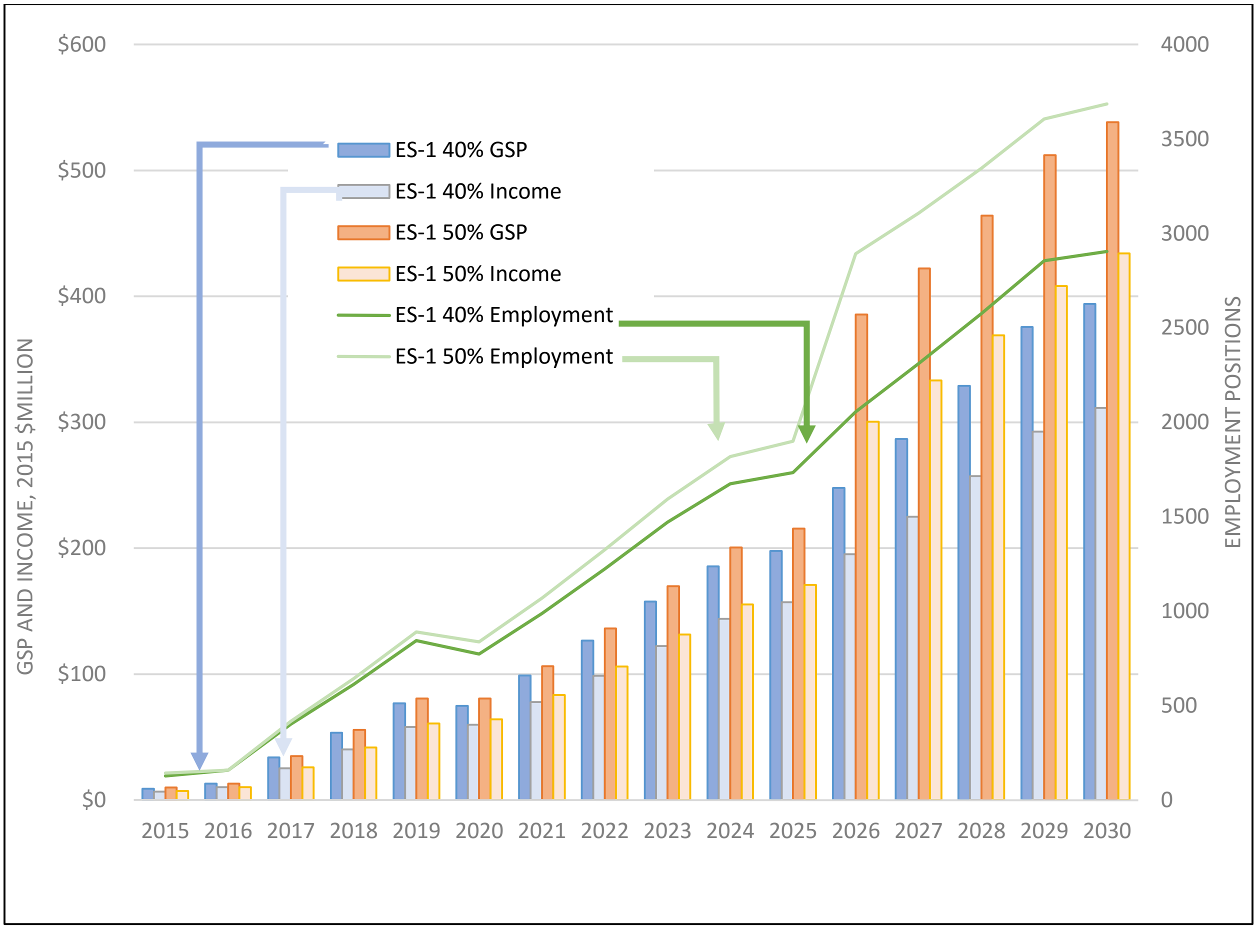






Graph below shows the magnitude of expected differences in impacts between the ES-1 default and sensitivity scenario.

Figure F-1.23 ES Policies Macroeconomic Impacts of Raising ES-1 Target to 50%



Principal Drivers of Macro-Economic Changes

The principal drivers of macroeconomic changes (in income, jobs and GDP) are investments into new renewable technology generation capacity that Minnesota's electricity utilities are projected to make (to meet the electric sales requirements under the expanded RES), and monetary savings the utilities are achieving. These investments are increases in production costs for the utilities.

The savings consist of avoided fuel (primarily coal and natural gas) and capital cost spending on conventional generation that would be required to meet forecasted electric demand under business and usual scenario (without RES in place).

The investments into new renewable generation expand the following sectors: construction, truck transportation, machinery and electric equipment manufacturing etc.

Starting in 2020, the savings utilities are achieving are consistently higher than production costs in that sector. By 2030, that difference is nearly $100 million statewide. This continuous net savings lowers production costs, leading to a mix of expansion of the industry (likely very little) and lower prices (likely almost all of the effect). This savings trend, through the consequences it creates, is a primary driver of a general upward trend in GDP in the entire state, induced by the implementation of the policy. It also suggests that the electricity sector is essentially saving money with the realization of this policy.

Sectors of Economy Most Affected by the Policy

- Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy. For ES-1, which targets the utility sector first and foremost, it is in fact a range of other, related sectors that most benefit from the economic gains found within. The utility sector itself, while the initial target of this policy, sees almost no change in the total scale of its operations or labor required, as the demand for electricity itself is not changed by this policy.
- However, sectors related to the conversion of so much power from one set of sources to others see significant growth. Chief among these is the construction sector, which immediately begins to gain jobs as the policy begins and ends up supporting over 1,300 new employees in the 50% scenario. Back-office positions and retail positions throughout the economy each end up expanding by up to 400 positions in 2030, and other service-sector positions in technical and professional fields, health care, food service, administration and transportation all add at least 100 new positions. The cause of these jobs all around the economy is most likely the relatively low cost of expanding renewables – per unit of energy, the expansion is cheaper than the baseline scenario of expanding conventional energy. These savings translate to a mix of price drops and utility expansions, which drive consumer gains throughout the state in ways unrelated to energy production.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is developed by balancing financial flows for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs by another party as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills on a policy, that is a $100 savings to the household (which expands its spending capacity for other things) but a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy.

These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the ES-1 policy, important data included:

- Capital, operating, maintenance, and fuel costs for a range of electricity generation technologies, including existing coal, existing and potential natural gas (NGCT and NGCC), wind, solar, hydroelectric, and biomass-fired combined heat and power.
- The exact amounts of increased or reduced spending on each of those items, in each year of the period of analysis.
- The geographic location of each activity, to differentiate and accurately model wholly domestic transactions from imports and exports.
- The identities of the parties on each side of every transaction. Government spending affects the economy differently from spending by households, and differently again from spending by entities in the productive sectors of the economy.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model variant built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.

- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.
- State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

PTC/ITC extension: Uncertainty in Federal renewable policy option, such as extension of the Production Tax Credit (PTC) for wind energy and Investment Tax Credit (ITC) for solar electricity, may impact the cost to implement a higher RES. The fact that many utilities have reached RES compliance early may have been influenced by the expected expiration of the PTC & ITC; but if the PTC or ITC is not extended, it's not certain whether this trend will continue.

Increased energy efficiency will amplify the effect of existing renewable energy resources on percent goals.

Additional Benefits and Costs

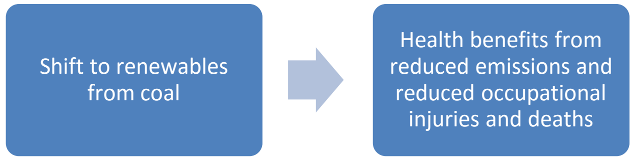
- Job creation (construction, maintenance, project design, manufacturing, forest product harvesting, etc.).
- Reduced GHG emissions from fossil fuels.
- Increased county property tax income from wind and solar energy production taxes.

Potential Health Impacts

Decreasing reliance on fossil fuels and increasing the use of renewable energy sources is likely to reduce health risks for the public and energy workers. Shifting to renewable energy sources from coal will decrease emissions of a variety of pollutants, including particulate matter ($PM_{2.5}$), carbon dioxide, sulfur dioxide, nitrogen oxides, and mercury compounds. (EPA; Kappos) These pollutants have been shown to have a variety of negative cardiac and pulmonary health effects. $PM_{2.5}$ can have especially serious effects, including significant increases in cardiovascular and cardiopulmonary disease and cancer mortality, exacerbation of respiratory illness, and long-term effects on respiratory function, particularly in children and older adults. (Pope 2002, Pope 2000, Bernard) Reducing these emissions may have a notable impact on morbidity and mortality associated with electricity generation, as health and environmental damages from electricity generation in Minnesota total an estimated $2.1 billion, with coal combustion-related emissions accounting for 94% of these damages. (Goodkind and Polasky)

This shift is also likely to decrease occupational injuries and deaths associated with energy extraction, generation, and distribution. Mining is the second most dangerous industry in the United States, with 15.6 fatal occupational injuries per 100,000 workers having occurred in 2012, and conventional energy generation and distribution also present significant occupational risks. (Bureau of Labor Statistics, Sumner) By contrast, occupational risks appear lower in both the wind and solar industries. (Fthenakis, Sumner)

Figure F-1.24 Potential Health Benefits ES-1



*Reducing energy-related emissions is likely to reduce the risk for respiratory and cardiovascular illness, and cancer in exposed populations.

Feasibility Issues

Reliability study - The results from the study show that the addition of wind and solar generation to supply 40% of Minnesota's annual electric retail sales can be reliably accommodated by the electric power system. The analyses show that with upgrades to existing transmission, the power system can be successfully operated for all hours of the year with wind and solar to achieve 40% renewable energy. Additional analysis would need to be done for adding renewables at levels significantly higher than 40%. (More details above in the section on Related Policies and Recent Actions)

EPA 111(d) – An increased RES could be an effective component in Minnesota's plan to meet EPA targets for reducing carbon pollution from existing power plants.

Large Hydro - Certain interests (e.g. Utilities, MH) will push to allow large hydro in an increased RES.

Cost - Large Industrial/commercial & low income customers may resist higher RES based on the assumption of higher cost. A Lawrence Berkeley National Lab Report Lawrence Berkeley National Lab Report suggests that the RES in Minnesota is saving ratepayers' money in some cases or that there is a modest cost increase associated with it in other cases:

Minnesota's Renewable Portfolio Standard (RPS)[11] requires Xcel Energy (Northern States Power) to obtain 31.5% by 2020, including 1.5% solar. Other utilities have separate requirements. Public utilities are required to obtain 26.5% renewable energy by 2025, including 1.5% solar. Non-public utilities are required to obtain 25% renewable energy by 2025 but do not have a solar requirement (DSIRE 2013). In 2012, Northern States Power met the RPS requirement of 13% with 5,637,456 MWh of RECs. Northern States Power has generated surplus RECs each year since 2008. The REC bank provides them the flexibility to defer the installation of new renewables and use banked RECs to comply with RPS obligations (Xcel Energy 2011).

Of the fourteen utilities that submitted compliance reports, eight stated that complying with the RPS has resulted in little or no additional costs, if not slight savings for customers. Northern States Power reported that its renewable investments have been cost-effective and actually kept prices in 2008-2009 about 0.7% lower than they would have been without renewables. Northern States Power calculated the rate impact by determining the difference between the costs of implementing and not implementing the RPS, and then by determining the cost difference on a ¢/kWh basis by dividing the costs by total retail sales (Xcel Energy 2011).

Six utilities, including Great River Energy (GRE), reported that their efforts to comply with the policy option are leading to increased costs for customers. GRE found that its wind energy

[11] http://emp.lbl.gov/sites/all/files/lbnl-6589e.pdf

purchases increased retail customer bills by about 1.6%, or about $1.50/month for an average residential customer (Haugen 2011).

ES-2. Efficiency Improvements, Repowering, Retirement, and Upgrades to Existing Plants

Policy Option Description

Of the 24 utility-owned coal-fired boilers operating in Minnesota, most have been retrofitted to meet Clean Air Act requirements (1758 MW’s), repowered with natural gas (776 MW’s), or are retired or scheduled to retire by 2020 (734 MW’s). While it is not inconceivable that plants retrofitted within the last 10 years would be soon repowered or retired, it is unlikely given the size of these recent investments and resulting impacts to ratepayers.

Decisions remain pending on the future of Minnesota’s three largest coal-fired boilers at Xcel Energy’s Sherburne County (Sherco) generating plant. Due to their size, they are also the largest emitters of CO_2 in the state. The newest and largest of these boilers, Sherco 3, has been retrofitted with advanced mercury controls and is the most efficient boiler in the Minnesota fleet. However, Units 1 and 2 are susceptible to both mercury and Regional Haze requirements, and may therefore be useful to analyze for some combination of repowering or retirement strategies.

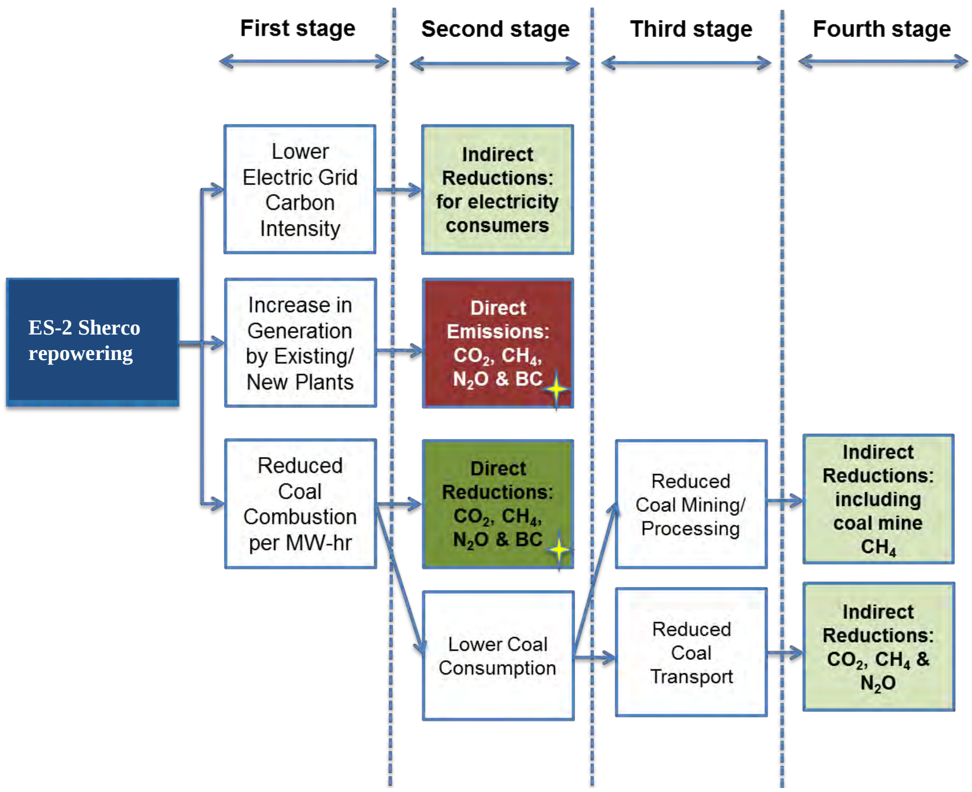
The purpose of this exercise is to analyze one scenario for the Sherco Units 1 and 2 as follows: Repower Sherburne County unit 1 by 2025; retire Unit 2; replace with NGCC by 2023.

Causal Chain for GHG Reductions

The diagram below illustrates how the policy option leads to GHG reductions.

- "First Stage" refers to the direct physical impacts of the policy option, namely a lower CO2e intensity of the electric system, increased generation from lower CO2e-emitting resources, and lower coal use for every MWh of electricity produced;
- "Second Stage" refers to indirect physical impacts of the policy option, namely GHG reductions allocated to consumers, GHG increases associated with natural gas-fired generation, and lower absolute levels of GHGs and coal use;
- "Third Stage" refers to reductions in direct upstream GHGs from coal mining and coal use; and
- "Fourth Stage" refers to indirect upstream GHGs and coal use.

Figure F-1.25 Causal Chain for ES-2 GHG Reductions



Policy Option Design

Goals: Each scenario described above will have its own CO_2 reduction goal, as follows:

- Scenario 1: Repower Sherburne County unit 1 by 2025; retire unit 2 and replace it with NGCC by 2023
- Scenario 2: Retire both units and replace them with NGCCs by 2020
- Scenario 3: Repower unit 1 by 2020 and retire unit 2 and replace it with NGCC by 2020
- Scenario 1 was chosen for the purposes of analyzing integrative effects with other sectoral policies.

Timing: This analysis assumes that repowering or retirements are completed in 2023 and 2025.

Parties Involved:

- State regulators: Public Utilities Commission, Minnesota Department of Commerce, Pollution Control Agency, State Legislature.
- Plant owner: Xcel Energy.

Implementation Mechanisms

To be implemented, this policy option will require action by state regulators (PUC, Commerce, and PCA) to review and approve the planned actions at Sherco 1 and 2, based on plans submitted by the plants' owner, Xcel Energy. Initially, decisions would need to be made in the context of an Integrated Resource Plan submitted by Xcel (next plan due in early 2015), reviewed and approved by the Public Utilities Commission. Xcel is already under an order from the Commission to review these issues in its 2015 plan. It is possible that legislation would be needed to authorize the plan or approve special cost recovery authority.

Related Policies/Programs in Place and Recent Actions

- Clean Air Act requirements: Sherco Units 1 and 2 susceptible to mercury and Regional Haze requirements.
- Current Minnesota law allows investor-owned electric utilities to propose emission reduction projects and receive expedited cost recovery on approval from the Public Utilities Commission.

Estimated Policy Impacts

Direct Policy Impacts

Table F-1.7 ES-2 Estimated Net GHG Reductions and Net Costs or Savings

	2030 In-State GHG Reductions (Tg CO_2e)	2015 – 2030 Cumulative In-State Reductions (Tg CO_2e)	Net present Value of Societal Costs, 2015 – 2030 ($2014)	Cost effectiveness ($2014/ Tg CO_2e)
Repower Unit 1 & Retire Unit 2	6.3	44	$752	$19

<u>Data Sources</u>

- Common Forecast assumptions spreadsheet developed for the Minnesota CSEO project by Steve Roe ("Minnesota Common Forecast Data 20140829.xlsx")
- Electric system assumptions: final version of the power sector forecast prepared by the Pollution Control Agency.
- U.S. Department of Energy, The Energy Information Administration (EIA); EIA-923 Monthly Generation and Fuel Consumption Time Series File, 2012 Final Release; Sources: EIA-923 and EIA-860 Reports

- Operating cost data by plant provided in a spreadsheet entitled: "FERC op costs.xlsx" attached to an email from the Pollution Control Agency to Bill Dougherty on 3 October 2014
- Xcel report entitled: "Life Cycle Management Study for Sherburne County (Sherco) Generating Station Units 1 and 2", Minnesota Public Utilities Commission Docket Number E002/RP-13-368, July 1, 2013
- ES-2 data request 022615.xlsx

Quantification Methods

Using the assumptions below, a spreadsheet analysis was undertaken using the methods summarized in the bullets below:

- The cost and performance characteristics of Sherco Units 1 and 2 was obtained and projected based on the assumption in the Xcel report cited above.
- The costs and performance characteristics of the repowered NGCC were assumed based on a combination of Xcel and Energy Information Administration (EIA) sources.
- The annual difference in costs and CO_2e emissions was calculated.
- The present value of the incremental cost using a 5% real discount rate was determined and divided by the undiscounted cumulative CO_2e reductions to obtain an estimate of the cost effectiveness of the policy option.

Key Assumptions

- The analysis assumed the costs and performance of Sherburne County units 1 & 2 based on the Xcel report entitled: "Life Cycle Management Study for Sherburne County (Sherco) Generating Station Units 1 and 2", Minnesota Public Utilities Commission Docket Number E002/RP-13-368, July 1, 2013. These assumptions are summarized in the bullets below:
    - Year of unit replacement: 2025 for Sherco 1; 2023 for Sherco 2
    - Maximum capacity: 681 MW for Sherco 1; 682 MW for Sherco 2
    - Average Heat Rate (approximately 75% load HR): 10,507 Btu/kWh for Sherco 1; 10,513 Btu/kWh for Sherco 2
    - Average annual capacity factor: 70% for Sherco 1; 70% for Sherco 2
    - Variable O&M cost in 2012 (including activated Hg control): $0.33/MWh escalating at 1.8%/yr for Sherco 1; $0.34/MWh escalating at 1.8%/yr for Sherco 2
    - Fixed O&M cost in 2012: $21,214,000 escalating at 2.18%/yr for Sherco 1; $21,214,000 escalating at 2.18%/yr for Sherco 2
    - Annual ongoing capital improvement cost in 2012: $17,572,000 escalating at 2.24%/yr for Sherco 1; $13,244,000 escalating at 2.24%/yr for Sherco 2.

- The analysis assumed the costs and performance of an NGCC providing annual generation equivalent to the same annual generation projected for Sherco 1 and 2. These assumptions differed from Xcel assumptions in the aforementioned report and are summarized in the bullets below:
- Average annual capacity factor: 40%
- Levelized electric generation costs: $70.26/MWh
- CO_2e intensity: 0.414 tons/MWh
- Average Heat Rate (approximately 75% load HR): 7,050 Btu/kWh

Macroeconomic (Indirect) Economic Impacts of RCII Policies

Table F-1.8 below provides a summary of the expected impacts on jobs and economic growth during the CSEO planning period.

Table F-1.8 ES-2 Macroeconomic Summary Impacts on GSP, Employment and Income

Scenario	**Gross State Product** (GSP, $2015 Millions)			**Employment** (Full & Part-Time Jobs)			**Income Earned** ($2015 Millions)		
	Year 2030	**Average (2016-2030)**	**Cumulative (2016-2030)**	**Year 2030**	**Average (2016-2030)**	**Cumulative (2016-2030)**	**Year 2030**	**Average (2016-2030)**	**Cumulative (2016-2030)**
ES-2	-$73	-$39	-$309	170	310	2,470	-$16	-$3	-$22

Figure F-1.26 ES-2 GSP Impacts ($2015 MM)

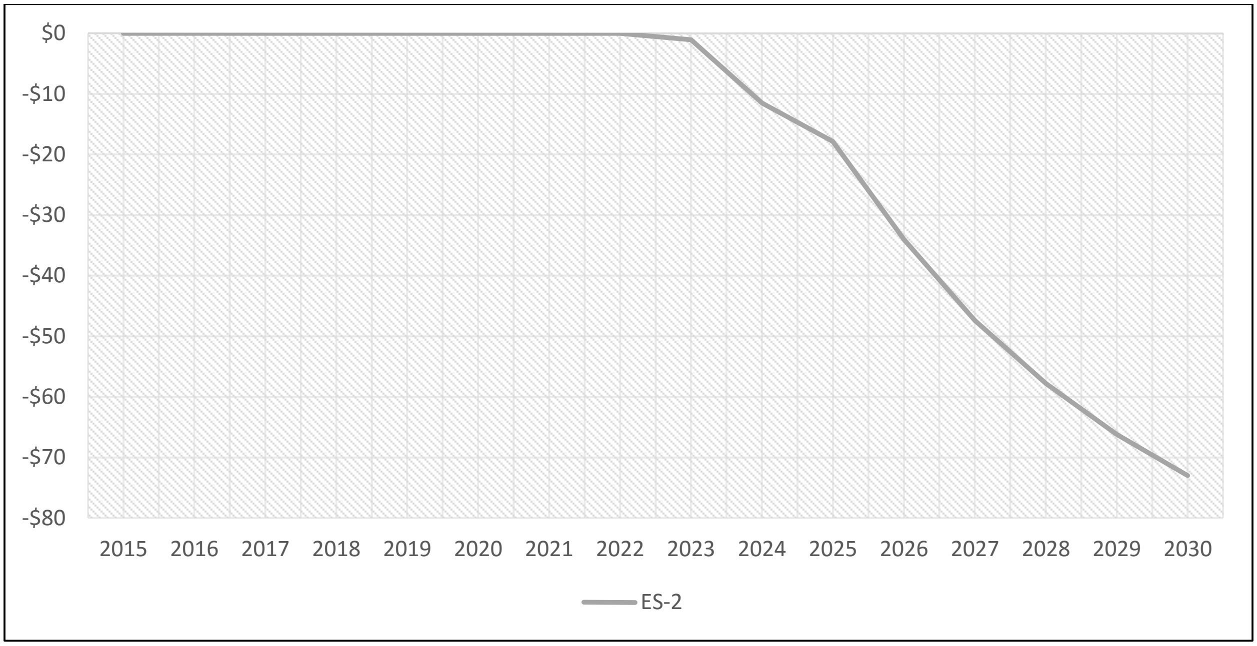


Figure F-1. 27 ES-2 Employment Impacts (Individual Jobs)

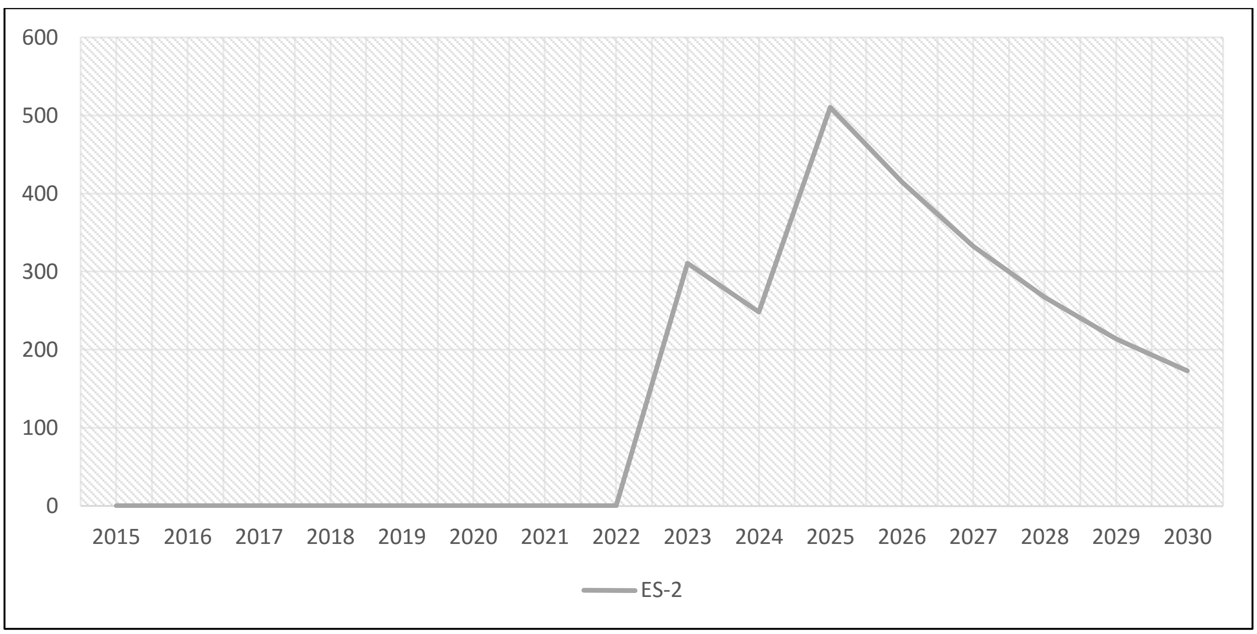
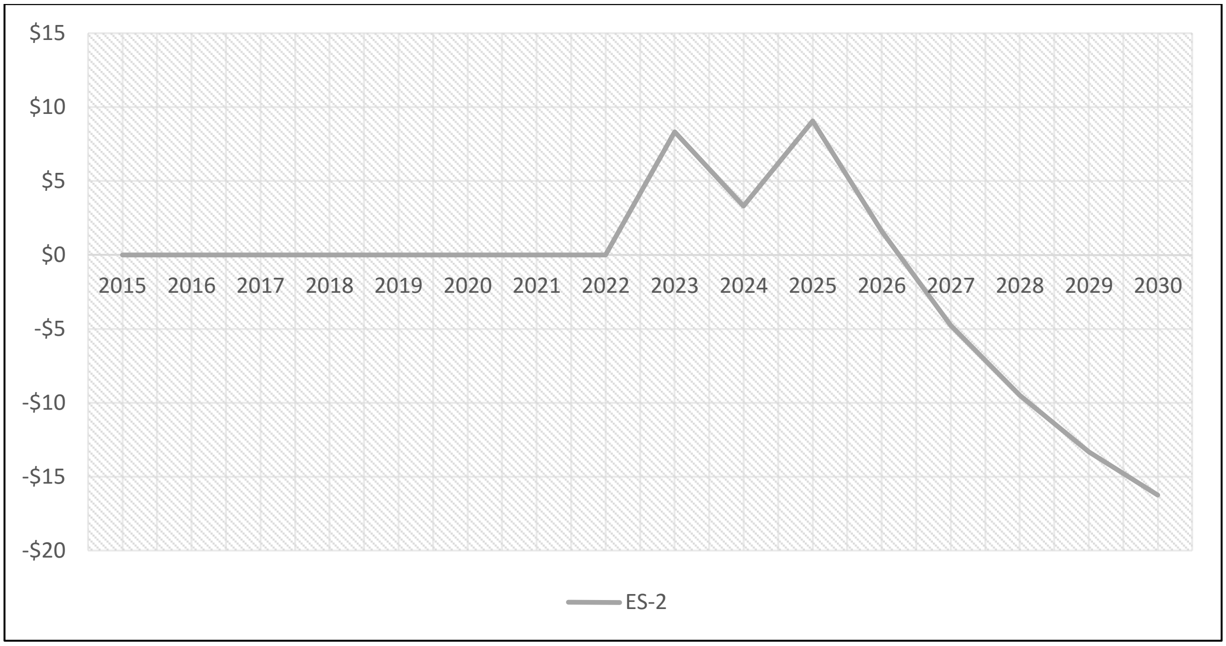
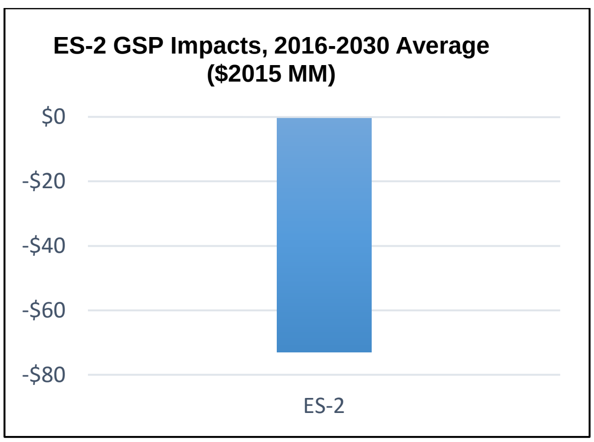
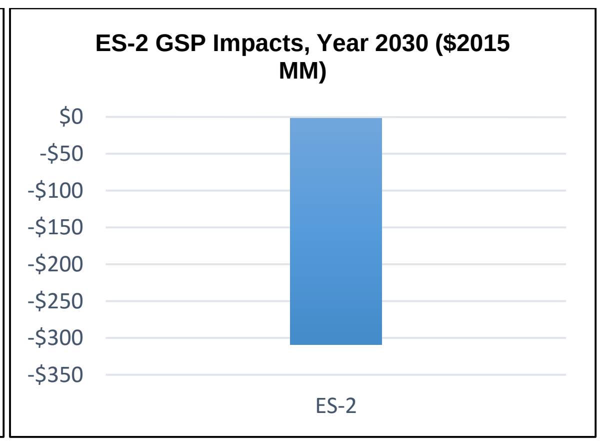


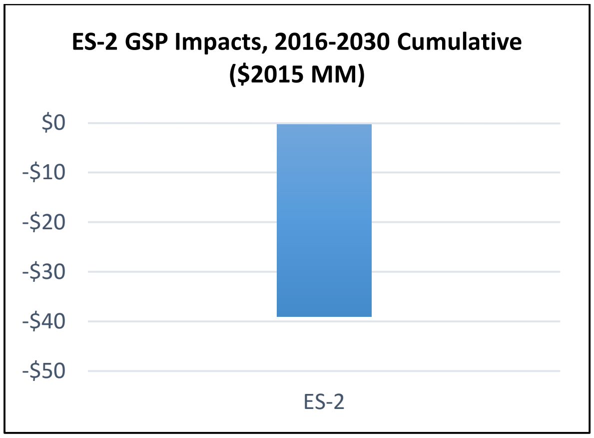
Figure F-1.28 ES-2 Income Impacts ($2015 MM)

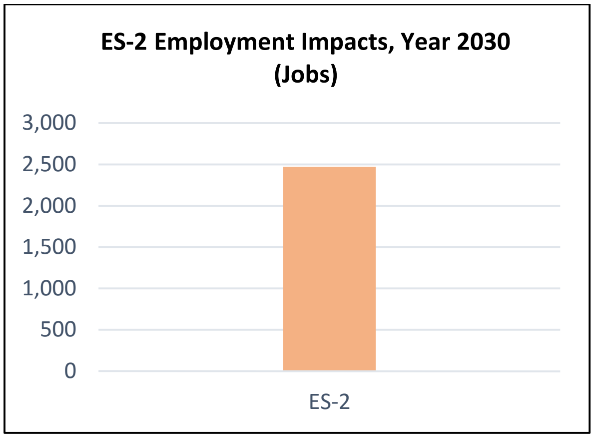


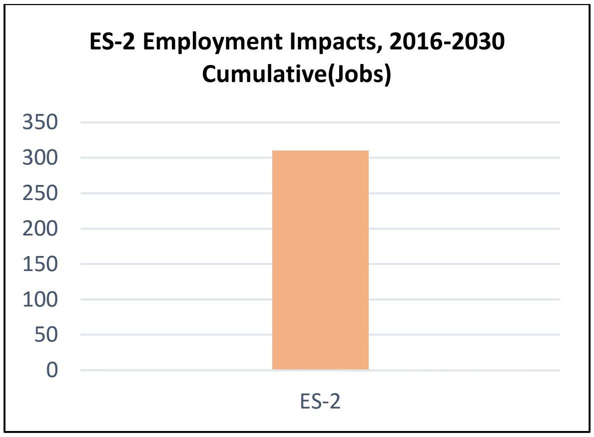
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030).

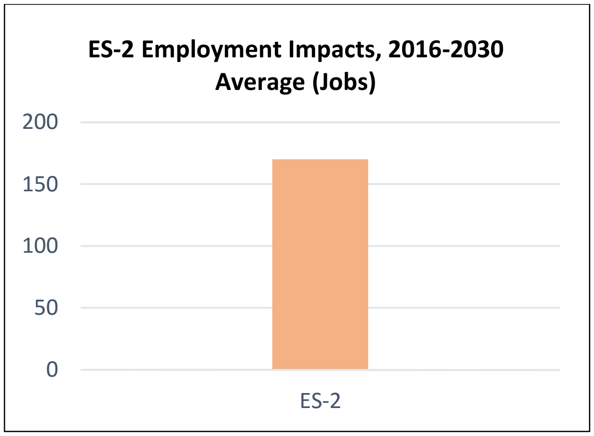


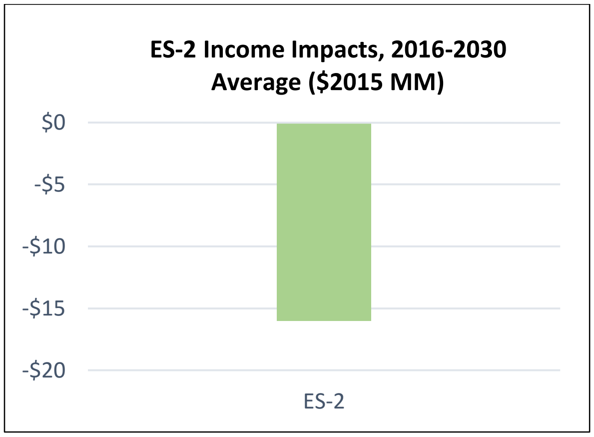


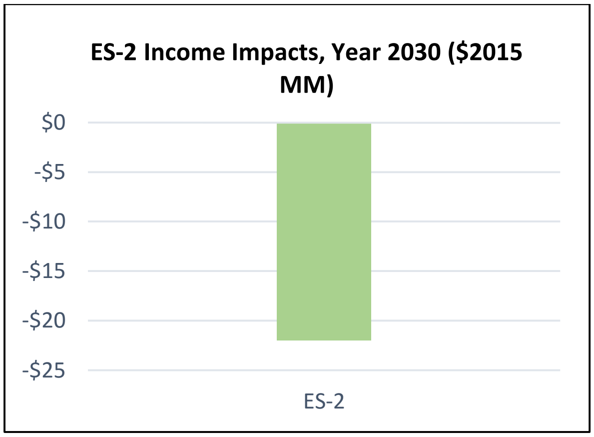

ES-2 GSP Impacts, 2016-2030 Cumulative ($2015 MM)
$0
-$10
-$20
-$30
-$40
-$50
ES-2

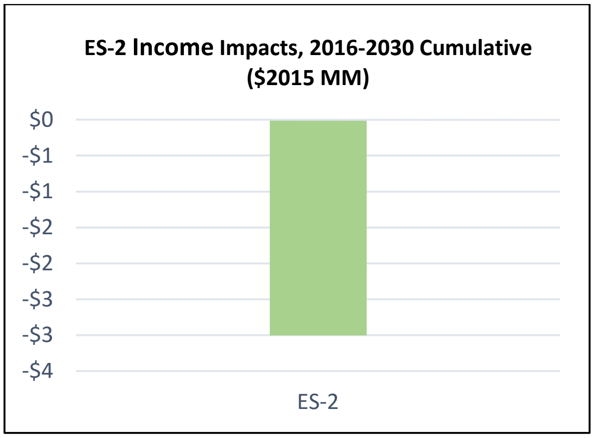

ES-2 Employment Impacts, Year 2030 (Jobs)
3,000
2,500
2,000
1,500
1,000
500
0
ES-2


ES-2 Employment Impacts, 2016-2030 Cumulative(Jobs)
350
300
250
200
150
100
50
0
ES-2


ES-2 Employment Impacts, 2016-2030 Average (Jobs)
200
150
100
50
0
ES-2


ES-2 Income Impacts, 2016-2030 Average ($2015 MM)
$0
-$5
-$10
-$15
-$20
ES-2


ES-2 Income Impacts, Year 2030 ($2015 MM)
$0
-$5
-$10
-$15
-$20
-$25
ES-2



Principal Drivers of Policy Impact on the Broader Economy

The principal drivers of macroeconomic change are investments into new natural gas generation capacity that Minnesota's electricity utilities are projected to make in order to replace the capacity currently met by the generation facilities at the Sherburne County facility. In addition, the reduced flow of costs because Xcel Energy would no longer be operating, fueling, maintaining and eventually upgrading the existing coal-fired generation is the other major driver. This produces a mix of positive direct impacts, and higher operating costs which create a downward pressure on the larger economy. As a result, GDP falls, but total jobs rise and incomes hold close to neutral.

Unlike the impact of the Renewable Energy Standard in ES-1, which resulted in a net monetary savings to the utilities achieve as a result of the shift in sources, this policy produces a net cost. The savings resulting from shutting down Sherco did not fully offset the cost of constructing. The investments in natural gas facilities take the form of increases in production costs for the utility, but the reduced flow of spending on coal-fired energy generation is by the same token a reduction in those production costs. The net production cost to the utility sector increases somewhat, which macroeconomic models anticipate will drive a combination of price increases and fewer available funds. This net cost increase to the utility, more than any other single factor, applies a downward pressure to the broader statewide economy. As a result, total GDP (the amount spent in the economy drops). Much of this is likely a reduction in spending on electricity – that sector will shrink most.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For ES-2, while the operating-cost shift sends some downward pressure through the economy, the direct impact of the policy (from the investment in building the new facilities) drives direct positive gains. The start of the repowering and retirement construction phases, in 2023 and 2025, drive net gains in employment that are larger than the losses created. The construction sector gains the most – between 200 and 400 jobs per year as it expands to build this new capacity. Natural gas production also grows, as does machinery manufacturing. The utility sector is the only sector to see a noticeable reduction in scale, though even that is never larger than a loss of about 75 positions – a number that should be taken as an indicator of slight downward pressure on the overall scale of the utility sector.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction

- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a

party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

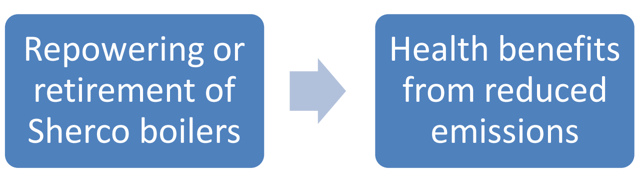
- The type of replacement power to meet Minnesota demand during the repowering construction period (assumed to be zero).
- The ratio of the capital cost of a repowered facility to a new facility, as well as impact on combustion efficiency and operating costs.
- The system performance and cost impacts associated with replacing the total annual generation for Sherco 1 and 2 with generation from NGCC.

Additional Benefits and Costs

- Reduced degradation of air quality and other urban heat island impacts
- Improved surface/ground water quality
- Mitigated health care costs for air quality and carbon emissions related illness in Minnesota.
- Costs could include employment impacts at the power plant and any incrementally higher costs of power.

Health Impacts: Retiring the Sherco coal-fired boilers will reduce emissions of air toxics that negatively impact health by eliminating those emissions. Repowering the Sherco coal-fired boilers with natural gas would also benefit health because the health burdens associated with natural gas are much lower than those associated with coal; in fact, one recent study estimated that the number of deaths per TWh for natural gas was only 2.8, compared with 24.6 deaths per TWh for coal. (Markandya)

Figure F-1.29 Potential Health Benefits ES-2



Reducing energy-related emissions is likely to reduce the risk for respiratory and cardiovascular illness, and cancer in exposed populations.

Feasibility Issues

Power plant repowering projects involve detailed engineering analyses to determine if existing equipment can be reused or completely replaced, which can affect feasibility and project timelines. Natural gas must also be available in sufficient quantity to the site.

Chapter XIII. Appendix F-2.Residential, Commercial, Institutional, and Industrial Policy Option Recommendations

Overview

The tables below provide a summary of the direct impacts and microeconomic analysis of Climate Solutions & Economic Opportunities (CSEO) policies in the Residential, Commercial, Institutional, and Industrial (RCII) sector. The first table provides a summary of results on a "stand-alone" basis, meaning that each policy option was analyzed separately against baseline (business as usual or BAU) conditions. Details on the analysis of each policy option are provided in each of the Policy Option Documents (PODs) that follow within this appendix.

Direct, Stand Alone Economic Impacts

The "Stand-Alone" results provide the annual greenhouse gas (GHG) reductions for 2020 and 2030 in teragrams (Tg) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030 (1 Tg is equal to 1 million metric tons). The reductions shown are only those that have been estimated to occur within the State, that is, the net emissions reduction from fuels combustion plus the estimated emissions reduction from reduction of the need for electricity generation. Additional GHG reductions, typically those associated with upstream emissions in the supply of fuels or materials, have also been estimated, and upstream emissions results are reported within each of the analyses in each POD.

Also reported in the stand-alone results is the net present value (NPV) of societal costs/savings for each policy option. These are the net costs of implementing each policy option reported in 2014 dollars. The cost effectiveness (CE) estimated for each policy option is also provided. Cost effectiveness is a common metric that denotes the cost/savings for reducing each metric ton (t) of emissions. Note that the CE estimates use the total emission reductions for the policy option (that is, cumulative emissions reductions counting reductions occurring both within and outside of the State).

CCS did not utilize any generalized co-benefit estimate (such as a social cost of carbon) or estimate a consistent suite of co-benefit impacts across all policies. In some policies, however, aspects of specific co-benefits were isolated and quantified. For the transit policy, as one example, a small improvement in access to employment was applied to the macroeconomic modeling. The larger economic benefit of any savings to either businesses, households or the government is captured in the macroeconomic impact analysis (as is, by the same token, the economic burden of any increases in prices or costs of living/doing business).

Integrative Adjustments & Overlaps

Table F-2.2 below provides the GHG emissions reductions and net costs for each option after an assessment was made of any policy option interactions or overlaps between RCII options. In the RCII sector, overlaps were identified between the RCII-1 policy option promoting combined heat and power (CHP) and RCII-2, which sets combined energy efficiency and renewable energy production/use requirements for new and renovated buildings. RCII-4, which increases energy efficiency targets for electric and gas utility programs that apply to both new and existing consumers, also has some overlap with RCII-2. The RCII-4 overlap with RCII-2 was calculated based on estimates of the fraction of state building floor area that participates in RCII-2, relative to estimates of the total state building floor area in a given year.

As indicated in the summary table, RCII-5 overlaps with both RCII-2 and RCII-4. The overlap with RCII-2 is the gas savings in RCII-2 resulting from renewable energy use in new homes. The overlap with RCII-4 is the fraction of gas savings resulting from the application of renewable energy systems included in RCII-4. These gas savings are not explicitly included in the RCII-4 Policy Option Document, nor explicitly calculated in the estimate of the costs and impacts of RCII-4. The overlap between RCII-5 and RCII-4 was therefore estimated to be 10% of the natural gas impacts of RCII-4 and a corresponding share of the gas-related costs of RCII-5.

Macroeconomic (Indirect) Economic Impacts

Table F-2.3 below provides a summary of the expected impacts of RCII policies on jobs and economic growth during the CSEO planning period. This table focuses on the impact of policies on Gross State Product (the total amount spent on goods and services produced within the state), Employment (the total number of full-time and part-time positions), and Incomes (the total amount earned by households from all possible sources). These metrics represent three valuable indicators of both the overall size of the economy and that economy's structural orientation toward supporting livelihoods and utilizing productive work.

For the purposes of macro-economic analysis of CSEO policies, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software. This particular REMI model is developed specifically for Minnesota, and is developed consistently with the design of models in use by state agency staff within Minnesota for a range of economic analyses. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

The main inputs for macro-economic analysis are microeconomic estimates of direct costs and savings expected from the implementation of individual policy options. These inputs are supplemented with additional data and assumptions necessary to complete the picture of how these costs and savings (as well as price changes, demand and supply changes, and other factors) influence Minnesota's economy. These additional data and assumptions typically regard how various actors around the state (households, businesses and governments) respond to change by changing their own economic activity. A full articulation of the general and policy-specific assumptions made by the macroeconomic analysis team is provided in the Policy Option Documents, contained as appendices to this report.

Table F-2.1 Residential, Commercial, Institutional & Industrial Policy Options, Direct Stand-Alone Impacts

"Stand-Alone" Analysis							
		GHG Reductions				Costs	
Policy Option ID	Policy Option Title	Annual CO_2e Reductions[a]		2030 Cumula-tive[a]	2030 Cumula-tive[b]	Net Costs[c] 2015-2030	Cost Effective-ness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/$tCO_2e$
RCII-1	Incentives and Resources to Promote Combined Heat and Power (CHP) for Biomass and for Natural Gas.	2.2	4.9	46	50	($1,112)	($22)
RCII-2	SB2030/Zero Energy Transition/Codes	0.92	9.3	54	60	($2,050)	($34)
RCII-3	Reduce High Global Warming Potential (GWP) Greenhouse Gases	Not Applicable - Option not quantified					
RCII-4	Increase Energy Efficiency Requirement (2.5% annual electric energy savings)	1.4	4.7	36	42	($1,882)	($45)
RCII-4	Increase Energy Efficiency Requirement (2% annual electric energy savings)[e]	*1.0*	*3.2*	*25*	*29*	*($1272)*	*($44)*
RCII-5	Incentives and Resources to Promote Thermal Renewables.	0.80	3.0	22	30	$872	$29
Totals		**5.3**	**22**	**157**	**182**	**($4,171)**	**($23)**

Notes:
[a] In-State (Direct) GHG Reductions
[b] Total (Direct and Indirect) GHG Reductions
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014)
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of State. Dollars expressed in 2014$.
[e] 2% annual electric energy savings scenario is an alternative scenario of RCII-4 policy evaluated for a reference, and is not included in the "**Totals**" row calculation

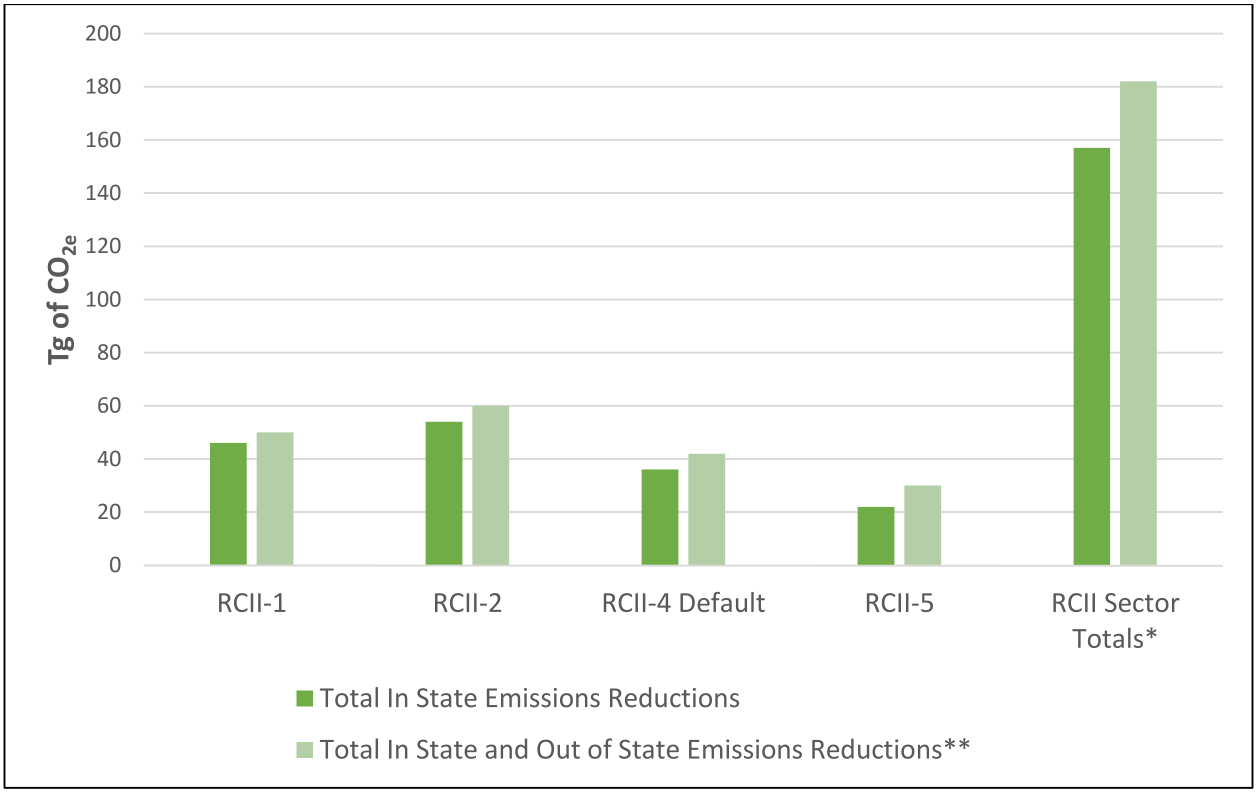
Table F-2.2 Residential, Commercial, Institutional & Industrial Policy Options, Intra-Sector Interactions & Overlaps

Intra-Sector Interactions & Overlaps Adjustments							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual CO_2e Reductions[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/tCO₂e
RCII-1[e]	Incentives and Resources to Promote Combined Heat and Power (CHP) for Biomass and for Natural Gas	2.2	4.8	46	49	($1,098)	($22)
RCII-2[f]	SB2030/Zero Energy Transition/Codes	0.92	9.3	54	60	($2,050)	($34)
RCII-3	Reduce High Global Warming Potential (GWP) Greenhouse Gases	Not Applicable - Option not quantified					
RCII-4[g]	Increase Energy Efficiency Requirement (2.5% annual electric energy savings)	1.3	4.4	34	40	($1,744)	($43)
RCII-4	Increase Energy Efficiency Requirement (2% annual electric energy savings)[j]	*1.0*	*3.0*	*23*	*28*	*($1180)*	*($42)*
RCII-5[h]	Incentives and Resources to Promote Thermal Renewables	0.82	3.0	22	30	$844	$28
Total After Intra-Sector Interactions /Overlap		**5.3**	**22**	**156**	**180**	**($4,049)**	**($23)**

Notes:
[a] In-State (Direct) GHG Reductions
[b] Total (Direct and Indirect) GHG Reductions
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014)
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of State. Dollars expressed in 2014$.
[e] RCII-1 overlaps with RCII-2 in its use of gas-fired CHP in the C/I sector. Approximate overlaps are calculated on that basis.
[f] This option is used as the basis on which overlaps from other options are calculated
[g] Overlaps with RCII-1 are already removed from RCII-4 results. As RCII-4 applies to all homes and businesses, and RCII-2 only applies to new and renovated buildings, the RCII-4 overlap with RCII-2 is estimated based on an estimate of the fraction of total Minnesota building floor area that participates in RCII-2 relative to a rough estimate of the total Minnesota building floor area.
[h] This option does not overlap with RCII-1. RCII-5 overlaps with the gas savings in RCII-2 from renewable energy use that apply to new homes, and to the fraction of gas savings in RCII-4 that comes about as a result of the application of renewable energy systems included in RCII-4. The latter are not explicitly included in the RCII-4 Policy Option Document, or explicitly calculated in the estimate of the costs and impacts of RCII-4. We therefore roughly

estimate the overlap between RCII-5 and RCII-4 at 10% of the natural gas impacts of RCII-4 and a corresponding share of the gas-related costs of RCII-5.
[j] 2% annual electric energy savings scenario is an alternative scenario of RCII-4 policy evaluated for a reference, and is not included in the "**Total**" row calculation.

Figure F-2.1 RCII Policies GHG Emissions Abatement, 2016-2030



Notes:
* All Policies Total's comprise emissions reductions achieved by RCII default policies combined.
** Total in and out-of-state emissions reduction are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Table F-2.3 Macroeconomic (Indirect) Impacts of RCII Policies

Macroeconomic (Indirect) Impacts Results									
Policy	**Gross State Product** (GSP, $2015 Millions)			**Employment** (Full & Part-Time Jobs)			**Income Earned** ($2015 Millions)		
	Year 2030	Average	Cumulative (2015-2030)	Year 2030	Average	Cumulative (2015-2030)	Year 2030	Average	Cumulative (2015-2030)
RCII-1	$508	$202	$3,026	3,840	2,330	35,020	$434	$213	$3,191

RCII-2	-$69	-$6	-$91	6,020	2,750	41,190	$336	$134	$2,011
RCII-4	$137	$141	$2,111	1,430	1,560	23,340	$163	$143	$2,140
RCII-5	-$345	-$149	-$2,081	-1,680	-690	-9,610	-$154	-$58	-$809
RCII Sector Total	**$262**	**$210**	**$3,149**	**9,820**	**6,080**	**91,270**	**$801**	**$444**	**$6,658**

Notes:
[a] Gross State Production changes in Minnesota. Dollars expressed in $2015.
[b] Total employment changes in Minnesota.
[c] Personal Income changes in Minnesota. Dollars expressed in $2015.
[d] Single final year value. Year 2030 is the final year of analyses in this project.

Figure AP F-2.2 – Average Annual Jobs Impact of RCII Policies, Individually and in Concert

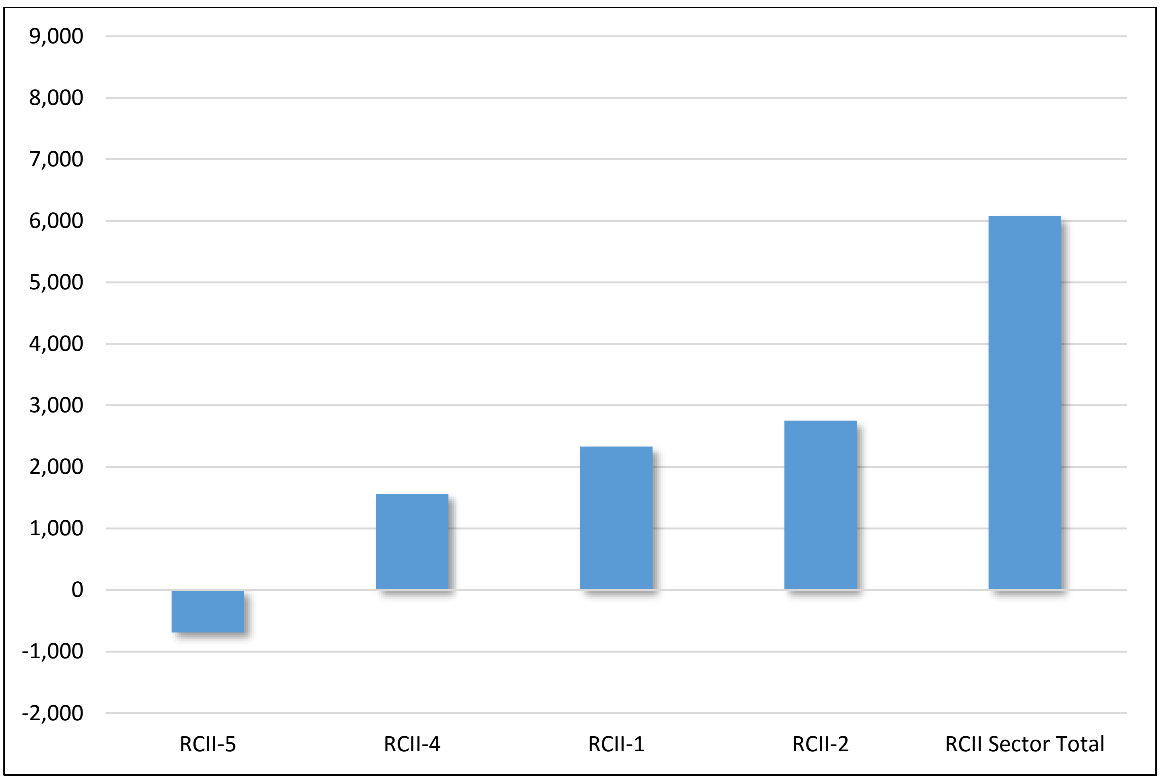
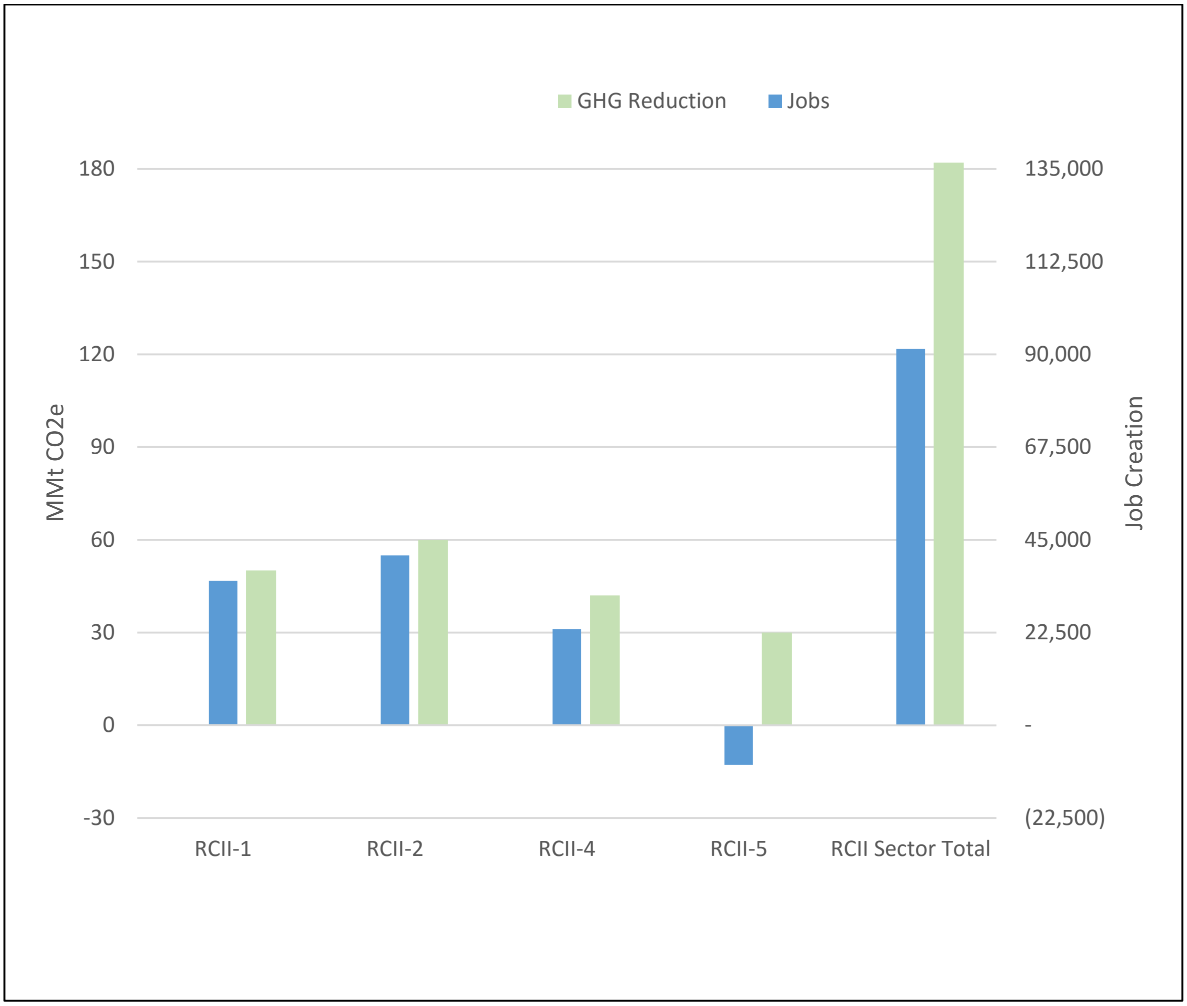


Figure F-2.3 below summarizes a potential for job creation and GHG emissions abatement of RCII sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against a crucial environmental and economic indicator.

Figure F-2.3 RCII Policies Jobs and GHG Reduction, 2016-2030



Macroeconomic index

The graph below expresses the overall economic impact from each scenario in a single score, and compares those scores. CCS created this single score (a Macroeconomic Impact Index) in order to encapsulate in one measurement the relative macroeconomic impacts (including jobs, GSP and incomes) of each policy. We have found in our own work and in the literature that indexed scores can be helpful to many readers when comparing options with multiple characteristics.

To produce this score, CCS set the results from the absolute best-case scenario (i.e. the implementation of all CSEO policies with all their optimal sensitivities in place) equal to 100, with that scenario's jobs, GSP and incomes impacts weighted equally at one third of the total score. Each policy's jobs, GSP and income impacts are scaled against that measure, and given a total score. The overall score indicates how significant a policy's impact is projected to be. Negative impacts are scaled the same way, except that those impacts are given negative scores and pull down the total score of the policy.

These scores are calculated separately for the final year of the study (2030), the *average* impact over the 2016-2030 period, and the *cumulative* impact of the policies over that period. While each scenario has one line, the relative importance of jobs, income and GSP remain visible as differently-shaded segments of that line.

Figure F-2.4 RCII Macroeconomic Impacts, Final Year 2030

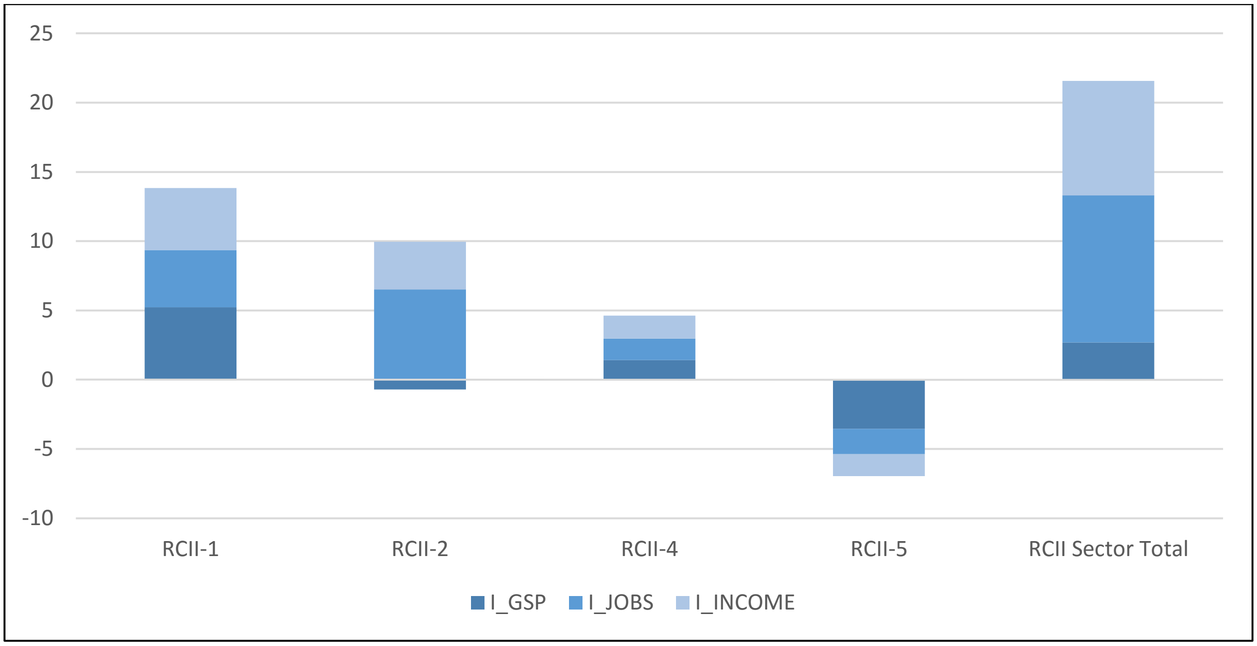


Figure F-2.5 RCII Macroeconomic Impacts, 2016-2030 Yearly Average

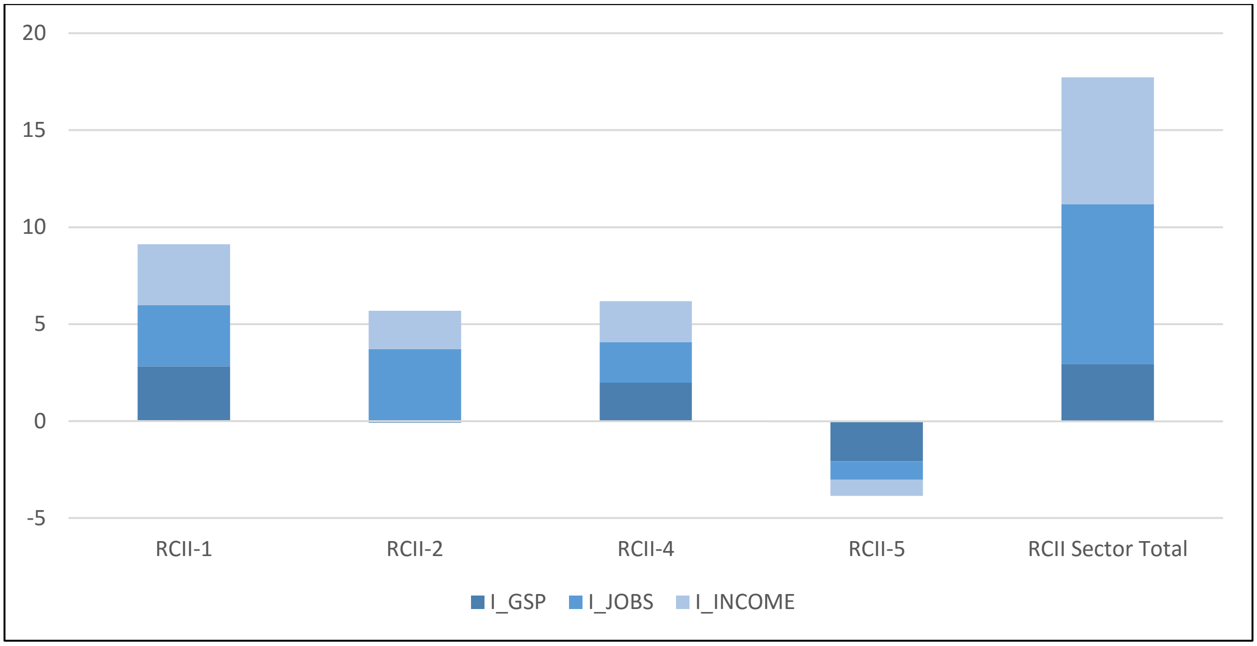
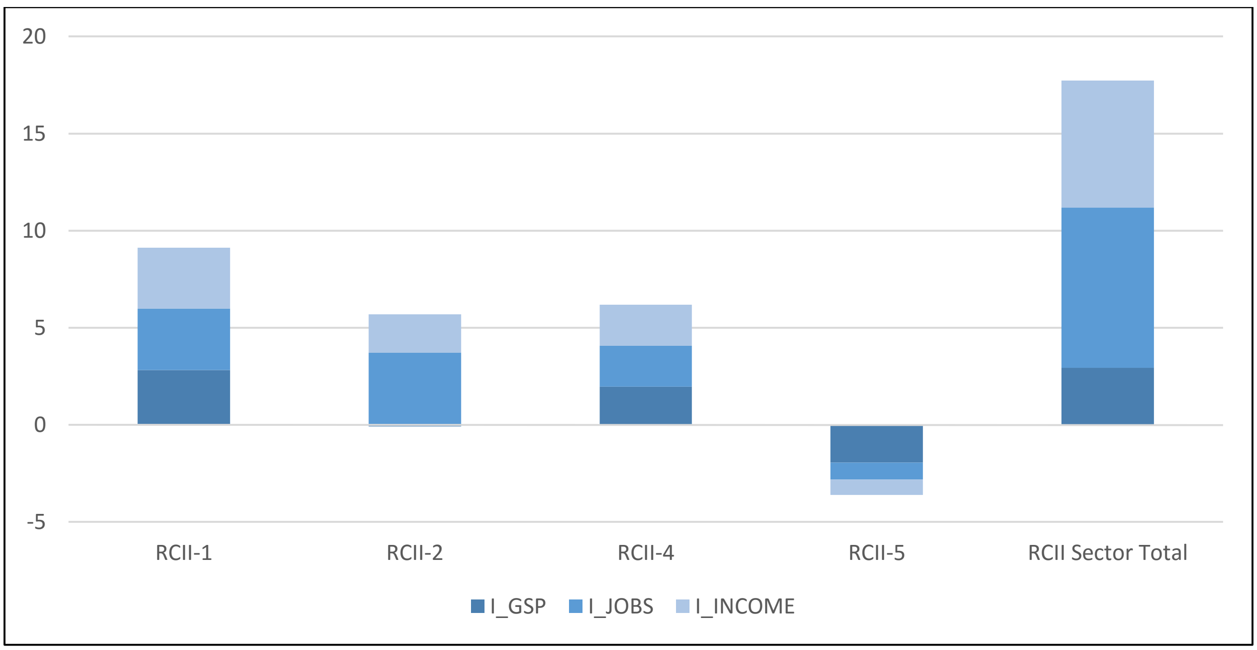


Figure F-2.6 RCII Macroeconomic Impacts, 2016-2030, Cumulative



The RCII Sector policies, when taken together, produce significant positive economic impacts on the Minnesota economy. As a bundle, they are projected by this analysis to drive a growth of between $180 million and $270 million per year in the state's GSP through most of the 2016-2030 period.

While GSP holds steady in that range, the jobs and income levels project actually continue to rise throughout the period. Incomes reach $800 million in gains, and the state adds approximately 10,000 new full-time and part-time positions as part of this growth. This profile, where employment metrics respond more strongly than total spending levels (GSP), is a common characteristic of efficiency measures, and much of the focus of the RCII sector policies is on achieving efficiencies.

The most positive policy is RCII-1, which focuses on the implementation of combined heat and power generation (CHP) by utilities and industries. Alone, it is projected to increase GDP by approximately a half billion dollars by 2030, nearly the same amount in incomes, and total employment by 4,000 positions. This is due to a combination of the stimulus from investing in new equipment and technology and the fundamental efficiency achieved by capturing waste heat rather than having to produce that heat separately. RCII-4, which raises the statewide energy efficiency requirement, is also positive but to a smaller scale of impact.

RCII-5, which focuses on renewable thermal energy, however, fares least well. Its overall cost burden, in terms of required investments by households and by institutions and other larger buildings, is never recovered back as savings. Because not all of the expenses incurred go into sectors that are powerful in expanding the economy of the state (either because they rely on imports or because they produce few intermediate demands for other economic activity as inputs), the economy does not benefit from the spending requires as much as it suffers from the burden imposed.

RCII-2 presents a classic efficiency profile: The impact on GSP is neutral, as spending on energy falls aggressively and balances out the spending gains in other sectors. But the efficiency effect – lower costs of living and doing business – drive large growth in incomes and jobs. This pattern is characteristic of efficiency policies, which seek to produce the same welfare benefit (what we use energy for, such as heat and light and productive work) on less input (smaller amounts of electricity or gas).

Line graphs and bar graphs that follow illustrate the above explained policy impacts and economic implications.

Figure F-2.7 RCII GSP Impacts ($2015 MM)

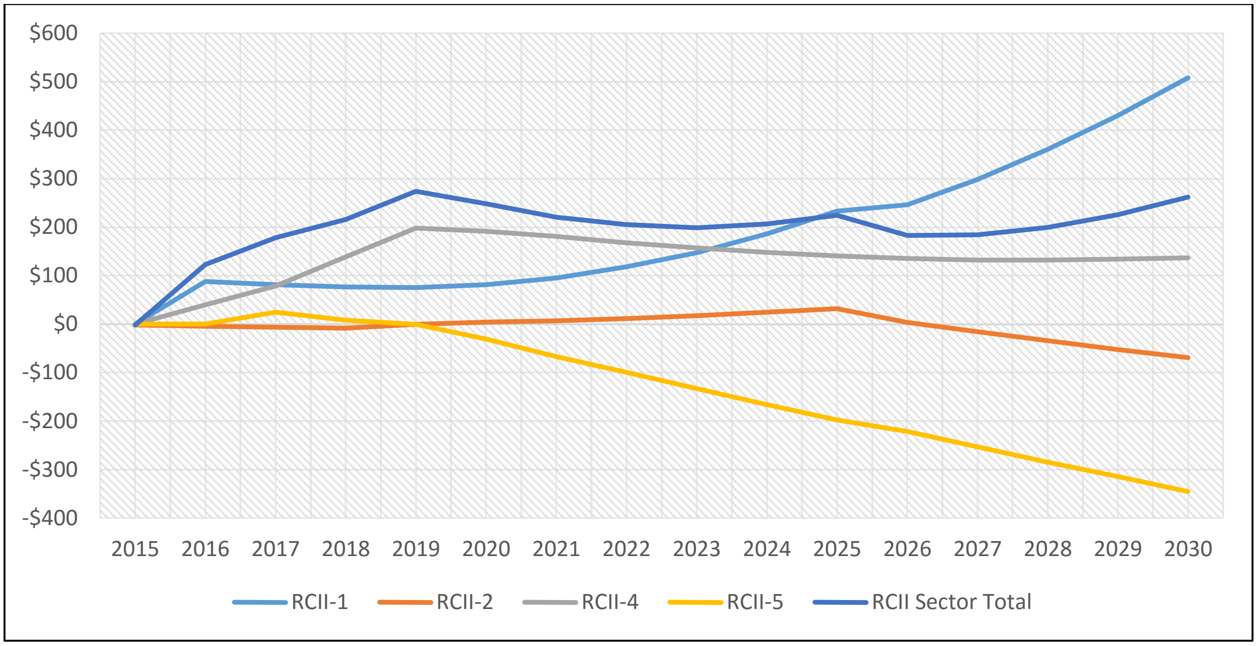


Figure F-2.8 RCII Employment Impacts (Individual Jobs)

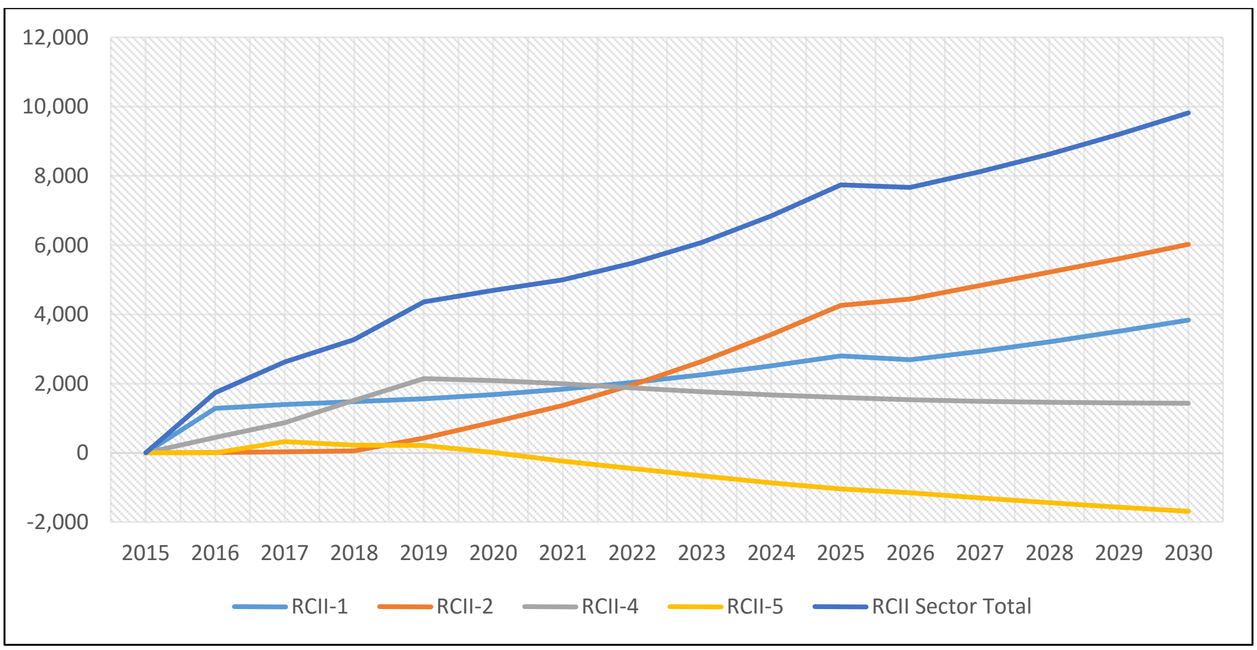
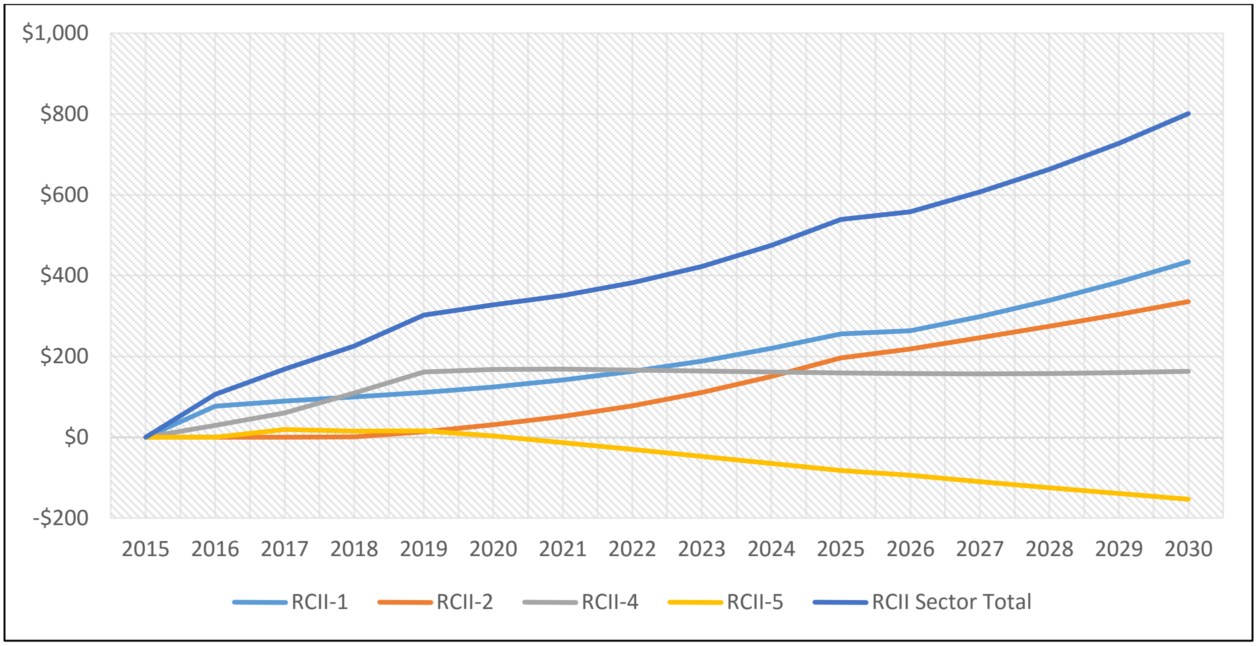


Figure F-2.9 RCII Income Impacts ($2015 MM)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030).

Figure F-2.10 RCII GSP Impacts, 2016-2030 Average ($2015 MM)

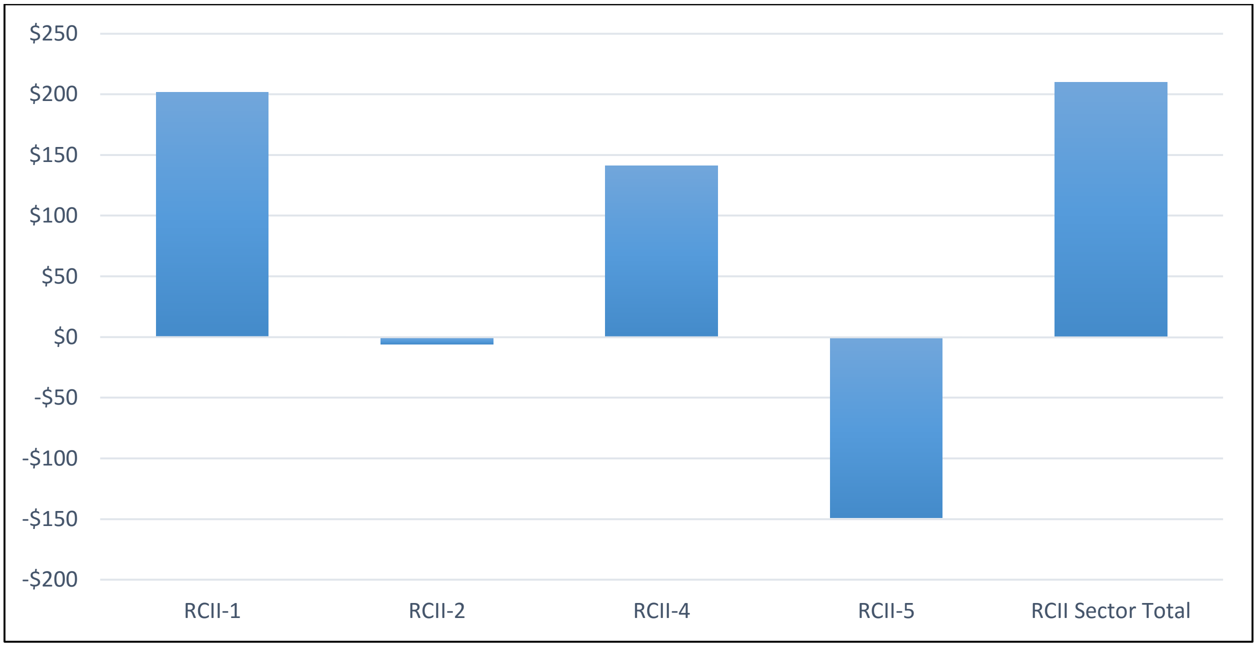


Figure F-2.11 RCII GSP Impacts, Year 2030 ($2015 MM)

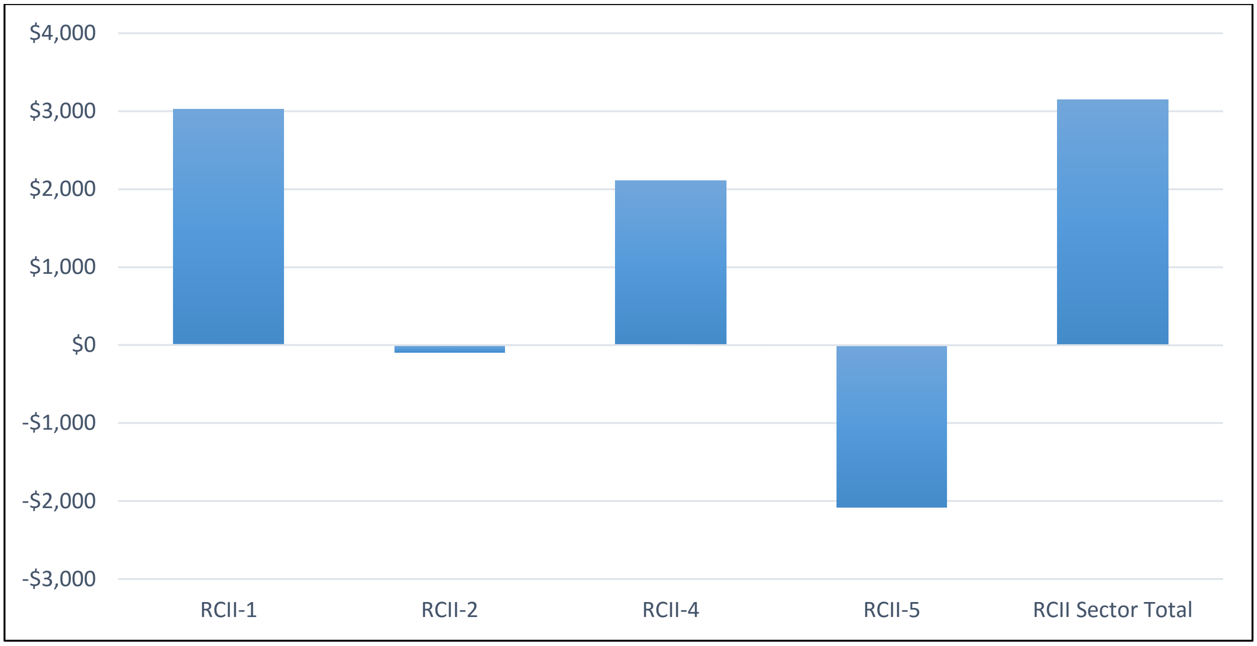


Figure F-2.12 RCII Employment Impacts, 2016-2030 Average (Jobs)

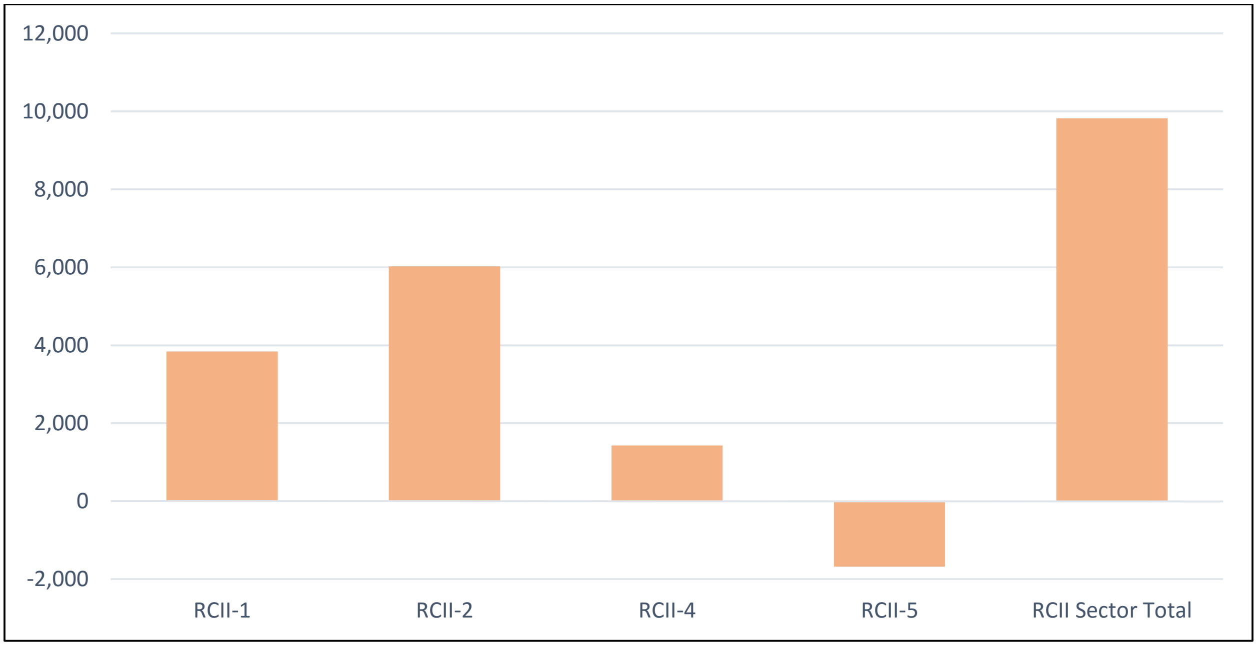


Figure F-2.13 RCII Employment Impacts, 2016-2030 Cumulative (Jobs)

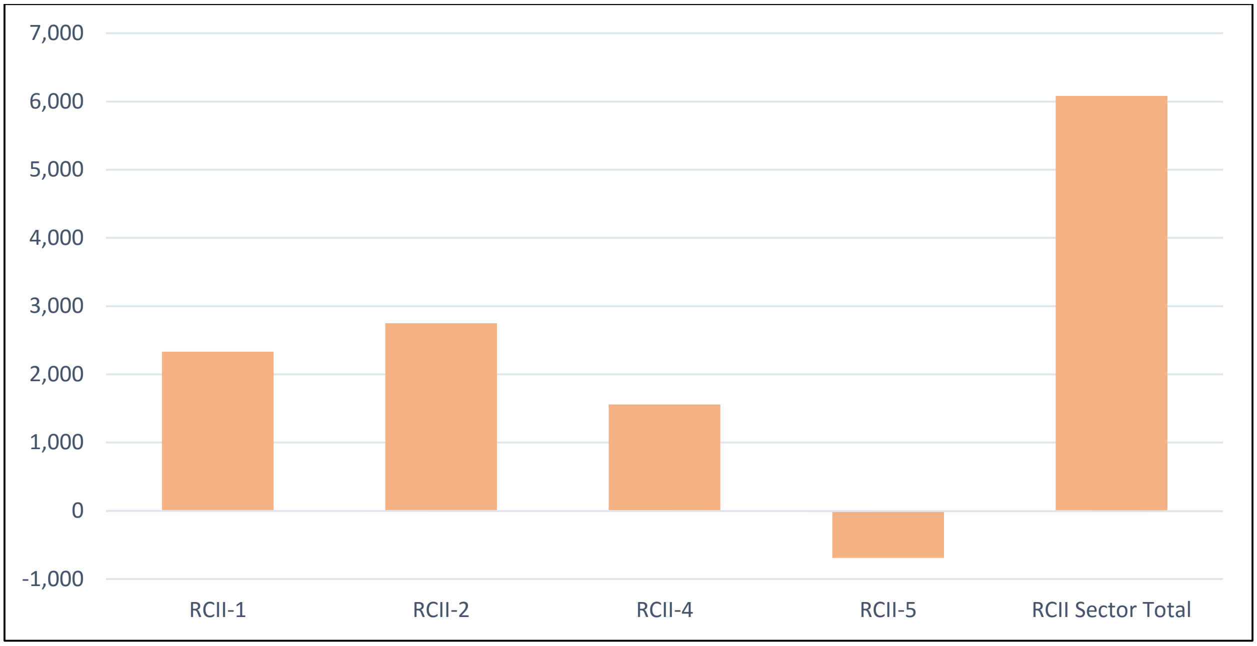


Figure F-2.14 RCII Employment Impacts, Year 2030 (Jobs)

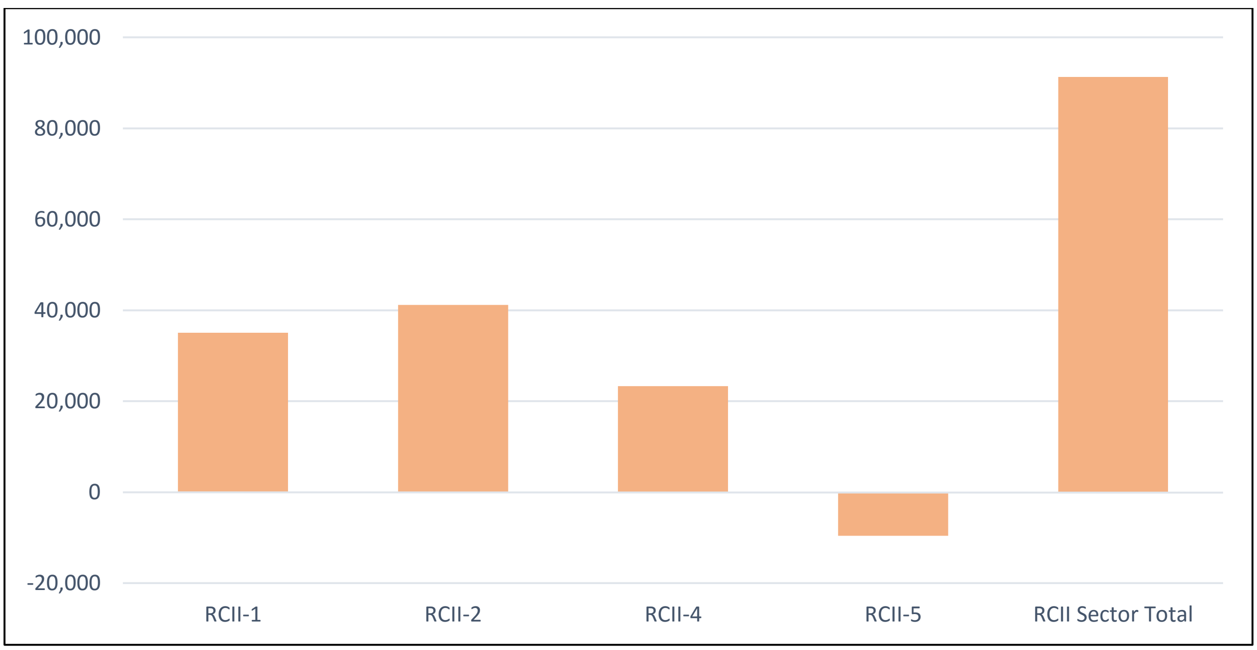


Figure F-2.15 RCII Income Impacts, 2016-2030 Average ($2015 MM)

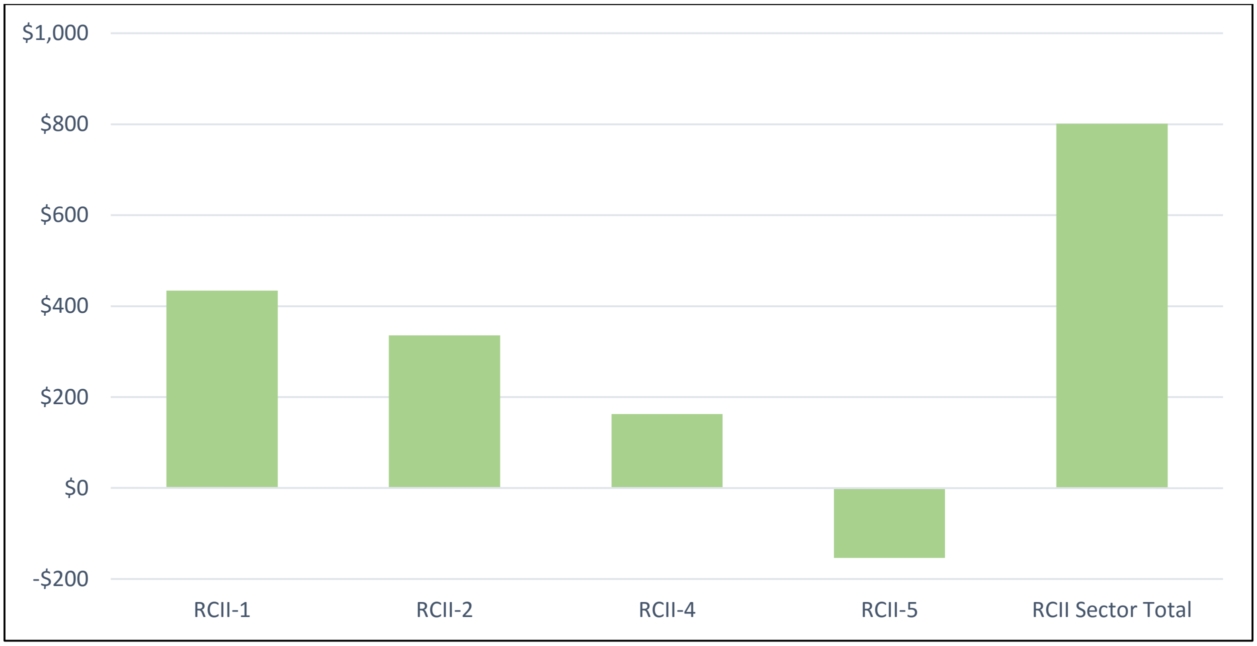


Figure F-2.16 RCII Income Impacts, 2016-2030 Cumulative ($2015 MM)

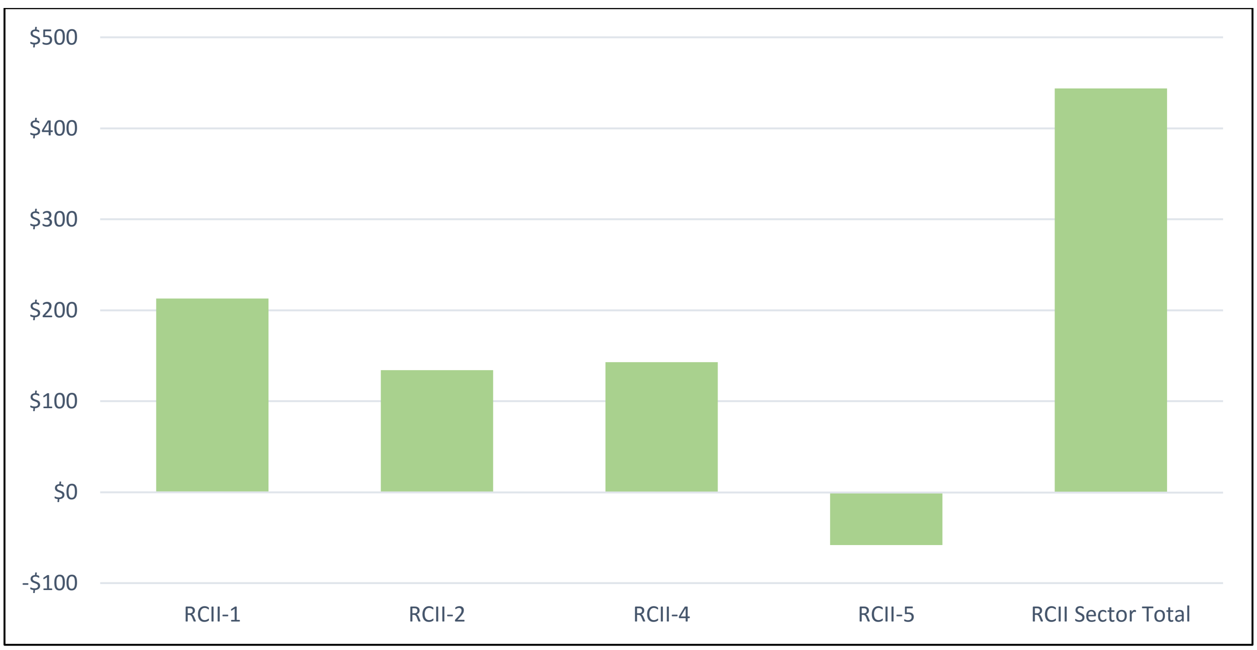
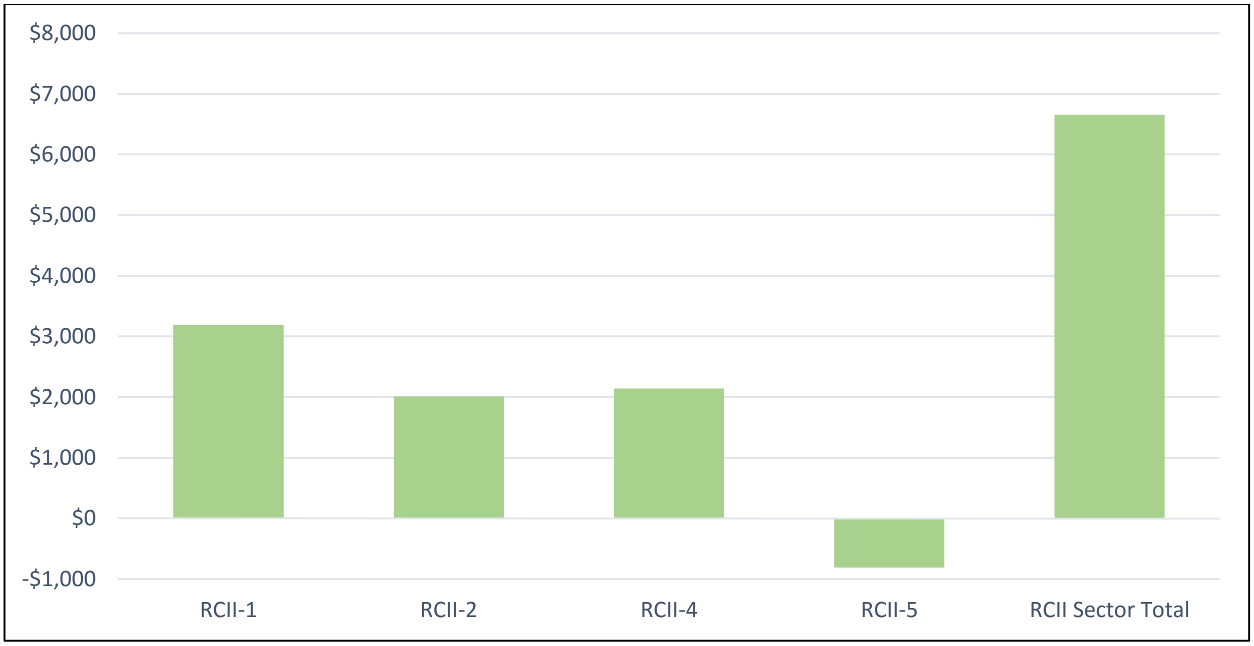


Figure F-2.17 RCII Income Impacts, Year 2030 ($2015 MM)



RCII-1. Combined Heat and Power (CHP) for Natural Gas or Biomass

Policy Option Description

Combined heat and power (CHP) systems reduce fossil fuel use and GHG emissions by recovering heat that is usually wasted as reject heat in power plants for useful purposes (heating buildings, domestic hot water, industrial process heat, or conversion to cooling energy for air conditioning or industrial cooling energy).

Additionally, reductions are achieved both through the improved efficiency of the CHP systems, relative to separate heat and power technologies, and by avoiding transmission and distribution losses associated with moving power from central power stations that are located far away from the point of electricity end use. This policy option description details Minnesota's overarching policy option for Combined Heat and Power. Within this overarching policy option, existing regulatory frameworks are leveraged and new standards developed to be included in other policy option development areas addressing greenhouse gas emissions reductions. As follows:

Conservation Improvement Program (Minnesota Statute 216B.241) – Expand the electricity and natural gas utility CIP goals to promote use of CHP systems, including encouragement of electric or natural gas utility-owned CHP as well as incentives for implementation of non-utility-owned CHP.

Renewable Energy Standard (Minnesota Statute 216B.1691) – Expand the Renewable Energy Standard (RES) to include a specific goal within the RES for currently eligible CHP technologies, and incorporate additional provisions for RES credit to encourage use of biomass for thermal energy production without power production in areas of the state without access to natural gas service.

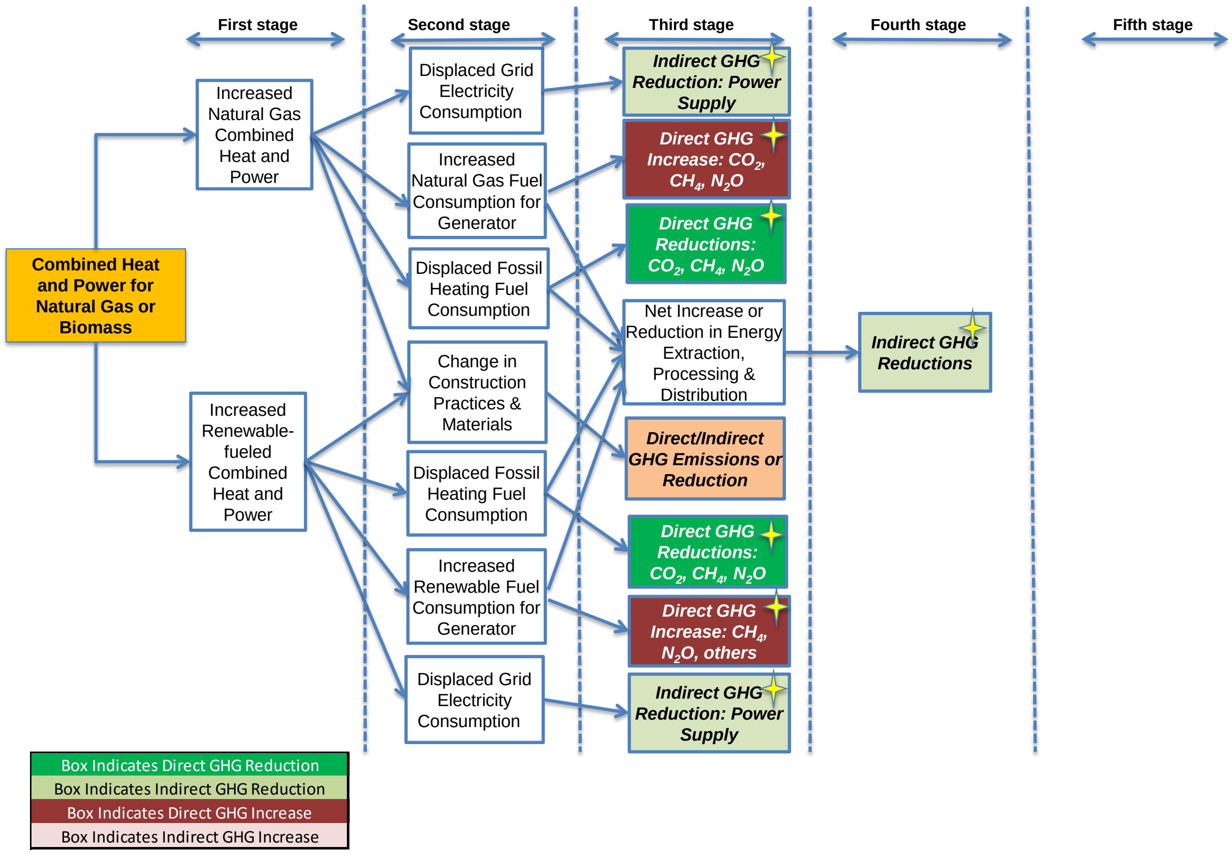
Integrated Resource Planning (Minnesota Statute 216B.2422) – Require electric utilities to demonstrate that, before power-only capacity is proposed, CHP opportunities within their service territory have been thoroughly assessed to determine the benefits of CHP (and associated technologies such as thermal energy storage) relative to existing and planned thermal loads total primary energy efficiency, GHG emissions, power grid resiliency, peak demand management and risk management.

Potential supporting measures for this policy option include technical assistance for utilities and industry to analyze feasibility and apply implementation actions to commercialize high performing CHP and other thermal recovery and advanced clean energy technologies, revision of net metering and standby rate practices, and establishment of clear and consistent interconnection standards.

Causal Chain for GHG Reductions

A schematic causal chain for this policy option is provided below. Increased capacity and use of CHP systems powered with natural gas and with renewable fuels (typically biomass of various types) displaces electricity from the central grid, and, through the use of cogenerated heat, displaces fossil fuels (natural gas, distillate oil, coal, and propane) used for space heat, water heat, and process heat produced in furnaces, boilers, and water heaters. As such, GHG emissions savings accrue through the reduction of central grid electricity supply and fossil fuels formerly used for heating, but these savings are partially offset by emissions from natural gas and renewable fuels combustion in CHP systems. In addition, reduced use of fossil fuel reduces "upstream" emissions associated with, for example, natural gas transmission and distribution, oil refining and transport, and natural gas and crude oil production. It is expected that these GHG emissions reductions and increases will be quantified. Increased use of renewable fuels will produce some increase in emissions associated with fuel processing and transport—for example, diesel-fueled equipment used for biomass harvesting and transport. These additional emissions, however, are highly variable depending on the source of the biomass fuel and the distance it must be shipped to the CHP facility. As a result, these incremental emissions may or may not be quantified, depending on data availability.

Figure F-2.18 Causal Chain for RCII-1 GHG Reductions



Policy Option Design

Table F-2.4 RCII Policy Option Design Goals

CSEO	Policy Option	Goal	Timeline	Details
RCII-1	Combined Heat and Power	CIP (RCII-4): Natural Gas 34TBtu by 2030 Electric 800 MW by 2030 RES (ES-1): 300 MW	2016 - 2030	Includes: All CHP (SEE BELOW)

CSEO	Policy Option	Goal	Timeline	Details
RCII-4	Increase EE Requirement (CIP)	Natural Gas Utility: 1.5% CIP Goal (Include 1% from Demand-side Management only) (Include 34 TBtu output of displaced fossil fuels goal by 2030) Electric Utility: 2.5% Demand-Side Management (1.5% must be DSM as defined in 216B.241) (Include an embedded 800 MW of generated electricity from CHP systems goal to be achieved by 2030)	2016 - 2030 3 Year ramp up period between 2016-2019 Minimum goal for End-Use Efficiency with an embedded CHP goal for electric and natural gas utilities.	Includes: Projects as defined in 216B.241, Subdivision 1 (e) (n) and (o); and Subdivision 10 Natural Gas CHP and distributed generation tech/fuel sources eligible under 216B.2411
ES-1	Increase RES All electric utilities subject to 216B.1691	5% Biomass CHP (300MW)	2016-2030	Includes: Tech/renewable fuel sources eligible under 216B.1691 (and 216B.2411) Minimum efficiency standard of 60%.

Goals: Establish minimum efficiency standards for non-renewable CHP in CIP, as follows:

- at least 20% of its total useful energy in the form of thermal energy which is not used to produce electrical or mechanical power (or combination thereof);
- at least 20% of its total useful energy in the form of electrical or mechanical power (or combination thereof); and
- total useful energy equal to or greater than 60% of the input fuel energy.

CHP Potential Information

The primary sources for developing this policy option framework are from two Department of Commerce-funded studies prepared by FVB Energy. The two sources include a Regulatory Issues and Policy Evaluation study and a Technical and Economic Potential study. This work was completed in August 2014.

- The Regulatory Issues and Policy Evaluation study can be found on the Department of Commerce web site: http://mn.gov/commerce/energy/images/CHPRegulatoryIssuesandPolicyEvaluation.pdf

- The Technical and Economic Potential study can be found on the Department of Commerce web site: http://mn.gov/commerce/energy/images/CHPTechnicalandEconomicPotential.pdf

CHP Technologies

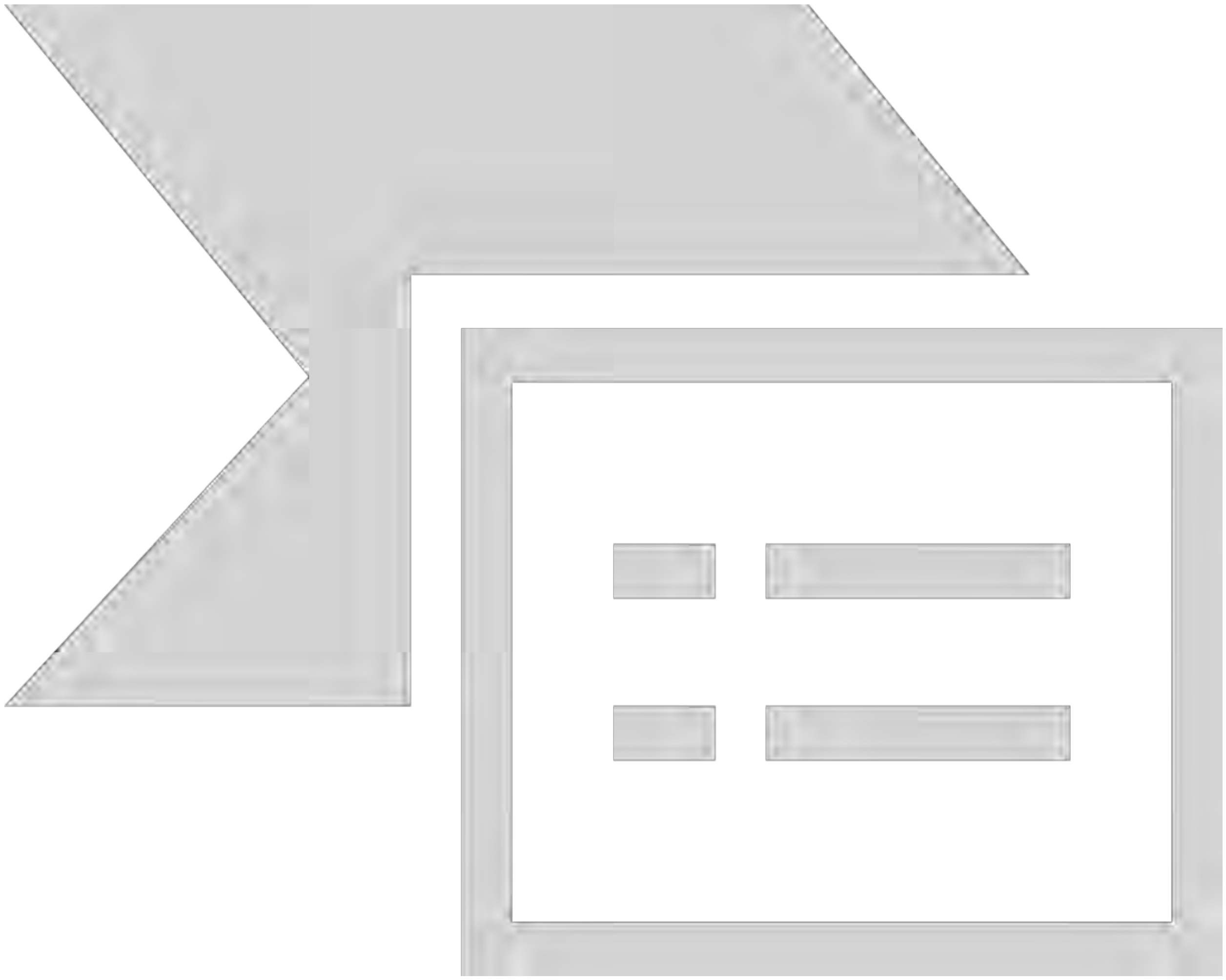
The primary source for the tables below (Table F-2.5 and Table F-2.6) is the U.S. Environmental Protection Agency Combined Heat and Power Partnership's Catalogue of CHP Technologies published in December 2008 (pages 6&7). The purpose of Table F-2.5 is to demonstrate the eligible CHP technologies and available sizes in the CHP policy option design. The purpose of Table F-2.6 is to demonstrate the different efficiencies, fuel sources, power to heat ratios, as well as other potentially useful variables for modeling the GHG emissions reductions from CHP.

Table F-2.5 Summary of CHP Technologies

Table II: Summary of CHP Technologies

CHP system	Advantages	Disadvantages	Available sizes
Gas turbine	High reliability. Low emissions. High grade heat available. No cooling required.	Require high pressure gas or in-house gas compressor. Poor efficiency at low loading. Output falls as ambient temperature rises.	500 kW to 250 MW
Microturbine	Small number of moving parts. Compact size and light weight. Low emissions. No cooling required.	High costs. Relatively low mechanical efficiency. Limited to lower temperature cogeneration applications.	30 kW to 250 kW
Spark ignition (SI) reciprocating engine	High power efficiency with part-load operational flexibility. Fast start-up. Relatively low investment cost. Can be used in island mode and have good load following capability. Can be overhauled on site with normal operators. Operate on low-pressure gas.	High maintenance costs. Limited to lower temperature cogeneration applications. Relatively high air emissions. Must be cooled even if recovered heat is not used. High levels of low frequency noise.	< 5 MW in DG applications
Compression ignition (CI) reciprocating engine (dual fuel pilot ignition)			High speed (1,200 RPM) ≤4MW Low speed (102-514 RPM) 4-75 MW
Steam turbine	High overall efficiency. Any type of fuel may be used. Ability to meet more than one site heat grade requirement. Long working life and high reliability. Power to heat ratio can be varied.	Slow start up. Low power to heat ratio.	50 kW to 250 MW
Fuel Cells	Low emissions and low noise. High efficiency over load range. Modular design.	High costs. Low durability and power density. Fuels requiring processing unless pure hydrogen is used.	5 kW to 2 MW

Table F-2.6 Summary Table of Typical Cost and Performance Characteristics by CHP Technology



Other Eligible CHP Technologies and Applications include:

- Waste Heat Recovery Systems
- Absorption/Adsorption Refrigeration Systems
- Thermal/Electric Energy Storage Systems for Load Management
- Emissions Control Systems

Displaced Fossil Fuel Sources: Information regarding Minnesota's energy consumption by source and by sector can be found on the U.S. Energy Information Administration's website (http://www.eia.gov/state/?sid=MN). Assumptions regarding the displaced fossil from CHP systems in different sectors can be made using this information. Below is a list of targeted fossil fuels to be displaced by implementation of the CHP technologies listed above. This list indicates the estimated amount of each fuel used in Minnesota in 2012. Most of these fuels are used to provide space, water, or process heat.[1]

- Natural Gas (Estimated consumption of 427.5 Trillion Btu)
- Coal (Estimated consumption of 257.9 Trillion Btu)
- Distillate Fuel Oil (Estimated consumption of 155.1 Trillion Btu)
- Propane (Estimated consumption of 27.9 Trillion Btu)

CHP Application and Markets: For more information regarding key existing commercial and industrial markets on a national level, and some detail on primary fuels and technologies per each application, refer to ICF International's May 2013 report prepared for the American Gas Association entitled *The Opportunity for CHP in the United States*. It is estimated that most, if not all, of the CHP potential in Minnesota will be achieved through the end uses listed below. The list below demonstrates the types of applications and markets available in Minnesota where the technologies mentioned above could be implemented.

Industrial (More information can be found in Tables 1-2 on pages 11-13 of the above mentioned report):

- Chemicals
- Petroleum Refining
- Pulp, Paper and Printing
- Food Processing
- Rubber/Plastics Manufacturing
- Transportation Equipment Manufacturing

Commercial (More information can be found in Tables 3-4 found on pages 13-16 of the ICF International report mentioned above):

- Colleges/Universities/Schools
- District Energy
- Hospitals/Health Care/Assisted Living/Nursing Care
- Government/Public Facilities
- Prisons
- Multifamily Buildings
- Office Buildings

[1] The exception here is distillate oil use. In this case, probably only 10-15 percent of total distillate oil used in Minnesota is used to provide heat, as the bulk of distillate oil is used in the form of diesel for vehicle and equipment engines. See, for example, http://www.eia.gov/dnav/pet/pet_cons_821dsta_dcu_nus_a.htm

- Hotels

Timing: Assuming any and all legislative solutions to address the policy option design goals are in place by mid-2015, the initiatives underway could begin in 2016 with related rule-making. The timing of this work would extend through 2030.

Parties Involved: Utilities (Subject to regulatory requirements):

Electric and natural gas utilities currently in CIP would be subject to the CIP CHP goals.

Electric utilities would be subject to the Biomass CHP RES.

All utilities subject to resource planning requirements would be required to consider natural gas and biomass CHP in their IRPs.

The prior list of commercial/industrial applications and market sectors may also serve as an indicator of other parties potentially involved in the achievement of the policy option design goals.

Implementation Mechanisms

Regulatory Frameworks

Conservation Improvement Program (CIP):

- Minnesota Statute 216B.241
- Using the CIP framework, establish a specific WHR/CHP goal for electric and natural gas utilities, which includes biomass and natural gas CHP, in addition to the existing conservation and end-use efficiency goal.

Renewable Energy Standard (RES):

- Minnesota Statute 216B.1691
- Using the RES framework, require electric utilities to include a certain percentage of their overall electricity generation from biomass CHP, with the option of crediting qualifying facilities producing only thermal energy.

Integrated Resource Planning:

- Minnesota Statute 216B.2422
- Minnesota Rules Chapter 7843
- Require all utilities subject to the requirements in 216B.2422 to consider both biomass-fired and natural gas CHP in its integrated resource plans.
- Require electric utilities to demonstrate in their Integrated Resource Plans that, before power-only capacity is proposed, CHP opportunities within their service territory have been thoroughly assessed to determine the benefits of CHP (and associated technologies such as thermal energy storage) relative to total primary energy efficiency, GHG emissions, power grid resiliency, peak demand management and risk management.

Standby Rates and Net Metering:

- Create transparent, concise and easily understandable standby rates so that customers can accurately predict future standby charges and assess financial impacts of CHP.

Renewable Energy Credits:

- When combined heating and power systems use eligible energy technology to generate both electricity and thermal energy for building and/or process heating, allow both electricity and thermal energy to meet the Renewable Energy Standard. One Renewable Energy Credit shall be created for each kWh generated by an eligible energy technology and one Renewable Energy Credit shall be created for each 3,415 British Thermal Units of heat generated by eligible energy technology. Commercial combustion plants that use eligible energy technology to replace the use of fossil fuels to generate thermal energy for building and/or process heating should be eligible to receive one Renewable Energy Credit for each 3,415 British Thermal Units of heat generated.

Financing and Incentive Mechanisms:

Utility:

- Financial incentives from energy savings credit received under Minnesota Statute 216B.16 Subdivision 6c. and 216B.241 Subdivision 2c should be provided to electric and natural gas utilities required to meet CIP CHP requirements.
- A decoupling mechanism should be established for each utility subject to the applicable CHP standard requirements to separate utility revenues from sales and rate design under Minnesota Statute 216B.2412.
- CHP should be an allowable rate-base investment for electric and gas utilities:
- Allow and encourage electric and gas utilities to invest in CHP using their relatively low-cost Weighted Average Cost of Capital, with clear guidelines to avoid utility ratepayer cross-subsidization.
- Allow and encourage electric and natural gas utilities to cooperate to implement CHP projects, with the CIP credit split based on the total financial contribution made by each utility.

Industry:

- CIP incentives should be available for qualifying projects under Minnesota Statute 216B.241.
- CHP incentives should be provided for both capital costs (tied to initial capital cost) and operating costs (tied to actual CHP production).
- Use existing financing options such as St. Paul Port Authority Trillion Btu Program, Guaranteed Energy Savings Program, or others to support CHP project implementation.
- Provide patent protection, R&D tax credits, production subsidies or tax credits to firms bringing new CHP/distributed generation-related/renewable energy technologies to

market, tax credits or rebates for new technology buyers, government procurement, and demonstration projects.

Technical Assistance:

Create a ratepayer-funded technical assistance program to help utilities and customers meet the requirements of this policy option design and description. A technical assistance program should offer engineering and financial expertise to help end-users determine the viability of CHP projects and provide tools/resources to help begin the implementation of CHP projects. The funding mechanism and amount should be sourced appropriately and proportionately to the standards being met.

Related Policies/Programs in Place and Recent Actions

To achieve the goals set in this policy option recommendation, existing regulatory frameworks are leveraged and new standards developed to be included in other policy option development areas addressing greenhouse gas emissions reductions. As follows:

Conservation Improvement Program (Minnesota Statute 216B.241) – Expand the electricity and natural gas utility CIP goals to promote use of CHP systems, including encouragement of electric or natural gas utility-owned CHP as well as incentives for implementation of non-utility-owned CHP.

Renewable Energy Standard (Minnesota Statute 216B.1691) – Expand the Renewable Energy Standard (RES) to include a specific goal within the RES for currently eligible CHP technologies, and incorporate additional provisions for RES credit to encourage use of biomass for thermal energy production without power production in areas of the state without access to natural gas service.

Integrated Resource Planning (Minnesota Statute 216B.2422) – Require electric utilities to demonstrate that, before power-only capacity is proposed, CHP opportunities within their service territory have been thoroughly assessed to determine the benefits of CHP (and associated technologies such as thermal energy storage) relative to existing and planned thermal loads total primary energy efficiency, GHG emissions, power grid resiliency, peak demand management and risk management.

Estimated Policy Impacts

Direct Policy Impacts

Summary in-state (direct) GHG emissions reduction and option costs results for RCII-1, “Combined Heat and Power (CHP) for Natural Gas or Biomass”, are provided in the table below. These values include costs for program administration. Negative values are shown in parentheses. In the “Net present value of societal costs” column, negative values, and denote instances where the costs of the implementing option (or part of the option) are LESS than the direct economic benefits of the option in avoided energy and other costs. Negative values in the "cost effectiveness" column indicate that there is a net direct economic benefit per metric ton of carbon dioxide equivalent saved. Overall, this option results in 4.87 million metric tons (which is the same as teragrams—trillion grams or Tg in the table below) of annual CO_2e savings in 2030, with about 46 million metric tons of CO_2e savings over the analysis period. Somewhat more than half of the savings comes from implementation of natural gas CHP systems. In addition to these in-state reductions, RCII-1 produces an estimated 0.39 TgCO_2e of out-of-state (upstream) emissions reductions in 2030, and 3.26 TgCO_2e in cumulative out-of-state reductions from 2015-2030, yielding total 2030 emissions reductions of 5.26 TgCO_2e in 2030, and 49.71 TgCO_2e over 2015-2030.

Table F-2.7 RCII- 1 Estimated Net GHG Reductions and Net Costs or Savings

	2030 GHG reductions (TgCO_2e)	2015 – 2030 cumulative reductions (TgCO_2e)	Net present value of societal costs, 2015 – 2030 (million $2014)	Cost effectiveness ($2014/t CO_2e)
Expanded Natural Gas-fueled CHP Implementation	2.55	25.09	$(771.03)	$(31.21)
Expanded Renewable-fueled CHP Implementation	2.32	21.37	$(340.48)	$(13.62)
TOTAL	4.87	46.46	$(1,111.50)	$(22.36)

Notes: Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Data Sources

In addition to the USEPA documents referenced above, see notes in "Key Assumptions", below.

Quantification Methods

The quantification of this option is carried out using the following step-wise process:

- Quantification begins by interpreting the goals for additional MW of gas-fired and renewable (mostly biomass)-fueled CHP to be implemented in each program year.
- Next, assumptions are made regarding the average electricity generation efficiency, useful heat production efficiency, and average capacity factors of the CHP systems implemented. Settling on these factors required identifying representative types of CHP systems (for example, steam-cycle, micro-turbine, reciprocating systems, and other) and representative types of applications in the end-use sectors in Minnesota.

- The goals and CHP technical assumptions as above are used to calculate the amount of available heat that the CHP systems will produce, along with the amount of electricity generated.
- A combination of assumptions regarding the fraction of fuels displaced, by sector (industrial, commercial, and possibly residential), based on Minnesota state consumption of fuels by sector, plus estimates of the average efficiency of heat production using those fuels (at typical furnace/boiler efficiencies) that are displaced, taking into account technologies in use in Minnesota, are used to calculate the amount of fossil fuel use displaced by fuel type. This also requires an estimate of the fraction of cogenerated heat actually used to displace heating fuel use.
- The annual amounts of electricity generated, factoring in transmission and distribution (T&D) losses avoided by using distributed generation, are multiplied by a representative statewide GHG emission factor for marginal avoided generation (a combination of emissions mostly from natural gas-fired and coal-fired units, given that nuclear energy is unlikely to be displaced by CHP output) to yield an estimate of avoided emissions from electricity generation.
- The annual amounts of heating fuel use displaced, by type of fuel, are multiplied by emission factors for each fuel type to estimate reductions in emissions of GHGs from displaced heating fuel use.
- The annual amounts of natural gas and renewable fuels used to fuel the CHP systems are multiplied by appropriate emission factors to estimate the emissions associated with the CHP systems themselves, which are netted out against GHG emission savings from the two steps above.
- A stream of future avoided costs of electricity generation is used to estimate the value of the electricity from the central grid displaced by CHP output.
- Estimates of future costs for natural gas and other fossil fuels, derived in part from United States Department of Energy (DOE) projections, are used to estimate the value/cost of inputs to gas CHP and avoided fossil fuel use from displaced heat demand.
- Estimates of the representative future costs of renewable fuels (biomass) for CHP generation are used to calculate the fuel cost of renewable CHP systems.
- Representative average capital and non-fuel operating and maintenance (O&M) costs of CHP systems are used to estimate the additional cost of buying and using CHP systems.
- Representative average capital and non-fuel operating and maintenance (O&M) costs of displaced boiler and furnace systems are used to estimate the avoided cost of buying and using these heat-only systems.
- Full energy cycle GHG emissions for new and avoided fossil-fuel consumption are calculated through the application of representative upstream emission factors. For renewable fuels, a single set of emission factors, derived as a part of the analysis of forestry and land use (FOLU) options, are used to estimate direct emissions, but these

factors also incorporate Minnesota-specific studies of the GHG emissions associated with biomass fuel provision as well as combustion.

Key Assumptions

In addition to the goals described above, key assumptions used in the analysis of RCII-1, as reflected in the listing of analytical steps in the previous section of this document, include:

- Fraction of CHP deployment goals above achieved over the analysis period are assumed to be as follows: 2016-2020—37.5%, 2021-2025—37.5%, 2026-2030—25%.
- The fraction of gas-fired CHP capacity by type of technology was assumed to be as shown in the table below, based on input from FVB Energy staff. All biomass-fired CHP was assumed to use steam-cycle technology.

Table F-2.8 Fractions of Gas-Fired CHP Capacity by Type Deployed by Sector

Fractions of gas-fired CHP capacity by type deployed by sector

	Steam Turbine	Reciprocating Engine	Gas Turbine	Microturbine	Fuel Cells
Residential	0%	10%	0%	90%	0%
Commercial	5%	75%	20%	0%	0%
Industrial	30%	20%	50%	0%	0%

Average capacity factors, electricity generation efficiencies, heat generation efficiencies, and assumed fraction of CHP heat output used by type of CHP systems are as described in the tables below, based on a combination of data from the EPA documents described above, the *Minnesota Combined Heat and Power Policies and Potential: Conservation Applied Research & Development (CARD) FINAL REPORT*, dated July 2014, and the judgment of analysts and Minnesota Agency Staff.

Table F-2.9 Average Gas-fired CHP Performance Assumptions

Average Gas-fired CHP Performance Assumptions

	Steam Turbine	Reciprocating Engine	Gas Turbine	Microturbine	Fuel Cells
Electricity Generation Efficiency	28%	34.9%	33.8%	23%	45%
Heat Production Efficiency	52%	43.6%	36.6%	47%	30%
Total Fuel-to-output Efficiency	80%	78.5%	70.4%	70%	75%

Table F-2.10 Average Renewables-fired CHP Performance Assumptions

Average Renewables-fired CHP Performance Assumptions

Electricity Generation Efficiency	26%
Heat Production Efficiency	50%
Total Fuel-to-output Efficiency	76%

Table F-2.11 Average CHP Annual Capacity Factor and Heat Use Fraction Assumptions

Average CHP Annual Capacity Factor and Heat Use Fraction Assumptions

	Capacity Factor		Fraction of Heat Output Used	
	Gas-fired	Renewable-fired	Gas-fired	Renewable-fired
Residential	40%	40%	70%	70%
Commercial	70%	70%	90%	90%
Industrial	85%	85%	90%	90%

- The fractions of CHP heat displacing specific fuel types (coal, gas, propane, distillate fuel) by sector are based on the proportion of each fuel that is forecast to be used in each sector. Natural gas represents approximately 80 to 90 percent of the fuel displaced.
- Average boiler/furnace efficiencies for heat displaced by CHP heat are 86% for both the commercial/institutional and industrial sectors.[2]
- Estimated avoided marginal emission factors for electricity generation, on a delivered basis, falls from 0.936 tCO_2e per MWh in 2015 to 0.758 in 2030, with avoided costs of electricity generation (again based on delivery to consumers, that is, factoring in transmission and distribution losses) rising from $92.6 to $148.1 per MWh delivered (nominal dollars) over the same time period. Natural gas avoided (wholesale) costs rise from $4.78 to $8.97 per GJ (again nominal dollars) over the same time period.
- Avoided costs for other fossil fuels used for heating, the use of which is displaced by CHP, are as defined in the Common Assumptions used across all sectors in the analysis of GHG Mitigation options for Minnesota.
- Wholesale costs of biomass fuels rise from $2.96/GJ in 2015 to $6.73/GJ in 2030 (nominal dollars).
- CHP capital and O&M costs by type of CHP system and by sector, are as presented in the tables below for gas-fired and biomass-fired systems, respectively. Costs are derived from several sources, including the EPA documents described above and *Minnesota Combined Heat and Power Policies and Potential: Conservation Applied Research & Development (CARD) FINAL REPORT,* dated July 2014, provided by Minnesota Agency Staff.

[2] Average boiler and furnace efficiencies based on an estimate from Minnesota Agency Staff.

Table Ap F-2.12 CHP Capital and Operating Cost Calculations

CHP CAPITAL AND OPERATING COST CALCULATIONS

Average Gas-fired CHP Cost Assumptions by System Type (cost figures assumed $2014)

	Parameter	Steam Turbine	Reciprocating Engine	Gas Turbine	Microturbine	Fuel Cells
Residential and Commercial/ Institutional Applications	Capial Cost ($/kW)	$ 1,800	$ 3,606	$ 2,334	$ 3,000	$ 5,000
	Variable Non-fuel O&M Cost ($/MWh)	$ 5.00	$ 21.81	$ 11.72	$ 20.00	$ 35.00
	Fixed O&M Costs ($/kW-yr)	$ -			$ -	$ -
	Lifetime (years)	30	15	20	20	20
	Interest Rate (%/yr)	5.0%	5.0%	5.0%	5.0%	5.0%
	Annualized Capital Payment ($/kW)	$ 117.09	$ 347.41	$ 187.30	$ 240.73	$ 401.21
Industrial Applications	Capial Cost ($/kW)	$ 1,200	$ 3,352	$ 1,792	$ 3,000	$ 5,000
	Variable Non-fuel O&M Cost ($/MWh)	$ 5.00	$ 19.56	$ 8.44	$ 20.00	$ 35.00
	Fixed O&M Costs ($/kW-yr)	$ -			$ -	$ -
	Lifetime (years)	30	15	20	20	20
	Interest Rate (%/yr)	5.0%	5.0%	5.0%	5.0%	5.0%
	Annualized Capital Payment ($/kW)	$ 78.06	$ 322.97	$ 143.82	$ 240.73	$ 401.21

Table F-2.13 Average Renewables-fired CHP Cost Assumptions (Cost Figures Assumed $2014)

Average Renewables-fired CHP Cost Assumptions (cost figures assumed $2014)

	Commercial/ Institutional	Industrial
Capial Cost ($/kW)	$ 4,551	$ 3,761.21
Variable Non-fuel O&M Cost ($/MWh)	$ 30.45	$ 23.84
Fixed O&M Costs ($/kW-yr)	$ -	$ -
Lifetime (years)	25	25
Interest Rate (%/yr)	5.0%	5.0%
Annualized Capital Payment ($/kW)	$ 322.90	$ 266.87

Boiler/furnace capital and O&M costs avoided by the application of CHP systems, by type and sector, are as follows, based on estimates from various sources.

Table F-2.14 Average Fossil-fired Heating Source Cost Assumptions (Cost Figures Assumed $2014)

Average Fossil-fired Heating Source Cost Assumptions (cost figures assumed $2014)

Parameter	Residential	Commercial	Industrial
Capial Cost ($/(MMBtu/hr))	$ 25,000	$ 15,000	$ 10,000
Variable O&M Costs ($/MMBtu output)	$ 1.00	$ 1.50	$ 1.50
Lifetime (years)	20	20	20
Interest Rate (%/yr)	5.0%	5.0%	5.0%
Annualized Capital Payment ($/(MMBtu/hr))	$ 2,006.06	$ 1,203.64	$ 802.43

- GHG Emission factors for natural gas, coal, oil products, and wood, as well as upstream fuel cycle GHG emission factors for natural gas, coal, and petroleum products, and biomass fuels are as defined in the Common Assumptions used across all sectors in the analysis of GHG Mitigation options for Minnesota.
- Administrative costs are estimated based on the assumptions that a CHP program sponsor will provide incentives equal in value to 40 and 25 percent of CHP system capital costs for the commercial/institutional and industrial sectors, respectively, and that administrative costs (marketing, accounting, customer service, evaluation, etc.) will be 15 and 10 percent of incentive costs for the commercial/institutional and industrial sectors, respectively.

Macroeconomic (Indirect) Policy Impacts

Table below provides a summary of the expected impacts on jobs and economic growth during the CSEO planning period.

Table F-2.15 RCII-1 Macroeconomic Impacts on GSP, Employment and Income

Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
RCII-1	$508	$202	$3,026	3,840	2,330	35,020	$434	$213	$3,191

Following three graphs below show detail in GSP, employment and personal income impact of the RCII-1 policy.

Figure F-2.19 RCII-1 GSP Impacts ($2015 MM)

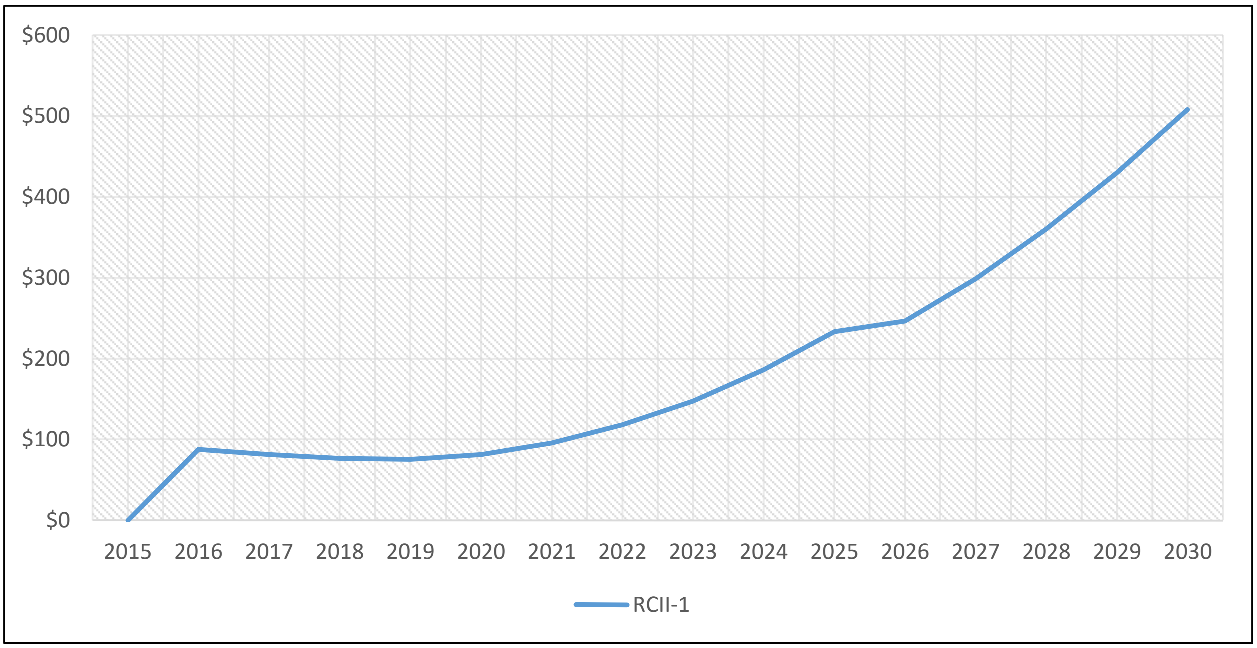


Figure F-2.20 RCII-1 Employment Impacts (Individual Jobs)

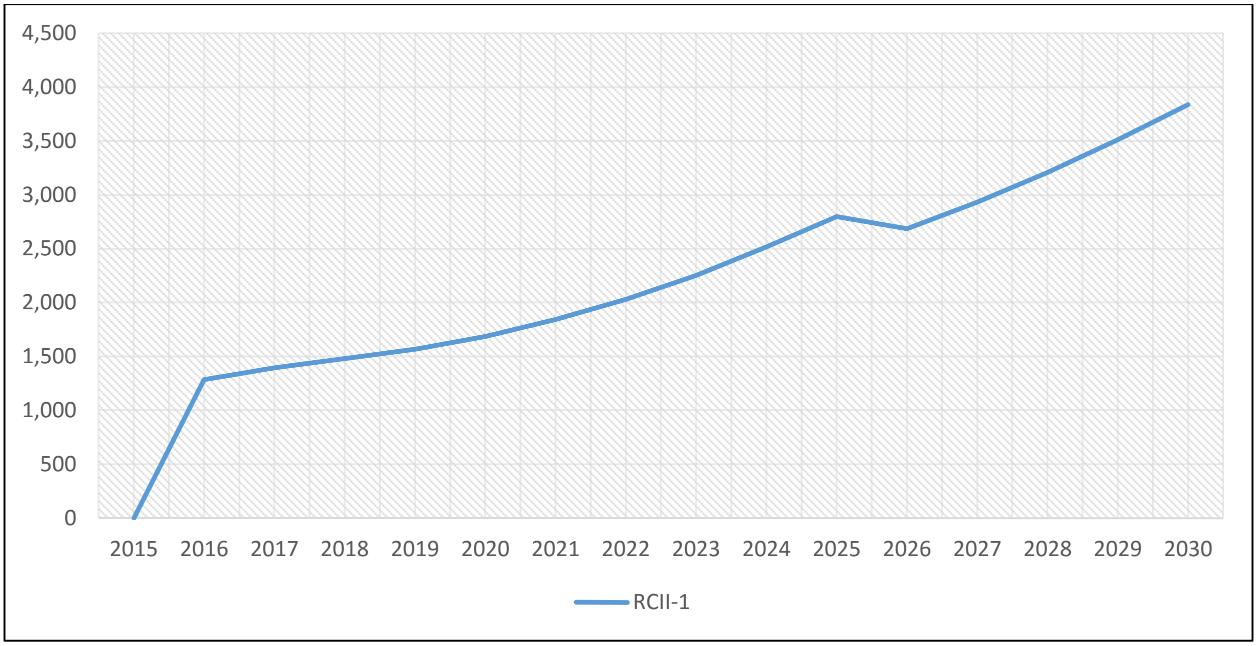
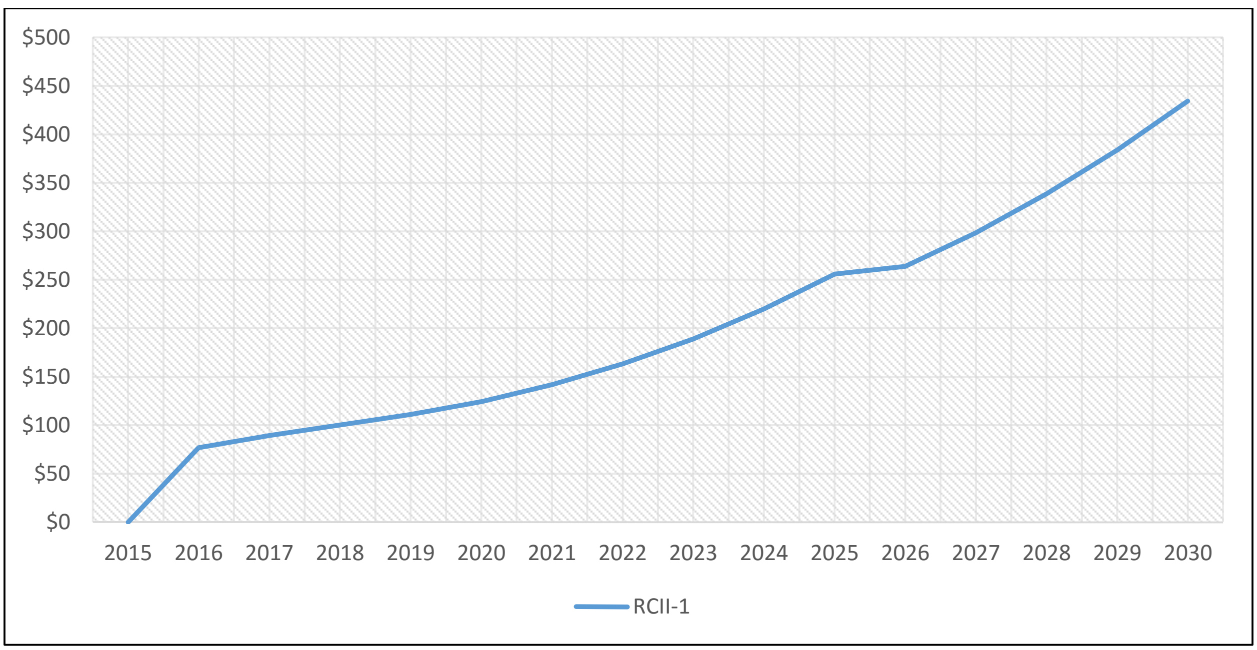
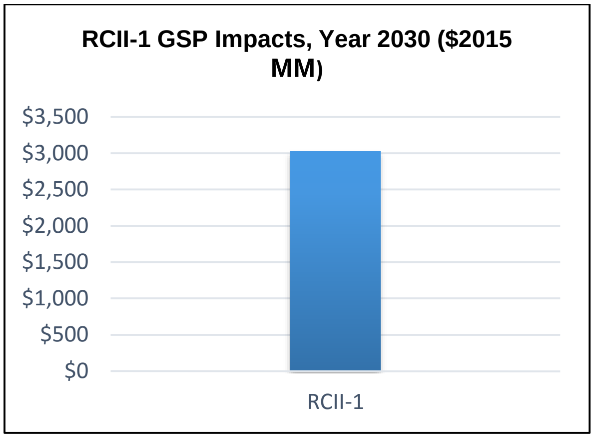
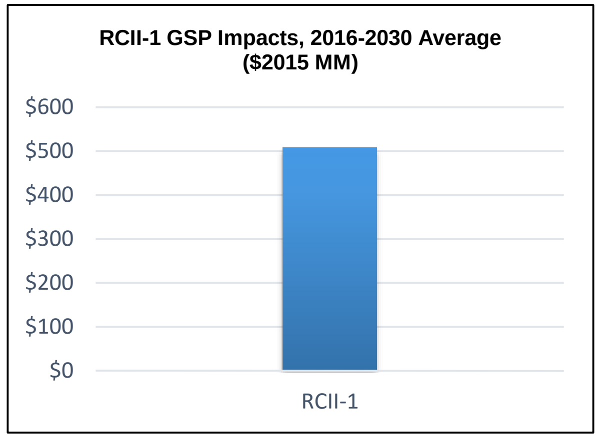


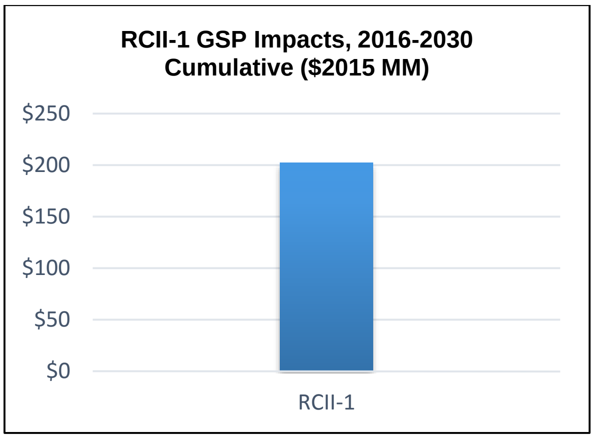
Figure F-2.21 RCII-1 Income Impacts ($2015 MM)

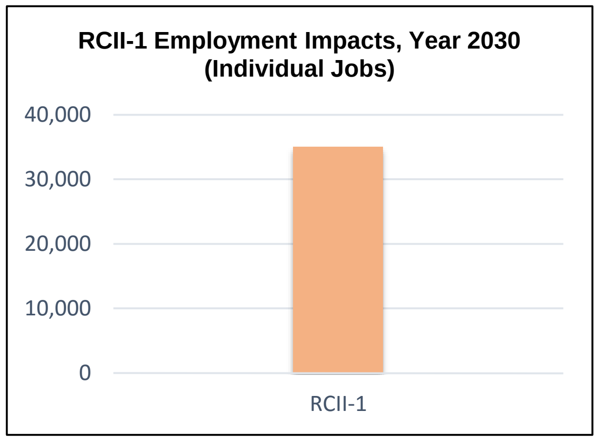


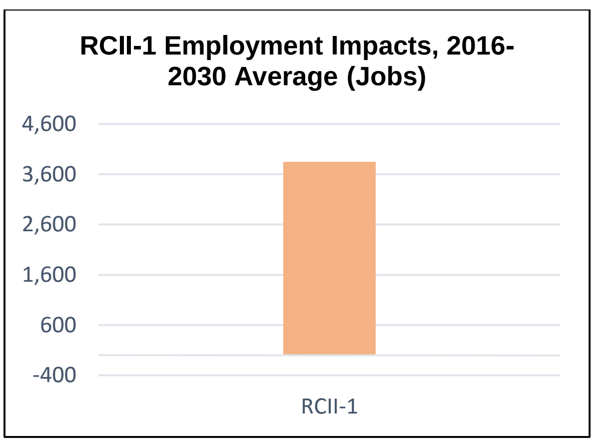
Bar charts below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030). Light color means sensitivity scenarios.

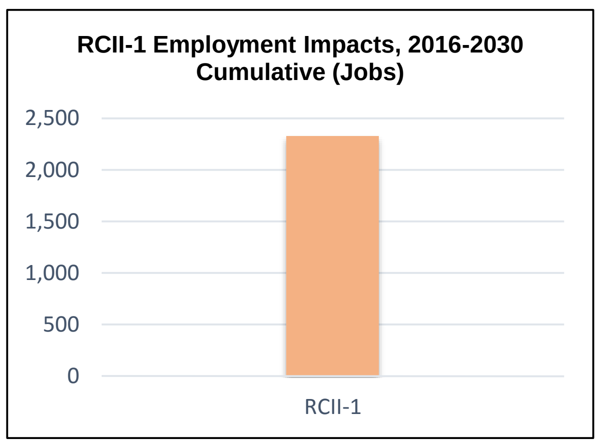

RCII-1 GSP Impacts, Year 2030 ($2015 MM)
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
RCII-1

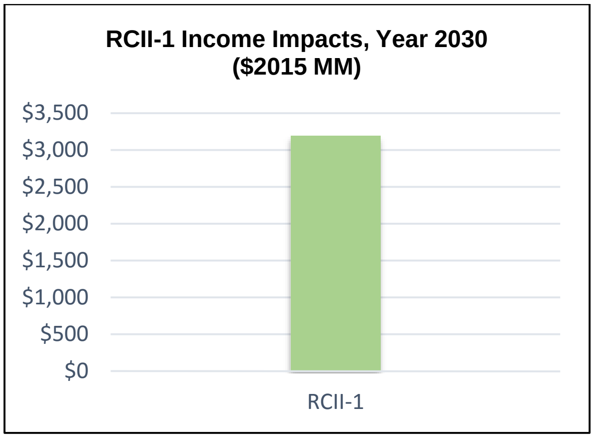

RCII-1 GSP Impacts, 2016-2030 Average ($2015 MM)
$600
$500
$400
$300
$200
$100
$0
RCII-1

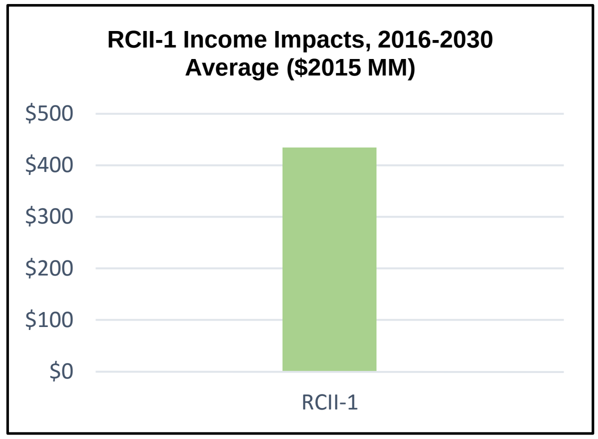

RCII-1 GSP Impacts, 2016-2030 Cumulative ($2015 MM)
$250
$200
$150
$100
$50
$0
RCII-1

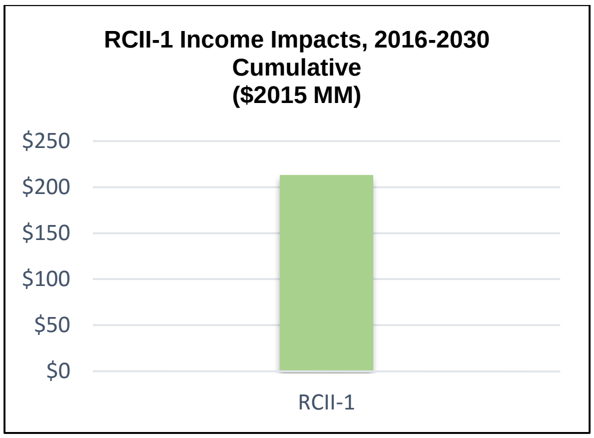

RCII-1 Employment Impacts, Year 2030 (Individual Jobs)
40,000
30,000
20,000
10,000
0
RCII-1


RCII-1 Employment Impacts, 2016-2030 Average (Jobs)
4,600
3,600
2,600
1,600
600
-400
RCII-1


RCII-1 Employment Impacts, 2016-2030 Cumulative (Jobs)
2,500
2,000
1,500
1,000
500
0
RCII-1







Principal Drivers of Macro-Economic Changes

The principal drivers of macroeconomic change are a significant savings in energy requirements by the industries and facilities that adopt CHP generation to produce both heat and power. While CHP units require large amounts of natural gas and biomass (both assumed to be utilized as fuel), the reductions in the use energy from other sources, such as conventional power and heat from coal and natural gas, or on-site power from diesel, coal or gas, far outweigh the requirements to run CHP. These savings reach hundreds of millions of dollars' worth of energy costs by 2030.

A second major driver is the spending on the construction and machinery involved in installing CHP generation. While this cost is borne over time by the entities putting them in place (a burden that applies a downward pressure on economic activity), the stimulus to the productive sectors that provide that construction and machinery drives growth. The ability of entities to finance the capital cost protects the economy from a sudden dislocation, so the spending stimulus happens quickly and the technological efficiency shift is put in place in time for the economy to benefit from both while absorbing the cost over time of the capital installation.

The state does spend money on administration of this policy as well, though it displaces other state spending. Both are similarly labor-intensive, within the assumptions of this analysis, and this is only a minor influence by comparison to those described above.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For RCII-1, the largest losses are direct: the utilities sector sees less demand because a more efficient economy requires less energy to generate the same level of activity and prosperity. As a result, total demand for that sector falls, and it spends less on the inputs to its production (fuel, operations and maintenance, labor and other inputs). This sector sees a drop in direct employment of about 300 positions by 2030 (against a total policy gain of around 4,000 positions in the same year).

The gains, as is common in an efficiency policy, are indirect: less spending over time on energy frees up money for other inputs, and business operating costs fall. This frees up money for other spending and applies a downward pressure to prices as well – which in turn frees up cash for purchasers and creates a positive income effect. The sectors that grow the most are consumer-oriented (apparel sales, educational services, restaurants and health care) as well as energy-related (natural gas and biomass both see increase in demand, as do associated transportation sectors). Efficiency gains also spread small boosts across nearly all the other sectors of the economy.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy.

These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the RCII-1 policy, important data included:

- The capital cost to industrial and commercial entities that install CHP generation units, and the timing over which those costs would be incurred.
- The total volumes, and total spending on those volumes, of each type of energy consumed – both those sources reduced as a result of the switch to CHP from other heat or power sources and those sources increased to fuel the CHP units.
- The operating and maintenance costs associated with the entities' adoption of and operation of the CHP units.
- The costs to state government agencies to oversee and implement this policy.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs.

Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.

- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

There are a few key uncertainties that should be considered in the development and implementation of this proposed policy option:

- If Minnesota stakeholders are resistant to including CHP in the EERS and RES, is there a viable alternative to create an Alternative Energy Portfolio?

- How will stand-by rates and net metering practices need to be modified to facilitate greater implementation of CHP?
- What kind of expenditures will be required of utilities and ratepayers to provide incentives and programs aimed toward achieving the CHP standard?
- What impact will changing electric and natural gas prices have on the long-term operating costs for CHP projects?
- In achievement of the CHP standard, how will ratepayer cross-subsidization of incentivizing projects be avoided or managed?
- In the absence of an existing CHP technical assistance program for potential projects, how the state and its utilities drive demand for customer on-site generation?
- How could CHP be used as resource in the future to comply with pending EPA regulations from the Clean Power Plan (111(d))?

Additional Benefits and Costs

Only 42% of the total energy consumed in Minnesota is converted to useful energy. Of the total 1,817 trillion Btu (TBtu) of energy used in Minnesota:

- 384 TBtu was lost in electricity generation, transmission and distribution, resulting in an average power sector efficiency of only 32%;
- 229 TBtu was lost the Residential, Commercial & Industrial sectors (RCI) in converting RCI primary energy or electricity to useful energy services; and
- 434 TBtu was lost in transportation, primarily due to inefficiencies in cars.

In 2008, the total 384 TBtu of wasted energy in the power sector are estimated to consist of 12 TBtu of electrical line losses[3] and 372 TBtu of waste heat. This power generation waste heat in Minnesota is nearly equal to the total requirement for heat energy in the RCI sectors (390 TBtu).[4]

Given that the majority of the fuel sources in Minnesota are imported, any waste heat recovered for thermal distribution or electric generation would offset the fossil fuels that are currently imported into the state, potentially having a positive impact on Minnesota's economy.[5]

Additional Economic Benefits Could Include:

- Job creation from implementation of CHP technology

[3] Assumes 7.0 percent transmission/distribution losses.

[4] Assumes 90 percent of RCI primary energy is for heat production and is converted to useful energy at an average efficiency of 70 percent.

[5] 2008 Data from Lawrence Livermore National Laboratory Energy Flow Diagrams – hhttps://flowcharts.llnl.gov/index.html

- Increased innovation in the technology sector to address market needs for cogeneration
- Development of a robust CHP supply and value chain
- Reduced facility operating costs from implementation of CHP
- Low cost supply-side resource for the purpose of utility scale electric generation

Other Potential Grid Benefits:

- Reduction in losses of power along transmission and distribution lines, especially during peak demand periods.
- Increased utility access, through CHP installations, to ancillary and capacity services that help stabilize grid voltage and balance intermittent renewable resources such as wind and solar.
- CHP can operate as a critical capacity resource, providing cost-effective system capacity in smaller increments than a single large centralized power plant.
- CHP can be incorporated into a micro-grid strategy as part of an energy assurance plan at the local level ensuring community preparedness for energy related emergencies.

Feasibility Issues

Minnesota has been perpetually challenged to implement higher levels of CHP throughout the state. The feasibility of achieving the CHP standard embedded within the EERS will be dependent on many factors, a few of which include the following:

- Alignment of utility, regulatory, environmental, and market interests regarding the value proposition of CHP and a path forward toward inclusion of a CHP standard in Minnesota.
- Creation of utility programs that significantly reduce the upfront capital costs and overall risk of moving toward customer on-site generation.
- Establishment of reasonable stand-by rates by utilities and the Public Utilities Commission to remove obstacles in a customer’s ability to achieve a desired return on investment from project implementation.
- Potential adjustments made to net metering and interconnection standards and practices the reduce implementation barriers.
- Air quality impacts of on-site electric generation from CHP and regulatory requirements for implementation.
- Education and training programs established and available for customers who are implementing and/or considering implementing CHP.

RCII-2. SB2030/ Zero Energy Transition/Codes

Policy Option Description

Operating, and maintaining buildings involve the consumption of large amounts of energy. In 2011, Minnesota's residential and commercial sectors consumed 39.6% of the total energy consumed in the state-- the residential sector at 21.3 % while commercial consumed 18.3%. [6]

To ensure that new or renovated buildings serve us well into the future means constructing energy efficient buildings while pairing them with clean energy. Initiatives such as the national Architecture 2030, Zero Energy Ready or Minnesota's Sustainable Building 2030 (SB2030) can provide that assurance. As defined by National Renewable Energy Laboratory (NREL), a Net Zero Energy building "produces as much as or more energy than it uses annually and exports excess RE generation to the utility (electricity grid, district hot water system, or other central energy distribution system) to offset the energy used."[7] We adopt this definition for RCII-2 policy option.

Building energy codes specify minimum requirements for new and renovated buildings. But these codes will not make buildings zero energy in time for Minnesota to accomplish its climate change goals. Stretch goals can be achieved by adopting SB2030 as an appendix to the Minnesota Building Code, which then makes it available for local jurisdictions to use.

This policy option will provide incentives for or mandate construction of buildings so that net zero energy use in buildings is achieved incrementally by 2030 (60% - 2010; 70% - 2015, etc.) or upon completion of construction with zero-energy ready buildings.

Causal Chain for GHG Reductions

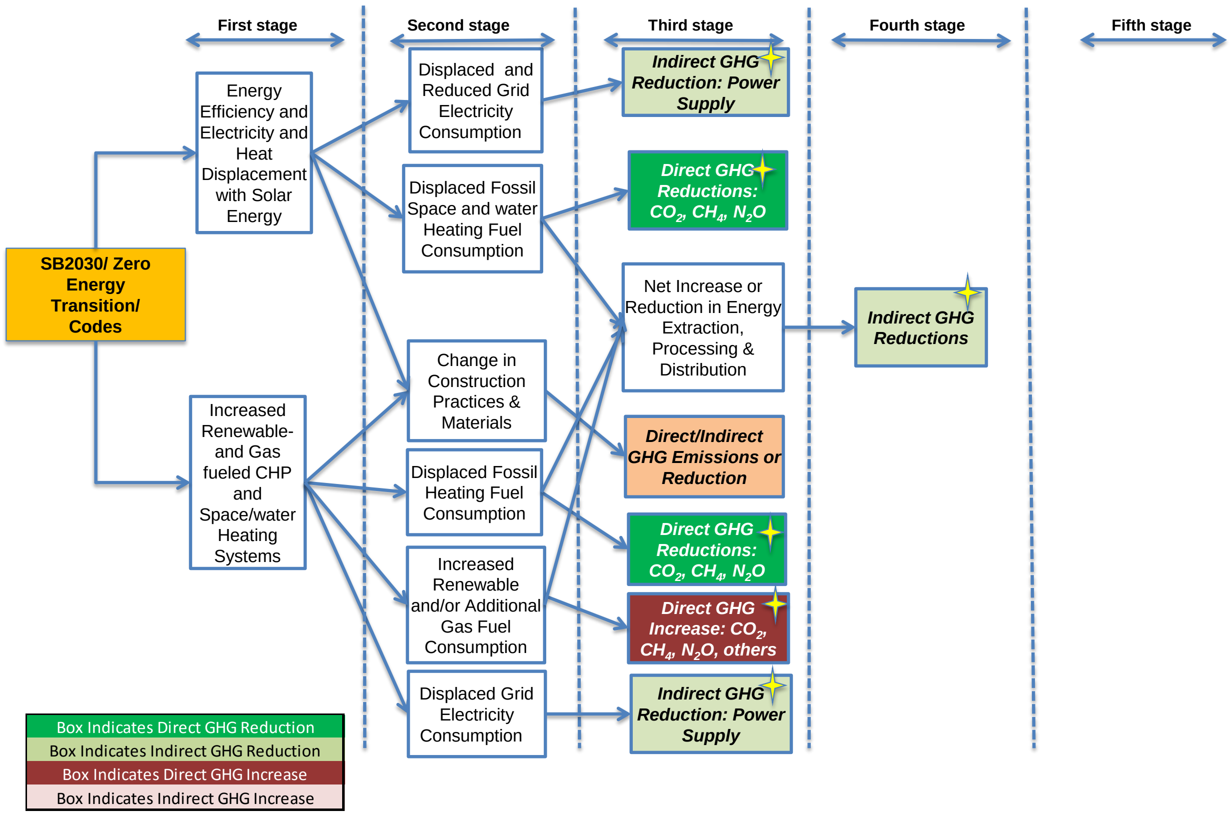
A schematic causal chain for this policy option is provided below. Increased capacity as well as use of CHP systems powered with natural gas to displace electricity from the central grid, and the use of cogenerated heat that displaces the fossil fuels (natural gas, distillate oil, coal, and propane) used for space heat and water heat that are under standard practice produced in furnaces, boilers, and water heaters. The application of solar water and space heat, and of energy efficiency, also displaces electricity and fossil fuel use. As such, GHG emissions savings accrue through the reduction of central grid electricity supply and fossil fuels formerly used for heating, but these savings are partially offset by emissions from natural gas and renewable fuels combustion. In addition, the reduced use of fossil fuel reduces "upstream" emissions associated with, for example, natural gas transmission and distribution, oil refining and transport, and natural gas and crude oil production. It is expected that these GHG emissions

[6] Energy Information Administration, State Energy Data Systems.

[7] *Net-Zero Energy Buildings: A Classification System Based on Renewable Energy Supply Options,* Shanti Pless and Paul Torcellini , National Renewable Energy Laboratory, U.S. Department of Energy, Technical Report NREL/TP-550-44586, June 2010 .

reductions and increases will be quantified. Increased use of renewable fuels will produce some increase in emissions associated with fuel processing and transport—for example, diesel-fueled equipment used for biomass harvesting and transport. These additional emissions, however, are highly variable depending on the source of the biomass fuel and the distance it must be shipped to the CHP facility. As a result, these incremental emissions may or may not be quantified, depending on data availability. Changes in building practices and in space and water heating equipment/appliance use in buildings may also produce changes in construction practices and materials that may have a positive or negative impact on GHG emissions. These impacts are indirect and uncertain, and will not be quantified.

Figure F-2.22 Causal Chain for RCII-2 GHG Reductions



Policy Option Design

Minnesota will develop a process for both commercial and residential buildings to reach zero energy status by 2030 through the Minnesota Sustainable Building 2030 process – a performance-based process. The current SB2030 team will continue its training program to architects and engineers. It will also need to develop a residential SB2030 program and create training elements for residential developers and builders.

The Department of Labor and Industry (DLI) will adopt SB2030 as its green stretch code and incorporate it as an appendix chapter. Jurisdictions that adopt it will then be able to require that all buildings in its jurisdiction be built to SB2030. Early adopting cities will assist in leading by example.

By stepping the requirement of voluntary use of SB2030 to mandatory use of SB2030, there will be time for appropriate training to get into place.

Goals:

- All new and renovated commercial buildings in the state, and all multi-family residential buildings four or more stories in height, will be required to use SB2030 through a stepped process, by 2020.
- All new one and two family dwellings and multi-family residential buildings three stories or less in height in the state will be required to use SB2030, through a stepped process, by 2025.
- Sufficient technical assistance and training is available to assist local units of government, architects, engineers, builders, and developers in moving toward SB2030.

Timing:

New and Renovated Commercial Buildings:

- 2015:
    - State-bonded buildings and state-licensed buildings (a new requirement) must use SB2030.
    - All public buildings may use SB2030 and receive appropriate technical assistance
    - DLI adopts SB2030 as an appendix for statewide building code for green commercial buildings.
- 2016:
    - Implement incentive program for voluntary adoption by commercial private sector.
    - Local units of government may begin adopting commercial SB2030 Appendix for use in its city.
- 2018: SB2030 mandatory for all public buildings
- 2020: SB2030 mandatory for all new and major renovated commercial buildings

Residential Buildings:

- 2016: Complete design for energy standard for residential SB2030.
- 2018:
    - Implement design assistance program
    - DLI adopts residential SB2030 as an appendix for statewide building code for green residential buildings.

- Local units of government may begin adopting residential SB2030 Appendix for use in its city.
- Implement incentive program for voluntary adoption by residential private sector.

- 2025: SB2030 mandatory for all new and major renovated residential buildings

Parties Involved: All parties involved in owning, operating, renovating, occupying, or other activities associated with Minnesota's new or major renovations of residential, commercial, institutional, municipal, and industrial building stock.

Implementation Mechanisms

The program should be implemented as follows:

- Pass legislation mandating that all state-licensed buildings must now use SB2030 design guidelines. Provide funding mechanisms to assist state and local governments and school districts in meeting these criteria.
- Provide tax incentives, utility design assistance and incentive programs, financing incentives or other inducements for construction of new and major renovations of residential and commercial buildings to assist with voluntary adoption of SB2030 guidelines.
- Provide funding to provide additional technical assistance to local units of government, architects, engineers, builders and developers as the move toward SB2030 guidelines starts.
- Provide funding to develop residential SB2030 guidelines.
- Provide funding to ensure that the database of ongoing building performance tracking in all sectors continues to grow.
- Establish a clearinghouse that provides information and assistance on green building guidelines and standards, the best available technologies for certain applications, a database of ongoing building performance tracking in all sectors, and access to design assistance and software tools to calculate the impacts of energy efficiency and renewable energy strategies.
- Establish education and training programs for all key decision makers, building professionals, and other participants in implementing this policy option, including design professionals, such as architects, engineers, interior designers, planners, and landscape architects; building owners; developers, contractors/builders, and building operators/facility managers; and the financing, real estate, and insurance communities.
- Mandate that state boards of licensing exams for building professionals cover knowledge of and test on SB2030 guidelines.

Related Policies/Programs in Place and Recent Actions

Guidelines that are either required or voluntary in Minnesota include Minnesota Sustainable Building Guidelines (SB2030), Leadership in Energy and Environmental Design (LEED), Green Globes, National Association of Home Builders Guidelines, Green Star, Green Communities (Minnesota Housing Process), and ENERGY STAR.

Type(s) of GHG Reductions

Reductions in GHG emissions from avoided fossil-fuel combustion for electricity use, and from space and water heating.

Estimated Policy Impacts

Direct Policy Impacts

Summary in-state (direct) GHG emissions reduction and option costs results for RCII-2, “SB2030/ Zero Energy Transition/Codes”, are provided in the table below. These values include costs for program administration. Negative values are shown in parentheses. In the “Net present value of societal costs” column, negative values, and denote instances where the costs of the implementing the option (or part of the option) are LESS than the direct economic benefits of the option in avoided energy and other costs. Negative values in the “cost effectiveness” column indicate that there is a net direct economic benefit per metric ton (t) of carbon dioxide equivalent saved. Overall, this option results in over 9 million metric tons (which is the same as teragrams—trillion grams or Tg in the table below) of annual CO_2e savings in 2030, with about 54 million metric tons of CO_2e savings over the analysis period. Somewhat more than half of the savings comes from implementation of measures in the commercial and institutional sectors. In addition to these in-state reductions, RCII-2 produces an estimated 1.23 TgCO_2e of out-of-state (upstream) emissions reductions in 2030, and 6.88 TgCO_2e in cumulative out-of-state reductions from 2015-2030, yielding total 2030 emissions reductions of 10.52 TgCO_2e in 2030, and 60.38 TgCO_2e over 2015-2030.

Table F-2.16 RCII-2 - Estimated Net GHG Reductions and Net Costs or Savings

	2030 GHG reductions (TgCO_2e):	**2015 – 2030 cumulative reductions (TgCO_2e):**	**Net present value of societal costs, 2015 – 2030 (million $2014):**	**Cost effectiveness ($2014/ t CO_2e):**
Zero Energy Building Implementation in the Residential Sector	4.73	24.61	$(823.49)	$(29.59)

Zero Energy Building Implementation in the Commercial Sector	4.56	28.89	$(1,226.73)	$(37.69)
TOTAL	**9.29**	**53.50**	**$(2,050.22)**	**$(33.95)**

Quantification Methods

The quantitative analysis of this option uses the following overall approach:

1. Estimate the total square footage of new and renovated commercial and residential buildings constructed per year in Minnesota using Minnesota-specific, national, and regional data as appropriate and available.
2. Estimate the average energy consumption per square foot of average "standard" (pre-option) commercial and residential new and renovated buildings in Minnesota, based on CBECs, USDOE EIA, and other data as available. These are estimated separately for commercial and residential buildings, by major fuel type (electricity, gas, oil products), and represent averages over the new and renovated building stock in each sector.
3. Estimate the change in energy consumption per square foot, again starting with standard (pre-option) values, for buildings built in each year that comply with SB2030. That is, for example, buildings built in 2015 will use 30% of the fossil energy and grid electricity used in (and thus save 70% relative to) buildings meeting the SB203 Energy Standard, (which is based on reductions over the average 2003 building energy consumption,) buildings built in 2020 would use 20%, and buildings built in 2030 would use 0% (on a net basis).
4. Estimate, again separately for buildings in each sector, the fractional average reductions from energy use in standard commercial and residential buildings in moving to Zero Energy Buildings that comes from the following sources: energy efficiency improvement, gas-fired CHP, solar thermal energy (space and water heating), solar PV installations, and biomass energy (space heating).
5. Calculate the net reduction (or increase) in different energy sources used per square foot of new and renovated floor area in each of the residential and commercial sectors.
6. Develop and apply projections of building area in the residential and commercial sectors, using Minnesota-specific data as available plus expert judgment regarding building trends in Minnesota.
7. Multiply the net values developed in step 5 by the new and renovated building areas developed in step 6 and, for years before 2020 in the commercial sector, and 2025 in the residential sector, by the ramp-in rates specified above for each sector to yield estimates of the net impact on use of energy sources in each sector.

8. Multiply the net impacts on fuel and electricity use in each sector by GHG emission factors appropriate for each combusted fuel and an appropriate marginal emission factor for avoided electricity use, respectively, to yield net emissions reductions by sector, fuel/energy source, and year.
9. Adopt average cost estimates, by sector, for the net capital cost of building energy efficiency improvements needed to achieve the energy use reductions assumed, and of the other energy systems (solar thermal and PV, biomass energy, gas energy) needed to achieve ZEB as described in step 4, less the cost of standard practice.
10. Multiply the cost estimates from step 9 with the estimated energy savings by type of measure included in the option annually to provide an estimate of the net costs of the option, by sector and year.
11. Multiply the net impacts on purchased fuels as developed in Step 8 by appropriate avoided costs for electricity and fuels saved/used.
12. Estimate "upstream" emissions reduction from avoided/additional fuels and electricity use using common emission factors used in many options for fossil fuels.
13. Apply representative estimates of the fraction of the additional capital costs of technologies used in the option that might be paid by a program sponsor, plus estimates of the ratio of sponsor administrative costs to the sponsor outlays for incentives, to estimate the administrative costs of the option.

Key Assumptions

In addition to the goals described above, key assumptions used in the analysis of RCII-2, as reflected in the listing of analytical steps in the previous section of this document, include:

- Annual new and renovated square feet of commercial buildings, of multi-family buildings 4 or more stories tall, and of one and two family dwellings and multi-family residential buildings three stories or less constructed in Minnesota through the modeling period. Annual new building for these three groupings were estimated based on a combination of historical and short-term (5-year) forecast data from Reed Construction Data[8], combined with data and insights from Minnesota agency staff, and data from the Minnesota Economic Forecast (as of February 2014)[9]. The resulting forecast additions of new floor area range from 16 to 21 million square feet of commercial/institutional space, 4.1 to 4.5 million square feet of multi-family (4 stories and taller) space, and 35 to 56 million square feet of single family and small multi-family floor space annually from 2015 through 2030, with additions generally declining slowly in the later years of the analysis period. 0.6 units of renovated space were assumed to be added per unit of new commercial and institutional (CI) space. Renovated residential space was not included in the analysis of this option.

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[8] Reed Construction data was provided by The Weidt Group.

[9] "Budget and Economic Forecast." *Office of Management & Budget*, Feb. 2014. <http://www.mn.gov/mmb/images/Budget%2526Economic_Forecast_Feb2014.pdf.>.

- The fraction of new (and, for CI, renovated) floor space assumed to be covered by RCII-2 in specific years by sector is as shown in the table below. Values for other years were interpolated.

Table F-2.17 Fraction of Floor Space Assumed in RCII-2

Year	Commercial/ Institutional (Non-Residential)	Multi-family Residential as Defined In Policy Option Document	Single Family and Small Multi-family Residential
2015	12.0%	0%	0%
2016	15.0%	0%	0%
2018	20%	0.63%	0.63%
2020	75%	75%	25%
2025 and on	100%	100%	100%

- The annual target fraction of fossil energy use and off-site electricity to be reduced by year in each sector is as shown in the table that follows, based on RCII-2 targets. Again, values for other years were interpolated.

Table F-2.18 Annual Target Fraction of Fossil Energy Use and Off-Site Electricity Reductions

Year	Commercial/ Institutional (Non-Residential)	Multi-family Residential as Defined In Policy Option Document	Single Family and Small Multi-family Residential
2010/In Absence of Policy	**30%**	**30%**	**30%**
2015	70%	30%	30%
2018	70%	70%	70%
2030	100%	100%	100%

- The fractional savings above apply to the per-square-foot baseline values for energy use under SB2030 energy standard, based on estimates provided by Minnesota agency staff.

Table Ap F-2.19 Baseline Values for Energy Use (/ft2)

	Electricity		Heating Fuels	Total
	kBtu/sq ft-yr	kWh/sq ft-yr	kBtu/sq ft-yr	kBtu/sq ft-yr
Commercial/Institutional	71.50	20.96	61.10	132.60
Multi-family Residential	41.10	12.05	83.40	124.50
Single-family Residential	25.00	7.33	85.00	110.00

- 70% of the required energy savings (or on-site generation) in each year and in each sector come from electricity savings, with the remaining 30% from savings in on-site fossil fuel use (gas, oil, and propane/LPG).
- The fractions of reduction in energy use to achieve zero energy residential and commercial buildings from different sources of reduction were assumed, based on discussions with Minnesota agency staff, to be as shown in the table below, with 2015 values used as a starting point, 2030 values uses as an end-point, and values for other years linearly interpolated.

Table F-2.20 Technologies for Electricity Savings

	Contribution as of 2015			
	Technologies for Electricity Savings			
	Energy Efficiency	Gas-fired CHP	Solar Space and Water Heating	Solar PV
Commercial/Institutional	96.0%	1.0%	2.0%	1.0%
Multi-family Residential	96.5%	0.5%	2.0%	1.0%
Single-family Residential	97.0%	0.0%	2.0%	1.0%

Table F-2.21 Technologies for Fossil Heating Fuel Savings

	Technologies for Fossil Heating Fuel Savings			
	Energy Efficiency	Gas-fired CHP (heat output)*	Solar Space and Water Heating	Biomass Heating
Commercial/Institutional	96.0%	1.0%	2.0%	1.0%
Multi-family Residential	94.1%	0.9%	3.0%	2.0%
Single-family Residential	90.0%	0.0%	5.0%	5.0%

Table F-2.22 Technologies for Electricity Savings by 2030

	Contribution by 2030			
	Technologies for Electricity Savings			
	Energy Efficiency	Gas-fired CHP	Solar Space and Water Heating	Solar PV
Commercial/Institutional	78.0%	2.0%	10.0%	10.0%
Multi-family Residential	78.5%	1.5%	10.0%	10.0%
Single-family Residential	79.5%	0.5%	10.0%	10.0%

Table F-2.23 Technologies for Heating Fuel Savings

	Technologies for Fossil Heating Fuel Savings			
	Energy Efficiency	Gas-fired CHP (heat output)*	Solar Space and Water Heating	Biomass Heating
Commercial/Institutional	90.9%	2.1%	4.0%	3.0%
Multi-family Residential	85.2%	3.8%	6.0%	5.0%
Single-family Residential	76.5%	3.5%	10.0%	10.0%

The fractions of energy savings assumed to be achieved through solar space and water heating that is ascribed to application of transpired solar heating, a relatively inexpensive form of solar space heating, were as described in the table below:

Table F-2.24 Electricity Savings Due to Solar Heating

	Electricity Savings	Gas Savings
Commercial/Institutional	50%	75%
Multi-family Residential	50%	75%
Single-family Residential	50%	50%

- Performance assumptions for biomass and fossil-fueled heating sources used to estimate required new and avoided fuel consumption, respectively, were as follows, based on Minnesota agency staff input:

Table F-2.25 Performance Assumptions for Biomass and Fossil Fuel

	Commercial/ Institutional	Multi-Family	Single Family and Small Multi-Family
Average Conventional Heating Fuel Efficiency, Fuel to Useful Heat (all	86%	86%	78%
Average Biomass Heating Fuel Efficiency, Fuel to Useful Heat	75%	75%	70%

- The net capital costs of building energy efficiency performance and on-site renewable energy systems used to meet the goals of the option were as shown in the table below. These costs were compiled from a variety of sources—see the RCII-2 worksheet for complete notes on the estimates of these parameters.

Table F-2.26 Capital Costs as of 2015 (2014$)

	Capital Costs as of 2015 (2014 dollars)				
	Technologies for Electricity Savings				
	Energy Efficiency	Gas-fired CHP (See ***Note 4***)	Solar Space Heat with Transpired Solar Collectors	Other Solar Space and Water Heating	Solar PV (See ***Note 3***)
	$ /first-year MWh saved	$/kW	$ /first-year MWh saved	$ /first-year MWh saved	$/kW
Commercial/Institutional	$ 238.48	$ 3,606	$ 618.80	$ 1,037.52	$ 3,100
Multi-family Residential	$ 238.48	$ 3,606	$ 618.80	$ 1,037.52	$ 3,617
Single-family Residential	$ 238.48	$ 10,000	$ 558.66	$ 1,171.22	$ 4,134

Table F-2.27 Technologies for Fossil Heating Fuel Savings

	Technologies for Fossil Heating Fuel Savings			
	Energy Efficiency (as for Natural Gas in RCII-4)	Solar Space Heat with Transpired Solar Collectors*	Other Solar Space and Water Heating*	Biomass Heating*
	$ /first-year MMBtu saved	$ /first-year MMBtu saved	$ /first-year MMBtu saved	$ /(MMBtu/yr delivered)
Commercial/Institutional	$ 14.73	$ 211.04	$ 353.86	$ 31.45
Multi-family Residential	$ 14.73	$ 211.04	$ 353.86	$ 31.45
Single-family Residential	$ 14.73	$ 211.04	$ 442.45	$ 32.62

*Consistent with values used in RCII-5 analysis

Table F-2.28 Capital Costs as of 2030 (2014$)

	Capital Costs as of 2030 (2014 dollars)				
	Technologies for Electricity Savings				
	Energy Efficiency	Gas-fired CHP (See ***Note 4***)	Solar Space Heat with Transpired Solar Collectors	Other Solar Space and Water Heating	Solar PV (See ***Note 3***)
	$ /first-year MWh saved	$/kW	$ /first-year MWh saved	$ /first-year MWh saved	$/kW
Commercial/Institutional	$ 259.49	$ 3,606	$ 618.80	$ 1,037.52	$ 1,402
Multi-family Residential	$ 259.49	$ 3,606	$ 618.80	$ 1,037.52	$ 1,636
Single-family Residential	$ 259.49	$ 5,000	$ 558.66	$ 1,171.22	$ 1,870

Table F-2.29 Technologies for Fossil Heating Fuel Savings

	Technologies for Fossil Heating Fuel Savings			
	Energy Efficiency	Solar Space Heat with Transpired Solar Collectors*	Other Solar Space and Water Heating*	Biomass Heating*
	$ /first-year MMBtu saved	$ /first-year MMBtu saved	$ /first-year MMBtu saved	$ /(MMBtu/yr delivered)
Commercial/Institutional	$ 16.03	$ 211.04	$ 353.86	$ 31.45
Multi-family Residential	$ 16.03	$ 211.04	$ 353.86	$ 31.45
Single-family Residential	$ 16.03	$ 211.04	$ 442.45	$ 32.62

*Consistent with values used in RCII-5 analysis

- Measure lifetimes, used for calculating levelized (annual) capital costs, were assumed to average 15 years for energy efficiency improvements and 20 or 25 years for renewable energy systems.

- For Energy Efficiency, operating and maintenance (O&M) costs were assumed to be 10% of levelized capital cost. In practice these costs may be zero or even negative, as in cases where changes in technology (such as switching to long-lived LED bulbs) result in reducing maintenance costs, or may be modestly greater than for standard practice, such as for building energy controllers that need to be maintained, adjusted and calibrated periodically. O&M costs for gas-fired CHP were assumed to be the same as used for gas-fired CHP in RCII-1. Solar PV O&M costs were adapted from NREL, "Distributed Generation Renewable Energy Estimate of Costs"[10] at about $20 per kW-yr. O&M costs for biomass-fueled heating systems were assumed to be as estimated in RCII-5.
- Estimated avoided marginal emission factors for electricity generation (on an electricity delivered basis[11]) falls from 0.936 tCO2e per MWh in 2015 to 0.758 in 2030, with avoided costs of electricity generation (again based on delivery to consumers, that is, factoring in transmission and distribution losses) rising from $92.6 to $148.1 per MWh delivered (nominal dollars) over the same time period. Natural gas avoided (wholesale) costs rise from $4.78 to $8.97 per GJ (again nominal dollars) over the same time period.
- Wholesale costs of biomass fuels used for renewable CHP rise from $2.96/GJ in 2015 to $6.73/GJ in 2030 (nominal dollars). Avoided costs of other fossil fuels were assumed equal to avoided wholesale costs for the various fuels, as estimated in the Common Assumptions used for all options, as were direct and, where applicable, “upstream” GHG emission factors for each fuel whose use is avoided (or, in the case of biomass, increased) by the measures in RCII-2.
- Administrative costs are estimated assuming that program sponsors will provide incentives equal to 35% (commercial/institutional sector) to 45% (single family/small multi-family) of capital costs. Administrative costs are assumed to vary from 10% (commercial/institutional) to 20% (single family/small multi-family) of incentive costs.

Macroeconomic (Indirect) Economic Impacts

Table F-2.36 below provides a summary of the expected impacts of RCII-2 policy on jobs and economic growth during the CSEO planning period.

[10] Updated August 2013, and available as http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.

[11] That is, factoring in transmission and distribution losses, which, based on the electricity supply forecast prepared as part of this project, vary annually in the range of 5.77 to 5.86 percent over 2015 through 2030.

Table F-2.36 RCII-2 Macroeconomic Impacts on GSP, Employment and Income

Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
RCII-2	-$69	-$6	-$91	6,020	2,750	41,190	$336	$134	$2,011

Graphs below show detail in GSP, employment and personal income impact of the RCII-2 policy.

Figure F-2.23 RCII-2 GSP Impacts ($2015 MM)

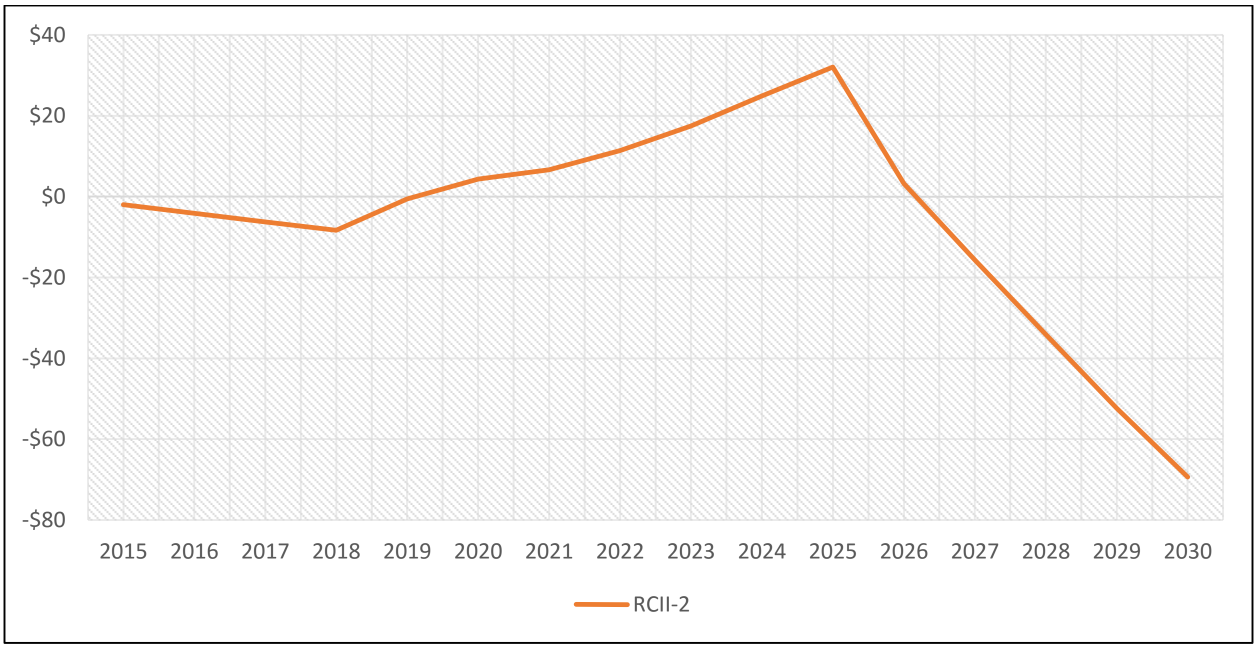


Figure F-2.24 RCII-2 Employment Impacts (Individual Jobs)

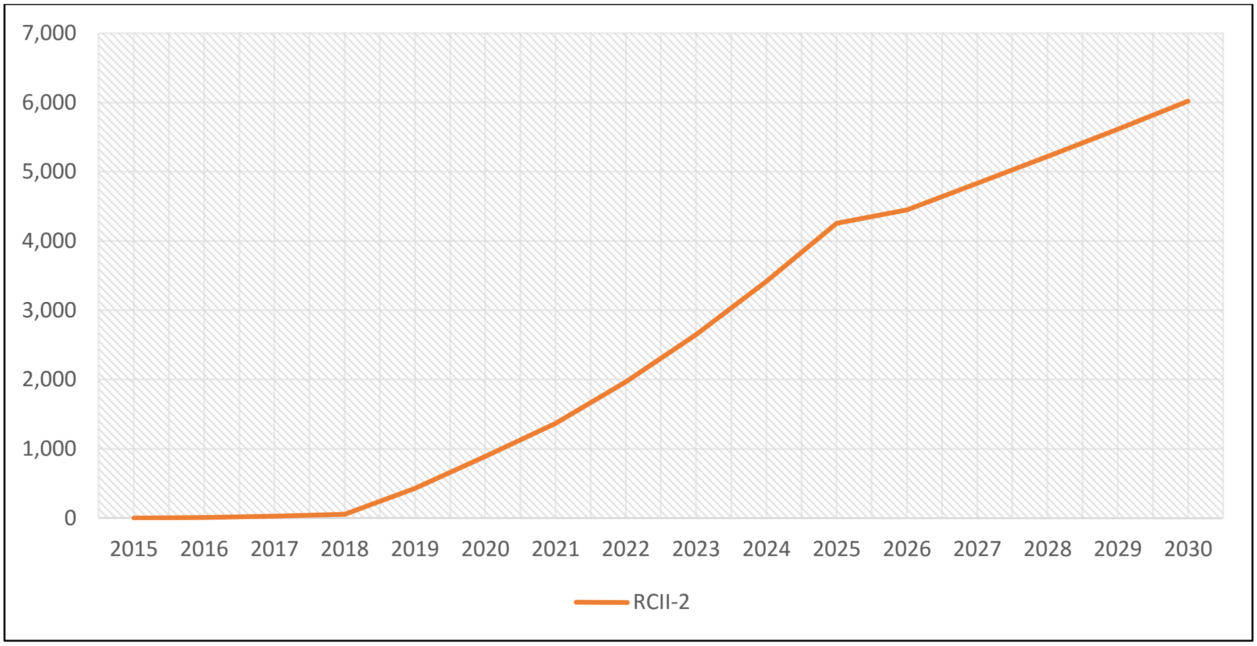
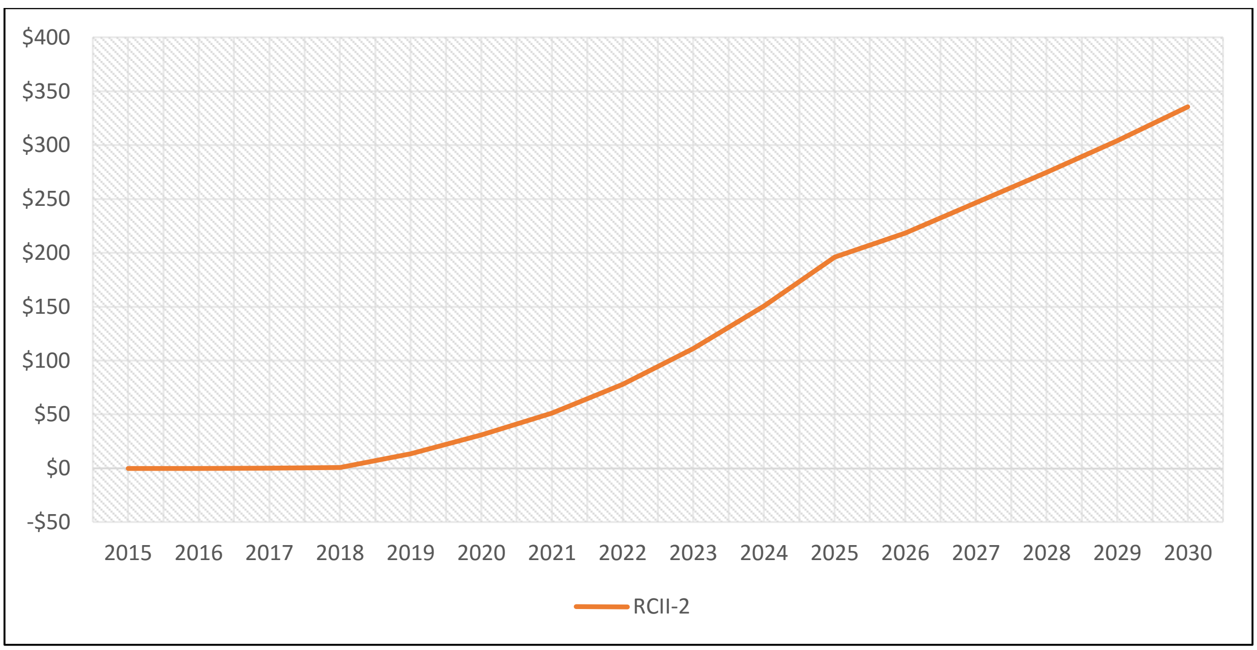
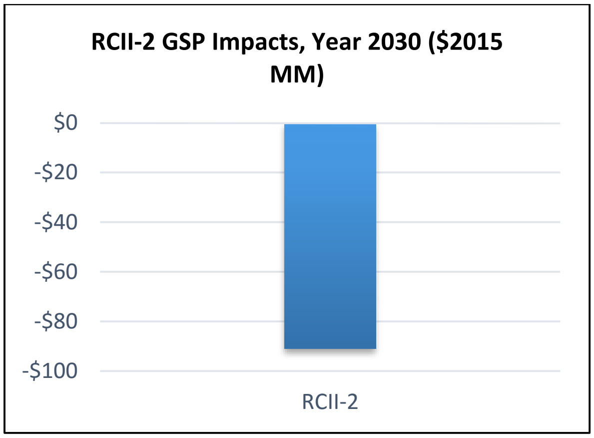
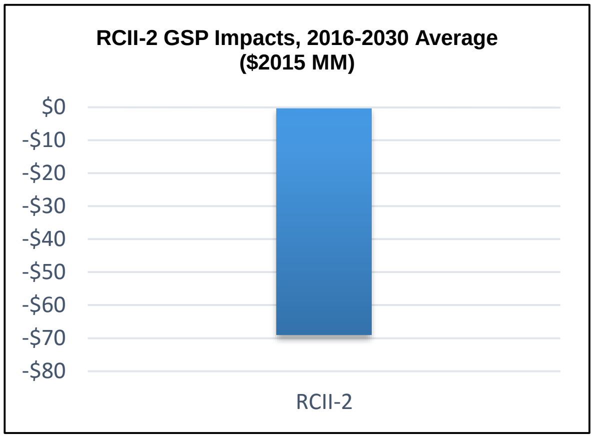


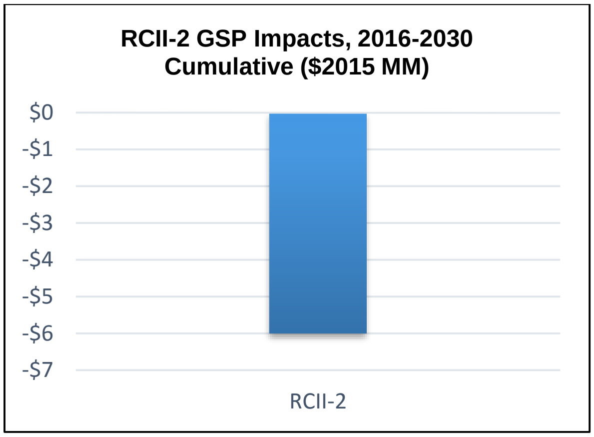
Figure F.25 RCII-2 Income Impacts ($2015 MM)

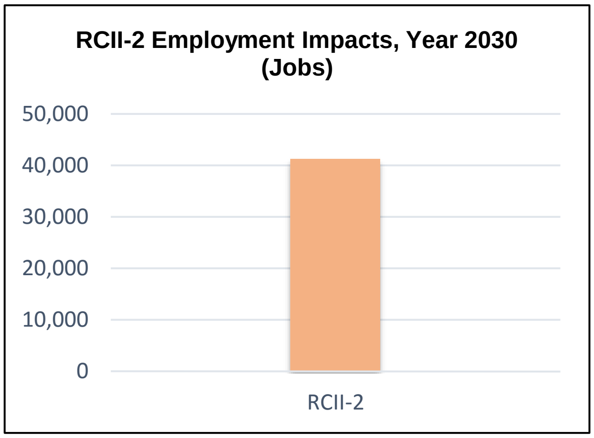


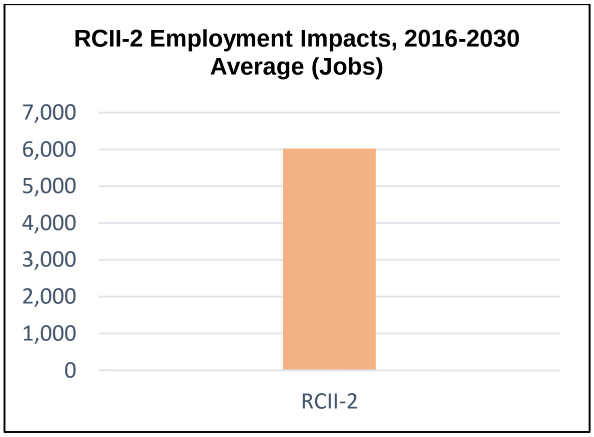
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030).

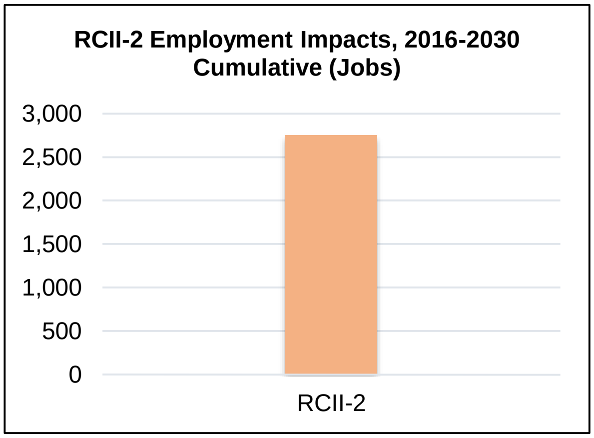

RCII-2 GSP Impacts, Year 2030 ($2015 MM)
$0
-$20
-$40
-$60
-$80
-$100
RCII-2

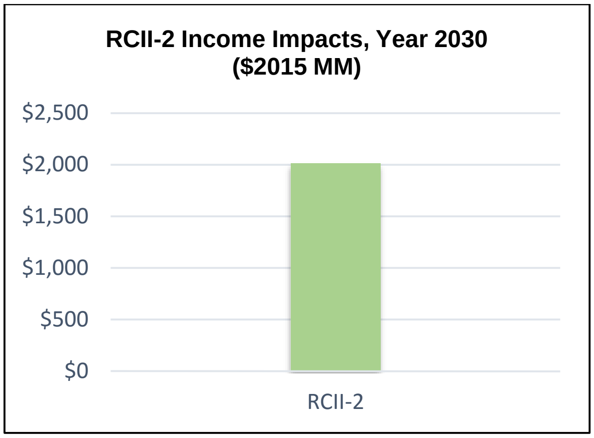

RCII-2 GSP Impacts, 2016-2030 Average ($2015 MM)
$0
-$10
-$20
-$30
-$40
-$50
-$60
-$70
-$80
RCII-2

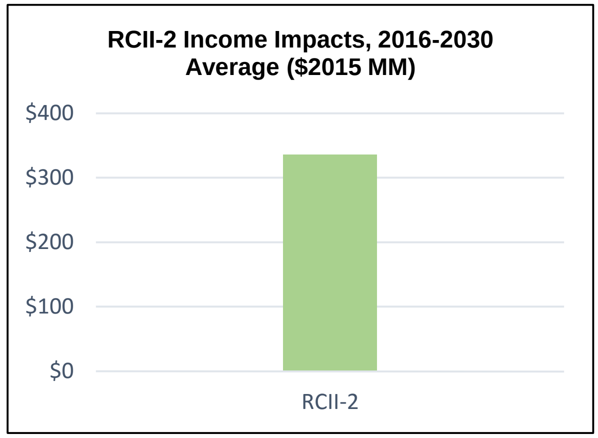

RCII-2 GSP Impacts, 2016-2030 Cumulative ($2015 MM)
$0
-$1
-$2
-$3
-$4
-$5
-$6
-$7
RCII-2

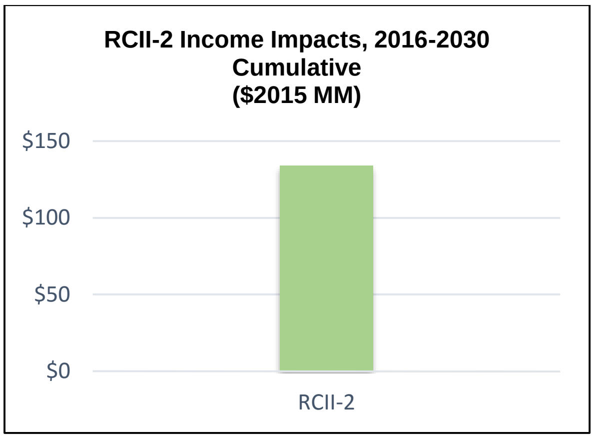

RCII-2 Employment Impacts, Year 2030 (Jobs)
50,000
40,000
30,000
20,000
10,000
0
RCII-2


RCII-2 Employment Impacts, 2016-2030 Average (Jobs)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
RCII-2


RCII-2 Employment Impacts, 2016-2030 Cumulative (Jobs)
3,000
2,500
2,000
1,500
1,000
500
0
RCII-2







Principal Drivers of Macro-Economic Changes

RCII-2 produces an efficiency impact profile that CCS has found in other policy analyses prior to the CSEO macroeconomic modeling effort. In this profile, a policy is neutral (as in RCII-2) or even negative in its GSP impacts, meaning that the same or even less total spending is being directed to the state's products and services as a result of the policy. However, employment rises and incomes rise as well – both by significant amounts. Generally, this is because the nature of efficiency policies, if they are effective, is to seek a reduction in spending on some key input (in this case, building energy for heat, power and electricity) while not reducing the total amount of those activities. GSP, which is measured as total spending, naturally sees a downward influence from this initiative. The resulting reduction in costs means that those buying less electricity have the money available to spend elsewhere, expanding other sectors, but the losing sector (the focus of the efficiency effort) has less to spend, and its supporting sectors also see losses.

But efficiency policies typically produce income-effect impacts, meaning that buying power rises faster than actual incomes and employment rises more from the sectors that gain than it falls from the sectors that lose. RCII-2 is one of those cases – GSP falls, but employment and incomes both rise.

RCII-2 sees building-owning sectors spend significant amounts on construction, operations and maintenance to convert their facilities (or better build new ones) to comply. However, the energy savings they achieve is larger in any given year (on the order of $200 million each for the residential and the commercial sectors, by 2030) than the financed cost of compliance. This positive return on investment helps this policy succeed, while in RCII-5 (which focuses on thermal renewables), the inability of the cost of investment to produce sufficiently large returns prevents it from generating positive income and employment impacts.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For RCII-2, private homes see the most benefits. Statewide, though they spend significantly to implement this policy (reaching approximately $500 million by 2030), they consistently save more on energy than they spend (again, when some financing for the home improvement element is taken into account). This savings exceeds $700 million by 2030, producing a net savings of about $200 million in the final year.

The resulting additional ability to spend shows up all over the consumer economy. Homes directly hire contractors and staff as part of the economy already (landscaping, home health care, and cleaning services are common examples of this), and that spending grows significantly under this policy scenario – over 2,000 more people work in these sectors by 2030 as a result. Retail spending also rises significantly, adding about 650 positions. Nursing, health care, and real estate also grow as consumers redirect money.

Construction also gains significantly, both directly from the investment and indirectly. Utilities, the target of the efficiencies, see the largest losses – they require nearly 500 fewer people by 2030.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the RCII-2 policy, important data included:

- The capital cost involved for commercial and residential buildings to adopt new technologies. This involves an additional cost of operation but provides a stimulus in spending to the construction and machinery production sectors.
- The cost to implement new practices and operating procedures around different equipment. These operating and maintenance costs also represent a cost to be borne by the commercial and residential sectors, but the additional labor engaged (exceeding 500 new people statewide by 2030) increases direct employment, direct incomes, and expands consumer spending – which is economically beneficial.
- The total volumes, and total spending on those volumes, of each type of energy consumed – both the sources reduced from other heat or power sources and those sources (limited in this policy to biomass) increased to fuel renewable generation.
- The costs to state government agencies to oversee and implement this policy. This is split between labor to regulate and implement, and capital spending on upgrading its own facilities. One third of this is funded through a rate surcharge to affected entities, and the remainder displaces the general treasury.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within

Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

<u>Key Assumptions</u>

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.
- State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government

entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

A few uncertainties include:

- Legislative action will be required to enact this type of statewide policy option. There are uncertainties around the support or resistance from various stakeholder groups regarding this kind of policy option change.
- Program scalability needs to be considered in the design and execution of this proposal. While there is already an infrastructure in place to meet the current SB2030 requirements written into law, considerations need to be made for the funding mechanism that will be required for expanding the existing work.
- Education and training will be needed to ensure that architects, engineers and other facility designers are able to meet the design requirements of the expanded SB3030 standard. While some training and education programs exist along with energy design assistance programs are able to meet the needs of the current requirements, some uncertainty remains as to the cost and effort of new training needs for an expanded standard.
- There are additional uncertainties regarding the interactive effects of this policy option with other policies relating to utility renewable and energy efficiency requirements. For example, as more net zero buildings are implemented, there may be upward pressure on costs to maintain the electric transmission and distribution system potentially shifting more of these costs to ratepayers still connected to the grid. This could have a negative impact to ratepayers that will have continued responsibility for these costs.

Additional Benefits and Costs

<u>Economy</u>

Increased activity within the construction industry provides an economic benefit to the state of Minnesota. Increased sales and increased innovation of technologies to meet the needs of advancing standards and goals are also a benefit.

<u>Environment</u>

Energy efficiency and renewable energy implementation directly results in reduced carbon emissions and has the potential to be one of the more cost effective solutions for reducing greenhouse gas emissions. The environmental impacts of this policy option could mitigate rising health care costs for air quality and carbon emissions related illness in Minnesota. Facilities that meet the standard also could reduce other environmental impacts to local water treatment systems and pollution control requirements as a result of more efficient and renewable operations from meeting the new standard.

Health

Per a Minnesota Department of Health analysis, increasing energy efficiency could benefit health by reducing climate change through reduced emissions. Emissions reductions may reduce the risk of cardiovascular and respiratory illness as well as cancer in communities exposed to energy-related emissions. (EPA; Kappos; Pope 2002, Pope 2000, Bernard) Building efficiency improvements could also reduce respiratory illness, reduce allergies and asthma, reduce sick building syndrome, and improve worker performance through changes in thermal environment and lighting.

Feasibility Issues

This policy option would require merging two existing policy option frameworks in Minnesota, Sustainable Buildings 2030 and Energy Codes. By adopting the SB2030 energy standard into Minnesota's Energy Code, the standard would be expanded to include new construction and major renovations for private commercial and residential facilities. Initial data indicates the costs for achieving the higher standard in the public sector remain competitive with building to a lower standard; however, the architecture, engineering and building construction industries may have concern over the cost impacts to delivering these services. If these industries believe the costs will increase exponentially, there may be feasibility issues with passing legislation. This is one example where additional collaboration with stakeholders will be required to determine specific areas of contention and/or alignment that will make this broad policy option shift feasible.

A specific example of a feasibility issue was provided above; however, below is a list of general items that need consideration to make SB2030 for private commercial and residential facilities feasible:

- Cost of building to meet standard; unintended costs
- Market acceptance of standard
- Availability of technology to meet performance requirements
- Trained network of service providers
- Incentives available for customers
- Accountability within policy option enforcement
- Measurement and verification of performance

RCII-3. Reduce High Global Warming Potential (GWP) Greenhouse Gases

This policy option was not moved forward to final CSEO recommendations due to current limitations on effective policy option design and impacts analysis.

RCII-4. Increase Energy Efficiency Requirement

Policy Option Description

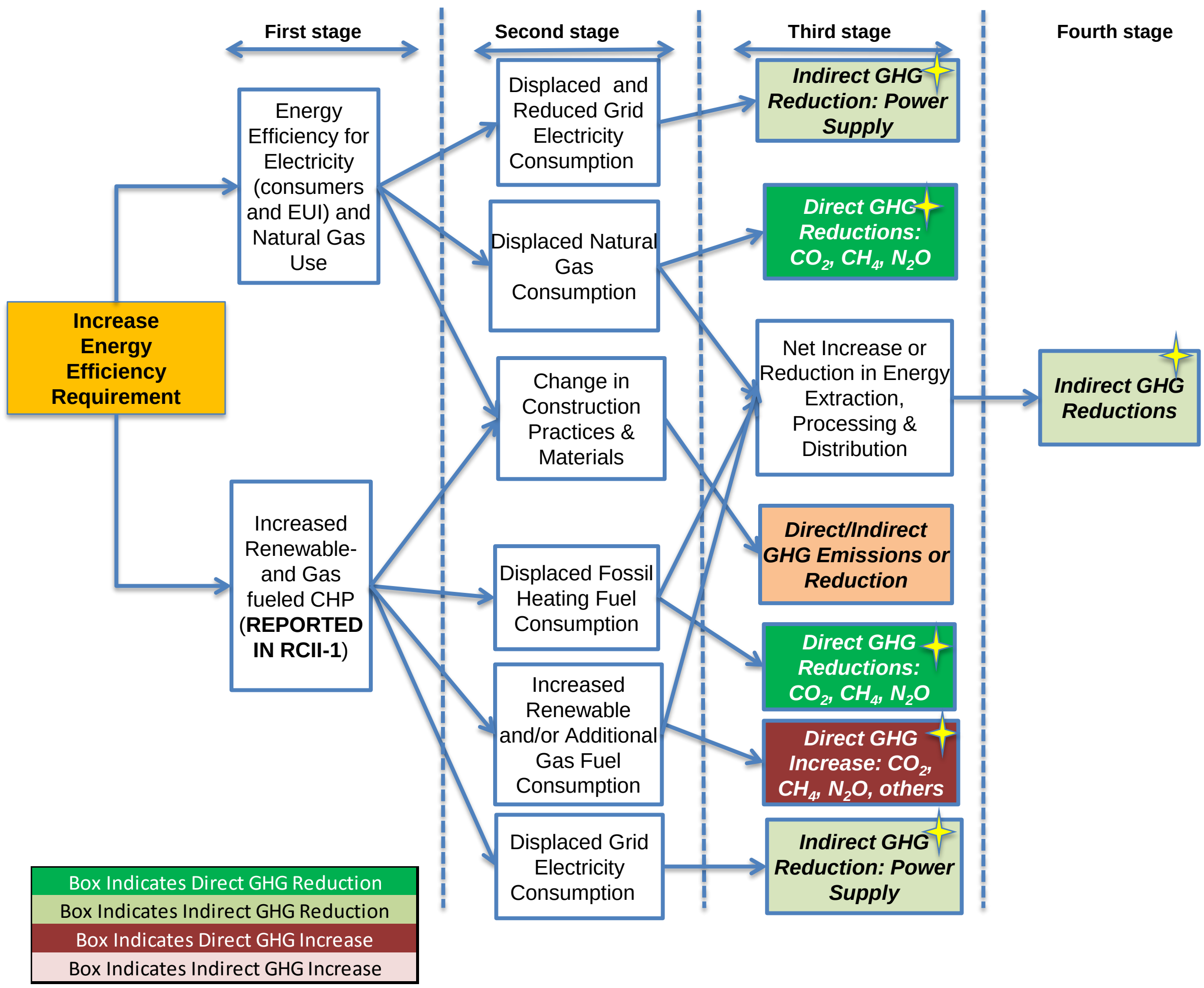
The purpose of this policy option is to increase the utility energy efficiency resource standard (EERS) requirements established in the Conservation Improvement Program (CIP) in the following manner:

- For electric utilities, increase the EERS to 2.5% with the ability to count electric energy savings from energy utility infrastructure (EUI) improvements and electricity displaced by combined heat and power projects (CHP) on top of a minimum savings goal of 1.5% from end-use efficiency.
- For gas utilities, retain the EERS of 1.5%, with a minimum savings goal of 1.0% for end-use efficiency and the addition of CHP as an eligible technology that could satisfy the remaining 0.5% requirement.
- In addition to the demand-side management requirements through the EERS, natural gas utilities and electric utilities will be required to meet a CHP standard that is embedded in the EERS. Collectively, the natural gas utilities will be required to meet a CHP goal of 34 Million MMBtu of displaced fossil fuel by 2030. Collectively, the electric utilities will be required to meet a CHP goal of 800 MW by 2030. (Details of the CHP policy option can be found in the policy option design section of RCII-1 for Combined Heat and Power.

Causal Chain for GHG Reductions

A schematic causal chain for this policy option is provided below. For energy efficiency improvements, emissions reductions occur through reduction of electricity and gas use, and their associated emissions. For CHP, as described also in RCII-1 and RCII-2, increased capacity and use of CHP systems powered with natural gas to displace electricity from the central grid, and, through the use of cogenerated heat, and displaces fossil fuels (natural gas, distillate oil, coal, and propane) used for space heat and water heat that are under standard practice produced in furnaces, boilers, and water heaters. As such, GHG emissions savings accrue through the reduction of central grid electricity supply and fossil fuels formerly used for heating, but these savings are partially offset by emissions from natural gas and renewable fuels combustion. In addition, reduced use of fossil fuel reduces "upstream" emissions associated with, for example, natural gas transmission and distribution, oil refining and transport, and natural gas and crude oil production. It is expected that these GHG emissions reductions and increases will be quantified. Increased use of renewable fuels will produce some increase in emissions associated with fuel processing and transport—for example, diesel-fueled equipment used for biomass harvesting and transport. These additional emissions, however, are highly variable depending on the source of the biomass fuel and the distance it must be shipped to the CHP facility. As a result, these incremental emissions may or may not be quantified, depending on data availability. The manufacturing and installation of energy-efficient devices and equipment, as well as CHP systems, may produce changes in construction and/or manufacturing practices and materials that may have a positive or negative impact on GHG emissions. These impacts are indirect and uncertain, and will not be quantified.

Figure F-2.26 Causal Chain for RCII-4 GHG Reductions



Policy Option Design

Goals:

- Achieve annual electric energy savings of 2.5% through customer end-use efficiency programs, electric utility infrastructure improvements, combined heat and power, energy codes and appliance standards, and other efforts.
    - A minimum of 1.5% savings will be achieved through end-use efficiency programs. The remaining 1.0% can be achieved through EUI, CHP and additional demand side management (DSM).
    - As in the current statute, there will be no minimum end-use efficiency goal for municipal and cooperative utilities.
    - Electric utilities (investor-owned, municipal, and cooperative) will be required to include EUI and CHP projects in their CIP plans.
- Achieve annual gas energy savings of 1.5% through customer end-use efficiency programs, energy codes and appliance standards, combined heat and power, and other efforts.
    - A minimum of 1.0% energy savings will be achieved through end-use efficiency programs. The remaining 0.5% can be achieved through implementation of CHP and additional DSM.
    - As in current statute, there will be no minimum end-use efficiency goal for municipal gas utilities.
    - Natural gas utilities will be required to consider CHP projects in their CIP plans.
- To be eligible for CIP savings credit, combined heat and power projects must meet or exceed a minimum total efficiency[12] of 60% and a minimum thermal efficiency[13] of 20%. See RCII-1 CHP Policy Option for additional details regarding CHP electric/thermal efficiency standards.

<u>Assumptions</u>

- Electric utilities achieve at least 1.5% from customer end-use efficiency (DSM).
    - For a partial list of eligible DSM measures established through the Department of Commerce's Technical Reference Manual (TRM), consult the latest TRM manual version 1.0 (http://mn.gov/commerce/industries/energy/utilities/cip/technical-reference-manual/)
- Electric utilities achieve 1.0% from CHP and EUI and/or additional DSM:
    - For more information about eligible CHP technologies, efficiency requirements and other potential variables, consult RCII-1 CHP Policy Option Design.

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[12] Defined as the ratio of useful thermal energy and electric energy produced to input energy.

[13] Defined as the ratio of useful thermal energy produced to input energy.

  - For more information about potentially eligible EUI technologies, consult the following sources:
    - Minnesota Environmental Initiative *1.5% Energy Efficiency Solutions Project*, Final Report March 2011. (Pages 17-46 and 113-142) (http://mn.gov/commerce/energy/images/1_5EESolutionsFinalReport_Appendices.pdf) .
    - Franklin Energy Utility Infrastructure Improvements for Energy Efficiency: Understanding the Supply-Side Opportunity, Final Report November 2010 (http://mn.gov/commerce/energy/images/CARD-Utility-EE-Improvements.pdf).
- Electric utilities (all) have a collective goal of 800MW CHP (via customer projects or utility EUI projects) by 2030.
  - For more information about eligible CHP technologies, consult RCII-1 CHP Policy Option Design.
- Natural Gas utilities achieve at least 1.0% from customer end-use efficiency (DSM).
  - For a partial list of eligible DSM measures established through the Department of Commerce's Technical Reference Manual (TRM), consult the latest TRM manual version 1.0 (http://mn.gov/commerce/energy/images/MN-TRM-2014-ver1%252E0.pdf)
- Natural Gas utilities achieve 0.5% from CHP and/or additional DSM.
- Natural Gas utilities (subject to CIP) have a collective CHP goal of 34 TBtu by 2030.
  - For more information about eligible CHP technologies, consult RCII-1 CHP Policy Option Design.

Additional Resources: Note - the 1.5% savings goal for each utility is calculated based on average weather-normalized retail energy sales, excluding sales to CIP-exempt customers, for the most recent three-year period prior to the filing year for the utility's conservation improvement plan.

Information regarding the historical performance and the baseline for CIP can be found at the following links:

- 2013 CIP CO_2 Report: http://archive.leg.state.mn.us/docs/2013/mandated/131112.pdf
- 2012 CIP CO_2 Report: http://archive.leg.state.mn.us/docs/2015/mandated/150585.pdf
- 2011 CIP CO_2 Report: http://www.leg.state.mn.us/docs/2011/mandated/110369.pdf

Timing: The new electric and gas requirements will begin in 2016 with a ramp-up to full requirements in 2019 as shown below:

Table F-2.31 Electric and Gas Ramp-up Periods

Electric Ramp-up Period

Year	Min. End-use Eff.	Total Savings Goal
2016	1.5%	1.75%
2017	1.5%	2.0%
2018	1.5%	2.25%
2019	1.5%	2.5%

Gas Ramp-up Period

Year	Min. End-use Eff.	Total Savings Goal
2016	1.0%	1.125%
2017	1.0%	1.25%
2018	1.0%	1.375
2019	1.0%	1.5%

Parties Involved:

- Minnesota utilities currently subject to Minnesota Statute 216B.241
- Minnesota households and businesses
- All parties (including utilities) involved in designing, implementing, and evaluating CIP programs including:
- HVAC, electric and mechanical contractors
- Program implementers
- Program evaluators
- Energy service companies
- Minnesota Department of Commerce, Division of Energy Resources
- Minnesota Public Utilities Commission
- Minnesota Pollution Control Agency

Other: No changes to CIP exemption laws are proposed (see Minn. Stat. §216B.241 subd. 1 (g), 1a (b) and (c), 1b (c) and 2 (d)). In 2012, sales to electric CIP-exempt customers were 13.8% of total electric sales; sales to gas CIP-exempt customers were 6.7% of total gas sales. However, for modeling purposes, it may be beneficial to model estimated displacement of fossil fuels through DSM and CHP that includes and excludes large consumer facilities that are currently exempt in CIP.

Implementation Mechanisms

The Next Generation Energy Act of 2007 established an Energy Efficiency Resource Standard (EERS) for electric and natural gas utilities in Minnesota, including investor-owned utilities, electric cooperatives, and municipal utilities (see Minn. Stat. §216B.241 subd 1c.) Under the EERS, utilities are required to develop plans to achieve energy savings equal to 1.5% of gross annual retail sales through conservation improvement programs (CIP) designed to help their customers improve end-use energy efficiency. In addition, electric utilities are allowed to count savings from electric utility infrastructure (EUI) improvements[14] approved by the Minnesota Public Utilities Commission (MPUC) under Minn. Stat. §216B.1636[15] towards the 1.5% savings goal on top of a minimum savings goal of 1.0% from end-use efficiency measures, as long as the infrastructure improvements result in increased energy efficiency greater than that which would have occurred through normal maintenance activity.

Utilities may request a lower goal than the 1.5% standard based on a conservation potential study, historical conservation experience and other factors. However, for investor-owned utilities, the commissioner of Commerce may not approve a savings goal less than 1.0%. Natural gas utilities have used this provision to receive approval for 1.0% annual savings goals.

The ability for utilities to carry forward savings achieved in excess of the 1.5% standard under Minn. Stat. §216B.241 subd. 1c (b) will be preserved but modified to reflect the higher electric and gas standards proposed. The statute allows excess savings to be carried forward to the succeeding three calendar years, although savings from electric utility infrastructure projects may be carried forward for five years. CHP projects should be included in the five year carry forward provision.

More specific implementation mechanisms include the following:

- Increase the capacity and resources of CIP Technical Assistance administered through the Department of Commerce for the purpose of providing increased assistance to utilities, and increased capacity to implement evaluation, measurement and verification activities and anticipated regulatory compliance efforts.
- To remove the disincentive for utilities to aggressively promote conservation and efficiency, pass legislation requiring the Public Utilities Commission to approve decoupling for all investor-owned utilities by 2020. Decoupling removes the link between utility sales and revenue by allowing the utility to adjust its rates (higher or lower) without a rate case to recover its revenue requirement when conservation programs, weather, or other factors cause sales to deviate from test year sales. The Public Utilities Commission can customize the details of each utility's decoupling plan (including whether it is full or partial decoupling, and what rate classes it applies to) and adjust it over time.
- Higher energy savings achievements and/or decoupling may necessitate adjusting the demand-side management (DSM) financial incentive mechanism for investor-owned utilities to keep utility earnings at reasonable levels while still providing a strong incentive to achieve high savings. There is already a mechanism in place (Docket No. E,G999/CI-08-133) whereby the Public Utilities Commission can direct the Department

[14] For example, installing higher than standard-efficiency transformers, low impedance distribution lines, or reconfiguring transmission system to reduce total losses.

[15] Minn. Stat. §216B.1636 does not apply to municipal or cooperative utilities. However, the Department of Commerce has allowed municipal and cooperative utilities to count qualifying electric utility infrastructure (EUI) project savings towards their CIP goals even though they are not subject to Minn. Stat. §216B.1636.

of Commerce to review current incentive levels and recommend changes, with utility and other stakeholder input.

- All utilities subject to the requirements of Minnesota Statute 216B.2422 should be required to consider both biomass-fired and natural gas CHP in their integrated resource plans. Electric utilities will be required to demonstrate in their Integrated Resource Plans that, before power-only capacity is proposed, CHP opportunities within their service territory have been thoroughly assessed to determine the benefits of CHP (and associated technologies such as thermal energy storage) relative to total primary energy efficiency, GHG emissions, power grid resiliency, peak demand management and risk management. Additionally, EUI (in addition to DSM) projects should be considered part of the integrated resource plan.
- Commerce will propagate rules, guidelines and standards to qualify, quantify, and report electric utility infrastructure projects, waste heat recovery converted into electricity projects, combined heat and power projects, and utility code compliance programs by end of year 2016 (efforts are currently underway.)
- Pass legislation modifying the provision in Minn. Stat. §216B.241 subd. 1c allowing utilities to carry forward savings in excess of 1.5% to subsequent years to reflect the new 2.5% goal for electric utilities and 1.5% goal for gas utilities.

Related Policies/Programs in Place and Recent Actions

Currently there are over 180 utilities subject to the CIP requirements that are administering some form of energy efficiency program. Within these 180 utilities, there are 1,250 unique programs dedicated to different types of efficiency activity. These programs address efficiency measures ranging from residential lighting programs to large industrial process efficiency to behavior change programs and energy audit services. To achieve the 2.5% standard, existing programs will need to expand and new programs will need to be developed.

Utilities file conservation improvement program plans with the Department of Commerce every three years for analysis and approval. The next anticipated filing date is in 2016 for the 2017-2019 CIP triennial period. At this time, utilities will be able to include in their new CIP plans efficiency activity that addresses the ramp up period for the increased EERS.

Other programs, such as B3 Benchmarking and the Sustainable Buildings 2030 standard, contribute toward achieving greater efficiency outside of CIP; they can also help provide efficiency savings to count toward CIP goals. These programs, along with other public sector efficiency programs such as the Guaranteed Energy Savings Program (GESP) and Local Energy Efficiency Program (LEEP), can be leveraged to help utilities meeting higher savings targets.

Estimated Policy Impacts

Direct Policy Impacts

Summary in-state (direct) GHG emissions reduction and option costs results for RCII-4, "Increase Energy Efficiency Requirement", are provided in Table Ap F-2.32 below. These values include costs for program administration. Negative values are shown in parentheses. In the "Net present value of societal costs" column, negative values, and denote, instances where the costs of the implementing option (or part of the option) are LESS than the direct economic benefits of the option in avoided energy and other costs. Negative values in the "cost effectiveness" column indicate that there is a net direct economic benefit per metric ton (t) of carbon dioxide equivalent saved. Overall, this option results in 4.7 million metric tons (which is the same as teragrams—trillion grams or Tg in the table below) of annual CO_2e savings in 2030, with just under 36 million metric tons of CO_2e savings over the analysis period. About 20% of the savings comes from natural gas utility programs. In addition to these in-state reductions, RCII-4 produces an estimated 0.77 TgCO_2e of out-of-state (upstream) emissions reductions in 2030, and 5.59 TgCO_2e in cumulative out-of-state reductions from 2015-2030, yielding total 2030 emissions reductions of 5.46 TgCO_2e in 2030, and 41.50 TgCO_2e over 2015-2030.

Table F-2.32. RCII-4 - Estimated Net GHG Reductions and Net Costs or Savings

	2030 GHG reductions (TgCO_2e):	**2015 - 2030 cumulative reductions (TgCO_2e):**	**Net present value of societal costs, 2015 - 2030 (million $2014):**	**Cost effectiveness ($2014/t CO_2e):**
Electric Utility EERS: Savings from EE Programs	1.85	13.87	$(590.16)	$(38.08)
Electric Utility EERS: Savings from CHP Implementation	INCLUDED IN RCII-1			
Electric Utility EERS: Savings from EUI Investments	1.93	15.24	$(964.23)	$(56.65)
Natural Gas Utility EERS: Savings from EE Programs	0.92	6.80	$(327.16)	$(36.41)
Natural Gas Utility EERS: Savings from CHP Implementation	INCLUDED IN RCII-1			
TOTAL	4.70	35.91	$(1,881.55)	$(45.33)

Data Sources

This information has been uploaded into CentralDesktop for review by CCS. Additional data may be available upon request.

Quantification Methods

1. Obtain estimates of forecast electricity and natural gas demand by sector and year through 2030 from the Inventory and Forecast (I&F) prepared to accompany the assessment of GHG Emissions Reduction options.
2. Estimate, based on historical averages and other information as available, the fraction of the electricity savings target to be provided by EUI investments and to be provided by combined heat and power (CHP, in RCII-1), as well as the fraction RCII-4 goals met by gas saved through application of CHP in RCII-1.
3. Calculate the total annual savings targets for electricity (2.5% of forecast demand, net of savings from other options) and natural gas (1.5% of forecast demand, net of savings from other options) under this option in energy units (GWh and MMBtu), by sector.
4. Calculate, for each of EE and EUI, the fraction of annual savings under each target and for each fuel that has already been included in the existing (pre-option) EERS, and thus is already included in the electricity and gas consumption forecasts, and reduce the savings targets from step 4 accordingly.
5. Calculate the annual EE savings targets by reducing the total annual savings targets by the reduction in electricity requirements and gas use from CHP implementation in each year, and, for electricity, from the implementation of EUI in each year.
6. Estimate the annual cumulative EE savings by sector for electricity and natural gas assuming that savings cease after 15 years, and thus that savings from all years of the option persist at least throughout the 15-year modeling period.
7. Estimate annual EUI savings by year based on the targets estimated above, net of EUI achieved under the existing EERS.
8. Multiply the annual impacts on electricity and natural gas use in each sector by appropriate avoided GHG emission factors to yield emissions reduction estimates. For electricity, a stream of Minnesota-specific marginal emissions-avoided factors (MEFs) was estimated for use in all RCII and other options as a part of the development of Common Assumptions for the planning effort.
9. Adopt average cost estimates, by sector If available (though likely not), for the cost of saved energy from electric and natural gas EE programs, and EUI investments, on a per-unit-energy-saved basis. Levelized costs estimated from CIP programs in Minnesota carried out in recent years, such as those reported below (“Additional Benefits and Costs”) were used as a source of cost estimates. A modest escalation factor is included to provide for the increase in EE costs over time and as potential EE opportunities are taken up.

10. Multiply the cost estimates from step 9 with the annual cumulative energy savings from steps 6 and 7 to provide estimates of the net costs of the option, by sector, fuel (electricity and gas), and year.
11. Calculate the annual costs of new (not ongoing) energy savings in each year.
12. Estimate (for macroeconomic modeling) the capital and O&M components of the levelized costs estimates derived in step 8, and for the capital cost component, estimate the capital cost outlay in each year by dividing the levelized value (less the O&M fraction) by an annual payment factor that incorporates an average interest rate (probably the same as the discount rate used for the analysis) and an assumed average lifetime (assumed to be the same as that used in step 6).
13. Multiply the net impacts on purchased fuels by end-users as developed in Step 6, and purchased fuels and other costs by utilities as avoided by EUIs, by appropriate avoided costs for electricity and fuels saved/used.
14. Calculate the total net cost impact from the results of step 10 and step 13.
15. Estimate “upstream” emissions reduction from avoided/additional fuels and electricity use using common emission factors used in many options.
16. Apply representative estimates of the fraction of the additional capital costs of technologies used in the option that might be paid by a program sponsor, plus estimates of the ratio of sponsor administrative costs to the sponsor outlays for incentives, to estimate the administrative costs of the option.

Key Assumptions

Key assumptions used in the quantification methods above to produce the estimated emissions savings and cost-effectiveness results shown for RCII-4 include the following:

- Of the 2.5% annual additional savings goal for electric utilities, and 1.5% annual goal for gas utilities, 1.8% and 1.4% annually are assumed to come from energy efficiency measures, respectively by 2019.
- EUI savings by electric utilities increases to 0.3% of new savings annually by 2019. EUI efficiency options counted in this total are those implemented at existing facilities only, not for building new generation (that is, for example, switching from coal to combined-cycle natural gas generation would not count toward this goal).
- Sales by municipal and cooperative utilities are included in the calculations of emissions savings and costs, but sales to CIP-exempt industrial consumer are excluded from the analysis.
- Based on a combination of 2012 CIP spending data[16] and Xcel Energy[17] information, the levelized costs of electric energy efficiency in the Residential, Commercial/Institutional,

[16] File "CIP Spending and Savings Information - 2012.xlsx" provided by Minnesota Agency Staff on 10/10/14.

[17] KEMA (2012), Xcel Energy Minnesota DSM Market Potential Assessment Final Report – Volume 1. Prepared for Xcel Energy, Minneapolis, Minnesota, Prepared by, KEMA, Inc., Oakland, California, dated April 20, 2012, and

and Industrial sectors were $15.5, $30.0, and $32.1 per lifetime MWh saved, respectively (2014 dollars), and the levelized costs of gas energy efficiency in the Residential, Commercial/Institutional, and Industrial sectors were $1.43, $1.42, and $1.51 per lifetime MMBtu saved, respectively. All of these levelized costs are escalated at an assumed 0.25%/yr (real) after 2015.

- Based on Xcel data as cited above, the average fraction of measure capital costs covered by program sponsors, in the Residential, Commercial/Institutional, and Industrial sectors were estimated at 74, 30, and 28 percent, respectively for both electric and gas utilities.
- Estimated avoided marginal emission factors for electricity generation, on a delivered basis, falls from 0.936 tCO_2e per MWh in 2015 to 0.758 in 2030, with avoided costs of electricity generation (again based on delivery to consumers, that is, factoring in transmission and distribution losses) rising from $92.6 to $148.1 per MWh delivered (nominal dollars) over the same time period. Natural gas avoided (wholesale) costs rise from $4.78 to $8.97 per GJ (again nominal dollars) over the same time period.

Macroeconomic (Indirect) Economic Impacts

Table F-2.33 below provides a summary of the expected impacts on jobs and economic growth during the CSEO planning period.

Table F-2.33 RCII-4 Macroeconomic Impacts on GSP, Employment and Income

Scenario	**Gross State Product** (GSP, $2015 Millions)			**Employment** (Full & Part-Time Jobs)			**Income Earned** ($2015 Millions)		
	Year 2030	**Average (2016-2030)**	**Cumulative (2016-2030)**	**Year 2030**	**Average (2016-2030)**	**Cumulative (2016-2030)**	**Year 2030**	**Average (2016-2030)**	**Cumulative (2016-2030)**
RCII-4	$137	$141	$2,111	1,430	1,560	23,340	$163	$143	$2,140

Graphs below show detail in GSP, employment and personal income impact of the RCII-4 policy.

provided by Minnesota Agency Staff. Table 3-1 Scenario Average Spending during 2011-2020 Forecast Period ($1000s) Electric Programs ("BAU" scenario). See "Supporting Data" worksheet in

Figure F-2.27 RCII-4 GSP Impacts ($2015 MM)

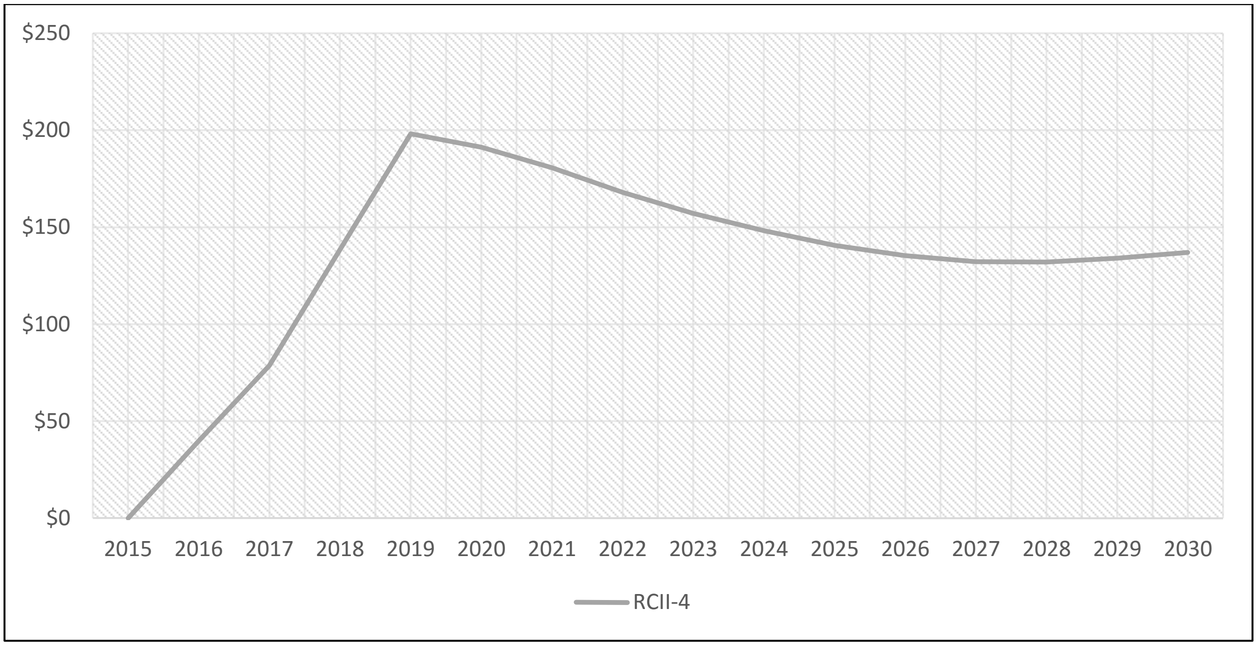


Figure F-2.28 RCII-4 Employment Impacts (Individual Jobs)

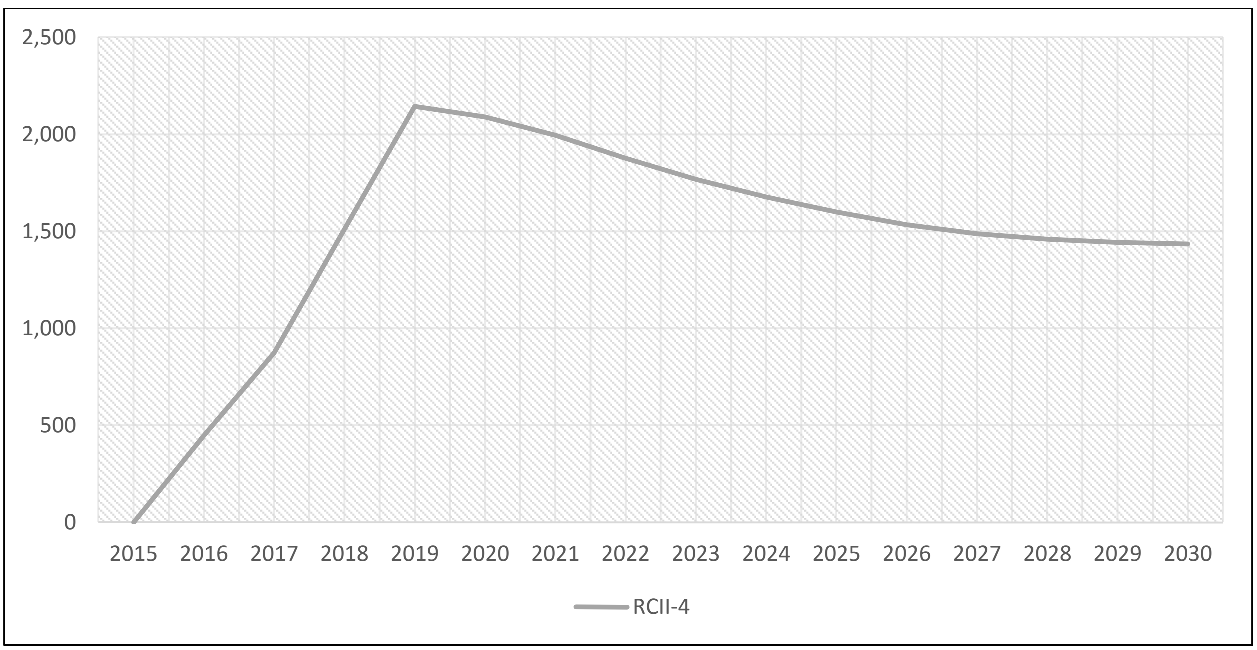
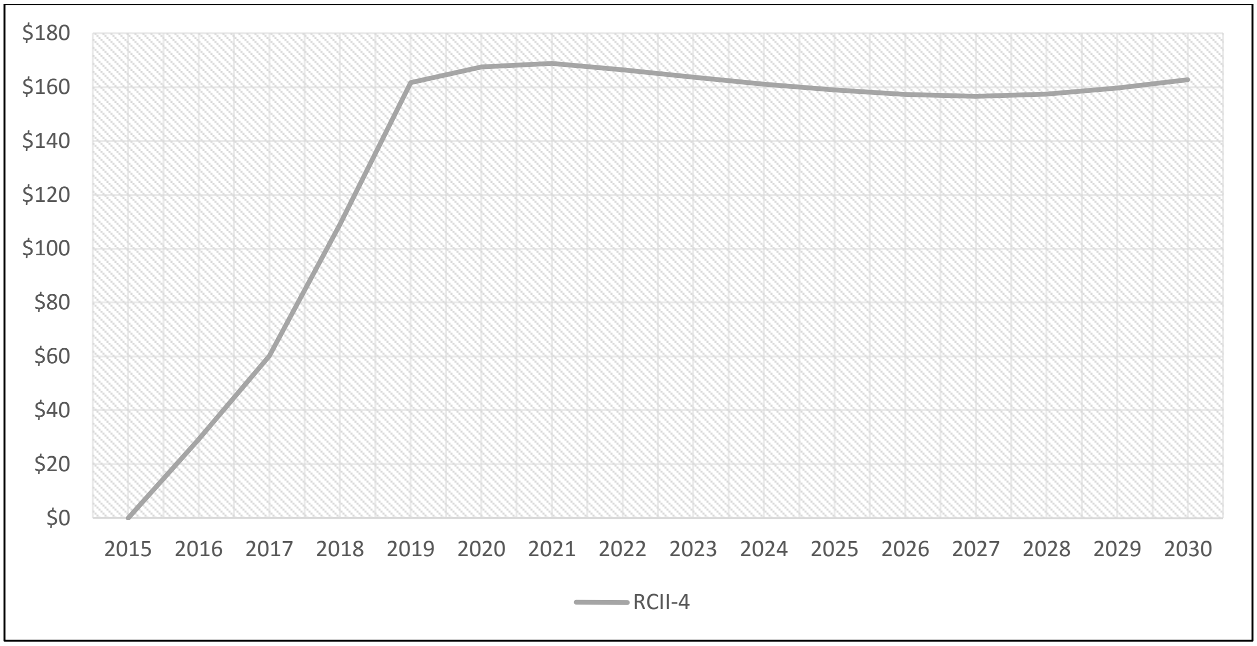
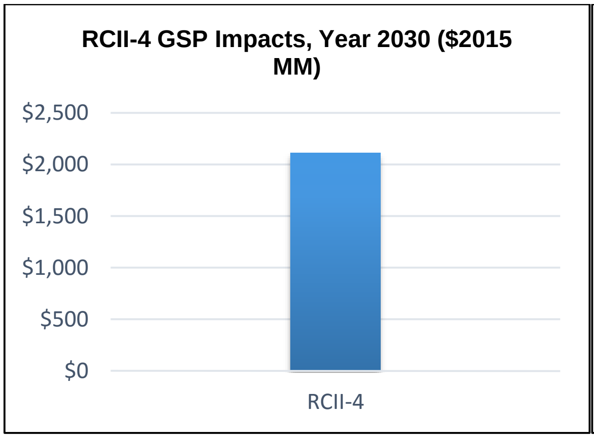
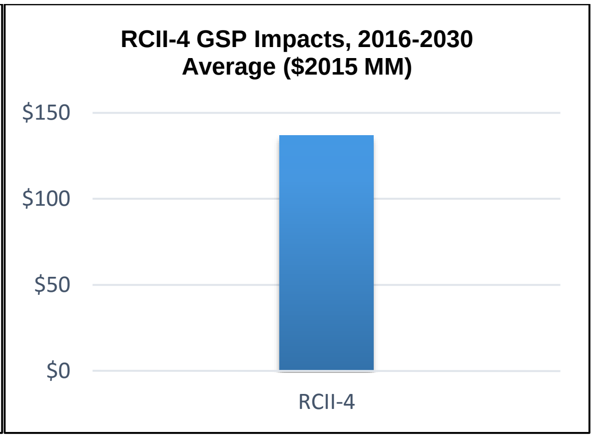


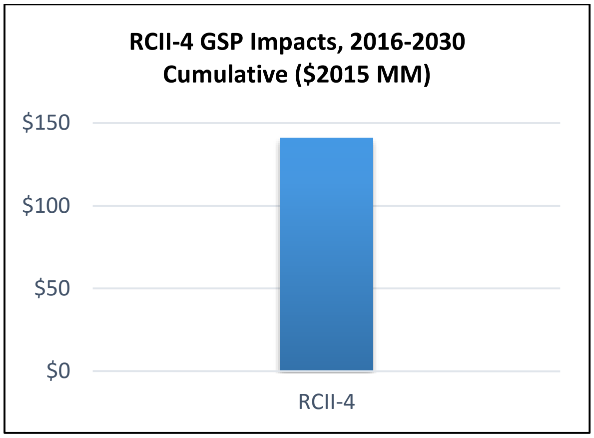
Figure F-2.29 RCII-4 Income Impacts ($2015 MM)

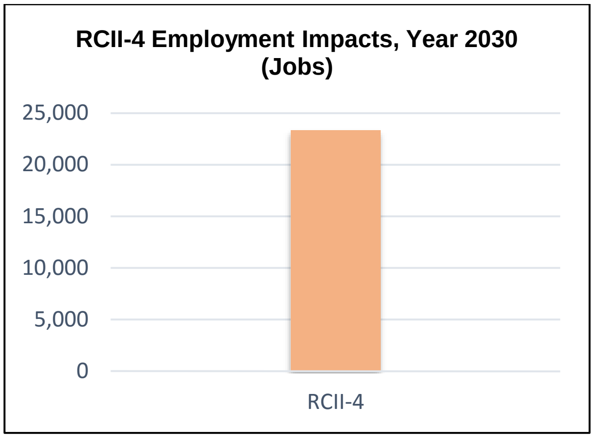


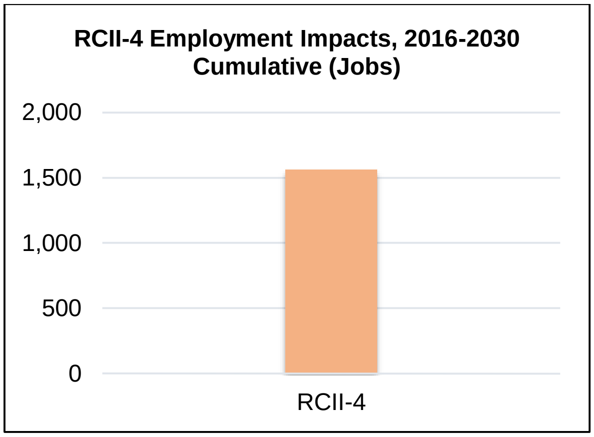
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030).

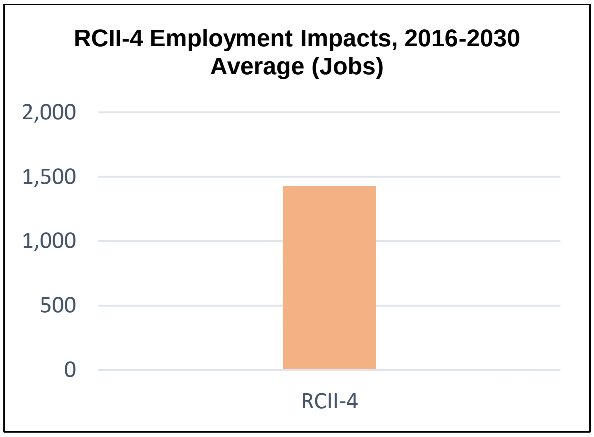


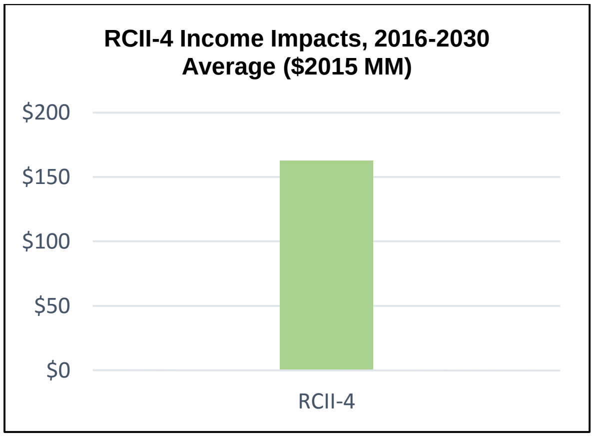


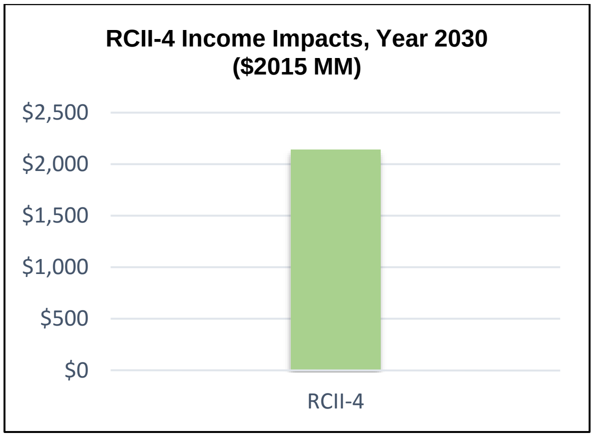

RCII-4 GSP Impacts, 2016-2030
Cumulative ($2015 MM)
$150
$100
$50
$0
RCII-4

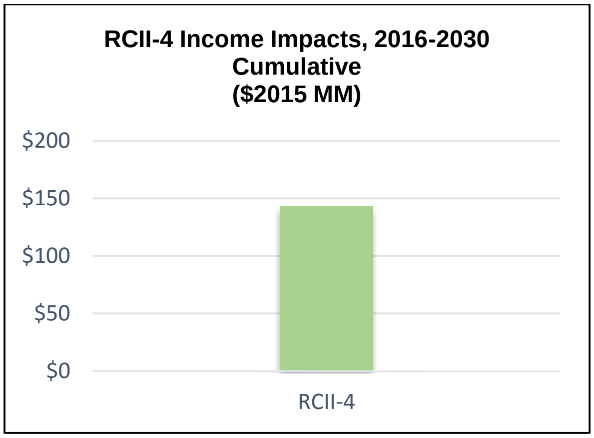

RCII-4 Employment Impacts, Year 2030
(Jobs)
25,000
20,000
15,000
10,000
5,000
0
RCII-4


RCII-4 Employment Impacts, 2016-2030
Cumulative (Jobs)
2,000
1,500
1,000
500
0
RCII-4


RCII-4 Employment Impacts, 2016-2030
Average (Jobs)
2,000
1,500
1,000
500
0
RCII-4


RCII-4 Income Impacts, 2016-2030
Average ($2015 MM)
$200
$150
$100
$50
$0
RCII-4


RCII-4 Income Impacts, Year 2030
($2015 MM)
$2,500
$2,000
$1,500
$1,000
$500
$0
RCII-4



Principal Drivers of Macroeconomic Changes

RCII-4 produces about $200 million each in annual gains in GSP and Income, with annual employment rising as a result of the policy by about 2,000 total positions statewide.

Energy savings play a big part. Statewide, various consuming sectors achieve a reduction in demand for electricity and natural gas reaching approximately $750 million by the year 2030.

The scale of those savings overwhelms the burden of program compliance, which is what produces the overall positive impacts.

The utility sector, which so often suffers under energy supply policies (and does lose volume of economic activity here as it does under other RCII policies) is somewhat helped in that it too participates in the energy-efficiency initiative and achieves large reductions in the requirements involved in its own operations, as it self-powers energy generation and provides water treatment.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For RCII-4, the utilities sector still sees losses in total demand, and thus reduces the amount of inputs it needs to production for a smaller total supply to produce.

The largest gains are actually in management positions, as the operating and maintenance investment that companies make to adopt this policy is large. At about 700 positions, the expansion of this labor pool is about double the size of the losses in jobs in the utilities sector.

Consumer-oriented sectors gain, as households see a net savings from this policy. Retail trade, restaurants, services, direct labor to homes, and health care all see gains. In general, the policy's net savings to affected parties frees up money for demand all around the economy, and most sectors see slight upward influence in the demand for their products and services.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.
- State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

Key uncertainties that should be considered in the development and implementation of this proposed policy option are as follows:

- Is 2.5% for electric utilities and 1.5% for natural gas utilities feasible?

To explore the GHG and net societal cost implications for this uncertainty, an alternative scenario was modeled in which the overall requirement for savings by electric utilities rises to 2.0% of sales annually over three years (as opposed to 2.5% over four years in the base case for this option), with the annual savings requirement from energy efficiency rising from 1.5% to 1.65% in three years. As a result of this change, the overall cumulative in-state (direct) GHG emissions savings over the period 2015-2030 from the policy option declines by about one-third relative to the base case, to 24.6 million $TgCO_2e$ (3.2 Tg in 2030), with a net cost of negative $1,270 million (about one-third less overall savings than in the base case), but with a similar cost-effectiveness (minus $51.70 per tCO_2e) as in the case where 2.5% annual savings is used as the electric utility target. The results of this alternative scenario are presented in Table F-2.34 below. In addition to these in-state reductions, when evaluated with an ultimate savings requirement of 2.0%/year for electric utilities, RCII-4 produces an estimated 0.57 $TgCO_2e$ of out-of-state (upstream) emissions reductions in 2030, and 4.26 $TgCO_2e$ in cumulative out-of-state reductions from 2015-2030, yielding total 2030 emissions reductions of 3.75 $TgCO_2e$ in 2030, and 28.87 $TgCO_2e$ over 2015-2030.

Table F-2.34 RCII-4 Alternative Scenario Results

	2030 GHG reductions ($TgCO_2e$):	2015 - 2030 cumulative reductions ($TgCO_2e$):	Net present value of societal costs, 2015 - 2030 (million $2014):	Cost effectiveness ($2014/t CO_2e):
Electric Utility EERS: Savings from EE Programs	0.98	7.78	$(336.11)	$(38.69)
Electric Utility EERS: Savings from CHP Implementation	INCLUDED IN RCII-1			
Electric Utility EERS: Savings from EUI Investments	1.28	10.02	$ (609.14)	$(54.41)
Natural Gas Utility EERS: Savings from EE Programs	0.92	6.80	$(327.16)	$(36.41)
Natural Gas Utility EERS: Savings from CHP Implementation	INCLUDED IN RCII-1			
TOTAL	3.18	24.61	$(1,272.41)	$(44.08)

- Is a 2.5% for electric utilities and 1.5% for natural gas utilities achievable and sustainable until 2030?
- What will the impact of changing market conditions, such as natural gas price fluctuations or decreases and advances in energy codes, be on cost-effectiveness of energy efficiency programs and energy savings?
- What is the technical and economic potential each utility has available to meet set CHP goals?
- How will the barriers that exist in Minnesota's current energy efficiency framework be addressed so they are not continued barriers in achieving the 2.5% goal?
- What will be the long-term impacts to utility rates and supply-side resources if the 2.5% EERS is achieved consistently through its effective period?
- What will be the impact on expenditures on energy efficiency and CHP efforts to achieve this higher standard?
- In achievement of the CHP standard, how will ratepayer cross-subsidization of incentivizing projects be avoided or managed?
- In the absence of an existing CHP technical assistance program for potential projects, how the state and its utilities drive demand for customer on-site generation?

Additional Benefits and Costs

Energy: Energy conservation and efficiency is the most cost-effective energy resource available in Minnesota. Increasing the 1.5% goal to a 2.5% goal will further alleviate the need to meet additional supply needs through other more costly energy resources. For example, in the most recent CO_2 Report where Commerce reports CIP performance to the legislature, a levelized cost-comparison found in 2011 energy efficiency as a result of CIP cost $21.43/MWh whereas the average cost of generating a kWh from coal cost $100.10/MWh.

Economy: Increased activity within CIP provides an economic benefit to the state of Minnesota in many different. Residents and businesses that participate in CIP benefit from lowered utilities bills through reduced demand and consumption. In 2013, Commerce estimated that, based on CIP historical performance, over $2.6 billion dollars has been saved by ratepayers through energy efficiency and conservation. Additional benefits include more sales for Minnesota's trade allies that implement and sell energy efficiency technology or services; dedicated low income spending required in CIP results in reduced need for Low Income Heating Assistance allowing those dollars to go further; and the financial incentives and policy option framework in CIP spur greater innovation of technologies and program design to meet the needs of advancing standards and goals.

Environment: DSM through the Conservation Improvement Program directly results in reduced carbon emissions and has the potential to be one of the more cost effective solutions for reducing greenhouse gas emissions. For example, in the most recent CO2 Report, Commerce found that in 2010-2011 (the first years of the energy savings requirement), nearly 2,000,000 tons of CO2 emissions were avoided which is roughly the equivalent of removing 371,000 cars from the road for one year.

Health: Per a Minnesota Department of Health analysis, increasing energy efficiency could benefit health by reducing climate change through reduced emissions. Emissions reductions may reduce the risk of cardiovascular and respiratory illness as well as cancer in communities exposed to energy-related emissions. (EPA; Kappos; Pope 2002, Pope 2000, Bernard) Building efficiency improvements could also reduce respiratory illness, reduce allergies and asthma, reduce sick building syndrome, and improve worker performance through changes in thermal environment and lighting.

Feasibility Issues

The Conservation Improvement Program is an existing regulatory framework that has evolved over the last three decades. Minnesota ratepayers already have contributed significant investments toward the development of energy efficiency programs and services to meet existing utility efficiency goals. Modifying the goal from 1.5% to 2.5% will increase the need for additional expenditures in CIP to achieve the more aggressive standard. While expenditures will increase, considerations need to be made to ensure efficiency activities remain cost-effective for the ratepayers. As a result of Minnesota's long standing commitment to efficiency, many opportunities to achieve greater efficiency and the ability to achieve savings cost-effectively are evolving.

While there may be some feasibility issues with a utility's ability meet a higher EERS, the inclusion of a CHP standard within the EERS will afford the utilities greater opportunity to achieve the EERS through implementation of this underutilized technology. As the opportunities exist to implement CHP, implementation of this embedded standard is not without challenge. Detailed below are a few areas of concern with regard to achieving a higher EERS and an embedded CHP standard.

Energy Efficiency Achievement Feasibility

Minnesota Energy Code: The Department of Labor and Industry is moving closer to finalizing the adoption of new residential and commercial energy codes. The new code will be based on the 2012 IECC. It is expected that the energy codes will be going into effect during the early to middle part of 2015. The new energy code will impact the incremental savings a utility can claim from projects implemented that are more efficient than code, a key criteria for project eligibility in CIP. The incremental savings, which will be reduced as a result of the code, directly impact the cost-effectiveness of CIP programs. As this change takes place, regulatory agencies and utilities will need to closely evaluate the impact the code change will have on the utility's ability to achieve a higher 2.5% goal.

Federal Standards: Similar to the issue with energy code change impacts to utility baselines, changes to federal standards for efficiency measures such as lighting or motors will also impact a utilities ability to achieve greater savings. Approximately 40% of the CIP portfolio is comprised of lighting efficiency measures. As federal standards phase out incandescent lamps from the market, compact fluorescent lighting becomes the new baseline. This will also result in reduced incremental savings that a utility can count toward its CIP goal, potentially negatively impacting the cost effectiveness of related programs. Given the size of lighting efficiency in the overall CIP portfolio, efforts will need to be made to diversify program offerings to achieve greater savings.

Sustainability of EERS Achievement: Utilities have been working with their customers to save energy since the early 1980s, but as of 2007 these efforts increased significantly with an energy savings requirement fully established by 2010. Since 2010, the utilities have collectively achieved a statewide performance of 1.5% for electric and approximately 1% for natural gas – some utilities have achieved higher savings while others have achieved less. Natural gas utilities have already successfully petitioned the Department of Commerce to approve a 1% goal based on current feasibility in meeting the standard. Additionally, lower natural gas prices are impacting the avoided cost component of cost-effective programs. If natural gas prices continue to remain low and as incremental savings decrease, utilities may have fewer programs that remain cost-effective.

Combined Heat and Power Implementation Feasibility

Minnesota has been perpetually challenged to implement higher levels of CHP throughout the state. The feasibility of achieving the CHP standard embedded within the EERS will be dependent on many factors, a few of which include the following:

- Creation of utility programs that significantly reduce the upfront capital costs and overall risk of moving toward customer on-site generation.
- Establishment of reasonable stand-by rates by utilities and the Public Utilities Commission to remove obstacles in a customer’s ability to achieve a desired return on investment from project implementation.
- Potential adjustments made to net metering and interconnection standards and practices the reduce implementation barriers.
- Education and training programs established and available for customers who are implementing and/or considering implementing CHP.

RCII-5. Incentives and Resources to Promote Thermal Renewables

Policy Option Description

Establish a **renewable thermal goal** of 5% of the total forecast heating load (measured as fuel delivered for heating use) that is fueled with non-electric sources including natural gas, fuel oil, and propane in Minnesota coming from eligible renewable thermal resources by 2020 and 20% by 2030[18]. Includes a small system carve out of 5%.

Establish a statewide **Renewable Thermal Incentive Fund** that provides incentives for the installation of thermal renewable technologies and targets high-value customers including farmers, delivered fuel customers, low income housing authorities and commercial users. The fund would collect 1 cent per therm[19] of energy content on natural gas, fuel oil, and propane sold in Minnesota. A portion of the funds collected could be reserved as a loan guarantee fund for large projects while the remainder would be issued as competitive grants for large systems and prescriptive incentives for small systems. The program sunsets in 2030.

Significant opportunity exists to meet heating load with in-state renewable energy resources, resulting in reduced GHG emissions. In addition, recent propane infrastructure changes and severe shortages of propane in the winter of 2013-2014 highlight the benefits of more diversity in heating options to mitigate volatility in fuel pricing and availability throughout greater Minnesota.

A **renewable thermal goal** is a leading state policy option to promote adequate and diverse thermal energy supplies, at a reasonable cost, with minimal impact on the environment and with side benefits of increased energy security and energy access for Minnesotans. The small system carve-out ensures that a variety of end-users benefit such as residential propane customers.

A **Renewable Thermal Incentive Fund** to provide incentives for the installation of renewable thermal systems statewide and support progress toward attainment of the renewable thermal goal. A one cent per therm charge on propane, fuel oil, and natural gas use will generate a fund of approximately $40 million annually to start.

Eligible Fuel sources:

- Biomass[20] (with emission controls and efficiency requirements)

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[18] State funded building projects currently follow SB 2030 guidelines including an assessment for on-site renewable thermal technologies. Adoption of the thermal goal would support the efforts of SB 2030.

[19] One therm is 100,000 British Thermal Units (Btu) or 0.1 MMBtu.

[20] The federal Biomass Thermal Utilization (BTU) Act of 2013 defines biomass as any plant-derived fuel available on a renewable or recurring basis, including agricultural crops and trees, wood and wood waste and residues, plants

- Biogas
- Biofuel
- Solar thermal (including solar air heat, solar water heating, industrial process heat, and transpired air heat)

Eligible technologies:

- Biogas thermal systems
- Biomass thermal systems with efficiency requirements and stringent emissions controls[21]
- Solar water and space heating systems including transpired air heat
- Solar industrial process heating and cooling systems
- Renewable combined heat and power systems[22]
- Renewable district heating and cooling systems

Causal Chain for GHG Reductions

A schematic causal chain for this policy option is provided below. Increased use of renewable heating fuels and systems displaces fossil fuel (natural gas, distillate oil, and propane) used for space heat, water heat, and process heat produced. As such, GHG emissions savings accrue through the reduction of use of fossil fuels formerly used for heating, but these savings are partially offset by emissions from renewable fuels combustion in biomass and biogas systems. In addition, reduced use of fossil fuel reduces “upstream” emissions associated with, for example, natural gas transmission and distribution, oil refining and transport, and natural gas and crude oil production. It is expected that these GHG emissions reductions and increases will be quantified. Increased use of renewable fuels will produce some increase in emissions associated with fuel processing and transport—for example, diesel-fueled equipment used for biomass harvesting and transport. These additional emissions are highly variable depending on the source of the biomass fuel and the distance it must be shipped to the users. At present, these incremental emissions are estimated using an upstream emission factor derived from a

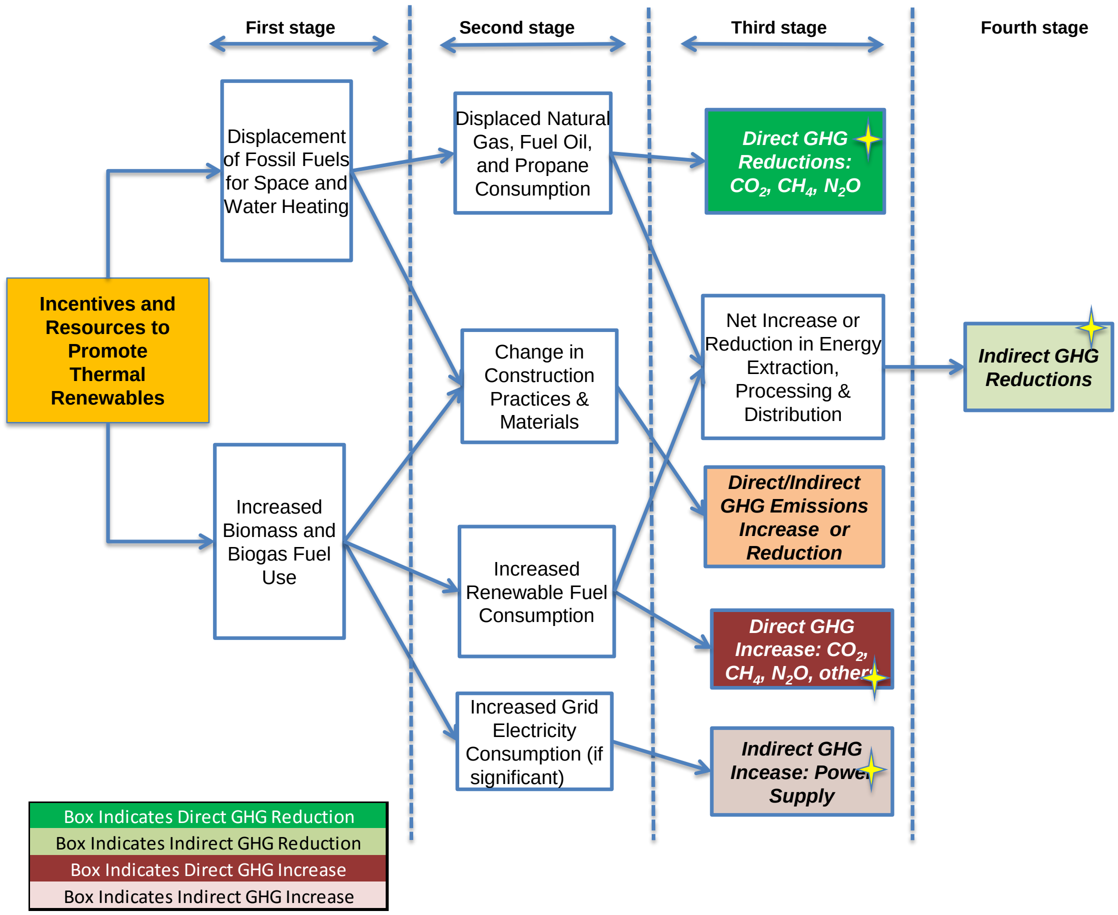
(including aquatic plants), grasses, residues, and fibers. This definition includes densified biomass fuels such as wood pellets.

[21] For example, the New York State Energy Research and Development Authority (NYSERDA) funds high efficiency and low emissions commercial and residential wood pellet heating equipment. The guidance documents are available by scrolling to the bottom of this link http://www.nyserda.ny.gov/Statewide-Initiatives/Cleaner-Greener-Communities/Implementing-Smart-Development-Projects/Guidance-Documents.aspx. This is not an endorsement to adopt NYSERDA’s preferred equipment, but an example. The State of Maryland’s emissions regulations should be considered as a model as well if this policy option is adopted.

[22] Included in the CHP policy option document RCII-1 for microeconomic and macroeconomic modeling rather than in this policy option.

study in Ontario,[23] but Minnesota-specific average might be different. Changes in the heating equipment/appliances used that are made as a result of this option may also produce changes in construction practices and materials manufacturing that may have a positive or negative impact on GHG emissions. These impacts are indirect and uncertain, and are not quantified.

Figure F-2.30 Causal Chain for RCII-5 GHG Reductions



Policy Option Design

The renewable thermal goal would apply to non-electric sources of heat including natural gas, propane, and fuel oil consumption statewide to diversify the state's use of heating fuels to include increasing amounts of renewable energy. Implementation of these policies will require enabling legislation and subsequent regulation by the Public Utilities Commission and the Department of Commerce. The Policy Option design must recognize the need to implement a

[23] The upstream emission factor for wood use is are based on an Ontario study of the Life Cycle Impacts of Wood vs Coal production (see Tables S-1 and S-2; http://pubs.acs.org/doi/suppl/10.1021/es902555a/suppl_file/es902555a_si_001.pdf). The value used is for pelletized wood fuel; less-processed forms of wood fuel would likely have somewhat lower emission factors.

renewable thermal goal that is broad enough to serve the state's various regions by matching resource preferences to regional availability with a strong emphasis on emissions impacts. The displacement of the most carbon-intensive conventional sources should be prioritized under the Renewable Thermal Incentive Fund, however, use of all fossil fuels for heating should be curbed through statewide implementation with geographic consideration.

Given Minnesota's significant heating load and the difficulty of addressing GHG reductions in the transportation sector, Minnesota cannot achieve the state energy policy option goal of 80% GHG reductions by 2050 without addressing the heating sector.

Commercial/industrial such as biomass for district energy systems, agricultural operations, institutional buildings, schools, and government buildings represents the biggest opportunity for cost effective reductions in GHG emissions and should represent most of the renewable thermal deployment. However, the 5% residential and small commercial carve out from the renewable thermal goal along with the Renewable Thermal Incentive Program will promote investment in small projects as well.

The Renewable Thermal Incentive Program would be established with fees collected by the Minnesota Department of Revenue and administered by Department of Commerce. The Department of Revenue would collect $0.01 per therm on natural gas, fuel oil and propane sold in Minnesota. Revenue currently collects $.001 per gallon of propane and fuel oil from wholesalers; a gallon of propane or fuel oil has energy contents roughly equivalent to 1 therm of heat (about 0.9 and 1.4 therms, respectively).

High-value customers include farmers, delivered fuel customers, low income housing authorities, and residential and commercials users. The program would sunset in 15 years.

Program participation would require cost-share commitments from residential, commercial, non-profit and public sector applicants. The incentive amount available to consumers should reflect the availability of other non-state incentives in order to maximize program effectiveness.

- Large and non-residential projects: Competitive grants with a suggested cost-share commitment from the applicant.
- Residential and small commercial projects: First come, first served year-round rebate with a minimum 50%cost-share commitment from the applicant.

Goals:

A. Reduce the use of fossil fuels (specifically, natural gas, fuel oil, and propane) for heating in Minnesota through the use of eligible renewable thermal resources by 5% by 2020 and 20% by 2030[24] and do so in a manner that doesn't create unacceptable exposures to air pollution from renewable-fueled heating systems.

[24] State funded building projects currently follow SB 2030 guidelines, which for state buildings includes an assessment for on-site thermal renewable technologies. Adoption of the thermal goal would support the efforts of SB 2030.

B. Annually deploy hundreds of renewable thermal systems from various renewable technologies through the new Renewable Thermal Incentive Program. These projects should represent high-value customers and demonstrate:
    - geographically diverse locations;
    - a variety of sector end-uses including residential, commercial, agricultural, and government facilities, and;
    - projects sized for small-scale, large-scale, and utility-scale installations.

Timing--**Renewable Thermal Goal** (as a fraction of total use of natural gas, fuel oil, and propane for heating):

- 2017 – 1%
- 2018 – 2%
- 2020 – 5%
- 2025 – 12%
- 2030 – 20%

Timing—**The Renewable Thermal Incentive Program** operates through December 2030. New projects receive total funding of approximately $38,000,000 (or 95% of the funds generated) annually, net of administration and promotion costs. Reservation of funds for awardees begins no later than January 2017.

Parties Involved in Implementation

- Minnesota Department of Commerce-tracking and administration
- Minnesota Pollution Control Agency-air quality emissions criteria and outreach/education
- Minnesota Department of Natural Resources-supply chain
- Minnesota Department of Revenue-fee collection for delivered fuels

Parties Affected:

- Natural gas utilities
- Minnesota Propane Association
- Delivered fuels wholesale providers
- 3rd party gas suppliers

Other: Given the significant contribution of residential wood combustion to the direct emissions of fine particles (PM2.5) in Minnesota, several wood smoke-related recommendations were supported by the Clean Air Dialogues project. These included development of a model ordinance to assist local governments addressing air quality impacts of outdoor wood boilers (hydronic heaters), education and outreach related to residential wood smoke, and support for EPA's work to finalize a New Source Performance Standard for residential wood heaters http://www.epa.gov/residential-wood-heaters/final-new-source-performance-standards-residential-wood-heaters

Implementation Mechanisms

1. Pass legislation requiring a **renewable thermal goal** for Minnesota's heating load similar to the state's successful Renewable Electricity Standard as well as requirement for a Renewable Thermal Incentive Program.

Develop a **Renewable Thermal Incentive Program** to reduce gas, propane and fuel oil consumption and price and availability volatility. Program will be funded with fees collected by Minnesota Department of Revenue. The fund will target high-value customers for thermal technologies, including farmers, commercial users and delivered fuel customers. The program will be administered by the Department of Commerce with on-going cooperation with Revenue for fee collection and informed by Pollution Control and Natural Resources. The administrative cost must not exceed 5% of the funds collected. Include an annual report of the **Renewable Thermal Goal** and **Renewable Thermal Incentive Program** results to optimize the policy option for maximum GHG reductions.

Related Policies/Programs in Place and Recent Actions

- **Minn. Statute 216C.05 Subd. 2 (2007)** states it is the energy policy option goal of the state of Minnesota that:
    - the per capita use of fossil fuel as an energy input be reduced by 15% by the year 2015 [with a base year of 2005], through increased reliance on energy efficiency and renewable energy alternatives; and
    - 25% of the total energy used in the state be derived from renewable energy resources by the year 2025.
- **Executive Order 11-13,** ***"Strengthening State Agency Environmental, Energy and Transportation Sustainability,"*** requires that Minnesota state agencies establish a Sustainability Plan to reduce greenhouse gas emissions in its operations. A requirement for new and remodeled public buildings to incorporate on-site renewable thermal or use of renewable thermal from a district energy system is consistent with the Executive Order's goals.
- 16B.32 Energy Use.
    - Subdivision 1. **Alternative energy sources.** Plans prepared by the commissioner [of Administration] for a new building or for a renovation of 50% or more of an existing building or its energy systems must include designs which use active and passive solar energy systems, earth sheltered construction and other alternative energy sources where feasible.

- Subd. 1a.**Onsite energy generation from renewable sources.** A state agency that prepares a predesign for a new building must consider meeting at least 2% of the energy needs of the building from renewable sources located on the building site. For purposes of this subdivision, "renewable sources" are limited to wind and the sun. The predesign must include an explicit cost and price analysis of complying with the two-percent requirement compared with the present and future costs of energy supplied by a public utility from a location away from the building site and the present and future costs of controlling carbon emissions. If the analysis concludes that the building should not meet at least 2% of its energy needs from renewable sources located on the building site, the analysis must provide explicit reasons why not. The building may not receive further state appropriations for design or construction unless at least 2% of its energy needs are designed to be met from renewable sources, unless the commissioner finds that the reasons given by the agency for not meeting the two-percent requirement were supported by evidence in the record.

- **Statute 16B.326** *Heating and Cooling Systems; State-Funded Buildings***.** The commissioner [of Administration] must review project proposer's study for geothermal and solar thermal applications as possible uses for heating or cooling for all building projects subject to a predesign review under section 16B.335 that receive any state funding for replacement of heating or cooling systems. When practicable, geothermal and solar thermal heating and cooling systems must be considered when designing, planning, or letting bids for necessary replacement or initial installation of cooling or heating systems in new or existing buildings that are constructed or maintained with state funds. The predesign review must include a written plan for compliance with this section from a project proposer.

Existing Programs

- Minnesota's Renewable Energy Equipment Grant Program works with the Weatherization Assistance Program to provide eligible households with supplemental heating systems to offset conventional heating loads in weatherized, low income households through deployment of solar air heat furnaces, high efficiency-low emission wood boilers and high efficiency-low emission wood stoves.
- DNR received a $250,000 grant from the U.S. Department of Agriculture to enhance the use of renewable wood energy systems throughout the state. The primary objective is to identify a number of commercial and institutional buildings that now use fuel oil and propane for energy and replace those systems with innovative wood energy systems.
- Business Energy Resources- IRRRB- Funding available for energy savings/renewable energy retrofits for private businesses in the Iron Range.
- Guaranteed Energy Savings Program (Commerce)
- The Made in Minnesota Solar Thermal Rebate Program provides $250,000 annually for solar air heat and solar water heating. (2014-2023)

Estimated Policy Impacts

Direct Policy Impacts

Summary in-state (direct) GHG emissions reduction and option costs results for RCII-5, "Incentives and Resources to Promote Thermal Renewables", are provided in the Table F-2.35 below. These values include costs for program administration. Overall, this option results in 3.0 million metric tons (which is the same as teragrams—trillion grams or Tg in the table below) of annual CO_2e savings in 2030, with about 22 million metric tons of CO_2e savings over the analysis period. Nearly three quarters of the overall savings come from implementation of measures in the industrial sector. This is a net positive cost option, as indicated by the positive cost per ton of CO_2e emissions avoided. In addition to these in-state reductions, RCII-5 produces an estimated 1.21 $TgCO_2e$ of out-of-state (upstream) emissions reductions in 2030, and 8.83 $TgCO_2e$ in cumulative out-of-state reductions from 2015-2030, yielding total 2030 emissions reductions of 4.19 $TgCO_2e$ in 2030, and 30.46 $TgCO_2e$ over 2015-2030.

Table F-2.35 RCII-5 Estimated Net GHG Reductions and Net Costs or Savings

	2030 GHG reductions ($TgCO_2e$):	2015 - 2030 cumulative reductions ($TgCO_2e$):	Net present value of societal costs, 2015 - 2030 (million $2014):	Cost effectiveness ($2014/t CO_2e):
Introduction of Thermal Renewables, Residential Sector	0.18	1.29	$114.65	$64.16
Introduction of Thermal Renewables, Commercial Sector	0.60	4.37	$250.35	$40.64
Introduction of Thermal Renewables, Industrial Sector	2.20	15.97	$507.21	$22.44
Total	2.98	21.63	$872.22	$28.55

Data Sources

Typical heat to fuel efficiencies for technologies commonly used in Minnesota:[25]

- Natural gas/propane water heaters – 70%
- Natural gas/propane furnaces – 80%

[25] Minnesota Department of Commerce, Mark Garofano et al.

- Commercial natural gas steam boilers – 85%
- Natural gas hot water boilers – 88%

In 2012, Minnesota used the following amounts of propane and natural gas in the residential, commercial and industrial sectors:

- Propane[26]
    - 349,485 million Cubic feet
    - 323,688,333 Therms
- Natural Gas[27]
    - 353,191,320 Gallons
    - 4,338,459,152 Therms

Quantification Methods

1. Obtain estimates of forecast natural gas, distillate oil, and propane (or liquefied petroleum gas—LPG) demand by sector and year through 2030 from the Inventory and Forecast (I&F) prepared to accompany the assessment of GHG Emissions Reduction options.
2. Calculate the fraction of forecast use of the above fuels by sector that is used for space and water heating by applying relevant factors from the literature or the inventory and forecast.
3. Based on the goals set out above, define a stream of annual fractional savings for the covered fuels, and apply it to estimate the reduction in fuel use of each type by year.
4. Prepare, in consultation with Minnesota Agency staff, estimates of the fraction of savings to ascribe to each sector, and use those estimates to calculate reductions in fuel use by sector and by year.
5. Calculate the annual emissions reduction from avoided fossil fuel use as estimated in step 4 by applying emission factors from the I&F.
6. Use a stream of values interpolated from those provided in Key Assumptions, below, to estimate the fraction of the reduction in fuel use calculated in step 4 that will be provided by renewable systems (biogas, biomass, and solar thermal).
7. Calculate the fuel input to biogas and biomass renewable heating systems by applying estimates to compare the heating efficiency of the biomass fuels to the fossil fuels displaced to the estimates of avoided fuel use from step 4.

[26] Minnesota's Supply and Demand for Propane and Anhydrous Ammonia, Minnesota Department of Agriculture April 1, 2011.

[27] U.S. Energy Information Administration, Natural gas delivered to consumers by sector, 2008-2012. http://www.eia.gov/naturalgas/annual/pdf/table_016.pdf

8. Apply emission factors from the I&F to the biomass and biogas fuel use calculated in step 7 to estimate the new emissions of GHGs (methane and nitrous oxide, as carbon dioxide emissions from biomass/biogas will be assumed to be offset by carbon uptake, assuming sustainable use of biomass inputs).
9. Compile and convert into applicable forms representative cost estimates, by sector, if available, for renewable energy systems replacing conventional heating systems, on a per-unit-energy provided basis, and apply them to the savings in fuel use calculated in step 4 to estimate the annual costs by sector, technology, and year for the program, splitting costs into capital and O&M costs. This step will involve application of capital costs to only the new systems added in each program year.
10. Multiply the net impacts on purchased fuels as developed in Step 4 by appropriate avoided costs for the fossil fuels saved to yield avoided fuel costs by sector.
11. Multiply the new biomass fuels use by appropriate estimated costs for those fuels to yield renewable fuel costs by sector and technology.
12. Calculate the total net cost impact from the results of steps 9 through 11.
13. Estimate "upstream" emissions reduction from avoided fossil fuels use using common emission factors used in many options.
14. Apply representative estimates of the fraction of the additional capital costs of technologies used in the option that might be paid by a program sponsor, plus estimates of the ratio of sponsor administrative costs to the sponsor outlays for incentives, to estimate the administrative costs of the option.

Key Assumptions

- The overall goal of 20% displacement of fossil heating fuels by renewable energy sources is achieved incrementally based on the following milestones: 1% in 2017, 2% in 2018, 5% in 2020, and 12% in 2025.
- The overall savings target is divided into small and larger systems, and by sector, as shown below:

Table F-2.36 Overall Savings Target by Sector

	Fractions of savings by all systems by sector	Fractions of small system set-aside by sector	larger system system total by sector
Residential	5%	100.0%	0%
Commercial	20%	0.0%	21.1%
Industrial*	75%	0.0%	78.9%

*Industrial includes agricultural users

- 85 to 100 percent of the fossil fuels used in each sector is assumed to be used for heating, and thus can be avoided by the measures included in this option. The exception is distillate oil use in the industrial sector, where only 8% is assumed to be used for heating (the rest being for internal combustion engines in equipment, including in agriculture).

- Heating fuels are displaced in proportion to their use for heating, as derived based on forecast values and the assumptions as to fraction of fuel use for heating shown above.
- The fractions of the overall savings targets achieved by the use of different measures are as shown in the Table F-2.37 below.

Table F-2.37 Fractions of Overall Savings Target

Fractions of Thermal Fuels Use Displaced by Systems of Different Types, by Sector

	Biogas	Biomass	Solar Water and Space Heating	Solar Industrial Process Heating and Cooling	Renewable District Heating and Cooling (Biomass-fired)	Combined Heat and Power
Residential	0%	65%	25%	0%	10%	0%
Commercial	5%	50%	20%	0%	10%	15%
Industrial*	5%	50%	15%	15%	0%	15%
Small Systems	5%	60%	35%	0%	0%	0%

*Industrial includes agricultural users

- The capital cost, operating and maintenance cost, and capacity factor assumptions assumed for each type of measure included in RCII-5 are as presented in Table F-2.38 below. Solar transpired heat was assumed to produce 75% of the total savings by the solar measures above in the commercial/institutional and industrial sectors. A variety of sources were used to derive the cost estimates shown. References to “Notes” in the column headers of the table below are to notes included in the RCII-5 analysis worksheet.

Table F-2.38 Costs by Parameter

Parameter	Biogas (see ***Note 8***)	Biomass, Residential (see ***Note 3***)	Biomass, Commercial and Industrial (see ***Note 5***)	Solar Water Heat, Residential (for O&M, see ***Note 11***)	Solar Water Heat, Commercial and Industrial (for O&M, see ***Note 11***)
Capial Cost ($/(MMBtu/yr))	$ 124.16	$ 32.62	$ 31.45	$ 465.10	$ 380.54
Variable Non-fuel O&M Cost ($/MMBtu)	$ -	$ -	$ 1.63	$ -	
Fixed O&M Costs ($/MMBtu-yr)	$ -	$ 0.24	$ -	$ 4.65	$ 3.81
Lifetime (years)	25	20	25	25	25
Interest Rate (%/yr)	5.0%	5.0%	5.0%	5.0%	5.0%
Annualized Capital Payment ($/(MMBtu/yr))	$ 8.81	$ 2.62	$ 2.23	$33	$27
Average Capacity Factors by Sector (see ***Note 7***)					
Residential	35%	35%	35%	100%	100%
Commercial	45%	45%	45%	100%	100%
Industrial	80%	80%	80%	100%	100%
Fraction of Solar Water and Space Heating by Technology					
Residential*	N/A		N/A	19.7%	N/A
Commercial**	N/A		N/A	N/A	12.7%
Industrial***	N/A		N/A	N/A	1.4%

Table F-2.39 Costs by Parameter (continued)

Parameter	Solar Space Heating, Residential (for O&M, see ***Note 11***)	Solar Commercial and Industrial Transpired Air Heating (see ***Note 6***)	Solar Commercial and Industrial Space and Process Heating and Cooling (for O&M, see ***Note 11***)	Renewable District Heating and Cooling (See ***Note 4***)
Capial Cost ($/(MMBtu/yr))	$ 436.91	$ 219.92	$ 352.35	$ 101.45
Variable Non-fuel O&M Cost ($/MMBtu)	$ -	$ -	$ -	$ 0.51
Fixed O&M Costs ($/MMBtu-yr)	$ 4.37	$ -	$ 3.52	$ 5.98
Lifetime (years)	25	25	25	30
Interest Rate (%/yr)	5.0%	5.0%	5.0%	5.0%
Annualized Capital Payment ($/(MMBtu/yr)	$31	$ 15.60	$ 25.00	$ 6.60
Average Capacity Factors by Sector (see ***Note 7***)				
Residential	100%	100%	100%	35%
Commercial	100%	100%	100%	35%
Industrial	100%	100%	100%	60%
Fraction of Solar Water and Space Heating by Technology				
Residential*	80.3%	N/A	N/A	N/A
Commercial**	N/A	65.4%	21.8%	N/A
Industrial***	N/A	74.0%	24.7%	N/A

Notes:

Blue shaded values in table above provided by Stacy Miller, 9/22/14 and 11/10/14.

* Fractions derived from averages of 2015-2030 residential forecasts by end-use prepared for this project. See "Supporting Data" worksheet in this workbook.

** Relative shares of commercial water heat and space heat estimated based on US DOE EIA CBECS data for natural gas use by end use in the West North Central Region. See worksheet http://www.eia.gov/consumption/commercial/data/2003/xls/e07a.xls.

*** Relative shares of industrial water heat and space/process heat estimated based on US DOE EIA MECS data for natural gas use by end use in the Midwest Region. See worksheet http://www.eia.gov/consumption/manufacturing/data/2010/xls/Table5_6.xls. Note that the MECS category "Other Facility Support" is assumed to be mostly water heating.

- Renewable energy systems were assumed to displace the capital costs of fossil-fueled boilers, water heater, and furnaces except for solar technologies, which were assumed to require a fossil-fueled back-up. The assumed average capacity factors for the fossil-fueled heating technologies displaced by renewable systems in the residential, commercial/institutional, and industrial sectors were 35%, 45%, and 80%, respectively. The capital costs for the avoided fossil heating systems are based on the same sources as used to derive similar assumptions in RCII-1, and are as shown below.

Table F-2.40 Average Fossil-fired Heating Source Cost Assumptions

Average Fossil-fired Heating Source Cost Assumptions (cost figures assumed $2014)

Parameter	Residential	Commercial	Industrial/ Agricultural
Capial Cost ($/(MMBtu/yr))	$ 4.48	$ 2.57	$ 1.71
Variable O&M Costs ($/MMBtu output)	$ 0.25	$ 1.00	$ 1.00
Lifetime (years)	20	20	20
Interest Rate (%/yr)	5.0%	5.0%	5.0%
Annualized Capital Payment ($/(MMBtu/yr))	$ 0.36	$ 0.21	$ 0.14

- To calculate administrative costs, program sponsors were assumed to offer incentives averaging 30% of total capital costs (all sectors). Administrative costs were set equal to 5% of incentive costs in each sector, based on the assumption that significant economies of scale in program administration could be captured in a program of the size envisioned in this option.
- Wholesale costs of biomass fuels rise from $2.96/GJ in 2015 to $6.73/GJ in 2030 (nominal dollars). Avoided costs of other fossil fuels were assumed equal to avoided wholesale costs for the various fuels, as estimated in the Common Assumptions used for all options, as were direct and, as applicable, “upstream” GHG emission factors for each fuel whose use is avoided (or, in the case of biomass, increased) by the measures in RCII-5.

Macroeconomic (Indirect) Economic Impacts of RCII Policies

Table below provides a summary of the expected impacts on jobs and economic growth during the CSEO planning period.

Table F-2.41 RCII-5 Macroeconomic Impacts on GSP, Employment and Income

Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
RCII-5	-$345	-$149	-$2,081	-1,680	-690	-9,610	-$154	-$58	-$809

Graphs below show detail in GSP, employment and personal income impact of the RCII-5 policy.

Figure F-2.31 RCII-5 GSP Impacts ($2015 MM)

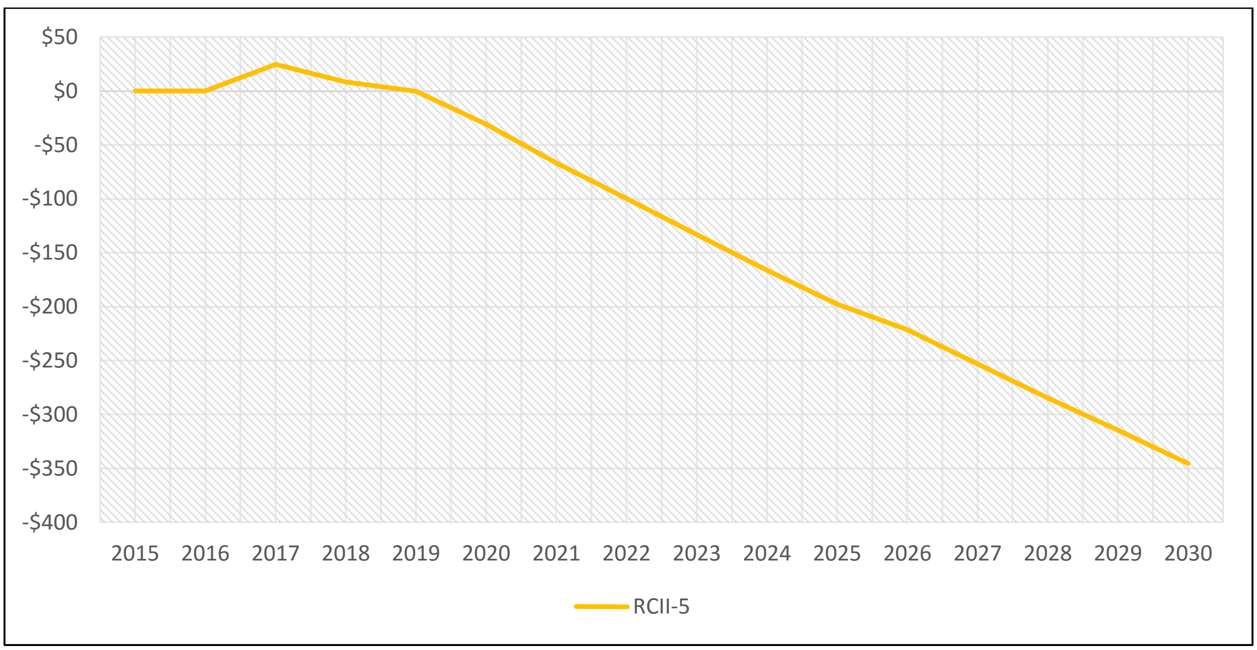


Figure F-2.32 RCII-5 Employment Impacts (Individual Jobs)

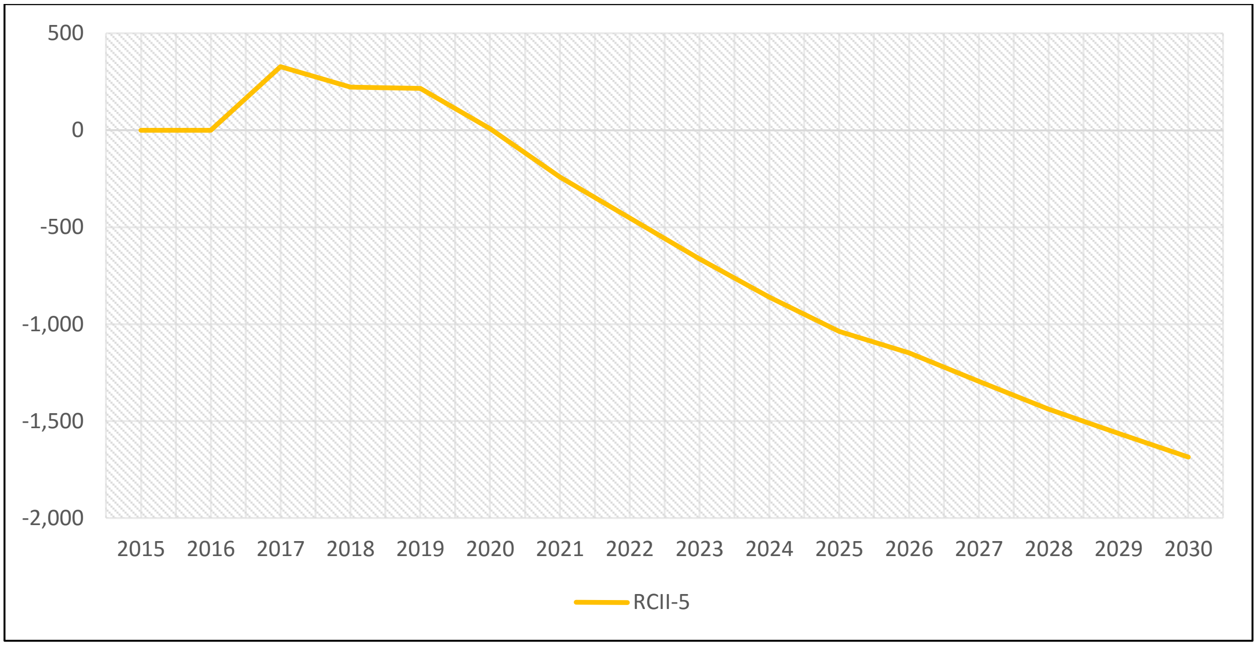
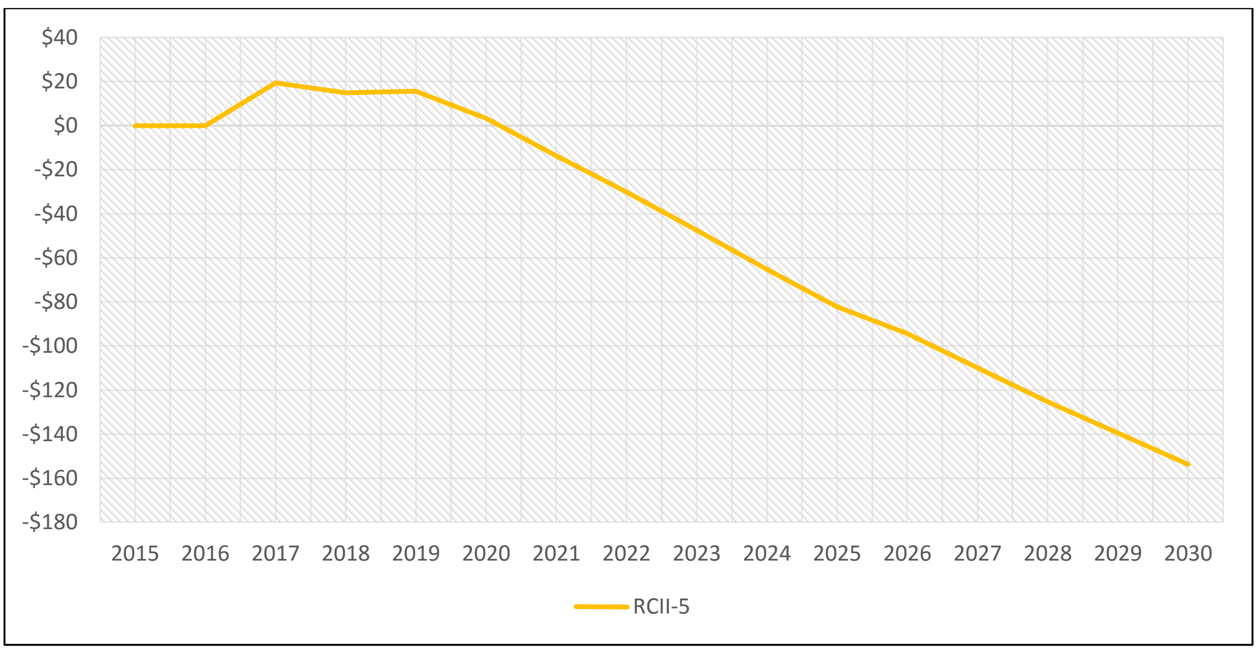
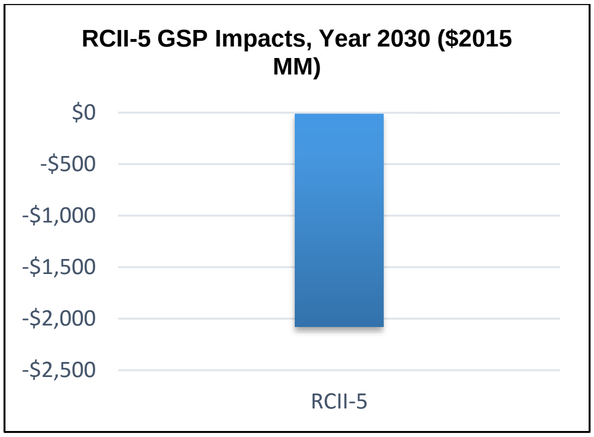
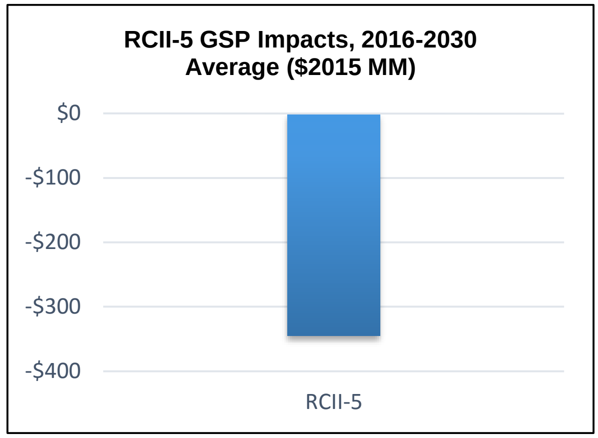


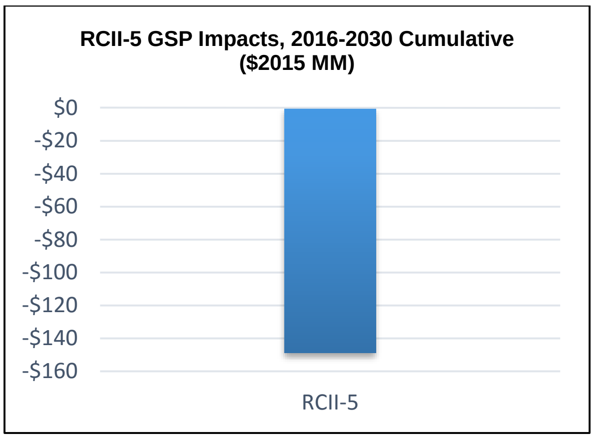
Figure F-2.33 RCII-5 Income Impacts ($2015 MM)

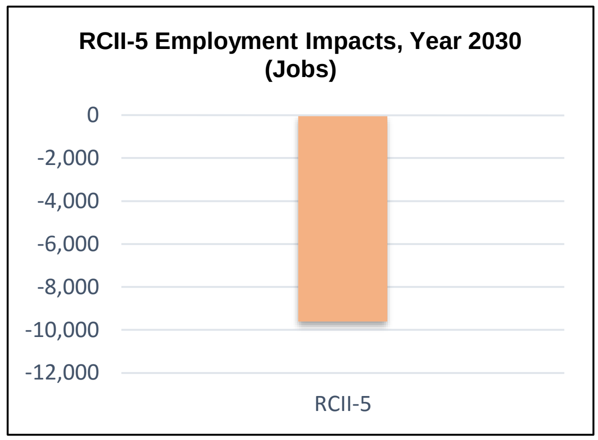


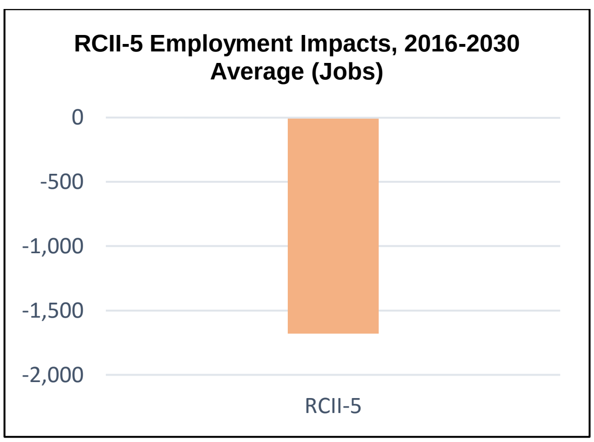
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030).

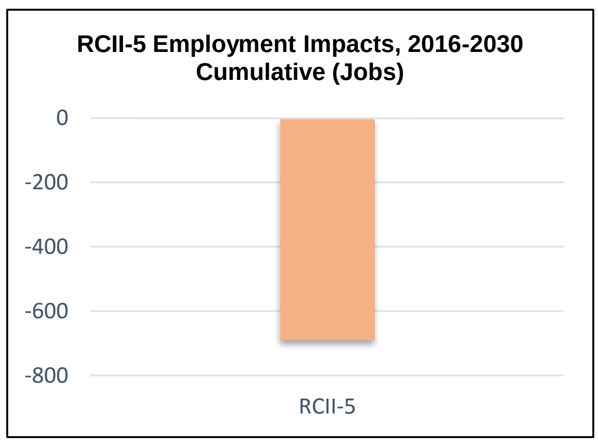

RCII-5 GSP Impacts, Year 2030 ($2015 MM)
$0
-$500
-$1,000
-$1,500
-$2,000
-$2,500
RCII-5

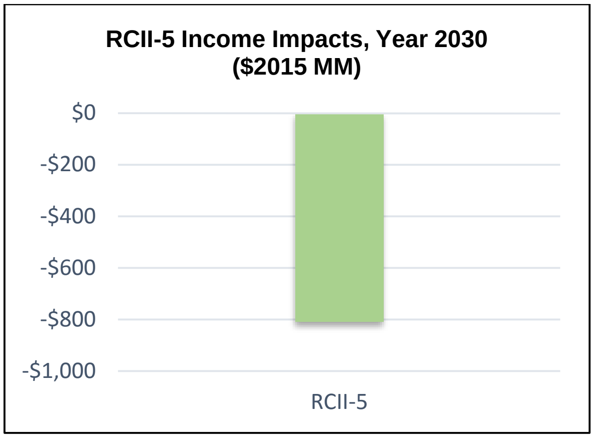

RCII-5 GSP Impacts, 2016-2030 Average ($2015 MM)
$0
-$100
-$200
-$300
-$400
RCII-5

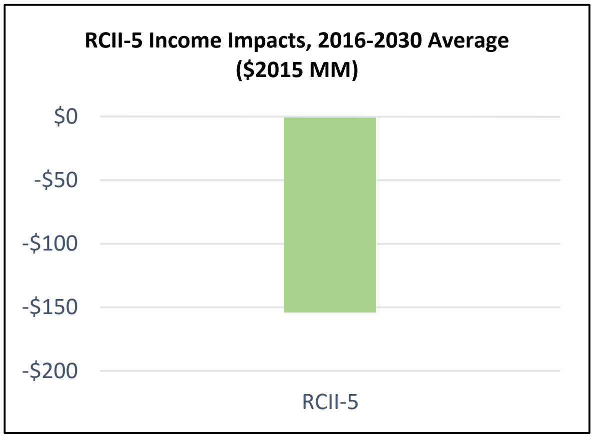

RCII-5 GSP Impacts, 2016-2030 Cumulative ($2015 MM)
$0
-$20
-$40
-$60
-$80
-$100
-$120
-$140
-$160
RCII-5

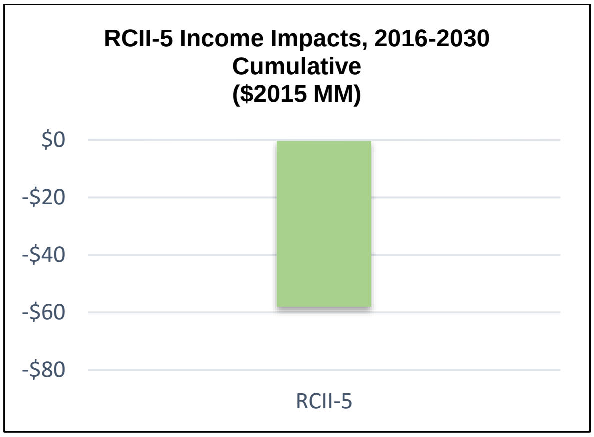

RCII-5 Employment Impacts, Year 2030 (Jobs)
0
-2,000
-4,000
-6,000
-8,000
-10,000
-12,000
RCII-5


RCII-5 Employment Impacts, 2016-2030 Average (Jobs)
0
-500
-1,000
-1,500
-2,000
RCII-5


RCII-5 Employment Impacts, 2016-2030 Cumulative (Jobs)
0
-200
-400
-600
-800
RCII-5







Principal Drivers of Macroeconomic Changes

RCII-5 ends up producing negative impacts statewide, in terms of all three major indicators. This is driven, fundamentally, by the fact that the costs borne to adopt the new energy source outweigh the savings and reductions in conventional fuel use that the policy produces.

Unlike many other of the RCII policies, this policy does not seek to create a large efficiency gain, but rather to switch from one set of energy sources to another. As a result, the expansion in available spending power for other productive sectors, as well as the lowered production costs with their inducement to economic growth and lower prices, are not generated by this policy. As a result, while the investment in renewable thermal technology does generate a spending stimulus and the operating and maintenance spending does boost direct hiring, the overall higher cost of operation under this policy pulls down total economic activity across all markers.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For RCII-5, the construction and biomass producing sectors see direct gains from the policy-driven investments. Households also hire more on a direct basis, as they adapt to the operation and maintenance of these new energy sources.

But the sectors that do so well as jobs and incomes rise (restaurants, retail, health care, etc.) all see losses as consumers and businesses have less in pocket with this policy than without.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the RCII-5 policy, important data included:

- The capital cost involved for buildings to adopt new heat energy sources (in this case, biomass). This involves an additional cost of operation but provides a stimulus in spending to the construction and machinery production sectors. For residential investments, the stimulus is to home improvement and construction.

- The cost to implement new practices and operating procedures around different equipment. These operating and maintenance costs also represent a cost to be borne by the commercial and residential sectors, but the additional labor engaged drives employment, direct incomes, and expands consumer spending – which is economically beneficial.
- The total volumes, and total spending on those volumes, of each type of energy consumed – in this case, all sources are reduced except the biomass which is replacing conventional fuels.
- The costs to state government agencies to oversee and implement this policy. This is split between labor to regulate and implement, and capital spending on upgrading its own facilities.
- All the capital costs, operating and maintenance costs, and energy spending figures were developed individually for the industrial, commercial, residential and utility sectors.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.

- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

There is uncertainty surrounding the percentages of various eligible renewable thermal technologies that would be implemented. For example, the share of solar thermal deployment versus biomass and the adoption rate within commercial versus industrial applications. The future cost of conventional fuels and biomass feedstocks is also uncertain.

To explore the GHG and net societal cost implications of targeting the residential sector portion of this option towards users of propane for heating and water heating, an alternative scenario was modeled in which the heating fuel displaced by renewable energy use in the residential sector was assumed to be 75% propane/LPG, reflecting the higher fuel costs paid by propane/LPG consumers. As a result of this change, the overall cumulative in-state (direct) GHG emission savings over the period 2015-2030 from the policy option increases very slightly, by about 0.5% relative to the base case, to 21.74 million $TgCO_2e$ (3.0 Tg in 2030), with a net cost of $804 million (about 8% less than in the base case—the result of more costly propane being displaced rather than natural gas), and with similarly-reduced cost per t CO_2e ($37.00), also about 8% less than for the overall base case. Focusing only on the residential sector, the impact of the alternative scenario is more striking, reducing net residential sector costs and costs per t CO_2e of GHG emissions reduction by about 60% (to $47 million and $33.39, respectively) relative to the base case. The results of this alternative scenario are shown in the table below. In addition to these in-state reductions, when evaluated with the assumption of targeted displacement of propane fuel as above, RCII-5 produces an estimated 1.21 $TgCO_2e$ of out-of-state (upstream) emissions reductions in 2030, and 8.82 $TgCO_2e$ in cumulative out-of-state reductions from 2015-2030, yielding total 2030 emissions reductions of 4.21 $TgCO_2e$ in 2030, and 30.56 $TgCO_2e$ over 2015-2030.

Table F-2.42 RCII-5 Alternative Scenario Results

	2030 GHG reductions ($TgCO_2e$):	**2015 - 2030 cumulative reductions ($TgCO_2e$):**	**Net present value of societal costs, 2015 - 2030 (million $2014):**	**Cost effectiveness ($2014/t CO_2e):**
Introduction of Thermal Renewables, Residential Sector	0.19	1.40	$46.84	$24.78
Introduction of Thermal Renewables, Commercial Sector	0.60	4.37	$250.35	$40.64
Introduction of Thermal Renewables, Industrial Sector	2.20	15.97	$507.21	$22.44
Total	3.00	21.74	$804.40	$26.24

Note: Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Additional Benefits and Costs

- Cost benefit study of renewable thermal policy option in Massachusetts showed between 2:1 and 3:1 benefits (mostly in fuel savings) + GHG emissions savings + higher tax revenue in state from sales + employment drivers for biomass fuel.

- Renewable thermal policies will provide new business opportunities to renewable fuel suppliers, developers and other energy service providers.
- A renewable thermal policy option will increase the local forestry market for biomass including the expansion of cord wood in Northwest Minnesota per DNR and can be achieved in a sustainable manner.
- A renewable thermal policy option will diversify resources and increase energy security resulting in less volatility in heating fuel availability.
- A renewable thermal policy option will mitigate fluctuations in the price of fossil fuels for heating by diversifying supply and reducing demand pressures.

Health Benefits: Establishment of a renewable fuel goal and incentive program may reduce emissions of air toxics and reduce associated health risks. Additionally, diversifying thermal energy may help to mitigate fuel price volatility. Volatility of fuel prices in recent years, especially in the Midwest and Northeast United States, has raised concerns that large numbers of people may be unable to access and pay for the cost of heating their homes in the winter. Mitigation of volatility in fuel pricing and availability throughout greater Minnesota will reduce risk among vulnerable communities in the future.

Figure F-2.33 Potential Health Benefits RCII-5

*Reducing energy-related emissions is likely to reduce the risk for respiratory and cardiovascular illness, and cancer in exposed populations.

Feasibility Issues

This policy option is framed as a goal with the analysis completed as though the goal will be achieved (as a standard would) according to the schedule included herein despite a lack of an existing enforcement mechanism within delivered fuels. However, the Renewable Thermal Incentive Program is the primary mechanism to advance the state's progress toward the goal and acts as the primary driver of voluntary renewable thermal deployment in practice.

The Renewable Thermal Incentive Program would be funded through a fee on each unit of thermal energy sold in the state, suggested at $.01 per therm for gas, propane, and fuel oil. For natural gas for thermal use, gas utilities will collect fees from customers to support the program. Since delivered fuel is currently taxed at the wholesale level by the Minnesota Department of Revenue, the Renewable Thermal Incentive Program will rely on assessments on wholesale transactions of propane and fuel oil [instead of retail sales.]

Eligible biomass technologies should be subject to best practices for reduction of particulate matter and other emissions. Best practice policy option may be more stringent than current EPA standards for biomass.

Northwest Minnesota has a plethora of excess biomass while in Northeast Minnesota (excepting the North Shore) there is competition for round wood. There will be wider inter-agency support for a policy option sensitive to the regional biomass market availability within the state (DNR, DEED).

Chapter XIV. Appendix F-3. Transportation and Land Use Policy Recommendations

Overview

This appendix provides greater detail regarding the policy analysis in the Transportation and Land Use area.

Direct, Stand Alone Economic Impacts

The stand-alone results provide the annual GHG reductions for 2020 and 2030 in teragrams (Tg) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030 (1 Tg is equal to 1 million metric tons). The reductions shown are just those that have been estimated to occur within the state. Additional GHG reductions, typically those associated with upstream emissions in the supply of fuels or materials, have also been estimated and are reported within each of the analyses in each POD.

Also reported in the stand-alone results is the net present value (NPV) of societal costs/savings for each policy option. These are the net costs of implementing each policy option reported in 2014 dollars. The cost effectiveness (CE) estimated for each policy option is also provided. Cost effectiveness is a common metric that denotes the cost/savings for reducing each metric ton (t) of emissions. Note that the CE estimates use the total emission reductions for the policy option (i.e. those occurring both within and outside of the state).

Results for individual parts of TLU-2 (PAYD insurance, carbon tax, and fuel tax) and TLU-3 (reduced home energy needs, reduced vehicle miles traveled [VMT]) are described within the POD for each policy option.

Integrative Adjustments & Overlaps

This appendix also provides the same values described above after an assessment was made of any policy option interactions or overlaps. The TLU-1, -2, and -3 policies all rely on a reduction of VMT. TLU-2 and TLU-3 were considered together, as described in the PODs for these policies; therefore the estimates already account for any overlap. TLU-1 was adjusted based on the reduction in VMT from TLU-2 and TLU-3. TLU-4 was considered last, with benefits adjusted downward to account for the savings in TLU-1, TLU-2 and TLU-3.

Macroeconomic (Indirect) Economic Impacts

Tables below provide a summary of the expected impacts of TLU policies on jobs and economic growth during the CSEO planning period. These focus on the impact of policies on Gross State Product (the total amount spent on goods and services produced within the state), Employment (the total number of full-time and part-time positions), and Incomes (the total amount earned by households from all possible sources). These metrics represent three valuable indicators of both the overall size of the economy and that economy's structural orientation toward supporting livelihoods and utilizing productive work.

For the purposes of macro-economic analysis of CSEO policies, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software. This particular REMI model is developed specifically for Minnesota, and is developed consistently with the design of models in use by state agency staff within Minnesota for a range of economic analyses. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

The main inputs for macro-economic analysis are microeconomic estimates of direct costs and savings expected from the implementation of individual policy options. These inputs are supplemented with additional data and assumptions necessary to complete the picture of how these costs and savings (as well as price changes, demand and supply changes, and other factors) influence Minnesota's economy. These additional data and assumptions typically regard how various actors around the state (households, businesses and governments) respond to change by changing their own economic activity. A full articulation of the general and policy-specific assumptions made by the macroeconomic analysis team is provided in the Policy Option Documents, contained as appendices to this report.

Table Ap F-3.1 Transportation & Land Use Policy Options, Direct Stand-Alone Impacts

Stand-Alone Analysis							
Policy Option ID	**Policy Option Title**	**GHG Reductions**				**Costs**	
		Annual CO_2e Reductions[a]		**2030 Cumulative[a]**	**2030 Cumulative[b]**	**Net Costs[c] 2015-2030**	**Cost Effectiveness[d]**
		2020 Tg	**2030 Tg**	**$TgCO_2e$**	**$TgCO_2e$**	**$Million**	**$/$tCO_2e$**
TLU-1	Transportation Pricing - Total	1.50	2.03	22	28	$2,718	$96
	- PAYD Insurance Component	0.46	1.0	8.8	11	($2,160)	($189)
	- Carbon Tax Component	0.58	0.57	7.1	9.2	$1,898	$205
	- Fuel Tax Component	0.45	0.42	5.8	7.6	$2,980	$394
TLU-2	Improve Land Development and Urban Form - Total	0.31	0.82	6.96	8.17	($425)	($52)
	- Reduced Home Energy Needs Component	0.31	0.82	6.9	8.1	($351)	($43)
	- Reduced VMT Component	0.0027	0.0080	0.064	0.064	($74)	($1,155)
TLU-3	Metropolitan Council Draft 2040 Plan	0.083	0.25	2.0	2.6	($330)	($126)
TLU-4	Zero Emission Vehicle Standard (100%) renewable electricity	0.09	1.25	6.4	7.9	$3,278	$417
TLU-4	*Zero Emission Vehicle Standard (0%) renewable electricity[e]*	*(0.02)*	*(0.42)*	*(2.1)*	*(1.1)*	*$3,237*	*N/A*
Totals		**2.0**	**4.4**	**37**	**47**	**$5,241**	$112

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).

[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] TLU-4 0% renewable electricity is a sensitivity scenario not included in "**Totals**" row calculation. This sensitivity scenario increases net GHG emissions above the baseline, thus **cost effectiveness** calculation is not applicable.

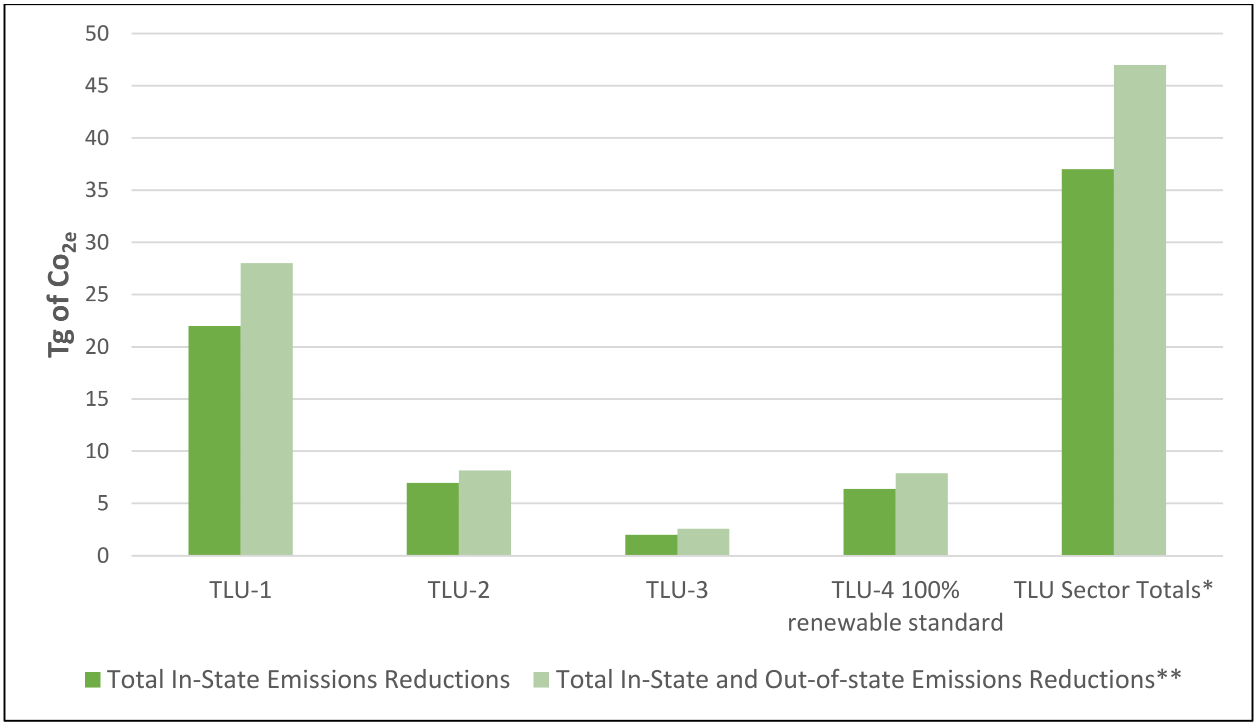
Table Ap F-3.2 Transportation and Land Use Policy Options, Intra-Sector Interactions & Overlaps

Intra-Sector Interactions & Overlaps Adjustments							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual CO_2e Reductions[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/$tCO_2e$
TLU-1	Transportation Pricing - Total	1.5	2.0	21	28	$2,718	$97.30
	- PAYD Insurance	0.46	1.02	8.67	11.30	($2,160)	($191)
	- Carbon Tax	0.58	0.56	7.01	9.14	$1,898	$208
	- Fuel Tax	0.45	0.41	5.75	7.49	$2,980	$398
TLU-2	Improve Land Development and Urban Form - Total	0.31	0.82	6.96	8.2	($425)	($52)
	- Reduced Home Energy Needs Component	0.31	0.82	6.9	8.11	(351)	($43)
	- Reduced VMT Component	0.0027	0.0080	0.064	0.064	(74)	($1,155)
TLU-3	Metropolitan Council Draft 2040 Plan	0.083	0.25	2.00	2.61	($330)	($126)
TLU-4	Zero Emission Vehicle Standard (100%) renewable electricity	0.08	1.05	5.5	6.8	$3,278	$484
TLU-4	*Zero Emission Vehicle Standard (0%) renewable electricity*[e]	*(0.02)*	*(0.35)*	*(1.8)*	*(1.0)*	*$3,237*	*N/A*
	Total After Intra-Sector Interactions /Overlap	**2.0**	**4.1**	**36**	**45**	**$5,241**	$115

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] TLU-4 0% renewable electricity is a sensitivity scenario not included in "**Totals**" row calculation. This sensitivity scenario increases net GHG emissions above the baseline, thus **cost effectiveness** calculation is not applicable.
Note: Intra-Sector overlap was estimated for all TLU options. TLU-1, 2 and 3 are all options that rely on reducing VMT. The Overlaps analysis looks at TLU-2 and 3 first. These were considered together, because the SmartGAP run indicated that the impacts of these policies are additive. Therefore, no adjustments were made to TLU-2 or TLU-3. TLU-1 is adjusted based on the reduction in VMT from TLU-2 and TLU-3. The benefits of TLU-4 were then adjusted downward to account for the expected VMT reductions from BAU due to implementation of TLU-1, 2 and 3.

There is also an inter-sector overlap of results between the TLU policies and the "Biofuels Package" (Policies A-4 and A-5). Those policies will introduce additional advanced biofuels into the Minnesota market which will reduce the overall GHG reduction potential of each TLU policy. The adjustments for that interaction are addressed in the Inter-Sector Integration results.

Figure Ap F-3.1 TLU Policies GHG Emissions Abatement, 2016-2030



Notes:
* All Policies Total's comprise emissions reductions achieved by TLU policies combined.
** Total in and out-of-state emissions reduction are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Table Ap F-3.3 Macroeconomic (Indirect) Impacts of TLU Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	Gross State Product GSP ($2015 Millions)			Employment (Full and Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030[d]	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
TLU-1	$711	$688	$10,319	8,140	8,230	123,400	$781	$659	$9,885
TLU-2	$4	-$2	-$31	500	220	3,290	$29	$10	$151
TLU-3 Low Transit Cost	$90	$41	$608	830	450	6,740	$43	$20	$302
TLU-3 High Transit Cost	$125	$165	$2,477	1,330	1,720	25,860	$78	$138	$2,068
TLU-4 Falling EV Price	$140	-$65	-$969	-810	-1,220	-18,300	-$56	-$108	-$1,622
TLU-4 High EV Price	-$711	-$354	-$5,315	-7,910	-3,750	-56,240	-$862	-$370	-$5,551
TLU Sector–Low Transit Cost	**$95**	**$372**	**$5,586**	**1,580**	**4,560**	**68,360**	**-$7**	**$319**	**$4,792**
TLU Sector–High Transit Cost	**$130**	**$497**	**$7,452**	**2,080**	**6,420**	**96,350**	**$27**	**$437**	**$6,555**
TLU Sector–Falling EV Price	**$946**	**$620**	**$9,293**	**8,670**	**7,680**	**115,170**	**$798**	**$581**	**$8,722**
TLU Sector–High Transit Cost & Low EV Price	**$981**	**$787**	**$11,799**	**9,170**	**8,950**	**134,270**	**$833**	**$699**	**$10,485**

As the table above shows, the macroeconomic impacts analysis of this sector comprises 5 scenarios including the sector wide analysis:

- TLU-1
- TLU-2
- TLU-3 Low Transit $: TLU-3 default scenario
- TLU-3 High Transit $: TLU-3 sensitivity scenario with high transit capital cost
- TLU-4 High EV $: TLU-4 default scenario
- TLU-4 Low EV $: TLU-4 sensitivity scenario with falling price of EV

- TLU Sector Total Low Transit $: TLU sector-wide default scenario
- TLU Sector Total High Transit $: TLU sector-wide with high transit capital cost scenario
- TLU Sector Total Low EV $: TLU sector-wide with falling price of EV scenario

TLU Sector Total Both Sensitivities: TLU sector-wide with both high transit capital cost and falling price of EV scenarios

The TLU sector has four policies. Two of them (TLU-1 and TLU-4) deal directly with the kinds of vehicles people drive and the incentives they face to drive less. Two deal with urban form and transit access (TLU-2 and TLU-3).

The vehicles policies generate large impacts on the Minnesota economy, with TLU-1 (focusing on fuel taxes, carbon taxes and pay-as-you-go insurance) producing very significant positive gains, and TLU-4 (focusing on driving adoption of electric vehicles) being weighed down in early years by electric vehicle prices. Once the vehicle prices recede (particularly after 2025), the policy trends upward and is positive in its impacts.

The urban form and transit policies, by comparison, produce relatively small impacts, outside of a short positive spike in construction spending driven by the investment by state and federal entities in new transit infrastructure.

Overall, the sector does very well as a result of TLU-1, 2 and 3, and as electric vehicle prices in TLU-4 fall gradually to parity with other vehicles (a point they reach in 2030, in this forecast), the sector's impacts trend positive again and appear to indicate further growth past 2030.

Line graphs and bar charts that follow illustrate the above explained broader economic impacts of the TLU policies.

Figure AP F-3.2 – Average Annual Jobs Impact of TLU Policies, Individually and in Concert

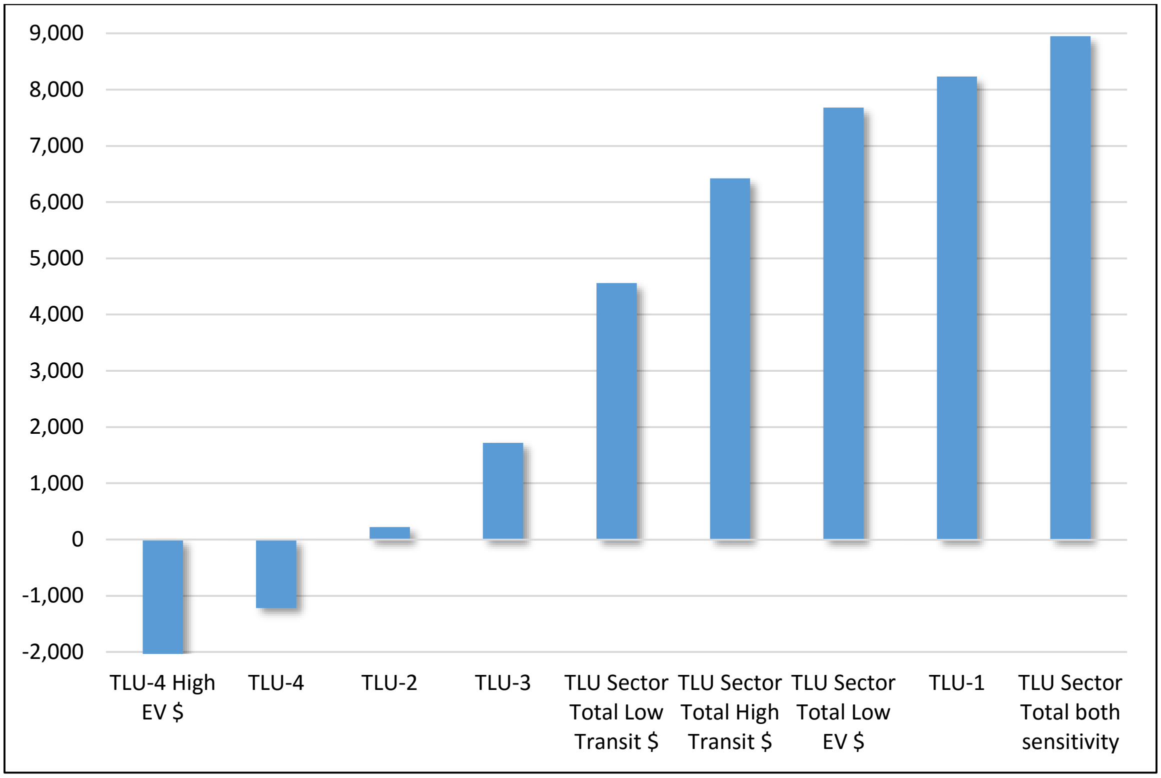
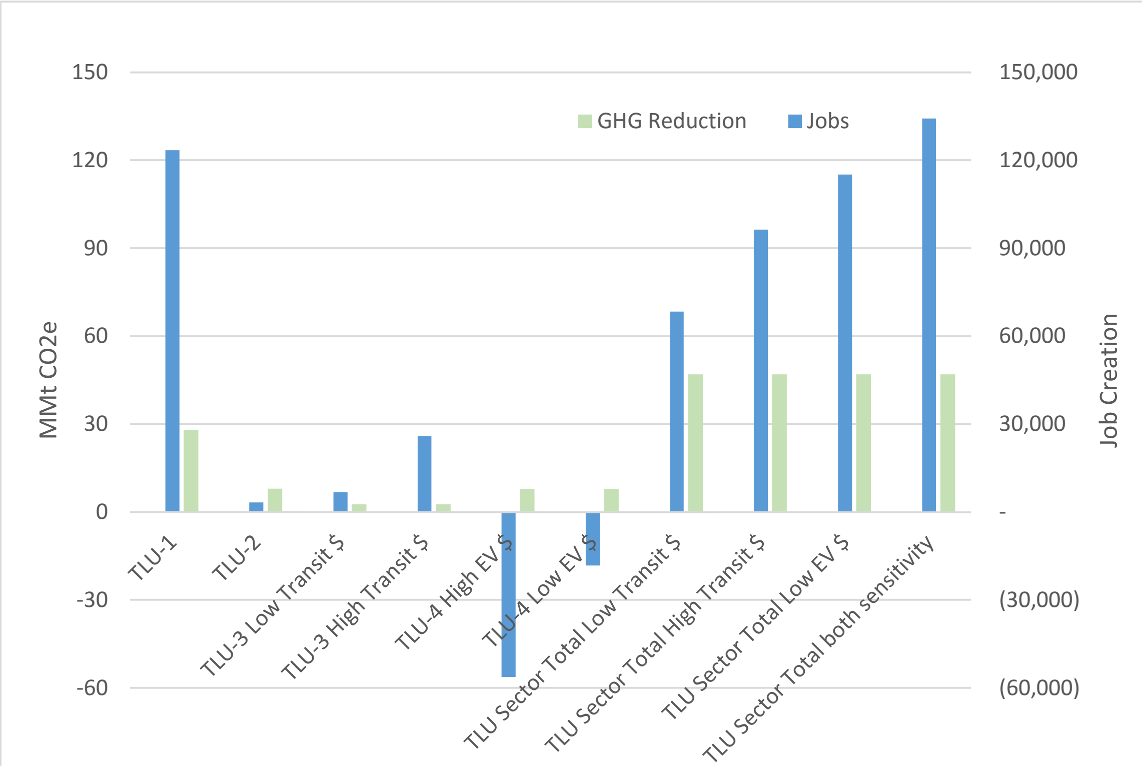


Figure F-3.3 below summarizes a potential for job creation and GHG emissions abatement of TLU sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure AP F-3.3 – Cumulative Jobs and Emissions Impacts of TLU Policies



Sector Level Index

The graphs below express the overall economic impact from each scenario in a single score, and compares those scores. CCS created this single score (a Macroeconomic Impact Index) in order to encapsulate in one measurement the relative macroeconomic impacts (including jobs, GSP and incomes) of each policy. We have found in our own work and in the literature that indexed scores can be helpful to many readers when comparing options with multiple characteristics.

To produce this score, CCS set the results from the absolute best-case scenario (i.e. the implementation of all CSEO policies with all their optimal sensitivities in place) equal to 100, with that scenario's jobs, GSP and incomes impacts weighted equally at one third of the total score. Each policy's jobs, GSP and income impacts are scaled against that measure, and given a total score. The overall score indicates how significant a policy's impact is projected to be. Negative impacts are scaled the same way, except that those impacts are given negative scores and pull down the total score of the policy.

These scores are calculated separately for the final year of the study (2030), the *average* impact over the 2016-2030 period, and the *cumulative* impact of the policies over that period. While each scenario has one line, the relative importance of jobs, income and GSP remain visible as differently-shaded segments of that line.

Figure Ap F-3.4: TLU Macroeconomic Impacts, 2030

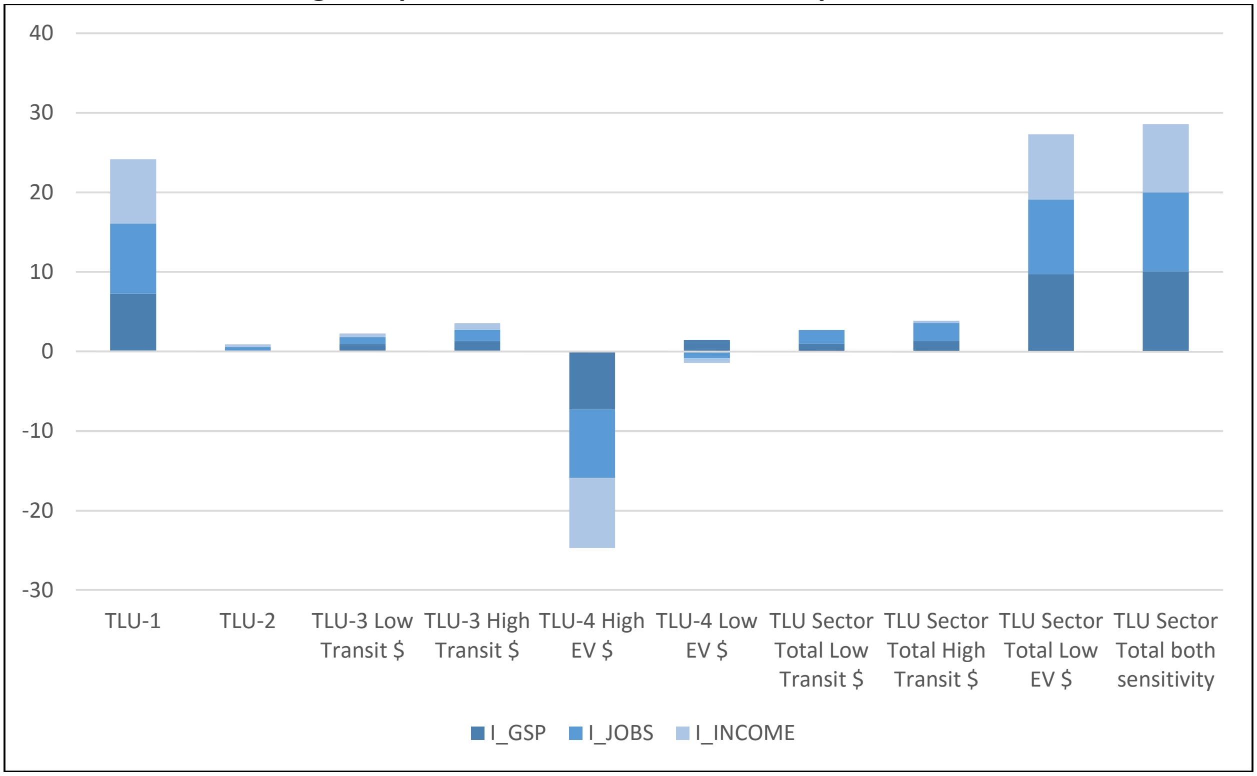


Figure Ap F-3.5: TLU Macroeconomic Impacts, 2016-2030 Yearly Average

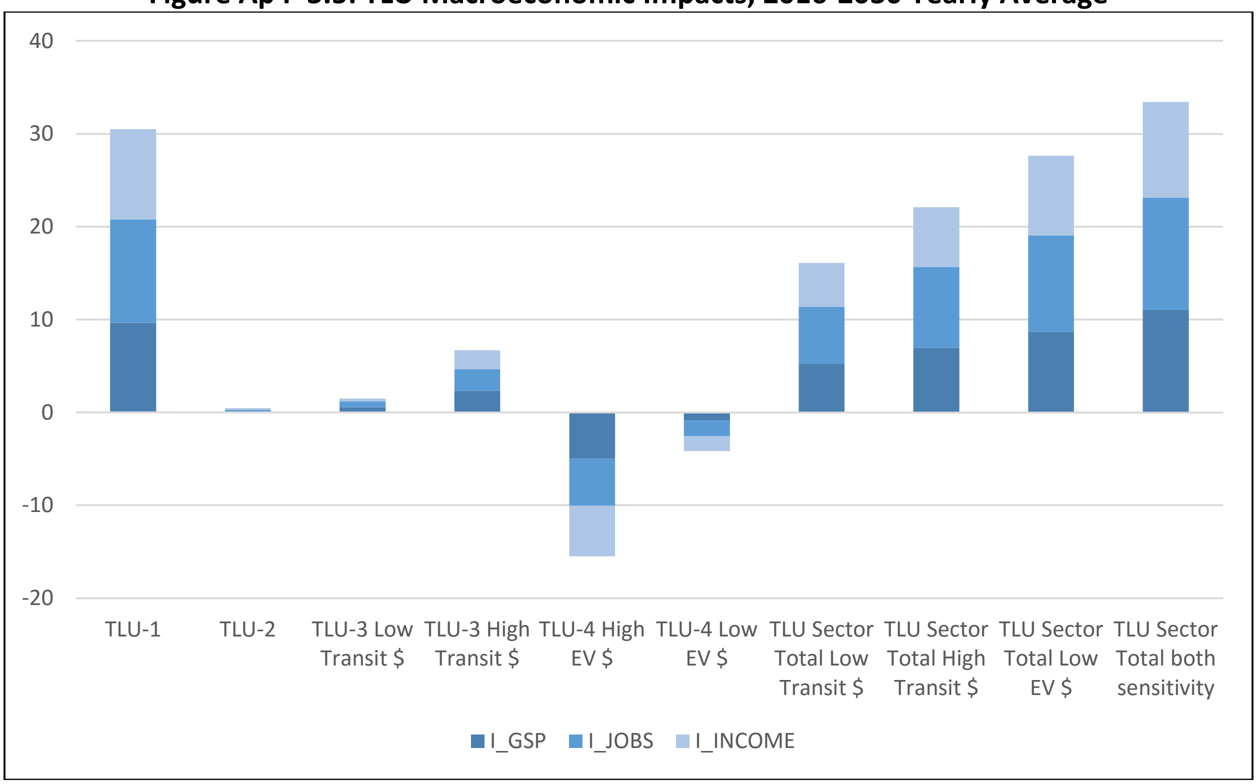
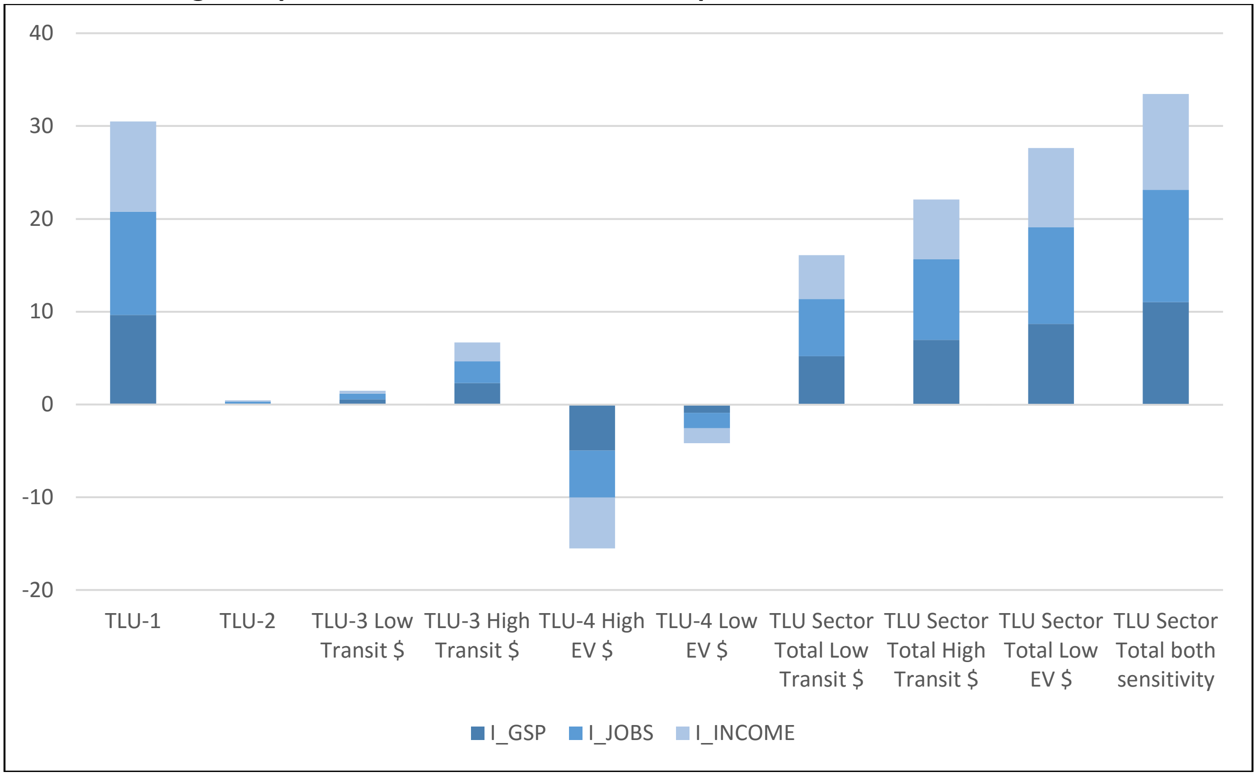


Figure Ap F-3.6: TLU Macroeconomic Impacts, 2016-2030, Cumulative



Graphs below show the trend of TLU policy macroeconomic impacts during the year 2015 to the year 2030.

Figure Ap F-3.7: TLU GSP Impacts (2015 $MM)

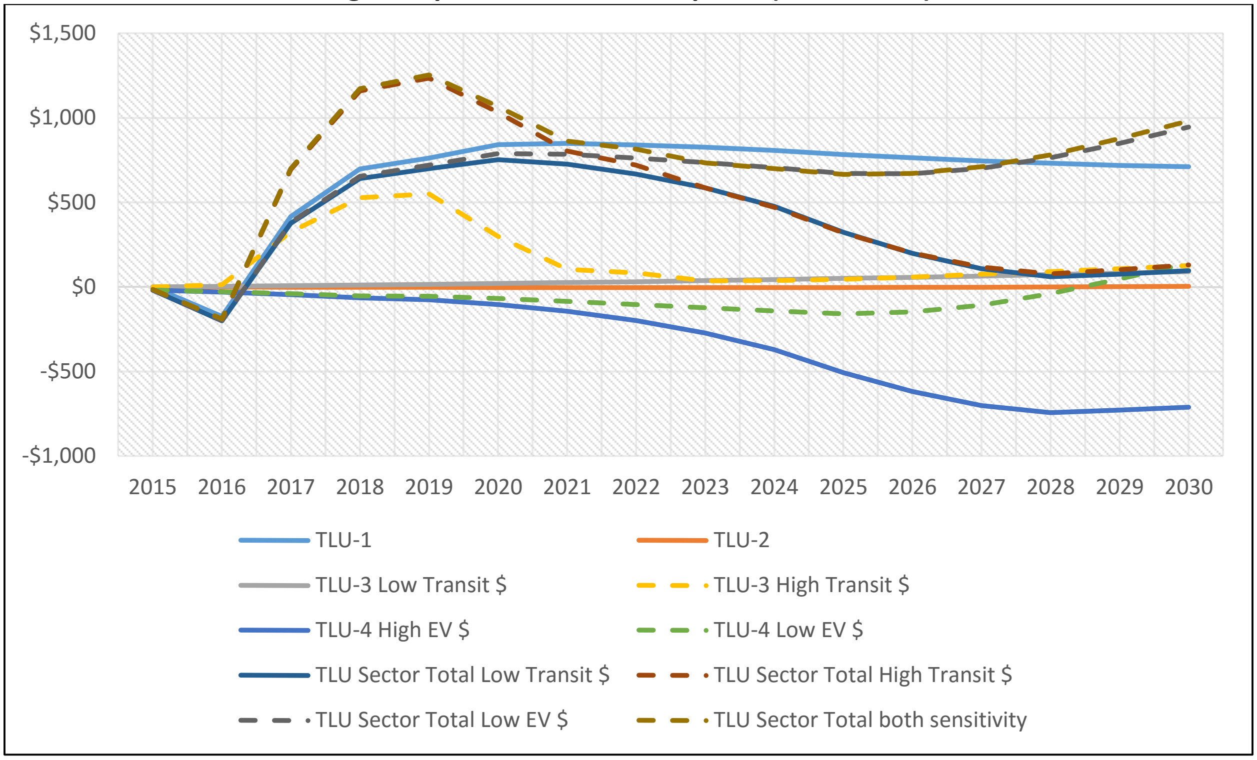


Figure Ap F-3.8: TLU Income Impacts (2015 $MM)

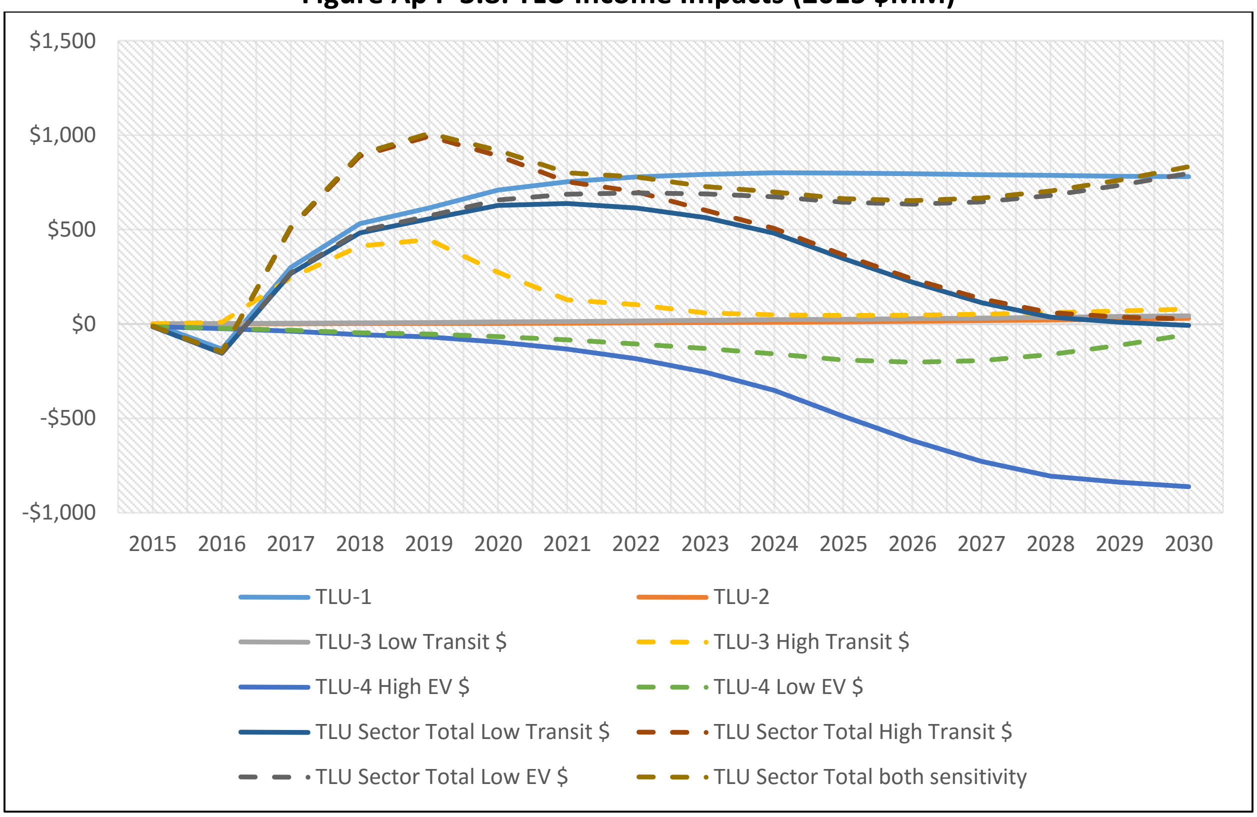
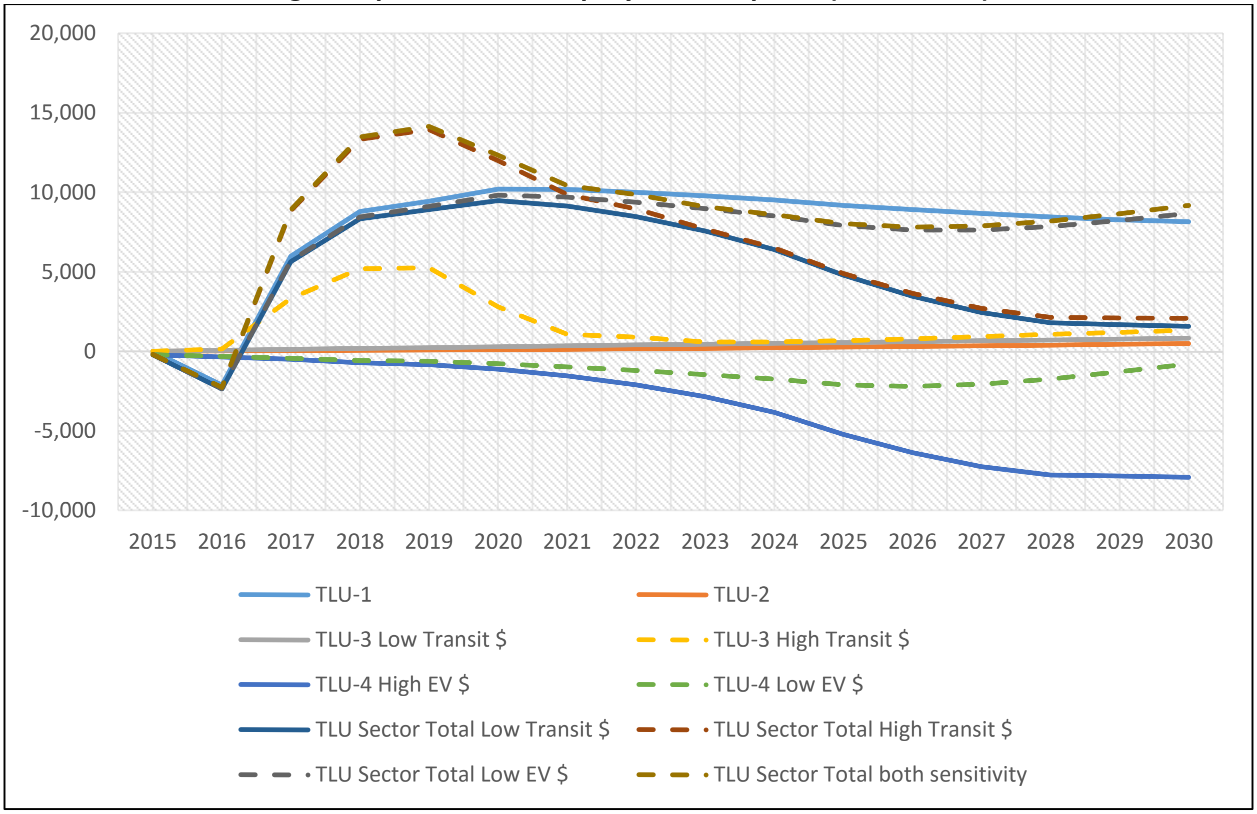


Figure Ap F-3.9: TLU Employment Impacts (2015 $MM)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030). Light color means sensitivity scenarios.

Figure Ap F-3.10: TLU GSP Impacts, 2016-2030 Average (2015 $MM)

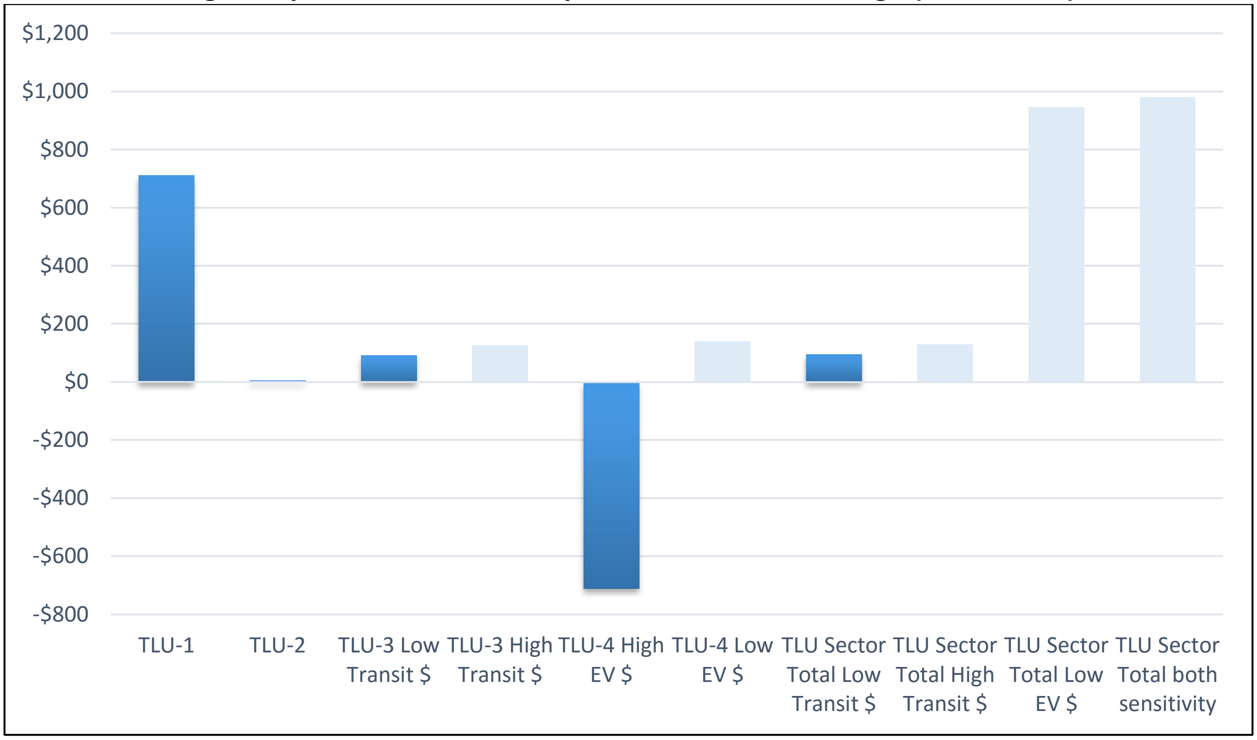


Figure Ap F-3.11: TLU GSP Impacts, 2016-2030 Cumulative (2015 $MM)

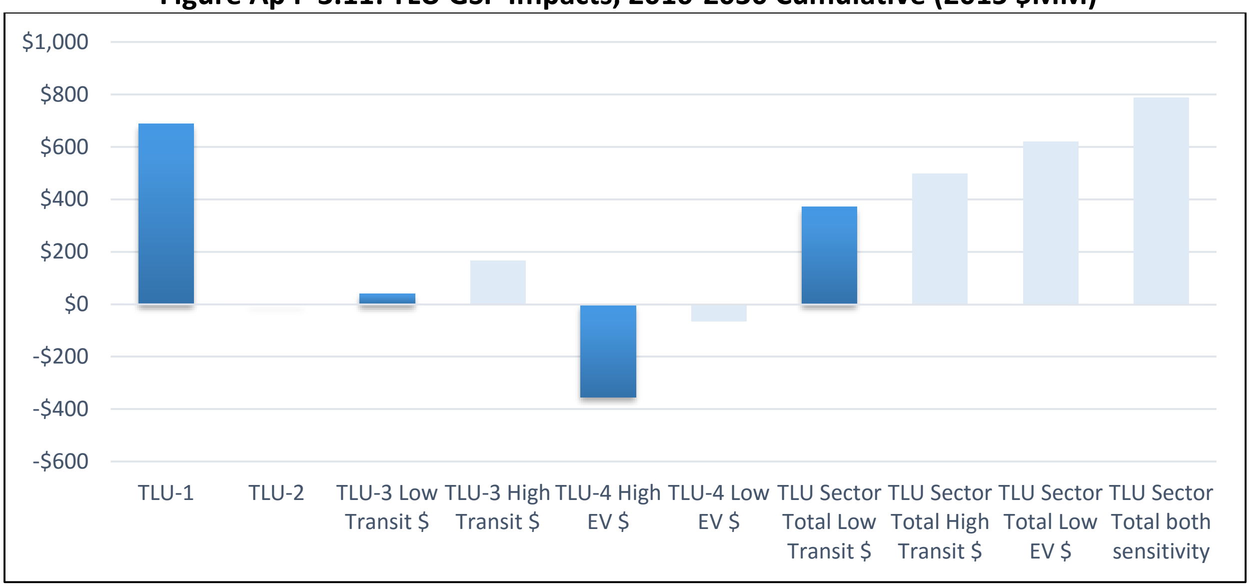


Figure Ap F-3.12: TLU GSP Impacts, Year 2030 (2015 $MM)

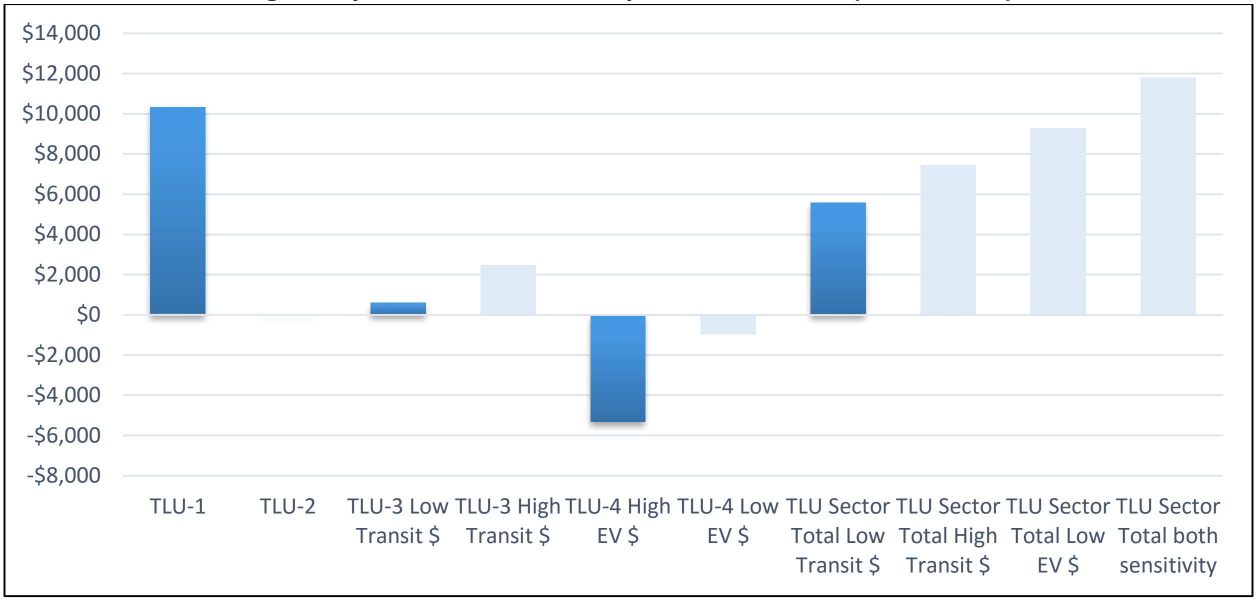


Figure Ap F-3.13: TLU Employment Impacts, 2016-2030 Average (Jobs)

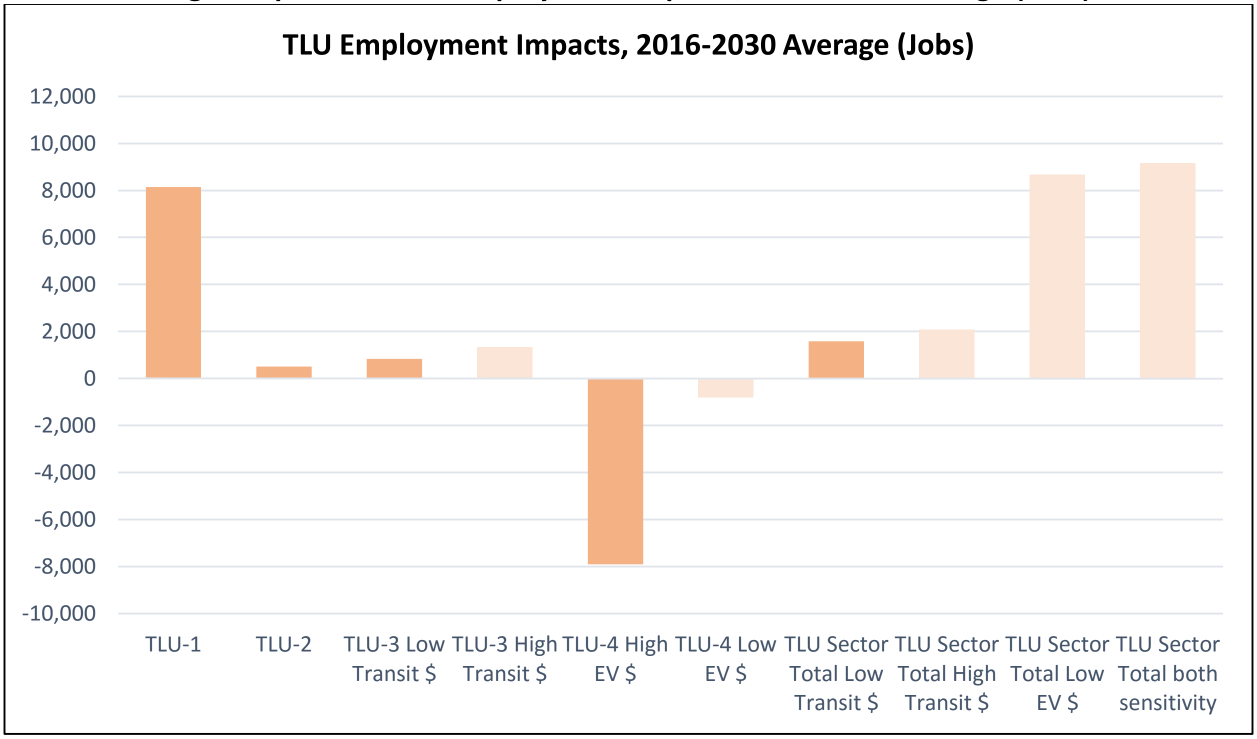


Figure Ap F-3.14: TLU Employment Impacts, 2016-2030 Cumulative (Jobs)

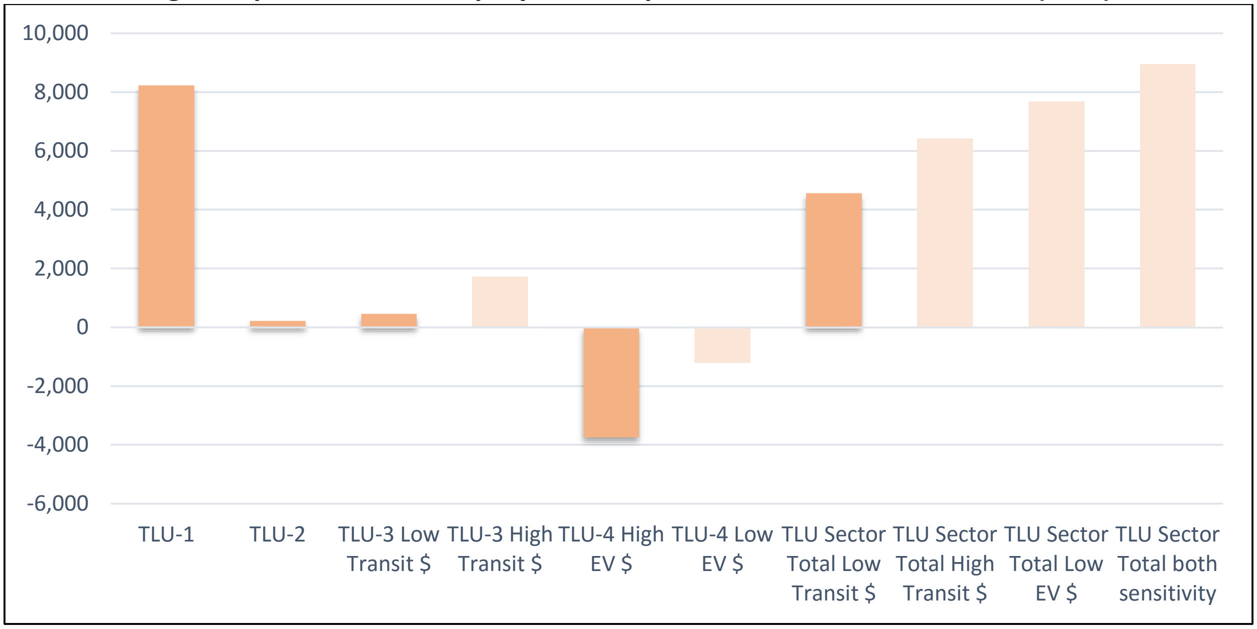


Figure Ap F-3.15: TLU Employment Impacts, Year 2030 (Jobs)

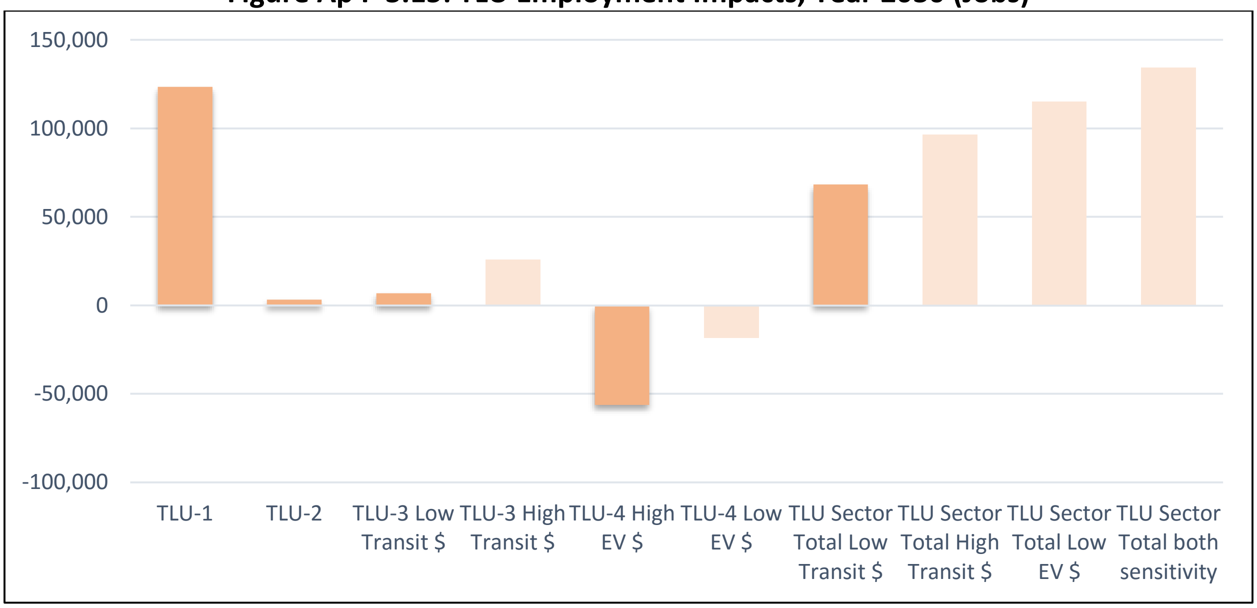


Figure Ap F-3.16: TLU Income Impacts, 2016-2030 Average (2015 $MM)

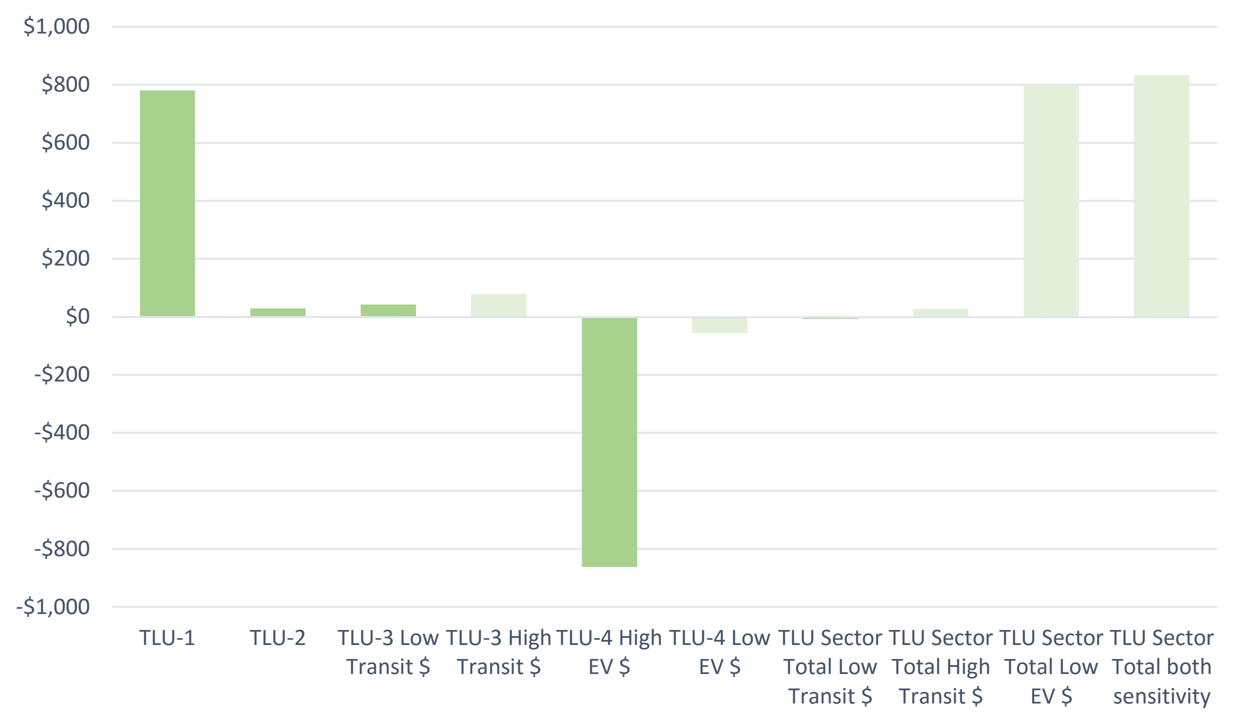


Figure Ap F-3.17: TLU Income Impacts, 2016-2030 Cumulative (2015 $MM)

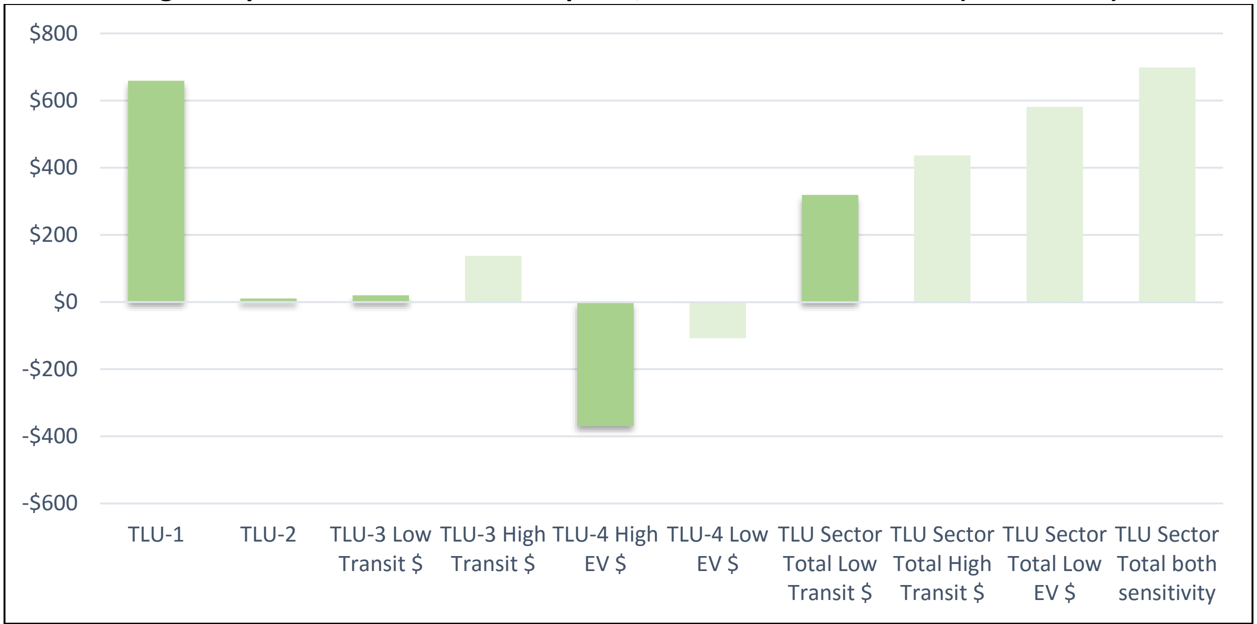
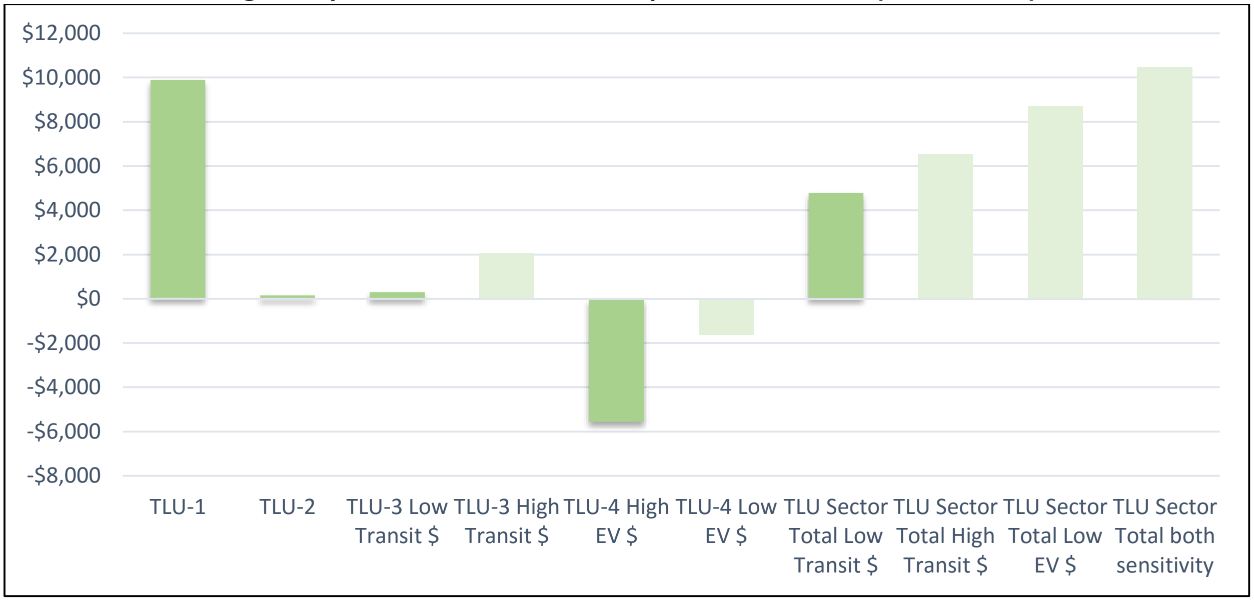


Figure Ap F-3.18: TLU Income Impacts, Year 2030 (2015 $MM)



TLU-1. Transportation Pricing

Policy Option Description

Transportation pricing can reduce greenhouse gas emissions by increasing the marginal and/or total cost of driving and thereby encourage behavior changes that reduce the total vehicle trips or encouraging the purchase of more fuel-efficient vehicles. This policy option is really three policies that can be independently implemented or combined.

The first two policies are specifically designed to reduce greenhouse gas emissions:

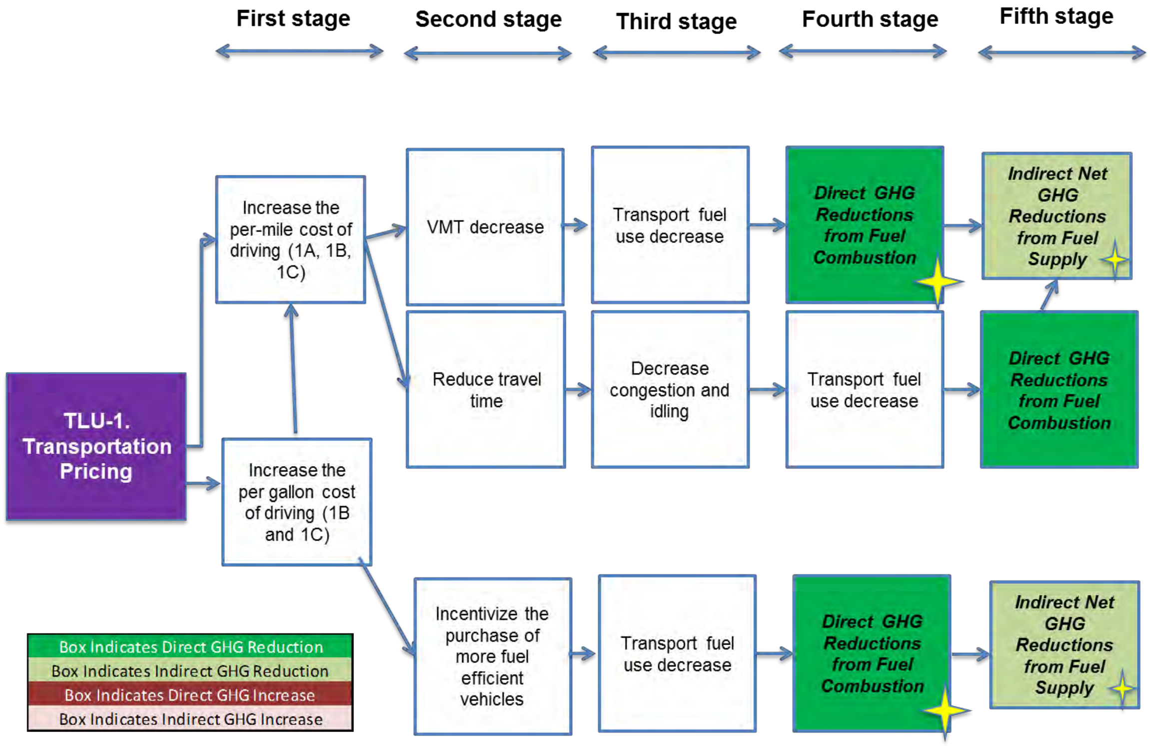
- TLU-1A: Provide incentives for automotive insurance companies to institute pay as you go insurance pricing.
- TLU-1B: Carbon tax on transportation fuels with rebates to low income households and to address other needs.

The third strategy is designed to provide more reliable funding for roads and bridges in Minnesota. It is included as part of this analysis to assess its potential to reduce greenhouse gas emissions.

- TLU-1C: Enact a 6.5% statewide wholesale fuel sales tax on gross gasoline and special fuel (including diesel) purchases.

Causal Chain for Greenhouse Gas Reductions

Figure Ap F-19. Causal Chain for TLU-1 GHG Reductions



Policy Option Design

Goals:

- TLU-1A: Achieve 30%, 50% and 80% market penetration of pay-as-you-drive insurance policies by 2020, 2025, 2030, starting in 2017.
- TLU-1B: Cost of operating a motored vehicle in Minnesota includes the social cost of greenhouse gas emissions (using US government data) starting in 2017 and in effect through 2030.
- TLU-1C: Generate sufficient revenue to achieve Minnesota Department of Transportation's (MnDOT) performance targets for pavement condition and bridge condition as well as have funding to complete the envisioned MnPASS system and complete several major highway capacity expansions throughout the state by 2030. Provide a revenue source less vulnerable to inflation.

Timing:

- TLU-1A: Assume some action by the Legislature in 2015 to encourage or otherwise incentivize greater market penetration of PAYD insurance policies

- TLU-1B: Passage of a carbon tax as part of a comprehensive transportation funding bill in 2015. Assume phase in over three years and then annual rate adjustments for inflation. Use of funds could begin in 2017.
- TLU-1C: The new wholesale fuel sales tax would be 6.5%, with no phase-in period. Up to a year of lead time should be expected following passage of the tax to institute collection procedures before the start of revenue generation (and fuel price effects).

Parties Involved:

Legislature, Department of Revenue, state licensed distributors of petroleum products, special fuel dealers, and bulk purchasers of fuel, Minnesota Management and Budget, and the Minnesota Department of Transportation, insurance companies, state Insurance Commission, Department of Commerce, and all vehicle owners.

Implementation Mechanisms

TLU-1A: PAYD Insurance

This policy option was analyzed in the Minnesota Climate Change Advisory Group work in 2008. From MCCAG: The state would encourage and support the provision of PAYD auto insurance, possibly including state support for additional pilot programs. This would also require the state Insurance Commission to conduct an active review of possibilities.

TLU-1B: Carbon Tax

Impose carbon tax on fuel approximately $0.24 per gallon for gasoline and diesel assuming E10 and B20 and $30 per ton social cost of Carbon. The carbon tax would be collected at the same time as the motor fuel excise tax from the state’s licensed distributors of petroleum products, special fuel dealers, and bulk purchasers—fewer than 600 in number. Cost would be passed on to consumers.

Use of funds would be split between maintaining/adapting highway infrastructure to climate change, rebating to low-income households to address equity concerns (estimated to be 30% of revenue raised), and funding other climate change mitigation strategies.

To ensure the tax appropriately levies the current social cost of carbon, a preferred mechanism would be to index the rate to inflation. However, an alternative could be a periodic commission review (every other year or every third year) of the current research and review of existing carbon markets for price signals. A third alternative would be to benchmark against some other national source and update annually.

TLU-1C: Wholesale Fuel Sales Tax

For state fiscal years 2010-2015, the national ratio of retail to wholesale gasoline prices averages 1.27 (in a narrow range of 1.25 to 1.31), according to Energy Information

Administration data and projections. Retail (as posted at the pump) and wholesale (“rack”) fuel prices will intuitively be highly correlated, and lagged wholesale prices have been shown historically to predict retail prices at the national level. For this reason, a driver demand elasticity analysis that assumes complete pass-through to the retail setting in the amount of the wholesale tax may be appropriate. To summarize, it is likely that the full cost of such a tax would be passed onto consumers.

The state’s licensed distributors of petroleum products, special fuel dealers, and bulk purchasers, who are already the remitting entities for prevailing excise taxes levied on a volumetric basis, would also be the collection points for the new price-sensitive wholesale tax. Demonstrating the precedent for a variable-rate fuel tax, the Institute on Taxation and Economic Policy calculates that a majority (55%) of Americans now live in a state with such a tax provision, a claim reinforcing the measure’s feasibility.

Revenue would be deposited into the Highway User Tax Distribution Fund and then constitutionally distributed to state, county, and municipal road jurisdictions for capital, operations, and maintenance expenditures.

Related Policies/Programs in Place and Recent Actions

GMAC and On Star Low-Mileage Discount Rates

(From original MCCAG appendix regarding TLU-1A)

Since mid-2004, the General Motors Acceptance Corporation Insurance has offered mileage-based discounts to OnStar[1] subscribers located in certain states. The system automatically reports vehicle odometer readings at the beginning and end of the policy term to verify vehicle mileage.

Motorist who drive less than the specified annual mileage receive insurance premium discounts of up to 40%:

- 1–2,500 miles: 40% discount
- 2,501–5,000 miles: 33% discount
- 5,001–7,500 miles: 28% discount
- 7,501–10,000 miles: 20% discount
- 10,001–12,500 miles: 11% discount
- 12,501–15,000 miles: 5% discount
- 15,001–99,999 miles: 0% discount

[1] http://www.onstar.com/us_english/jsp/low_mileage_discount.jsp.

The Federal Highway Administration's Value Pricing Pilot Program is now providing funding for PAYD insurance simulation projects in Georgia and Massachusetts.[2]

Distance-Based Program - Progressive Insurance offers distance-based insurance in Oregon, Michigan, and Minnesota. The program uses Global Positioning System technology to track vehicle location and use.

TripSense(SM) - In August 2004, the Progressive Direct Group of Insurance Companies introduced TripSense, a usage-based auto insurance discount. The group notes:

"Safer drivers and people who drive less than average should pay less for auto insurance. That's why we created the revolutionary TripSense (SM) discount program, which measures your actual driving habits and allows you to earn discounts on your insurance by showing us how much, how fast and what times of day you drive. TripSense gives you more control over what you pay for insurance, as your driving habits determine your discount." [3]

In 2012, Minnesota Governor Dayton established the Minnesota Transportation Finance Advisory Committee, which recommended increasing fuel taxes to help close the funding gap for road and bridge needs in the state.[4]

Estimated Policy Impacts

Direct Policy Impacts

Table Ap F-3.4: TLU-1a-c combined - Estimated Net GHG Reductions and Net Costs or Savings

Policy Option Component	2030 In-State GHG Reductions ($TgCO_2e$):	2015 – 2030 Total Cumulative Reductions ($TgCO_2e$):	Net Present Value of Societal Costs, 2015 – 2030 ($MM2014):	Cost Effectiveness ($2014/ ton CO_2e):
TLU-1A	1.0	11	-$2,160	-$189
TLU-1B	0.57	9.2	$1,898	$205
TLU-1C	0.42	7.6	$2,980	$394
TLU-1 Total	**2.0**	**28**	**$2,718**	**$96**

Note: Total cumulative reductions and cost effectiveness include reductions that occur both within and outside of the State.
Note: Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

[2] http://www.fhwa.dot.gov/policy/13-hmpg.htm
[3] http://newsroom.progressive.com/press-kit/tripsense-images.aspx
[4] http://www.dot.state.mn.us/tfac/

Data Sources

- Joseph Ferreira Jr. and Eric Minikel (2010), Pay-As-You-Drive Auto Insurance In Massachusetts: A Risk Assessment And Report On Consumer, Industry And Environmental Benefits, by the Department of Urban Studies and Planning, Massachusetts Institute of Technology (http://dusp.mit.edu) for the Conservation Law Foundation (www.clf.org).[5]
- Dan Brand (2009), Impacts of Higher Fuel Costs, Federal Highway Administration.[6]
- Phil Goodwin, Joyce Dargay and Mark Hanly (2004), "Elasticities of Road Traffic and Fuel Consumption With Respect to Price and Income: A Review," *Transport Reviews*
- Litman, Todd (2012). "Changing Vehicle Travel Price Sensitivities". 10 September 2012. Victoria Transportation Policy Institute.[7]
- Gar W. Lipow (2008), Price-Elasticity of Energy Demand: A Bibliography, Carbon Tax Center

Quantification Methods

For TLU-1A, the primary study used to estimate the VMT reductions and fuel savings that can be achieved with a PAYD insurance program came from Ferreira and Minikel (2010). This study indicated that a revenue neutral PAYD program, in which all insurance costs are converted into a per-mile fee, would achieve a reduction in VMT of 9.5% and a reduction in fuel consumption of 9.3% per driver. The fuel savings were estimated by multiplying the Minnesota highway fuel consumption per year (from the Minnesota Transportation Inventory) by the 9.3% reduction per driver by the implementation path (the percentage of Minnesota drivers in a PAYD program). The implementation path starts at 8% in 2017 and increases to 80% in 2030. This reduction in fuel consumption is then used to estimate total greenhouse gas reductions and overall fuel savings. There were no implementation costs included in the estimate at this time, because the switch from conventional to PAYD insurance is expected to have very few associated costs. The quantification results can be seen in tables below.

Table Ap F-3.5. TLU-1A Pay-As-You-Go Insurance Greenhouse Gas Savings and Costs

Year	Change in Fuel Consumption (000 gallons)	tCO_2e Change	Change in Fuel Cost ($2014 Million)
2015	0	0	$0
2016	0	0	$0
2017	-13,897	-121,351	-$42

5 http://www.clf.org/our-work/healthy-communities/modernizing-transportation/pay-as-you-drive-auto-insurance-payd
6 http://www.fhwa.dot.gov/policy/otps/innovation/issue1/impacts.htm
7 http://www.vtpi.org/VMT_Elasticities.pdf

Year	Change in Fuel Consumption (000 gallons)	tCO_2e Change	Change in Fuel Cost ($2014 Million)
2018	-27,330	-238,650	-$79
2019	-40,289	-351,817	-$111
2020	-52,816	-461,205	-$140
2021	-58,818	-513,612	-$149
2022	-64,550	-563,662	-$157
2023	-70,139	-612,472	-$164
2024	-75,484	-659,144	-$169
2025	-80,618	-703,977	-$173
2026	-88,763	-775,099	-$182
2027	-96,653	-843,998	-$190
2028	-104,312	-910,878	-$197
2029	-111,752	-975,840	-$202
2030	-118,991	-1,039,056	-$206
Total		**-8,770,761**	**-$2,160**

Note: Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

TLU-1B and -1C both focus on the affect that changing the cost of driving has on driver behavior. Where pay-as-you-go insurance is simply converting an existing cost (car insurance) into a per-mile cost, 1B and 1C are examining the effects of increasing the cost of driving.

The quantification for the carbon tax policy (1B) looked at the impacts of assessing a $30 per ton societal cost for each ton of carbon. According to Environmental Protection Agency's (EPA) emissions factors, each gallon of gasoline has an emissions factor of 8.59 kg per gallon, which averages to a tax of $0.24 per gallon of E10 gasoline. This is then indexed to inflation for 2015-2030, based on Minnesota's GDP price index. This would likely be implemented in the same manner as a fuel tax, and therefore TLU-1B was quantified in the same way as TLU-1C.

The impact of this increase in cost depends on the VMT elasticity that is selected. Goodwin, Dargay and Hanly (2004) found that as fuel and carbon taxes increase the per mile costs of travel, fuel consumption declines faster than vehicle travel. This is because fuel/carbon taxes provide an incentive to use a more fuel efficient vehicle as well as to drive less. Consumers have greater ability to reduce fuel consumption when they can adjust over a long period of time. Goodwin, Dargay and Hanly (2004) found that in the long run, 43% of the decline in fuel consumption is the result of VMT reduction, whereas 57% is the result of improved fuel efficiency. A study by the FHWA found VMT elasticity in the short term (four years or less) of -0.17, and of -0.40 in the longer term (Litman, 2012 and Lipow, 2008). Therefore, a 10% increase in the per mile cost of driving would result in a 1.7% decrease in fuel consumption in the short term, and a 4% decrease over a longer term (Litman, 2012 and Lipow, 2008). This estimate is used to estimate the change in VMT and fuel consumption as a result of TLU-1B and

-1C. The cost of collection in TLU-1B is assumed to be near zero, but a rebate program to address equity issues would take resources. For the purposes of this analysis, we assume one percent of collected revenues to administer the rebate program, which are included in the total costs of TLU-1B. The rebate program immediately reinvests 30% of the revenue raised in TLU-1B back into the economy.

The implementation costs, fuel consumption and greenhouse gas changes of TLU-1B are laid out in tables below. The fuel savings achieved decline over the 2019-2030 analysis period because vehicles are becoming more efficient, and therefore will be less affected by the carbon tax. These tables also present the revenue raised, fuel cost savings, and discounted total costs of TLU-1B.

Table Ap F-3.6: Fuel and Greenhouse Gas Impacts of TLU-1B – Carbon Tax

Year	Fuel Tax (Gasoline and Diesel) ($/gal)	Total Fuel Savings (million gallons)	$MtCO_2e$ Change
2015	$0.00	0.0	0
2016	$0.00	0.0	0
2017	$0.25	-28.6	-250,113
2018	$0.25	-28.6	-250,034
2019	$0.26	-28.6	-249,446
2020	$0.26	-66.9	-583,959
2021	$0.27	-66.7	-582,704
2022	$0.27	-66.5	-581,114
2023	$0.28	-66.4	-579,390
2024	$0.28	-66.2	-577,718
2025	$0.29	-65.9	-575,811
2026	$0.29	-65.7	-574,048
2027	$0.30	-65.6	-572,590
2028	$0.30	-65.5	-571,595
2029	$0.31	-65.4	-571,067
2030	$0.31	-65.4	-571,306
Total		-812	-7,090,895

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table Ap F-3.7: Costs of TLU-1B – Carbon Tax

Year	Revenue Raised (Million $)	Fuel Savings (Million $)	Rebate Program Costs	Rebate Program Reinvestment	TLU 1B Total Costs ($2014 Million)

Year	Revenue Raised (Million $)	Fuel Savings (Million $)	Rebate Program Costs	Rebate Program Reinvestment	TLU 1B Total Costs ($2014 Million)
2015	$0	$0.0	$0.00	$0	$0
2016	$0	$0.0	$0.00	$0	$0
2017	$589	-$100.1	$5.89	$177	$265
2018	$591	-$100.4	$5.91	$177	$253
2019	$592	-$100.7	$5.92	$178	$241
2020	$594	-$237.6	$5.94	$178	$129
2021	$596	-$238.4	$5.96	$179	$123
2022	$598	-$239.2	$5.98	$179	$117
2023	$600	-$240.1	$6.00	$180	$112
2024	$602	-$240.8	$6.02	$181	$107
2025	$604	-$241.5	$6.04	$181	$102
2026	$606	-$242.3	$6.06	$182	$98
2027	$608	-$243.2	$6.08	$182	$94
2028	$611	-$244.3	$6.11	$183	$89
2029	$614	-$245.6	$6.14	$184	$86
2030	$618	-$247.3	$6.18	$185	$82
Total					$1,898

Notes: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

TLU-1C, a 6.5% wholesale fuel tax, is quantified in a similar manner as TLU-1B. The reductions in fuel consumption and VMT that occur were also estimated based on the results in Litman, (2012), Lipow (2008) and Goodwin, Dargay and Hanly (2004). The fuel tax increases the per mile cost of driving, and incentivizes both driving a more efficient vehicle and reducing VMT. The implementation, fuel consumption and greenhouse gas changes of TLU-1C are shown in Table Ap F-3.8. Note that as vehicle efficiency (fuel economy) is projected to improve, the fuel savings as a result of the fuel tax are estimated to decrease. The next table shows the revenue raised, fuel cost savings, and discounted total costs of TLU-1C.

Table Ap F-3.8: Fuel and Greenhouse Gas Impacts of TLU-1C – Fuel Tax

Year	Fuel Tax (Gasoline and Diesel) ($/gal)	Total Fuel Savings (million gallons)	$MtCO_2e$ Change
2015	$0.000	0.0	0
2016	$0.193	-22.7	-197,905
2017	$0.195	-22.3	-194,677

Year	Fuel Tax (Gasoline and Diesel) ($/gal)	Total Fuel Savings (million gallons)	MtCO$_2$e Change
2018	$0.198	-22.2	-194,051
2019	$0.200	-52.0	-454,001
2020	$0.203	-51.5	-450,001
2021	$0.205	-51.2	-447,200
2022	$0.208	-50.8	-444,018
2023	$0.210	-50.5	-440,660
2024	$0.213	-50.1	-437,401
2025	$0.216	-49.7	-433,929
2026	$0.218	-49.3	-430,501
2027	$0.221	-48.9	-427,227
2028	$0.224	-48.6	-424,092
2029	$0.227	-48.2	-421,128
2030	$0.230	-47.9	-418,315
Total		-665.9	-5,815,105

Notes: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table Ap F-3.9: Costs of TLU-1C – Fuel Tax

Year	Revenue Raised (Million $)	Fuel Savings (Million $)	TLU-1C Total Costs ($2014 Million)
2015	$0	$0.0	$0
2016	$458	-$77.9	$345
2017	$458	-$77.9	$329
2018	$458	-$77.9	$313
2019	$458	-$183.2	$215
2020	$458	-$183.1	$205
2021	$457	-$182.9	$195
2022	$457	-$182.8	$186
2023	$456	-$182.6	$177
2024	$456	-$182.3	$168
2025	$455	-$182.0	$160
2026	$454	-$181.7	$152
2027	$454	-$181.5	$144
2028	$453	-$181.3	$137
2029	$453	-$181.1	$131
2030	$453	-$181.1	$124
Total			**$2,980**

Notes: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

The total greenhouse gas impacts of the TLU-1 policies are displayed in the following table, while the table immediately next shows the additional upstream savings from reduced fuel consumption of TLU-1. The next table yet (Table Ap F-3.12) shows the total costs of TLU-1. For all three tables, the total column shows the combined effects of all three policies, assuming they produce additive effects.

Table Ap F-3.10: Total In-State Greenhouse Gas Impacts of TLU-1 Policies ($MtCO_2e$)

	TLU-1A – PAYD	TLU-1B – Carbon Tax	TLU-1C – Fuel Tax	TLU-1 Total
2015	0	0	0	0
2016	0	0	-197,905	-197,905
2017	-121,351	-250,113	-194,677	-566,140
2018	-238,650	-250,034	-194,051	-682,735
2019	-351,817	-249,446	-454,001	-1,055,263
2020	-461,205	-583,959	-450,001	-1,495,166
2021	-513,612	-582,704	-447,200	-1,543,516
2022	-563,662	-581,114	-444,018	-1,588,793
2023	-612,472	-579,390	-440,660	-1,632,522
2024	-659,144	-577,718	-437,401	-1,674,262
2025	-703,977	-575,811	-433,929	-1,713,717
2026	-775,099	-574,048	-430,501	-1,779,649
2027	-843,998	-572,590	-427,227	-1,843,815
2028	-910,878	-571,595	-424,092	-1,906,566
2029	-975,840	-571,067	-421,128	-1,968,035
2030	-1,039,056	-571,306	-418,315	-2,028,677
Total	**-8,770,761**	**-7,090,895**	**-5,815,105**	**-21,676,762**

Notes: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table Ap F-3.11: Total Upstream Greenhouse Gas Impacts of TLU-1 Policies ($MtCO_2e$)

	TLU-1A – PAYD	TLU-1B – Carbon Tax	TLU-1C – Fuel Tax	TLU-1 Upstream Total	TLU-1 Upstream plus Instate
2015	0	0	0	0	0
2016	0	0	-58,514	-58,514	-256,420
2017	-36,051	-74,304	-57,835	-168,191	-734,331
2018	-71,231	-74,629	-57,919	-203,779	-886,514
2019	-105,490	-74,795	-136,130	-316,416	-1,371,679
2020	-138,912	-175,885	-135,537	-450,334	-1,945,500
2021	-154,898	-175,736	-134,869	-465,503	-2,009,019
2022	-170,215	-175,485	-134,085	-479,784	-2,068,577
2023	-185,196	-175,193	-133,244	-493,632	-2,126,154
2024	-199,568	-174,915	-132,431	-506,915	-2,181,177
2025	-213,421	-174,565	-131,552	-519,537	-2,233,255
2026	-235,289	-174,258	-130,683	-540,230	-2,319,879
2027	-256,538	-174,042	-129,858	-560,438	-2,404,253
2028	-277,228	-173,966	-129,074	-580,268	-2,486,834
2029	-297,387	-174,033	-128,339	-599,758	-2,567,793
2030	-317,065	-174,333	-127,648	-619,046	-2,647,723
Total				-6,562,346	-28,239,107

Notes: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table Ap F-3.12: Total Costs of TLU-1 Policies ($2014 MM)

	TLU-1A – PAYD	TLU-1B – Carbon Tax	TLU-1C – Fuel Tax	TLU-1 Total
2015	$0	$0	$0	$0
2016	$0	$0	$345	$345
2017	-$42	$265	$329	$551
2018	-$79	$253	$313	$487
2019	-$111	$241	$215	$345
2020	-$140	$129	$205	$193
2021	-$149	$123	$195	$169
2022	-$157	$117	$186	$146
2023	-$164	$112	$177	$125
2024	-$169	$107	$168	$106
2025	-$173	$102	$160	$89
2026	-$182	$98	$152	$67
2027	-$190	$94	$144	$48
2028	-$197	$89	$137	$30
2029	-$202	$86	$131	$14
2030	-$206	$82	$124	$1
Total	-$2,160	$1,898	$2,980	$2,718

Notes: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

TLU-1B and -1C both serve to increase the cost of driving. To better understand the price impact of these polices, it can be useful to express this cost change in terms of change in price per gallon. Table Ap F-3.13 shows the increase in $/gallon for both policies. TLU-1A cannot be expressed as a $/gallon impact, because it does not directly affect the price of gas; instead 1A converts an existing fixed cost (car insurance) to a variable cost.

Table Ap F-3.13: $/Gallon Increase of TLU-1B and 1C

	TLU-1B	TLU-1C	Total Increase in $/Gallon of All TLU-1 Policies
2015	$0.00	$0.00	$0.00
2016	$0.00	$0.19	$0.19
2017	$0.25	$0.20	$0.45
2018	$0.25	$0.20	$0.45
2019	$0.26	$0.20	$0.46
2020	$0.26	$0.20	$0.47
2021	$0.27	$0.21	$0.47
2022	$0.27	$0.21	$0.48
2023	$0.28	$0.21	$0.49
2024	$0.28	$0.21	$0.49
2025	$0.29	$0.22	$0.50
2026	$0.29	$0.22	$0.51
2027	$0.30	$0.22	$0.52
2028	$0.30	$0.22	$0.53
2029	$0.31	$0.23	$0.53
2030	$0.31	$0.23	$0.54

Notes: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

<u>Key Assumptions</u>

This analysis assumes no interaction or overlap within this policy option.

The baseline forecast assumes vehicle miles traveled in Minnesota increase annually at a rate of 0.8%.

The baseline fuel economy forecast is from the Energy Information Administration (EIA) which projects average efficiency of vehicles travelling in Minnesota to increase from 24.1 miles per gallon in 2015 to 33.4 miles per gallon in 2030.

The impacts of this policy option are based on gasoline powered light duty vehicles only, even though TLU-1B and -1C would provide an incentive to reduce emissions other than just in gasoline highway vehicles. In particular, the policy option options would reduce emissions from medium duty and heavy commercial vehicles albeit to a lesser degree than for light duty vehicles. Therefore, this analysis likely underestimates the total effect of TLU-1B and -1C.

Administrative costs of TLU-1 policies are assumed to be low, with only 1B including a specific administrative cost of one percent for a rebate program to address equity issues. The actual cost of administering the rebate programs envisioned for 1B could be substantially different. It is likely that TLU-1C would also need to address equity issues to avoid having an adverse impact on poorer communities.

The Pay-as-you-drive policy option in TLU-1A assumes that such a policy option can be implemented on a wide scale and will be widely adopted in Minnesota.

Macroeconomic (Indirect) Policy Impacts

Table Ap F-3.14: TLU-1 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
TLU-1	$711	$688	$10,319	8,140	8,230	123,400	$781	$659	$9,885

Graphs below show detail in GSP, employment and personal income impacts of the TLU-1 policy.

Figure Ap F-20. TLU-1 Impacts on Gross State Product ($2015 MM)

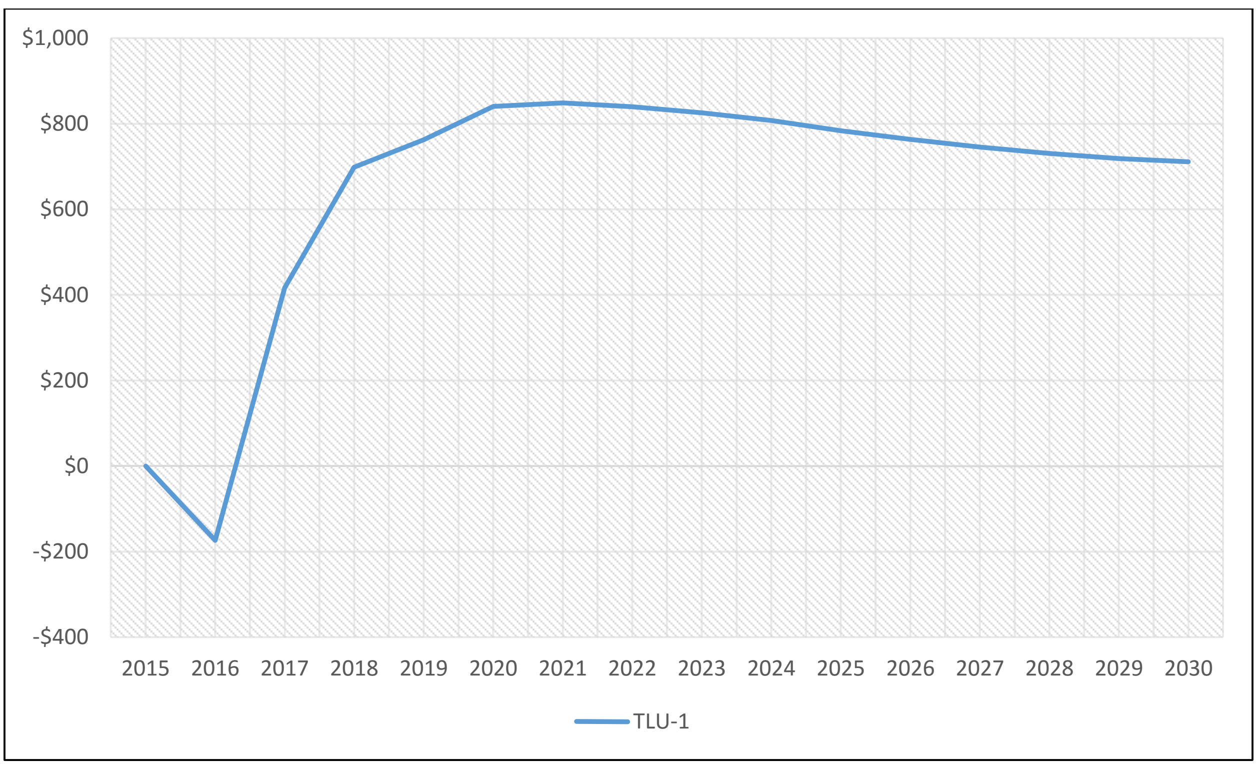


Figure Ap F-21. TLU-1 Impacts on Incomes ($2015 MM)

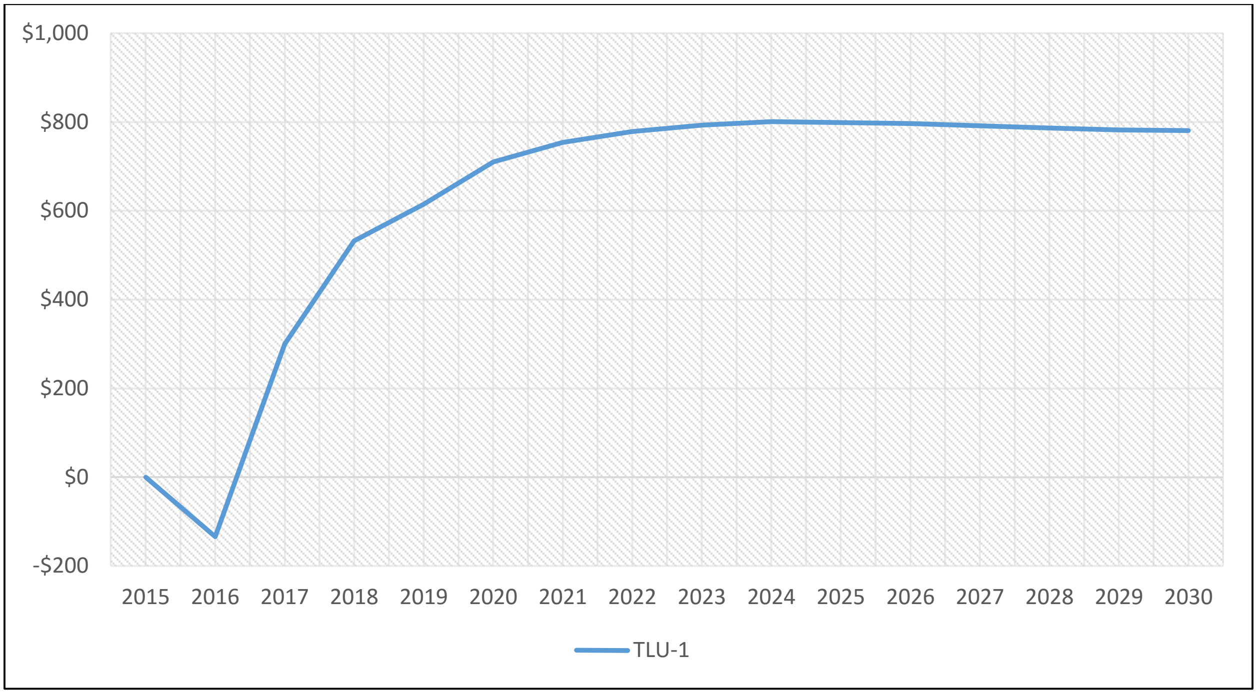
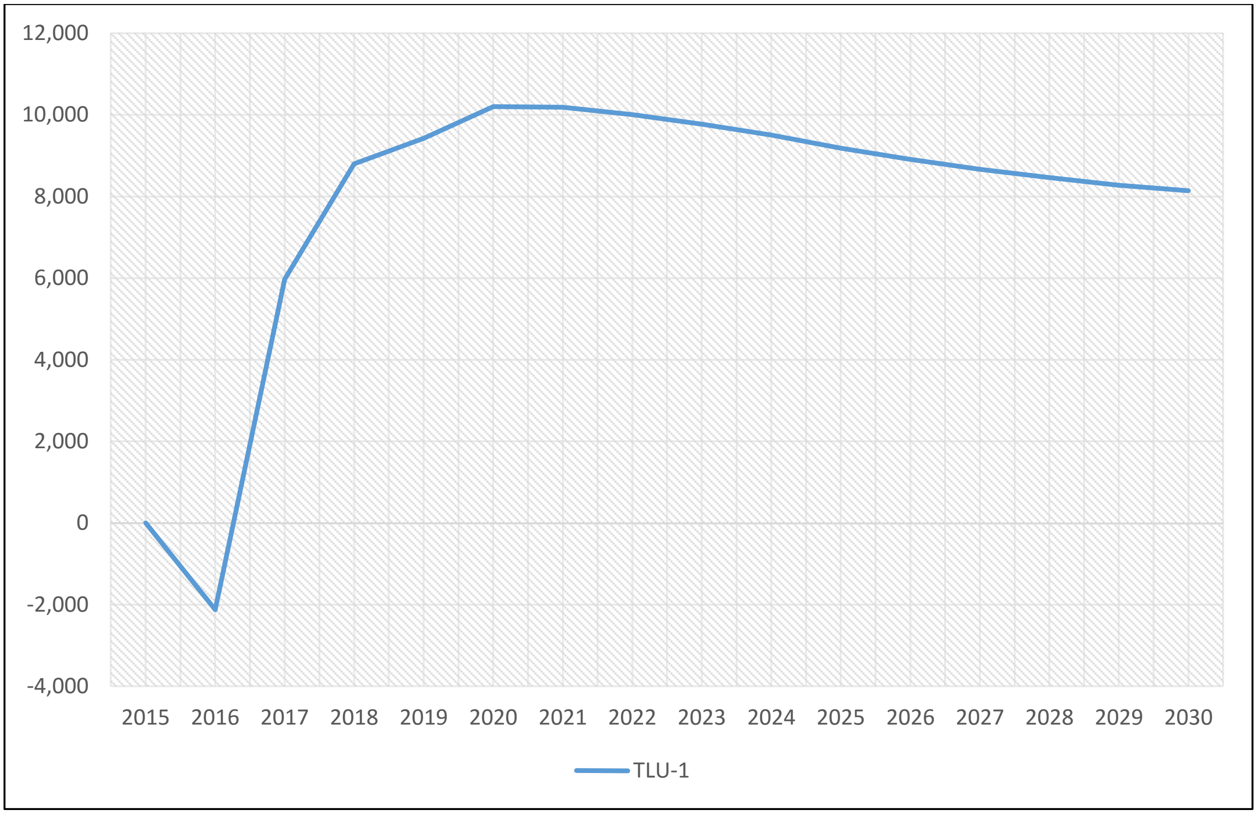
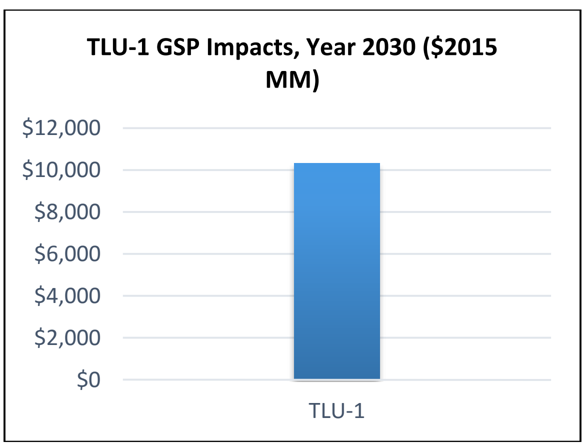
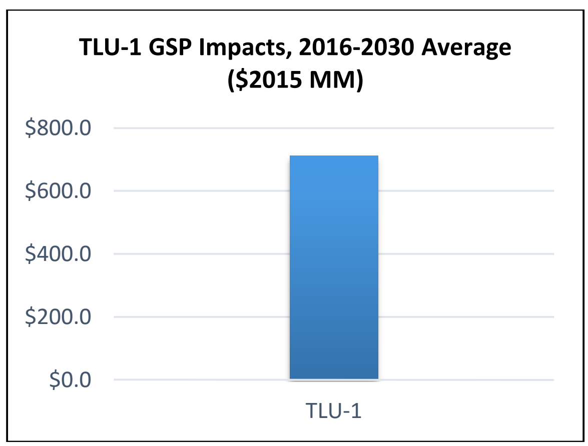


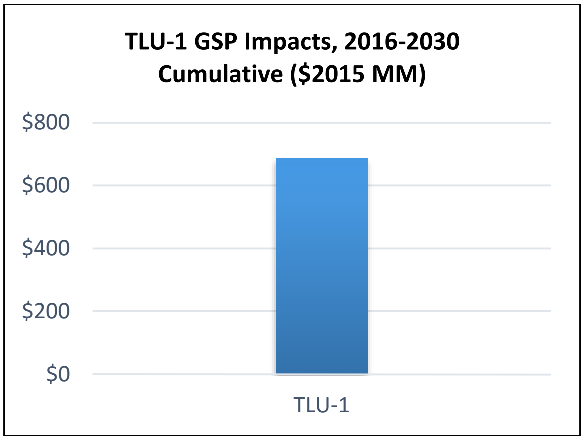
Figure Ap F-22. TLU-1 Impacts on Employment (Individual Jobs)

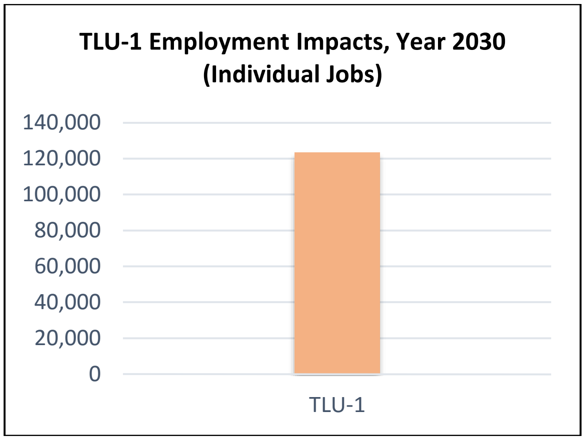


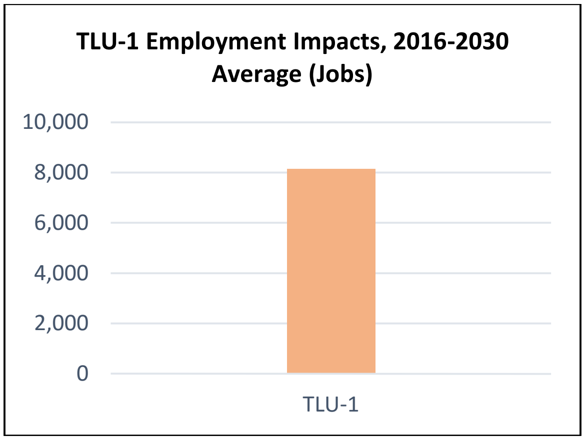
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030).

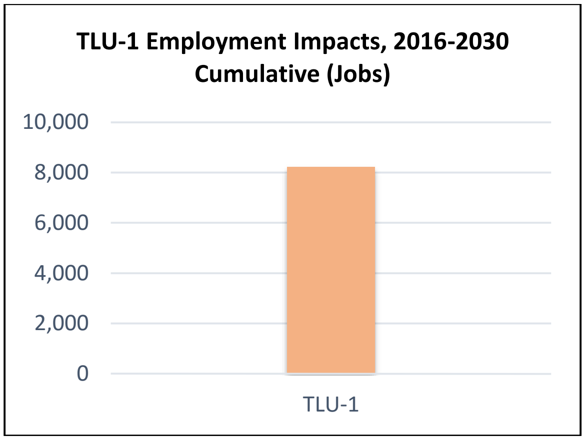


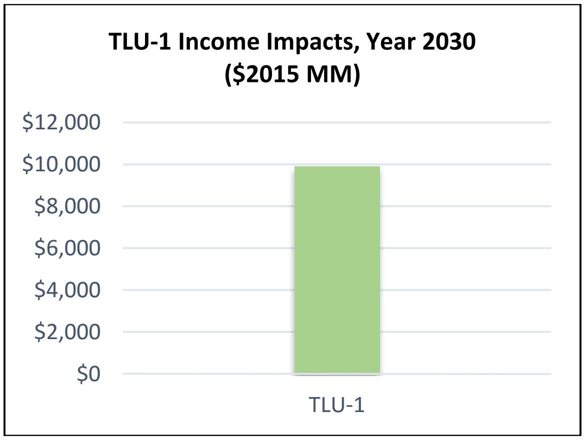


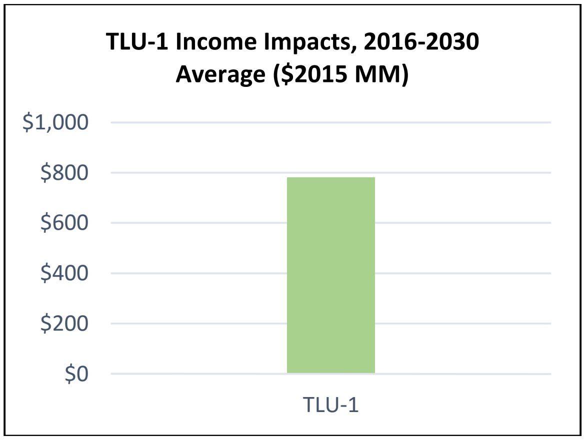

TLU-1 GSP Impacts, 2016-2030
Cumulative ($2015 MM)
$800
$600
$400
$200
$0
TLU-1

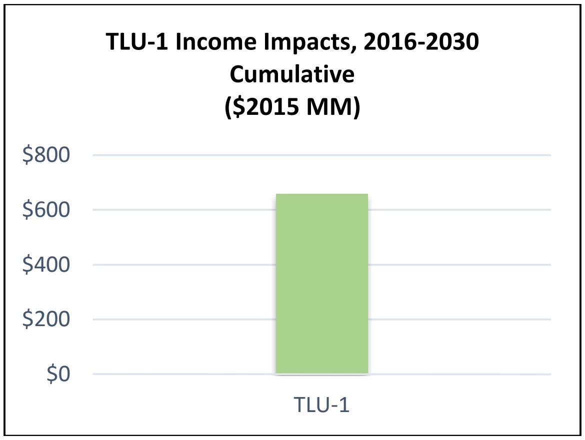

TLU-1 Employment Impacts, Year 2030
(Individual Jobs)
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
TLU-1


TLU-1 Employment Impacts, 2016-2030
Average (Jobs)
10,000
8,000
6,000
4,000
2,000
0
TLU-1


TLU-1 Employment Impacts, 2016-2030
Cumulative (Jobs)
10,000
8,000
6,000
4,000
2,000
0
TLU-1


TLU-1 Income Impacts, Year 2030
($2015 MM)
$12,000
$10,000
$8,000
$6,000
$4,000
$2,000
$0
TLU-1


TLU-1 Income Impacts, 2016-2030
Average ($2015 MM)
$1,000
$800
$600
$400
$200
$0
TLU-1



Principal Drivers of Macroeconomic Changes

TLU-1 presents a set of offsetting impacts to consumer spending, with the Pay-As-You-Go insurance policy producing a savings to consumers of nearly $450 million by 2030. However, In the other direction, the fuel tax and carbon tax elements produce costs to consumers of very similar amounts. As a result, consumers see little overall change in their total cost of transportation.

While consumers do not end up having lost very much money after balancing out the effects of these three initiatives, the government does have significant new revenue (all the funds collected from the carbon and gas taxes) as a result of those policies. This expands government budgets, and increases spending on programs and services – both of which are a component of GDP and are typically labor-intensive.

The result of this policy is highly positive. The policy generates about $800 million in new GDP annually, and a similar amount in incomes through the creation of nearly 10,000 new jobs.

The combination of the pay-as-you-go insurance with the taxes is crucial to this. The savings out of the former policy substantially offsets the burden imposed by the latter two. In the absence of this balancing force, while the government spending expansion would still be present and a positive force, the burden of the taxes would be significant as a driver of negative economic impacts. In that case, the impacts would tend much closer to neutral.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the TLU-1 policy, important data included:

- Fuel savings that result from the incentive of spending less on auto insurance by driving less
- Spending on the carbon tax on fuel by consumers and businesses, which reduces money to be spent on other goods and services.
- Spending on the gasoline tax, which reduces money to be spent on other goods and services.
- Government spending expansion as it utilizes the revenue from the carbon tax and gas tax.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.
- State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of

spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

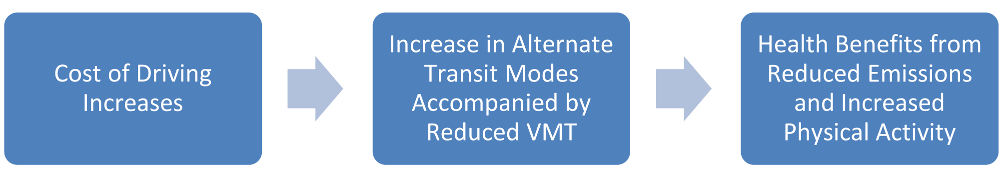
A key uncertainty in the analysis is how Minnesotans will adjust their travel and vehicle purchases in response to these policies. The response is likely to vary over time particularly as more fuel efficient vehicles will offset the marginal increase in driving costs from these policies.

The effectiveness and impacts of TLU-1B and -1C are greatly affected by the price of gasoline. If the price of gasoline is higher than is currently projected, then the cost savings of this policy option would increase. Additionally, the baseline assumed price of gasoline does not include significant price variability. Increase price volatility could affect the magnitude of TLU-1B and -1C emissions reductions.

Additional Benefits and Costs

All TLU-1 sub options reduce non-greenhouse gas transportation-related emissions (i.e. volatile organic compounds and particulate matter) and are therefore likely to reduce the risk for respiratory and cardiovascular illness, cancer, stress, premature birth weight, and premature death in exposed populations. As individuals reduce the amount that they drive, these policies may additionally generate health benefits from increased physical activity.

Figure Ap F-23. Potential Health Benefits of TLU-1



Both TLU-1B and -1C generate revenues, which could support a range of other benefits.

The revenues generated by TLU-1B would help to upgrade Minnesota's transportation infrastructure to be less vulnerable to the effects of a changing climate. This would create direct construction jobs, but also reduce travel delays and property damage to households and businesses from future floods and other climate-related damage. Additional TLU-1B revenue could help fund other CSEO strategies and their related benefits. A portion of TLU-1B revenue would be rebated to low-income households to help mitigate equity concerns.

Revenue from TLU-1C would be dedicated to highway and road infrastructure, which would create construction jobs. The funded projects would help to ensure a state of good repair for the state's roads and bridges, and would make improvements to travel time reliability and traveler safety. Some projects may include improvements for non-motorized travel, which would support improved health outcomes from increased physical activity.

Feasibility Issues

Both TLU-1B and -1C are technically feasible with established or easy to establish collection mechanisms. However, imposing or raising taxes on transportation fuels has historically been politically unpopular.

Establishing the rebate mechanisms for low-income households envisioned in TLU-1B would require substantial additional work and ongoing effort.

TLU-2. Improve Land Use and Urban Form

Policy Option Description

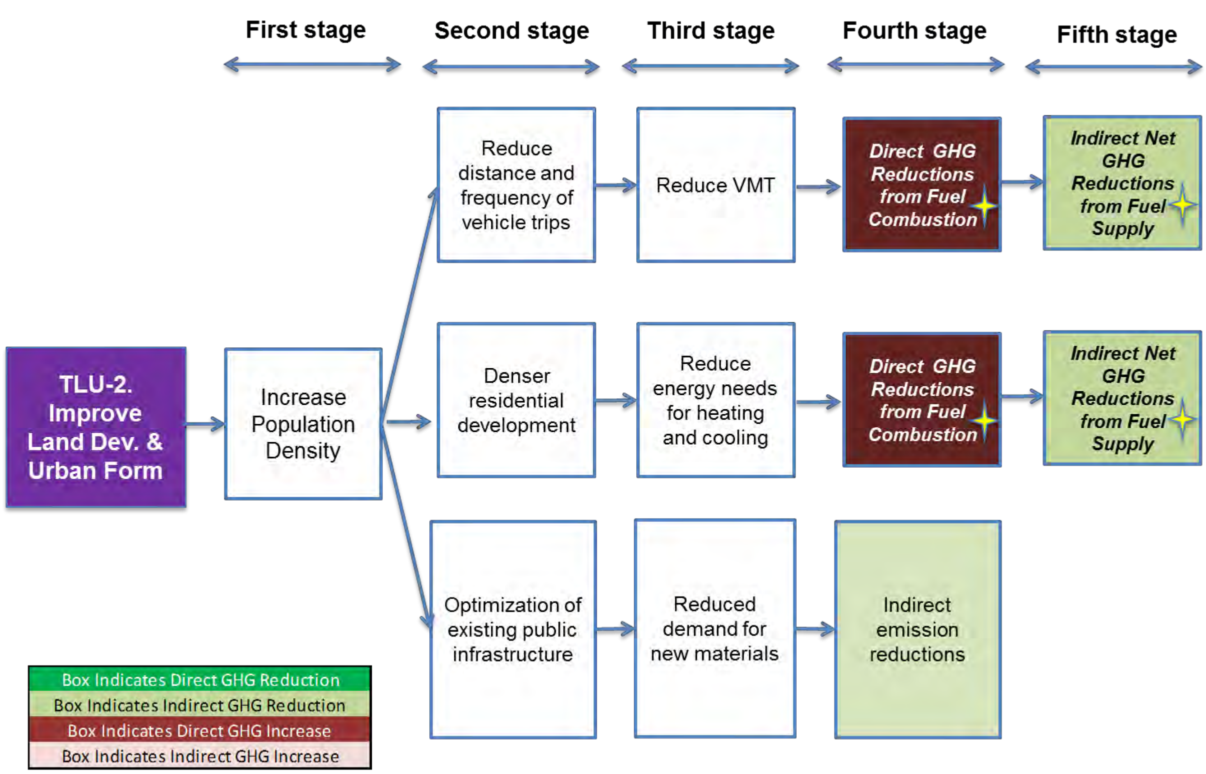
Implement urban planning and development practices in the seven-county metropolitan area that result in greater concentration of development, more compact urban form, more locally diverse uses, and shorter trip distances, thus mitigating Vehicle Miles Traveled (VMT) and greenhouse gas emissions (GHG) from transportation.

Compact urban form, which features increased shares of households in multi-unit buildings and commercial activity in multi-tenant buildings, can also reduce heating and cooling loads, thus mitigating GHG from buildings. Also, greater concentration and more compact urban form can economize on infrastructure expansion, reducing the associated GHG emissions.

Since urban form and travel behavior are mutually reinforcing factors, limiting growth of VMT will require a suite of coordinated land use and transportation actions. These actions are organized in four tiers of urban form: low-density urban development; compact centers; transit-supportive areas; and transit-oriented areas. Each bundle of actions is intended to optimize the performance of their urban form.

Causal Chain for GHG Reductions

Figure Ap F-24. Causal Chain for TLU-2 GHG Reductions



The causal chain above identifies the main policy option effects and the subsequent GHG impacts. The star symbol identifies significant GHG effects that will be quantified.

Policy Option Design

Goals: Starting in 2015 and continuing annually through 2040:

- Zero net growth of housing units in exurban areas (with density averaging one unit/acre) and rural areas of the seven metropolitan counties.
- Decrease household growth located in low-density suburban areas (with density averaging three units/acre) of the seven metropolitan counties. Goal is less than 25% of net housing growth locating in low-density suburban areas.
- Increase household growth located in compact centers, transit-supportive areas, transit-oriented areas (with density averaging eight or more units/acre) of the seven metropolitan counties. Goal is greater than 75% of net housing growth locating in such areas.
- Increase share of housing stock in multi-unit buildings and increase share of commercial space in multi-tenant commercial buildings.

These targets effect reduced VMT by situating people closer to their destinations, and by increasing compactness of development. At least two approaches are available for estimating VMT response; *see Data sources and Quantification section below*.

Compact urban form featuring increased share of households and commercial activity in compact buildings (multi-unit residential and multi-tenant commercial buildings) can also effect economies-of-scale in building heating and cooling, thus mitigating GHG from buildings.

Timing: Total forecasted growth is distributed equally in each year throughout the 2015-2030 period. In the metro area, 75% of household growth located in compact centers, transit-supportive areas, transit-oriented areas; 25% in low-density suburban areas; 0% in rural and exurban areas.

Parties Involved: Implementation: cities, townships, counties, and the Metropolitan Council create and implement land use policy option in the seven-county metropolitan region. Outside the metro, cities, counties, and townships have a comparable role.

Implementation Mechanisms

TLU-2 public policy option mechanisms asserted for analysis are centered on comprehensive land use planning. Land use and urban form respond to public policy option mechanisms, but they also rely heavily on economic trends, market forces, and private sector decisions that are beyond public control.

Additional mechanisms are also listed below, which are intended to encourage actions in the private arena. These mechanisms are not quantified in the analysis but would likely speed the implementation of TLU-2. They are provided here as a reference for discussion.

Comprehensive land use planning

TLU-2 is limited to the seven-county metropolitan area because much of the growth state is projected to occur there, and the policy option base and comprehensive planning process is already in place by statute.

- Plan for density of new development appropriate for the variety of geographic areas in the seven-county Metropolitan area.
- Coordinate land use and development patterns with transit modes and locations to increase transit ridership, especially on frequent, all day transit service and transit ways.

Actions to encourage transit-oriented, transit supportive and compact development patterns

- Align resources to support transit-oriented development in areas with density suitable for transit to create vibrant, mixed-income, walkable places where people can live without an automobile.
- Partner with local communities to improve land patterns to reduce vehicle miles traveled and generation of carbon emissions.
- Adopt land use regulations and government policies that support the growing market for compact development in order for it to function effectively as a climate change strategy.
- Encourage redevelopment and infill development in urban core areas across the region which can reduce trip length, and increase use of transit and non-motorized modes.
- Collaborate with metropolitan planning organization (MPOs) and local governments on technical analysis, including improved data, models, and scenario planning tools to help in developing and implementing high density and compact development
- Provide/increase funding for Main Streets programs and revitalization of downtowns.
- Incentivize employment density to encourage transit ridership.
- Promote development patterns that protect natural resources, the quality and quantity of our water resources and water supply.
- Provide/Increase Brownfield funding (cleanup and redevelopment).

Statutory regulatory actions to effect statewide implementation

- Adopt a statewide land use control legislation / State Planning and Zoning Law that requires each city, county, or city and county to prepare and adopt a comprehensive plan.
- Implement land use code changes that support GHG emissions reductions.

- Require that regions adopt a Sustainable Communities Strategy – designed to achieve certain goals for the reduction of greenhouse gas emissions (See California SB 375).

Funding possibilities

- Create state and metropolitan funding formulas with incentives for reducing transportation demand instead of rewarding increased driving, as current legislation does.
- Use funding from carbon tax to fund incentivizing programs (e.g., statewide version of LCDA, or any of the items listed above).
- Link funding for public infrastructure and other public investments to criteria for population density or location (e.g., adjacent to existing development), as a requirement or as an incentive.

Streamlining

- Ease environmental review requirements: (See California SB 375).

Implementation Mechanisms That Strongly Support TLU-2

Increase transportation options:

- Prioritize transit investments in areas where infrastructure and development patterns can support successful transit system.
- Identify transit-supportive land use and development patterns for coordination with cities, especially around high-investment projects such as frequent, all day transit service and transit-ways to increase transit ridership.
- Provide and promote alternatives to single-occupancy vehicle travel, including transit, carpooling, bicycling and walking.
- Provide bicycle facilities to promote bicycling for transportation, recreation and healthy lifestyles (including state trails, Regional Bicycle Transportation Network, regional trails, and local bicycle networks).
- Encourage local communities to include bicycle and pedestrian plans in their comprehensive plan.
- Expand safe routes to school programs.
- Fund sidewalk improvements (criteria for population served/density and/or mix of land uses).
- Provide/Increase Bike-share program funding/coordination.
- Implement travel demand management policies and ordinances that encourage use of travel options and decrease reliance on single-occupancy vehicle travel.

Related mechanisms

- Increase funding for statewide "Complete Streets" Policy Option and funding program that improve safety and mobility for all users.
- Adopt and sub-allocate VMT reduction targets. (These could be linked to GHG reduction goals. These goals could be translated into VMT reduction targets. The targets could be proportionally allocated to the Twin cities region, and each MPO could be charged with developing a plan for meeting its respective target. VMT targets could even be sub-allocated to localities).
- Enable lower-carbon freight movement.
- Manage/price parking.
- Teleworking programs, which give employees the choice to work from home or choose alternative travel schedule.

Related Policies/Programs in Place and Recent Actions

Met Council growth forecasts to 2040 have predicted market behavior of metro-area households, taking into account the existing policies and land availability. New policies and actions that affect this behavior should result in household location choices that are more favorable for compact development.

Estimated Policy Impacts

Direct Policy Impacts

Table Ap F-3.15: TLU-2 Estimated Net GHG Reductions and Net Costs or Savings

2030 In-State GHG reductions ($TgCO_2e$):	2015 – 2030 Total cumulative reductions (metric tons CO_2e):	Net present value of societal costs, 2015 – 2030 ($MM2014):	Cost effectiveness ($2014/ ton CO_2e):
0.82	**8.2**	**-$425**	**-$52**

Note: Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Data Sources

- Strategic Highway Research Program, 2013. "The Effect of Smart Growth Policies on Travel Demand".[8]
- FHWA, 2014. Smart Growth Area Planning Tool (SmartGAP) Model.[9]

[8] http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2prepubC16.pdf

- EIA, 2012. Energy Information Administration. "2009 Residential Energy Consumption Survey". Released December 2012.[10]
- Texas Transportation Institute, "Urban Mobility Report", latest version is currently from 2012.[11]

Quantification Methods

This policy option examines the VMT, fuel consumption and cost impacts of denser development within the seven-county Metropolitan area. The TLU workgroup determined that this type of denser development policy option is not practical for the rest of the state.

Scenario TLU-2 models the economic and environmental impacts of a more compact, centralized urban form in the metro region and a changed housing mix. The Federal Highway Association's SmartGAP model was used to perform this modeling. The SmartGAP model was created as part of the second Strategic Highway Research Program (SHRP 2) Capacity Project. That project culminated in the report "The Effect of Smart Growth Policies on Travel Demand" that explores the underlying relationships between households, firms, and travel demand. The SmartGAP model is a macroscopic scenario planning tool that can be used to evaluate the impacts of various smart growth policies. The SmartGAP model synthesizes households and firms in a region and determines their travel demand characteristics based on their built environment and transportation policies. In this case, we have used the SmartGAP model to estimate the impacts of a denser development policy on the 7 county Metro area (Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington counties), based on the results of the SHRP2 analysis.

SmartGAP provides an estimate of GHG and VMT impacts, as well as overall cost in the forecast year. In order to estimate the impacts of various policies, a business-as-usual scenario is compared against a policy option scenario, and the overall costs and GHG impacts are estimated based on the difference between these two scenarios. This output is provided only for the final year of the analysis, in this case 2030. For this analysis, a linear growth from 2015 (0% implementation) to 2030 (100%) is assumed.

In TLU-2, the business-as-usual case comes from Met Council's Thrive MSP 2040 forecast; the alternative scenario changes the geographic distribution of future growth and the housing products mix: 38% of new development is attached and multifamily in the BAU case; 75% attached and multifamily in the alternative scenario case.

Met Council provided regional population growth and employment growth forecasts, distributions of that growth by community type, auto trip rates, transit trip rates, daily VMT total, the highway share of that daily VMT, households growth, and distributions by housing type. This data was then input into the SmartGAP model for this analysis. In many cases (for example, trip rates and VMT distribution), this information is the same for both the BAU and scenario analysis. However, this data is nonetheless important to make the analysis more

[9] https://www.fhwa.dot.gov/planning/tmip/publications/other_reports/smartgap/index.cfm
[10] http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=consumption#summary
[11] http://mobility.tamu.edu/ums/

relevant for Minnesota, and because many of these variables are interdependent and systematically related to one another. Here are some additional details about the data sources and scenario assumptions which were used to differentiate between the BAU and policy option scenario in the SmartGAP model:

Spatial distributions of the growth using community types:

- **Spatial distributions** come from Met Council's *Thrive MSP2040* forecast, which used a real estate market and land use simulation model built with Citilabs CubeLand software. Met Council methodology is documented here: http://www.metrocouncil.org/Data-and-Maps/Data/Census,-Forecasts-Estimates/Forecast-Methodology-report,-2014.aspx
- For these scenarios, local Traffic Analysis Zone (TAZ) data was summarized to community type bins defined by the FHWA SmartGAP model; TAZs were assigned types based on regional geographic position, residential density and employment/population mix.
- For TLU2 and TLU3, the BAU baseline is: 21.5% of population growth in urban core; 14.4% in urbanized "close in" communities; 51.0% in low-density suburbs; 13.2% in rural and exurban areas.
- For TLU2, the analysis asserts an alternative in which many suburban areas evolve to be more urban, and are re-categorized accordingly: 29.4% of population growth in urban core; 44.6% in urbanized "close in" communities; 19.4% in low-density suburbs; 6.6% in rural and exurban areas.

Distributions of growth by housing type:

- **Distributions of new housing** come from Met Council's *Thrive MSP 2040* forecast.
- For the BAU baseline is: 38% of net housing additions are attached and multi-family; 62% are single-family-detached. The attached and multi-family can be broken down into subcategories.
- For the policy option alternative, there is a substantial shift toward attached and multi-family housing: 75% of net housing additions are attached and multi-family; 25% are single-family-detached. These distributions are asserted to be the result of an ambitious set of local and regional policies and restrictions.

The SmartGAP model estimates the GHG savings and economic impacts by comparing the BAU scenario against the denser growth policy option scenario. The net change between these two runs is displayed in Table Ap F-3.16 below. This analysis assumes a linear implementation path as the policy option has gradually increasing effects between 2015 and 2030. The impacts from 2031 onward are not estimated in this analysis, but would likely be higher as analyses focusing on increasing population density typically realize results over a long time frame.

Table Ap F-3.16: SmartGAP Estimated GHG and VMT Impacts of TLU-2

	Implementation Path	GHG Savings, Denser Growth (tCO_2e)	TLU-2 Annual VMT Change (Million Miles)
2015	0%	0	0
2016	7%	-534	26
2017	13%	-1,068	52
2018	20%	-1,602	79
2019	27%	-2,137	105
2020	33%	-2,671	131
2021	40%	-3,205	157
2022	47%	-3,739	184
2023	53%	-4,273	210
2024	60%	-4,807	236
2025	67%	-5,342	262
2026	73%	-5,876	289
2027	80%	-6,410	315
2028	87%	-6,944	341
2029	93%	-7,478	367
2030	100%	-8,012	393
Total		-64,100	3,148

Notes: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

The transportation-sector VMT results of TLU-2 amount to a -1.4% reduction from the projected business-as-usual scenario for the metro region. However, the changed spatial distribution in the scenario appears to cause elevated traffic congestion in the urban core and close-in, first-ring suburbs, such that fuel economy deteriorates by -1.3%. As a result, the transportation-sector GHG results are minimal – approximately -0.1%.

Table Ap F-3.17 shows the estimated costs of the TLU-2 policy option. The model estimates that there will be some additional government costs in terms of transit infrastructure and operations, but that these are much smaller than the overall societal cost savings of the policy option as a whole (which includes fuel and vehicles savings from reduced VMT). The cost savings from the SmartGAP run are the result of reduced vehicle use, which includes reduced fuel costs, fuel taxes, vehicle purchase costs, vehicle maintenance, insurance costs, and a monetized value of travel time. Travel time value comes from the Texas Transportation Institute's Urban Mobility Report.

Table Ap 3.17: SmartGAP Estimated Costs of TLU-2

	Implementation Path	TLU-2 Additional Govt. Spending ($ Millions)	TLU-2 Net Societal Spending ($ Millions)	TLU-2 Discounted Net Societal Spending ($2014 millions)
2015	0%	$0.0	$0.0	$0.0
2016	7%	$0.5	-$1.1	-$1.0
2017	13%	$0.9	-$2.1	-$1.8
2018	20%	$1.4	-$3.2	-$2.6
2019	27%	$1.8	-$4.2	-$3.3
2020	33%	$2.3	-$5.3	-$3.9
2021	40%	$2.7	-$6.3	-$4.5
2022	47%	$3.2	-$7.4	-$5.0
2023	53%	$3.6	-$8.4	-$5.4
2024	60%	$4.1	-$9.5	-$5.8
2025	67%	$4.5	-$10.6	-$6.2
2026	73%	$5.0	-$11.6	-$6.5
2027	80%	$5.4	-$12.7	-$6.7
2028	87%	$5.9	-$13.7	-$6.9
2029	93%	$6.3	-$14.8	-$7.1
2030	100%	$6.8	-$15.8	-$7.2
Total		**$54.3**	**-$126.6**	**-$74.0**

Notes: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

There were also GHG impacts and fuel savings from buildings. Denser development means fewer single family homes in favor of multi-family residential units, and these have significantly lower heating and cooling energy requirements. The US Energy Information Administration performed the 2009 Residential Energy Consumption Survey (RECS), which outlined the residential energy needs per household by region and by housing type (EIA, 2012). The average energy use per household in the Midwest (which includes Minnesota) was used for this analysis. Table Ap F-3.18 below shows how RECS data on energy use per household varies in the Midwest region depending on the type of housing.

Table Ap F-3.18: Annual Energy Use per Household by Housing Type

Metro Households (Occupied Units)	Million BTU per Household
Single Family Detached	128.0
Single Family Attached	98.6
Multi-Family 2-4 units	102.6
Multi-Family 5+ units	51.9
Mobile Homes	93.2

This information was then multiplied by the expected change in housing patterns between the BAU and the denser growth scenarios. Using this data, by 2030 the number of detached single family households is estimated to be 12% lower in the denser growth scenario, whereas the number of 5+ multifamily units increases 28%. Based on Met Council household distribution data, we estimate that overall household energy costs will be 5.0% lower in the denser growth scenario than the BAU. This reduced energy demand is assumed to come from natural gas (65%) and electricity (35%), based on information in the 2009 RECS. The energy and GHG savings for the Metro region are displayed in Table Ap F-3.19 below. The reduced cost savings are displayed in Table Ap F-3.20.

Table Ap F-3.19: Energy and GHG Savings from Reduced Household Energy Needs in TLU-2

	Implementation Path	Natural Gas Savings (TJ)	Electricity Savings (MWh)	GHG Savings From Lowered Heating Needs (tCO_2e)
2015	0%	0	0	0
2016	7%	333	49,690	62,611
2017	13%	665	99,381	124,397
2018	20%	998	149,071	185,603
2019	27%	1,331	198,761	246,184
2020	33%	1,664	248,452	306,047
2021	40%	1,996	298,142	361,099
2022	47%	2,329	347,832	417,258
2023	53%	2,662	397,523	473,949
2024	60%	2,994	447,213	527,962
2025	67%	3,327	496,903	577,367
2026	73%	3,660	546,594	628,576
2027	80%	3,992	596,284	677,596
2028	87%	4,325	645,974	724,814
2029	93%	4,658	695,665	770,887
2030	100%	4,991	745,355	815,022
Total				**6,899,372**

Notes: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table Ap F-3.20: Energy Cost Savings from Reduced Household Energy Needs in TLU-2

	Implementation Path	Fuel Savings From Reduced Natural Gas ($ Million)	Fuel Savings From Reduced Electricity ($ Million)	Total Fuel Savings ($ Million)
2015	0%	$0	$0	$0
2016	7%	$4	$6	$10
2017	13%	$9	$11	$20
2018	20%	$13	$17	$31
2019	27%	$18	$23	$41
2020	33%	$23	$29	$52
2021	40%	$28	$35	$63
2022	47%	$33	$41	$74
2023	53%	$39	$46	$85
2024	60%	$44	$53	$97
2025	67%	$50	$59	$108
2026	73%	$56	$65	$120
2027	80%	$62	$71	$133
2028	87%	$68	$77	$145
2029	93%	$74	$83	$158
2030	100%	$81	$90	$171
Total				**$1,307**

Notes: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

The total GHG Savings and Discounted Net Costs of the TLU-2 policy option are displayed in Table Ap F-58 below. Upstream GHG savings from reduced transportation fuel and heating needs are also displayed.

Table Ap F-3.21: Total GHG Impacts and Costs of TLU-2

	GHG Savings (tCO_2e)	Upstream Emissions Savings (tCO_2e)	Total Costs ($ Million)	Total Discounted Costs ($ Million)
2015	0	0	$0	$0
2016	63,145	9,834	-$5	-$5
2017	125,465	19,820	-$11	-$9
2018	187,206	29,920	-$17	-$14
2019	248,321	40,437	-$22	-$18
2020	308,718	50,885	-$28	-$21
2021	364,304	60,723	-$35	-$25
2022	420,997	71,066	-$41	-$28
2023	478,223	81,729	-$47	-$30
2024	532,769	91,924	-$54	-$33
2025	582,709	100,921	-$61	-$35
2026	634,451	111,175	-$68	-$38
2027	684,006	121,129	-$75	-$40
2028	731,759	130,860	-$82	-$41
2029	778,365	140,541	-$90	-$43
2030	823,034	150,105	-$97	-$45
Total	**6,963,472**	**1,211,069**	**-733**	**-425**

Notes: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Integration Analysis Between TLU-2 and TLU-3

Both TLU-2 and TLU-3 were analyzed using the SmartGAP model to estimate GHG savings and total costs in year 2030. A combined run based on the inputs of both TLU-2 (denser development) and TLU-3 (increased transit infrastructure) was also completed, to estimate the combined impacts of these two policies in a single run.

Results from the combined run strongly indicated that, for this situation, the SmartGAP model did not immediately capture the full range of mutually reinforcing relationships between land use and transportation that the SHRP 2 report discusses (see Data Sources section). Time constraints prevented further investigation. Because of this uncertainty, results from the combined run are reported in the TLU-3 write-up, but not in the overall project summaries.

Key Assumptions

The policy option context and completeness of the Met Council data make it the best data source for the purposes of this analysis.

- Population forecasts from the Metropolitan Council were used for TLU-2 (and TLU-3) analysis. Met Council forecasts were used because they were integral to the development of the business as usual policies, and because of the additional specificity and effort invested in them previously. These forecasts include an additional 826,000 residents, 392,000 households, and 558,000 jobs between 2010 to 2040. Other policies in the overall CSEO project used statewide forecasts developed by others.
- Shifts in household characteristics – a growing senior population, more single-person households and an increasingly diverse population are likely to increase demand for a wider variety of housing options.
- Constrained funding for transportation, combined with population growth, will likely decrease unimpeded mobility, and increase the focus on alternate ways for people to access work, goods and recreation. This dynamic supports the notion of increasingly compact development patterns where more people can make short trips by car, bike, foot or transit.

Macroeconomic (Indirect) Policy Impacts

Table F-3.22: TLU-2 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
TLU-2	$4	-$2	-$31	500	220	3,290	$29	$10	$151

Graphs below show detail in GSP, employment and personal income impact of the TLU-2 policy.

Figure Ap F-25. TLU-2 Impacts on Gross State Product ($2015 MM)

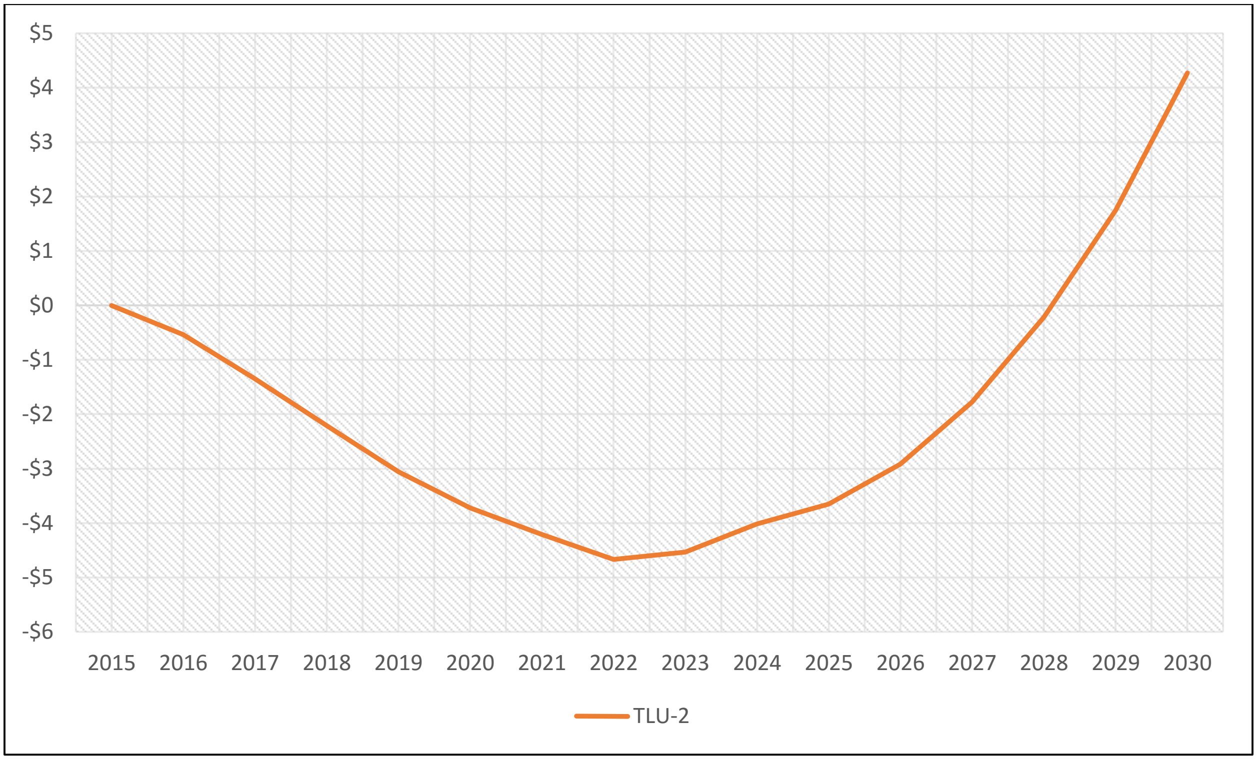


Figure Ap F-26. TLU-2 Impacts on Incomes ($2015 MM)

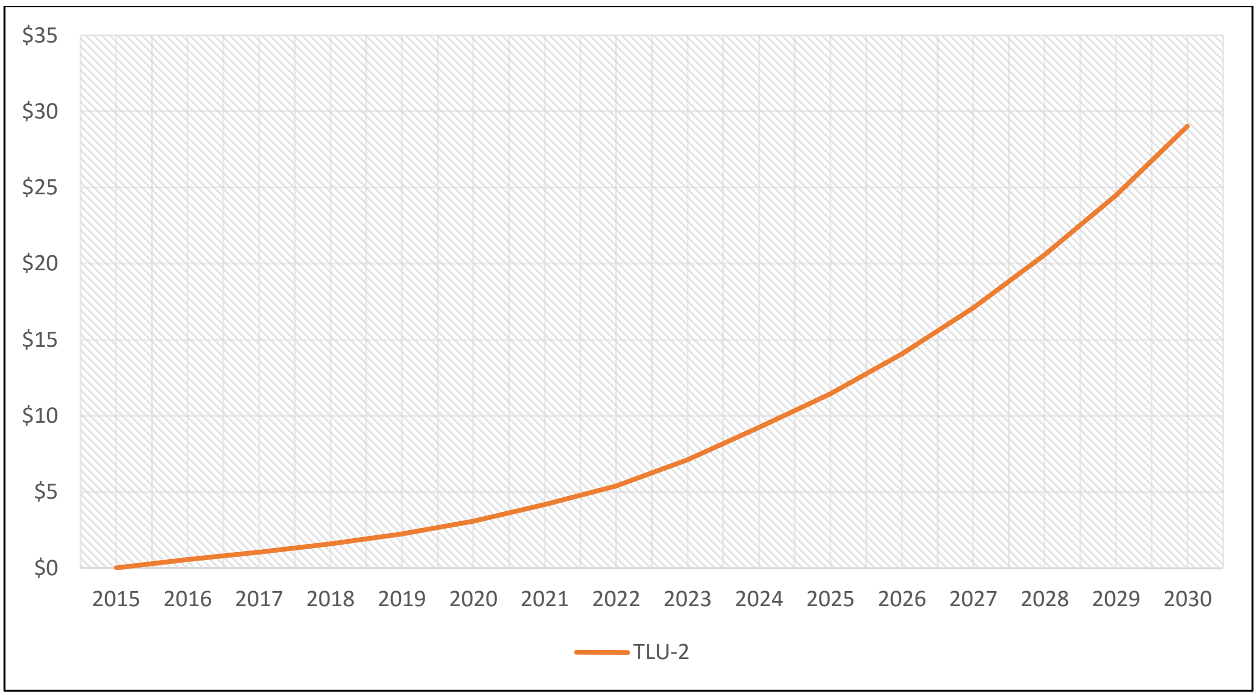
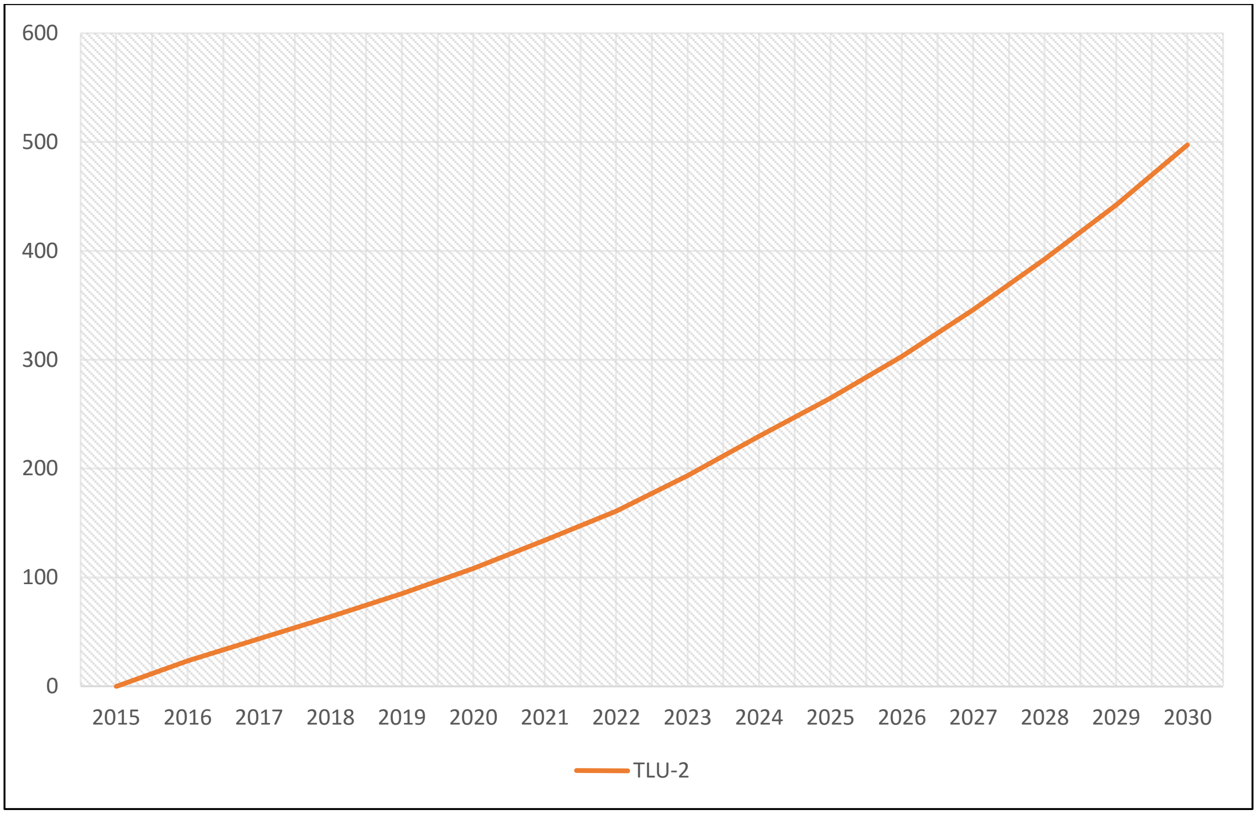
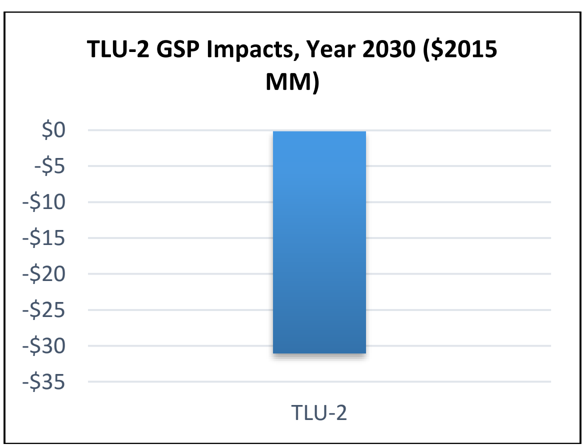
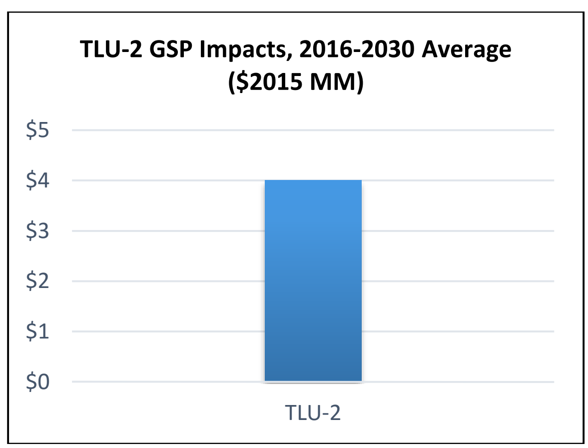


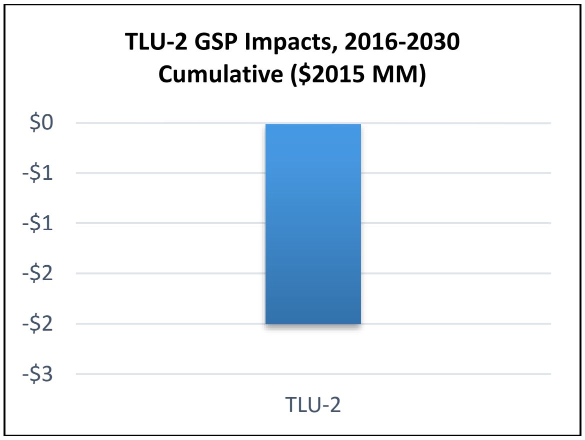
Figure Ap F-27. TLU-2 Impacts on Employment (Individual Jobs)

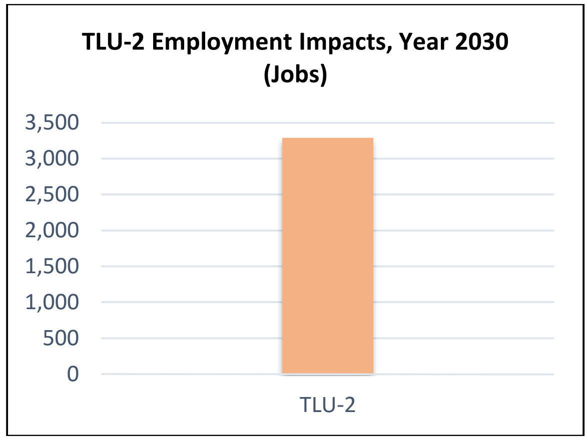


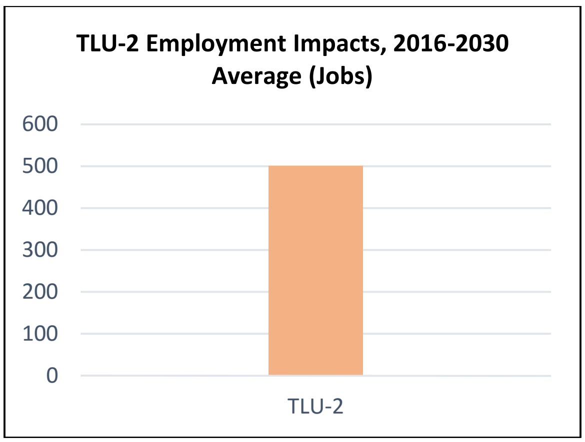
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030).

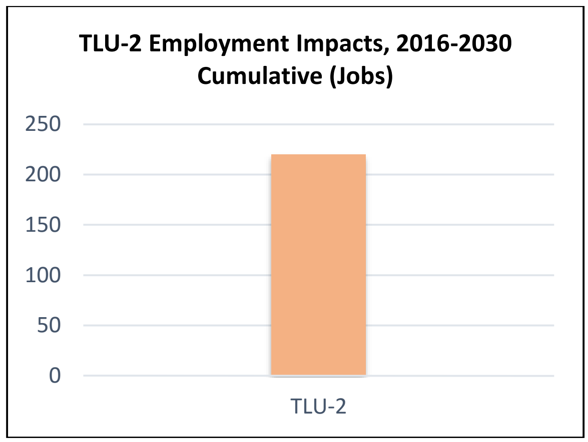


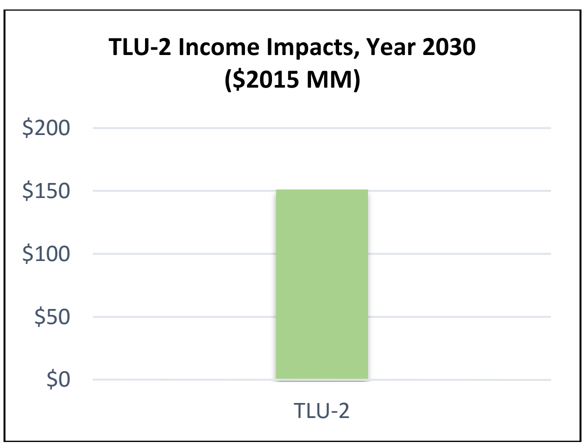


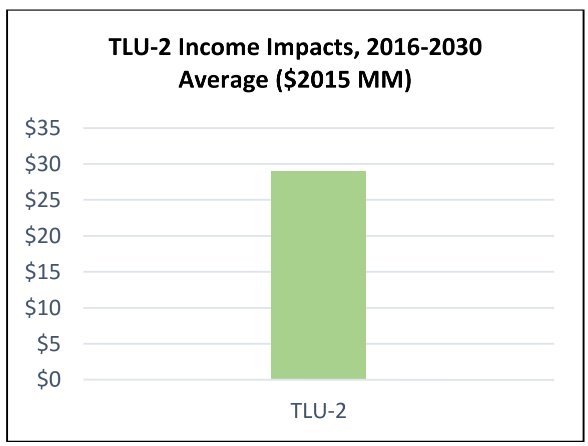

TLU-2 GSP Impacts, 2016-2030 Cumulative ($2015 MM)
$0
-$1
-$1
-$2
-$2
-$3
TLU-2

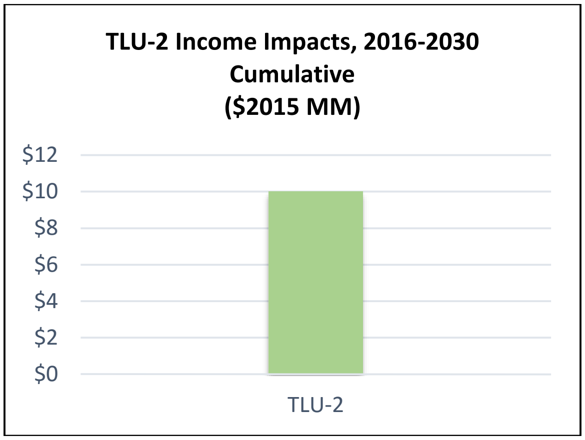

TLU-2 Employment Impacts, Year 2030 (Jobs)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
TLU-2


TLU-2 Employment Impacts, 2016-2030 Average (Jobs)
600
500
400
300
200
100
0
TLU-2


TLU-2 Employment Impacts, 2016-2030 Cumulative (Jobs)
250
200
150
100
50
0
TLU-2


TLU-2 Income Impacts, Year 2030 ($2015 MM)
$200
$150
$100
$50
$0
TLU-2


TLU-2 Income Impacts, 2016-2030 Average ($2015 MM)
$35
$30
$25
$20
$15
$10
$5
$0
TLU-2



Principal Drivers of Policy Impact on the Broader Economy

From TLU-2, the policy's drivers are very positive, as the total program costs to government are very small (less than $10 million per year even in the highest year) while savings to households on energy costs reach and even exceed $100 million in the final years. The policy anticipates significant reductions in the need for transportation energy and for heating energy from a more efficient urban form.

This follows the efficiency profile discussed in more detail in the RCII sector discussion. The reduction in spending from efficiencies pushes down total spending (and thus total GSP, which is measured by total spending). However, the money available as a result is now redirected to other spending, typically bringing the GSP impact back fairly close to neutral. The real benefits of efficiency are seen in the incomes and jobs gains, as commodity spending is replaced with value-added spending, which is more labor-intensive and requires more intermediate demands from other sectors of the economy.

Key Uncertainties

Major changes in urban form and development pattern can be expected to result in fiscal costs impacts, for costs (or savings) associated with infrastructure and services. These costs have only partially been identified and quantified.

This analysis relies on the SmartGAP model to estimate costs and GHG savings. This model is based on the results of the SHRP2 analysis, which are summarized in "The Effect of Smart Growth Policies on Travel Demand". However, with all modeling forecasts there is significant uncertainty with the results.

Additional Benefits and Costs

It is possible that reduced VMT as a result of denser development would result in reduced traffic injuries and fatalities.

TLU-3. Metropolitan Council Draft 2040 Transportation Policy Plan

Policy Option Description

The Metropolitan Council is currently updating the region's long range transportation plan known as the 2040 Transportation Policy Plan (2040 TPP). This plan is multimodal in character, addressing highway, transit, transitways, pedestrian facilities, bicycle facilities, freight, and aviation. Relevant objectives include reduced transportation-related air emissions; additional MnPASS managed lanes; additional transitways and arterial bus rapid transit lines; increased the use of transit, bicycling, and walking; increased availability of multimodal travel options.

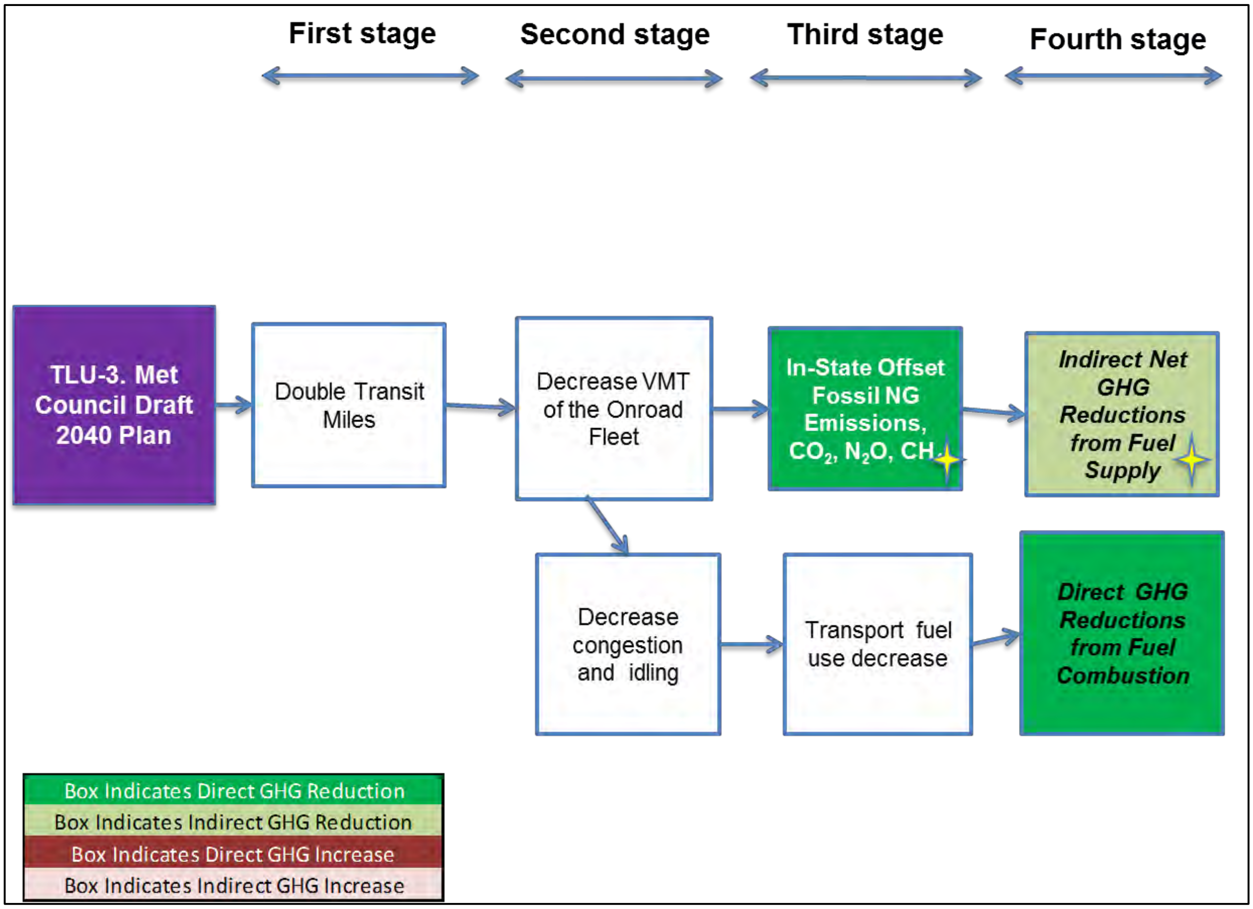
The 2040 TPP includes two investment scenarios: the Current Revenue Scenario (assumes revenues that can reasonably be expected to be available based on past experience and current laws and allocation formulas) and the Increased Revenue Scenario (assumes revenues that the region might reasonably be able to attain through policy changes, laws or decisions that increase local, state or federal funding sources. If additional revenues were provided, the projects in the Current Revenue Scenario could be implemented sooner, and the projects in the Increased Revenue Scenario also implemented by 2040.

For this policy option, the three focus areas from the 2040 TPP are:

- Expansion and operation of the MnPASS System
- Expansion and operation of the Transit System
- Expansion and operation of the Bicycle/Pedestrian System

Causal Chain for GHG Reductions

Figure Ap F-28. Causal Chain for TLU-3 GHG Reductions



The causal chain above identifies the main policy option effects and the subsequent GHG impacts. The star symbol identifies significant GHG effects that will be quantified.

Policy Option Design

Goals:

- Double transit ridership by 2030.

Timing:

As indicated above; assume implementation begins in 2015 with a linear progression toward the policy option goals.

Parties Involved:

State legislature, Minnesota Department of Transportation, Metropolitan Council, County Transit Improvement Board (CTIB), regional rail authorities.

Transit: Primarily operate and manage the existing bus network, continue operating Metro Mobility including anticipated growth to meet statutory requirements, continue operating Transit Link, continue providing Metro Vanpool subsidies, operate and maintain support systems, maintain and replace vehicles and existing facilities as needed, minimal expansion of vehicles and service to new markets or to improve experience of existing customers, and modernization of existing facilities.

Transitways: Continue to operate and maintain existing transit ways, implement METRO Orange Line (I-35W South BRT), implement METRO Green Line Extension (Southwest LRT), Implement METRO Blue Line Extension (Bottineau LRT), implement 4 arterial BRT projects.

Bicycle/Pedestrian: The 2040 TPP includes a proposed Regional Bicycle Transportation Network. Implementation of this network would come through TAP projects selected by TAB or local (state, county, city) street design and funding and rely on:

- Local planning
- Placement on highways
- Bicycle facility types that meet functionality
- Wide paved shoulders
- Bicycle boulevards
- Conventional bicycle lanes
- Buffered bicycle lanes
- Cycle tracks

Transitways:

Additional transit ways that would be implemented

Gateway*	Arterial BRT Projects
Highway 36*	American Boulevard
I-35W North*	Central Avenue NE
METRO Red Line – Future Stages*	Chicago-Emerson-Fremont
Red Rock*	East 7th Street
Riverview*	Hennepin Avenue
Robert Street*	Lake Street
Rush Line*	Nicollet Avenue

Highway 169	Penn Avenue
I-394	Robert Street
Midtown	West Broadway

*Transitway considered for acceleration by CTIB.

Implementation Mechanisms

The relevant state and regional agencies work with the state legislature to identify and commit sufficient financial resources to fund the Increased Revenue Scenario as outlined in the 2040 TPP.

Implement two additional LRT lines, one highway BRT line and 4 arterial BRT lines by 2040.

Related Policies/Programs in Place and Recent Actions

In January 2012, Governor Dayton established the Transportation Finance Advisory Committee with a charge to develop recommendations for the next 20 years to fund and finance the state's highways, roads, bridges, and public transport systems. That committee developed recommendations for increased funding from a variety of sources, such as increased motor vehicle registration fees, increased per-gallon excise tax rate on motor fuels, transit oriented sales tax, expand the option of local wheelage tax, enable formation of Transportation Improvement Districts, enable local sales taxes for transportation without need of a referendum, expand regional transit capital levy, expand MnPASS system, employ value capture concepts around transportation improvements. Several additional areas were recommended for further study as well.

Estimated Policy Impacts

Direct Policy Impacts

Table Ap F-3.23: TLU-3 Estimated Net GHG Reductions and Net Costs or Savings

2030 In-State GHG reductions ($TgCO_2e$):	2015 – 2030 Total cumulative reductions (tCO_2e):	Net present value of societal costs, 2015 – 2030 ($MM2014):	Cost effectiveness ($2014/$tCO_2e$):
0.25	**2.6**	**-$330**	**-$126**

The table below provides a summary of the expected impacts on jobs and economic growth during the CSEO planning period [*insert the results of macro-economic analysis*]

Table Ap F-3.24: TLU-3 Indirect Economic Impacts

Macroeconomic (Indirect) Impacts Results

Scenario	GSP[a] ($2015 MM)			Employment[b] (Individual)			Personal Income[c] ($2015 MM)		
	Year 2030[d]	Average (2016-2030)[e]	Cumulative (2016-2030)[f]	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
TLU-3 Low Transit $	$90	$41	$608	830	450	6,740	$43	$20	$302
TLU-3 High Transit $	$125	$165	$2,477	1,330	1,720	25,860	$78	$138	$2,068

Data Sources

Strategic Highway Research Program, 2013. "The Effect of Smart Growth Policies on Travel Demand". Can be found online at: http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2prepubC16.pdf

FHWA, 2014. Smart Growth Area Planning Tool (SmartGAP) Model. Information and User's Guide can be found here: https://www.fhwa.dot.gov/planning/tmip/publications/other_reports/smartgap/index.cfm

Texas Transportation Institute, "Urban Mobility Report", latest version is currently from 2012. Located online at: http://mobility.tamu.edu/ums/

Quantification Methods

This policy option examines the VMT, fuel consumption and cost impacts of expanded transit use within the 7 county Metro area. The TLU workgroup determined that this type of expanded transit policy option is not practical for the rest of the state. Any analysis outside of the Metro area should be modeled separately.

Scenario TLU-3 models the economic and environmental impacts of doubling transit ridership by 2030 The Federal Highway Association's SmartGAP model was used to perform this modeling. The SmartGAP model was created as part of the second Strategic Highway Research Program (SHRP 2) Capacity Project. The SmartGAP model is a macroscopic scenario planning tool that can be used to evaluate the impacts of various smart growth policies. The SmartGAP model synthesizes households and firms in a region and determines their travel demand characteristics based on their built environment and transportation policies. The model also allows spatial distributions of population and employment to shift, in response to the future accessibility terrain. For the present analysis, we have used the SmartGAP model to estimate the impacts of doubling transit usage on the seven-county Metropolitan area (Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington counties).

SmartGAP provides an estimate of GHG and VMT impacts, as well as overall cost in the forecast year. In order to estimate the impacts of various policies, a business-as-usual scenario is compared against a policy option scenario, and the overall costs and GHG impacts are estimated based on the difference between these two scenarios. This output is provided only for the final year of the analysis, in this case 2030. For this analysis, a linear growth from 2015 (0% implementation) to 2030 (100%) is assumed.

TLU-3 estimates the GHG and economic impacts of the Met Council-proposed 2030/40 transportation system investments in the metro region. The business-as-usual case is the fiscal-constrained highway investment program, with no new transit ways. The alternative scenario includes Met Council-proposed system investments. Both scenarios are discussed and documented in Met Council's regional transportation plan. It is worth remarking, the BAU vs. alternative difference in transport network measures (VMT, trips, etc.) is slight when spatial distributions of population and employment are held constant.

Met Council staff provided regional population growth and employment growth forecasts, distributions of that growth by community type, auto trip rates, transit trip rates, daily VMT totals, the highway share of that daily VMT, households growth, and distributions by housing type. This data was input into the SmartGAP model for this analysis. In many cases (for example, housing distribution), this information is the same or similar for both the BAU and scenario analysis. The significant difference between the BAU and the policy option scenario is that within the model, the policy option scenario doubles transit (Bus and Rail) demand in the forecast year.

The SmartGAP model estimates the GHG savings and economic impacts of TLU-3 by comparing the BAU scenario against the expanded transit policy option scenario. The net change between these two runs is displayed in Table 3-1 below. This analysis assumes a linear implementation path as the policy option has gradually increasing effects between 2015 and 2030. The impacts from 2031 onward are not estimated in this analysis, but would likely be higher as analyses focusing on increasing transit infrastructure and use typically realize results over a long time frame.

Table Ap F-3.25: SmartGAP Estimated GHG and VMT Impacts of TLU-3

	Implementation Path	GHG Savings, Expanded Transit (tCO_2e)	TLU-3 Annual VMT Reduced (Million Miles)
2015	0%	0	0
2016	7%	16,659	62
2017	13%	33,318	123
2018	20%	49,977	185
2019	27%	66,636	247
2020	33%	83,295	309
2021	40%	99,953	370
2022	47%	116,612	432

2023	53%	133,271	494
2024	60%	149,930	556
2025	67%	166,589	617
2026	73%	183,248	679
2027	80%	199,907	741
2028	87%	216,566	803
2029	93%	233,225	864
2030	100%	249,884	926
Total		**1,999,070**	**7,408**

The SmartGap model segments the metro region into community types and neighborhood types. In the TLU-3 scenario, VMT is reduced in all parts of the region. Specifically, in the urban core and close-in, first-ring suburbs, total VMT and VMT per capita is substantially reduced as the future population makes use of enhanced and expanded transit services. Concurrently, total VMT in lower-density suburbs and rural areas is also reduced as result of a small marginal reduction (-3.5%) in suburban and rural populations; the population reduction is balanced by an equivalent population increase in the urban core and close-in, first-ring suburbs.

Table 3-2 shows the estimated costs of the TLU-3 policy option. The government expenditures estimated through the SmartGAP model are estimated to be significant for the 2015-2030 period. However, these costs are more than made up for at the consumer level, where reduced trips and reduced fuel and vehicle costs more than make up for the increase in transit infrastructure expenditures. Note that the societal spending includes both the government spending and private spending.

The additional government spending within the SmartGAP model includes additional capital costs in transit/transportation infrastructure, the operating and maintenance costs of the transit system and the additional costs to the user of transit fares. The cost savings from the SmartGAP run are the result of reduced vehicle use, which includes reduced fuel costs, fuel taxes, vehicle purchase costs, vehicle maintenance, insurance costs, and a monetized value of travel time. Travel time value comes from the Texas Transportation Institute's Urban Mobility Report. The SmartGAP model estimates transit infrastructure and operating costs based on the costs in the National Transit Database, which are from 2009. The model assumes that some users will forego vehicle ownership entirely when additional transit options are available.

Table Ap F-3.26: SmartGAP Estimated Costs of TLU-3

	Implementation Path	TLU-3 Additional Govt. Spending ($ Millions)	TLU-3 Net Societal Spending ($ Millions)	TLU-3 Discounted Net Societal Spending ($2014 millions)
2015	0%	$0.0	$0.0	$0.0
2016	7%	$4.5	-$4.7	-$4.3

2017	13%	$9.0	-$9.4	-$8.1
2018	20%	$13.5	-$14.1	-$11.6
2019	27%	$18.0	-$18.8	-$14.7
2020	33%	$22.5	-$23.5	-$17.5
2021	40%	$27.0	-$28.2	-$20.1
2022	47%	$31.5	-$32.9	-$22.3
2023	53%	$36.0	-$37.6	-$24.2
2024	60%	$40.5	-$42.3	-$26.0
2025	67%	$45.0	-$47.0	-$27.5
2026	73%	$49.5	-$51.7	-$28.8
2027	80%	$54.0	-$56.4	-$29.9
2028	87%	$58.5	-$61.1	-$30.9
2029	93%	$63.0	-$65.8	-$31.7
2030	100%	$67.5	-$70.5	-$32.3
Total		**$540.0**	**-$564.3**	**-$329.9**

Integration Analysis for TLU-2 and TLU-3

Both TLU-2 and TLU-3 were analyzed using the SmartGAP model to estimate GHG savings and total costs in year 2030. A combined run based on the inputs of both TLU-2 (compact development) and TLU-3 (increased transit infrastructure) was also provided to estimate the combined impacts of these two policies in a single run. This ideally should provide an estimate of whether the combined benefits of the two policies would overlapping (as in, the benefits of the two combined policies is less than the two separately), additive or synergistic (the benefits are greater than the sum of the two policies separately).

Results from the combined run strongly indicated that, for this situation, the SmartGAP model did not immediately capture the full range of mutually reinforcing relationships between land use and transportation that the SHRP 2 report discusses (see Data Sources section). Time constraints prevented further investigation. Because of this uncertainty, results from the combined run are reported below and also mentioned in the TLU-2 write-up, but not in the overall project summaries.

This run was performed by evaluating both the compact development elements of TLU-2 and the increased transit availability and costs of TLU-3. The GHG impacts of the combined run is displayed in Table 3-3 below.

Table Ap F-3.27: SmartGAP Estimated GHG and VMT Impacts of Combined TLU-2 and TLU-3 Policy Option

	Implementation Path	GHG Savings, Expanded Transit (tCO_2e)	Annual VMT Reduced (Million Miles)
2015	0%	0	0
2016	7%	17,228	88
2017	13%	34,455	175
2018	20%	51,683	263
2019	27%	68,910	351
2020	33%	86,138	439
2021	40%	103,365	526
2022	47%	120,593	614
2023	53%	137,820	702
2024	60%	155,048	790
2025	67%	172,275	877
2026	73%	189,503	965
2027	80%	206,731	1,053
2028	87%	223,958	1,140
2029	93%	241,186	1,228
2030	100%	258,413	1,316
Total		**2,067,305**	**10,527**

Both the GHG Savings and the VMT reductions are similar to the sum of the results of the TLU-2 and TLU-3 policies considered separately. GHG Savings are slightly higher in the combined run, and the VMT reduction is slightly lower, but in both cases this difference is very small (less than 0.5% of the total).

Total costs of the combined run are displayed in Table 3-4 below. Costs have increased in the combined run, as compared to the additive impacts of TLU-2 and TLU-3. For example, the additional government spending of TLU-2 for 2015-2030 is $54 million, and for TLU-3 is $540 million, for a combined total of $594 million. In comparison, the combined SmartGAP run indicated costs of $680 million for the 2015-2030 period. The cost savings within the combined run are more or less comparable, once those additional costs are taken into account. Costs are estimated to be $86 million higher in the combined scenario, and overall cost savings are $86 million lower. There could be a variety of factors that could lead to this change in costs, but it is most likely the result of increased transit costs in a more densely developed area.

Table Ap F-3.28: SmartGAP Estimated Costs of Combined TLU-2 and TLU-3 Policy Option

	Implementation Path	Additional Govt. Spending ($ Millions)	Net Societal Spending ($ Millions)	Discounted Net Societal Spending ($ millions)
2015	0%	$0.0	$0.0	$0.0
2016	7%	$5.7	-$5.0	-$4.6
2017	13%	$11.3	-$10.1	-$8.7
2018	20%	$17.0	-$15.1	-$12.4
2019	27%	$22.7	-$20.2	-$15.8
2020	33%	$28.3	-$25.2	-$18.8
2021	40%	$34.0	-$30.2	-$21.5
2022	47%	$39.7	-$35.3	-$23.9
2023	53%	$45.3	-$40.3	-$26.0
2024	60%	$51.0	-$45.4	-$27.8
2025	67%	$56.7	-$50.4	-$29.5
2026	73%	$62.3	-$55.4	-$30.9
2027	80%	$68.0	-$60.5	-$32.1
2028	87%	$73.7	-$65.5	-$33.1
2029	93%	$79.4	-$70.6	-$33.9
2030	100%	$85.0	-$75.6	-$34.6
Total		**$680**	**-$605**	**-$354**

Key Assumptions

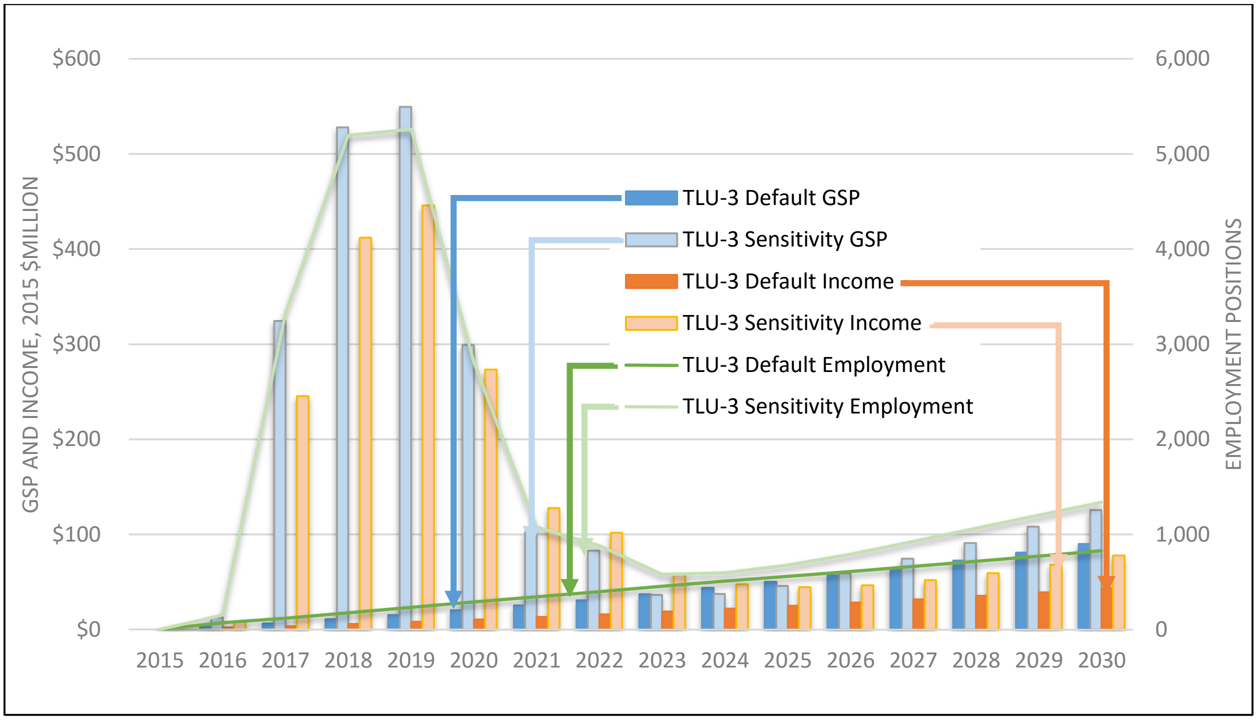
- Ideally, models are conceived and structured to represent the systems at issue, apply appropriate methods, and use reliable data. Still this does not eliminate the uncertainties inherent in modeling: The dynamics of represented systems change over time.
- There may be other, unknown limitations or issues associated with FHWA's SmartGap model.
- This analysis assumes the year 2030 employment and population levels forecasted by Metropolitan Council. Policy context and completeness of the Met Council data make it the best data source for the purposes of this analysis. However, over the course of three decades actual economic and population growth of the metro area could be higher or lower than Metropolitan Council forecasts.

Table F-3.29: TLU-3 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
TLU-3 Low Transit $	$90	$41	$608	830	450	6,740	$43	$20	$302
TLU-3 High Transit $	$125	$165	$2,477	1,330	1,720	25,860	$78	$138	$2,068

In TLU-3 policy analysis, a sensitivity scenario is also used for analyzing the macroeconomic impacts of the policy. The sensitivity scenario assumes higher capital cost of transit (the values are provided by MAT Council) than the capital costs assumed in the default scenario. The comparison of indirect macroeconomic results is shown in the graph below.

Figure Ap F-3.29: TLU Policy Impacts of Different Capital Cost Assumptions



Graphs below show annual changes in GSP, employment and personal income impact of the TLU-3 policy, both in the default and the sensitivity scenario.

Figure Ap F-30. TLU-3 Impacts on Gross State Product ($2015 MM)

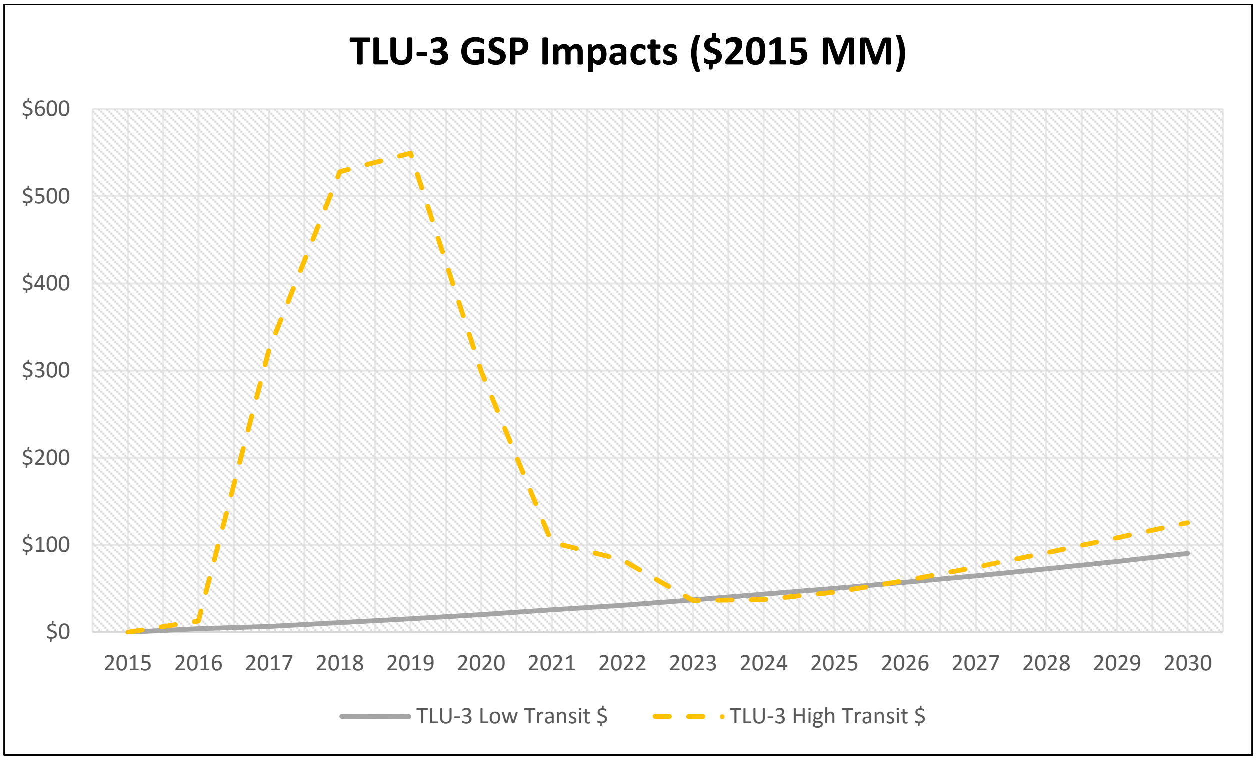


Figure Ap F-31. TLU-2 Impacts on Income ($2015 MM)

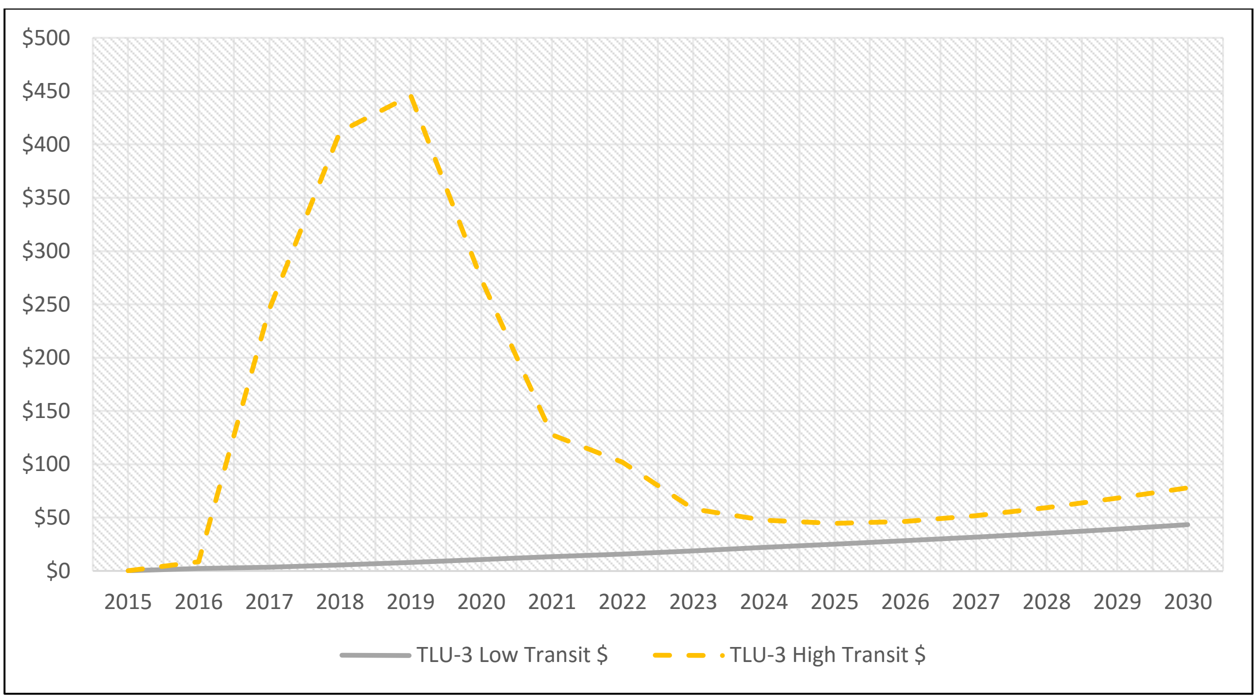
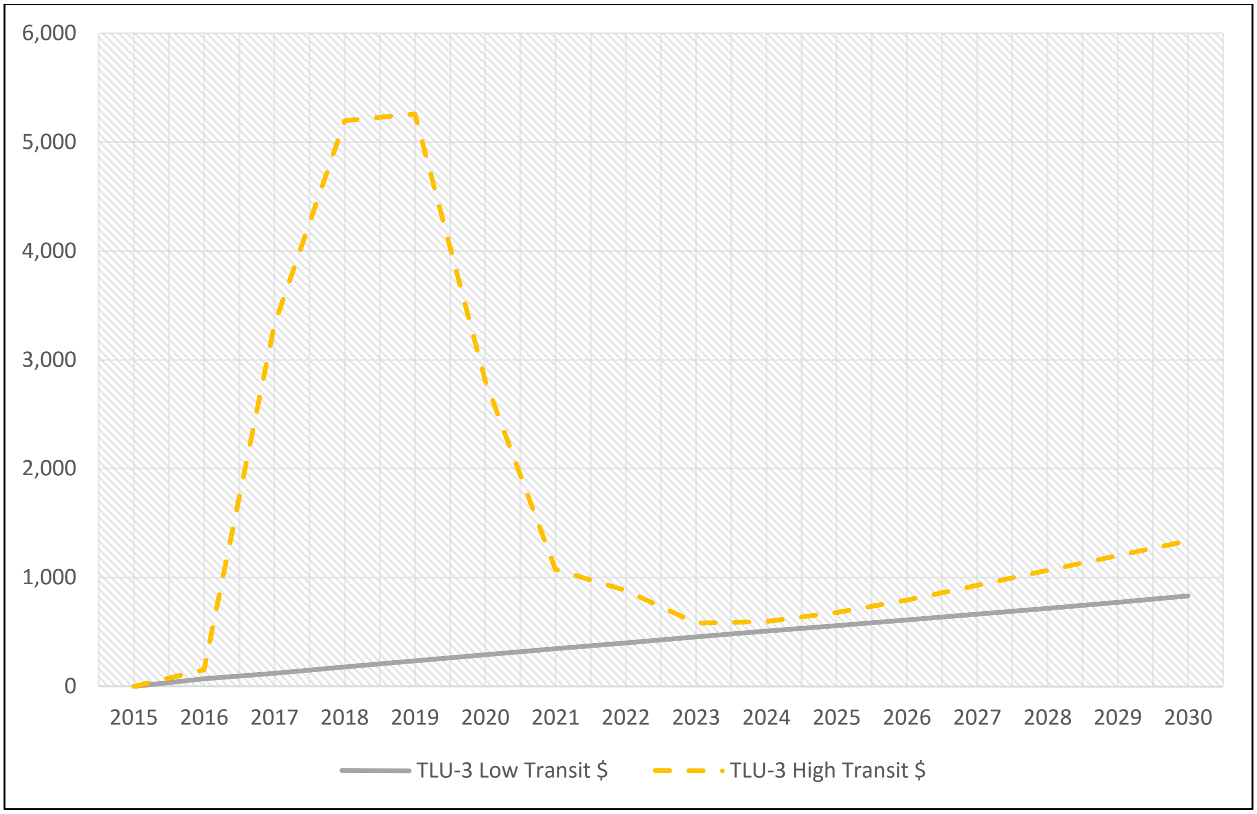
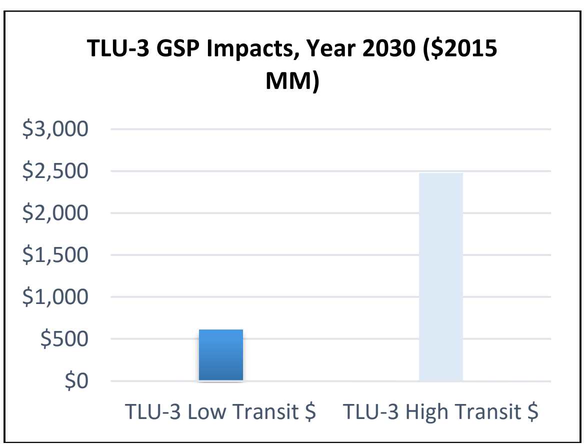
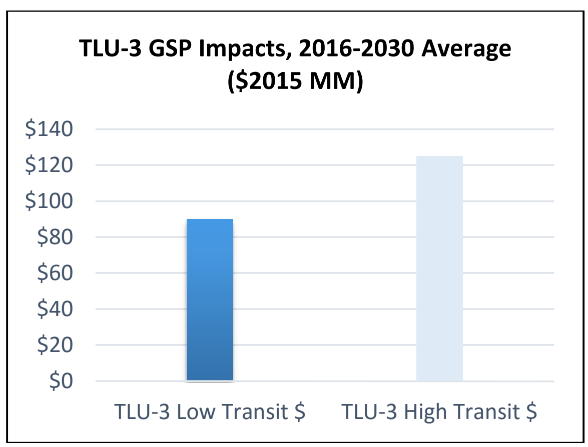


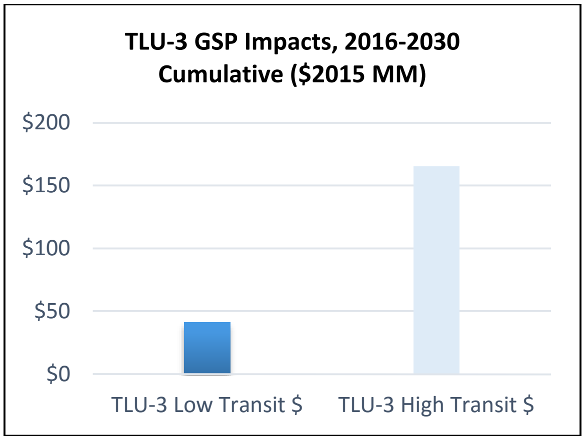
Figure Ap F-32. TLU-2 Impacts on Employment (Individual Jobs)

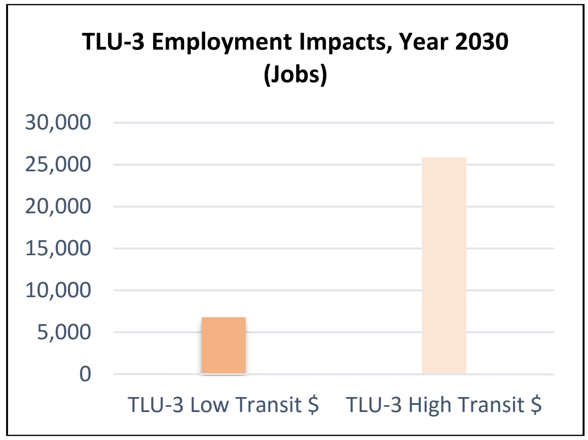


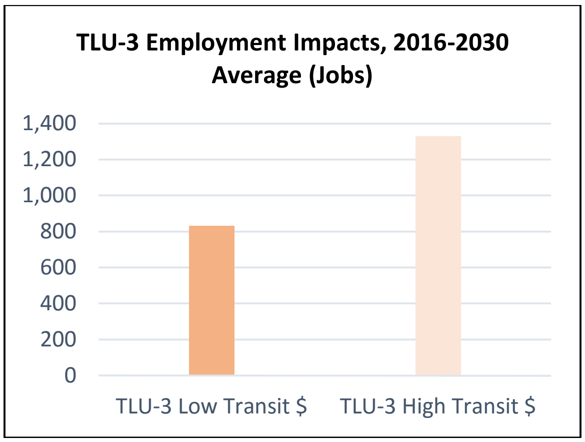
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), average (2016-2030) and cumulative (2016-2030). Lighter color indicates the sensitivity scenarios.

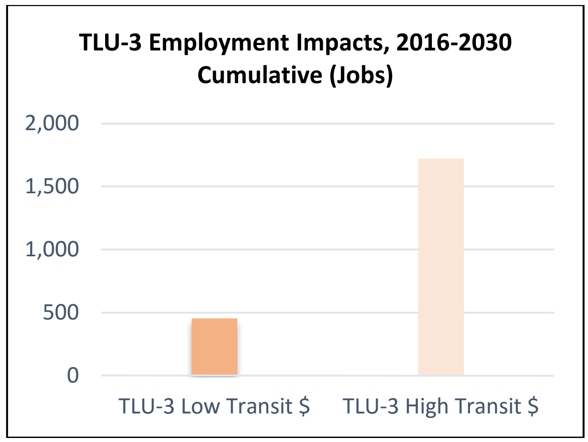


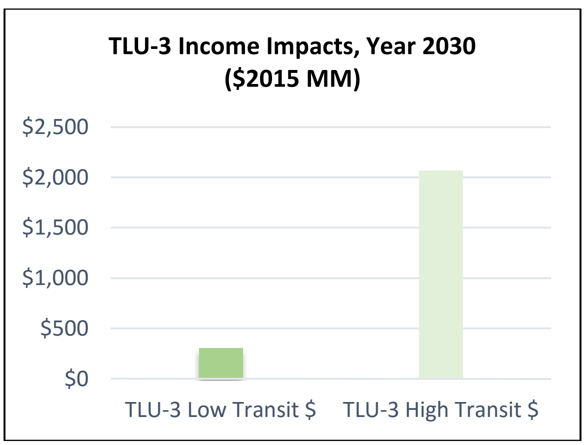


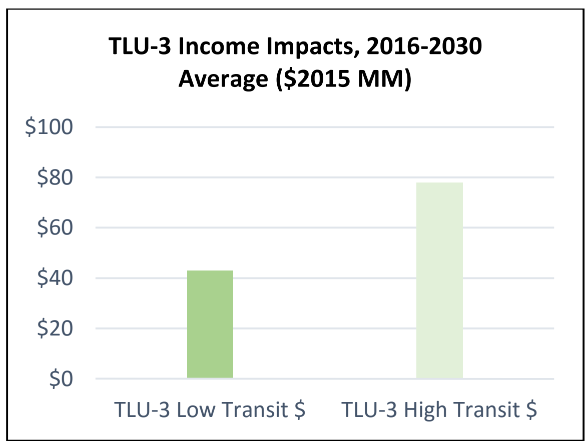

TLU-3 GSP Impacts, 2016-2030
Cumulative ($2015 MM)
$200
$150
$100
$50
$0
TLU-3 Low Transit $
TLU-3 High Transit $

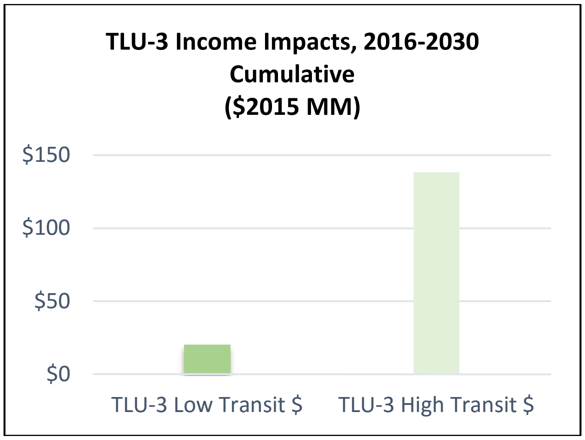

TLU-3 Employment Impacts, Year 2030
(Jobs)
30,000
25,000
20,000
15,000
10,000
5,000
0
TLU-3 Low Transit $
TLU-3 High Transit $


TLU-3 Employment Impacts, 2016-2030
Average (Jobs)
1,400
1,200
1,000
800
600
400
200
0
TLU-3 Low Transit $
TLU-3 High Transit $


TLU-3 Employment Impacts, 2016-2030
Cumulative (Jobs)
2,000
1,500
1,000
500
0
TLU-3 Low Transit $
TLU-3 High Transit $


TLU-3 Income Impacts, Year 2030
($2015 MM)
$2,500
$2,000
$1,500
$1,000
$500
$0
TLU-3 Low Transit $
TLU-3 High Transit $


TLU-3 Income Impacts, 2016-2030
Average ($2015 MM)
$100
$80
$60
$40
$20
$0
TLU-3 Low Transit $
TLU-3 High Transit $



Principal Drivers of Macroeconomic Changes

The first major driver of positive impacts of this policy is the significant savings that travelers in the Minneapolis-St. Paul metro area encounter by switching to transit.

- The additional transit costs paid by the new riders was estimated as part of the macroeconomic analysis to represent one third of the transit system's operating costs. This cost came out to a value beginning at approximately $1 million, and rising to $16 million by 2030.
- By comparison, the fuel savings avoided by reductions in the volume of driving (below a business-as-usual scenario) are nearly ten times that scale, rising from $9 million saved to approximately $138 million saved by 2030.
- The resulting savings is redirected from petroleum spending, which largely purchases imports and is very poor in terms of jobs creation, to other consumer spending, which directs money far more to domestically produced goods and services and is better in terms of jobs creation.

A second driver, though smaller, is an improvement in the labor access index. Improved transit systems expand access between labor and employers, improving the allocation of labor through better choice and improving productivity through shorter commute times. In macroeconomic models, this represents an increase in productivity. In this policy, the improvement is slight – 0.03% - but this will improve the output of the metro area's economy as a result.

Government spending on transit capital and operations expands to cover all the costs that the farebox revenue does not, but these costs must be offset with reductions in other government spending. Using the Federal Highway Administration model, this expenditure and its offset are less clearly a driver of the positive impacts shown in the results. However, using the Met Council estimates of capital spending required to build out this transit infrastructure, the investment is a far greater stimulus to the economy. The presence of an assumed 50% federal match to state and local funds to cover this cost means that this higher-cost scenario is actually far more positive for the economy, as the larger flow of federal dollars creates more stimulus. The resulting transit network is the same, and after the larger spike of investment ends, the economy shows the same minor (though still positive) gains as a result of lower transportation costs and a slightly higher labor access index.

Key Uncertainties

In recent years, two other studies have evaluated the impacts of building out the planned transit system. These studies were:

- Itasca Group: Regional Transit System Return on Investment Assessment
- Draft 2040 Transportation Policy Plan

These two previous studies, along with the analysis conducted by this effort provide a range of VMT reduction estimates and resulting CO_2e reductions. Each of the set of estimates were based in sound practice. However, there are differences, highlighted below, which result in differing impact estimates.

The present analysis relies on the SmartGAP model to estimate costs and GHG savings. This model is based on the results of the SHRP2 analysis, which are summarized in "The Effect of Smart Growth Policies on Travel Demand". However, SmartGAP appears to adjust the spatial distributions of population, households and employment based on the transportation investments.

The Itasca Group: Regional Transit System Return on Investment Assessment was conducted in 2011 predating the development of Thrive MSP 2040 population, household and employment data. As such, the ROI work was based on forecast 2030 socio-economic data. A comparison of the data between that used for the ROI work and that developed for Thrive MSP 2040 shows slower growth during 2010 to 2040 than was previously projected for 2030 in the earlier data set. Additionally, the ROI model network included one more LRT line than does the 2040 TPP, two more highway BRT lines, and five more arterial BRT lines. In the ROI study scenario, all of these transit system improvements were assumed to be complete and operational by 2023 – a highly aggressive assumption.

The modeling for the 2040 Transportation Policy Plan (TPP) was conducted using the region's standard four-step regional travel demand model. Population, household and employment allocations were held constant as to their location between the build and no-build scenarios. CO_2 equivalents were estimated using the EPA emissions model MOVES2010b.

Additional Benefits and Costs

Reduced emissions and increased use of transit, bicycling and walking may confer significant health benefits. (Younger) In particular, switching from driving to bicycling can not only reduce emissions but increase physical activity and reduce chronic diseases and deaths due to a sedentary lifestyle. (Rojas-Rueda) A study of the Midwest region found that eliminating short car trips and completing 50% of them by bicycle would result in fewer deaths due to improved air quality and fewer deaths due to increased physical activity. (Grabow et al.).

Ensuring the safety of pedestrians and cyclists as this plan is implemented will be critically important to reduce transit injuries. As with TLU-2, implementation of this plan may also provide communities with increased access to beneficial health services and nutrition.

Figure Ap F-33. Potential Health Benefits of TLU-3

*Reducing transit-related emissions is likely to reduce the risk for respiratory and cardiovascular illness, cancer, stress, premature birth weight, and premature death in exposed populations.

TLU-4. Zero Emission Vehicle Standard

Policy Option Options

The Zero Emission Vehicle (ZEV) Standard policy option would require automobile manufacturers, through their dealerships, to have a percentage of the total light and medium duty vehicle sales in Minnesota, designated as electric vehicle sales. This regulatory approach for states to increase use of electric in place of gasoline-powered vehicles through use of sales quotas, is allowed under the federal Clean Air Act, Section177, by the U.S. Environmental Protection Agency.

Electric vehicles are designated as ZEVs because these vehicles have zero emissions from the tailpipe when operating on battery power. ZEVs are four times more efficient than gasoline powered vehicles and have the unique capability of directly using renewable solar or wind-generated electricity for power. These electric vehicles can be plugged-in and charged at night, taking advantage of off-peak electricity production, to help balance utility production load. Transitioning vehicles from use of petroleum-based fuels to electricity reduces the state GHG emissions due to:

- An increase in energy efficiency from use of electric vehicles in place of gasoline-powered vehicles;
- Existing policies designed to incrementally deploy cleaner generation in the state's electricity grid.
- In 2010, 24% of GHG emissions in Minnesota were from the transportation sector, second only to electric utility GHG emissions. Addressing both sectors at the same time, leveraging the synergies between cleaner electricity production and electricity use, will result in bold GHG emissions reduction. California and nine other states view the ZEV

regulatory program as a primary means of meeting their respective GHG reduction goals.

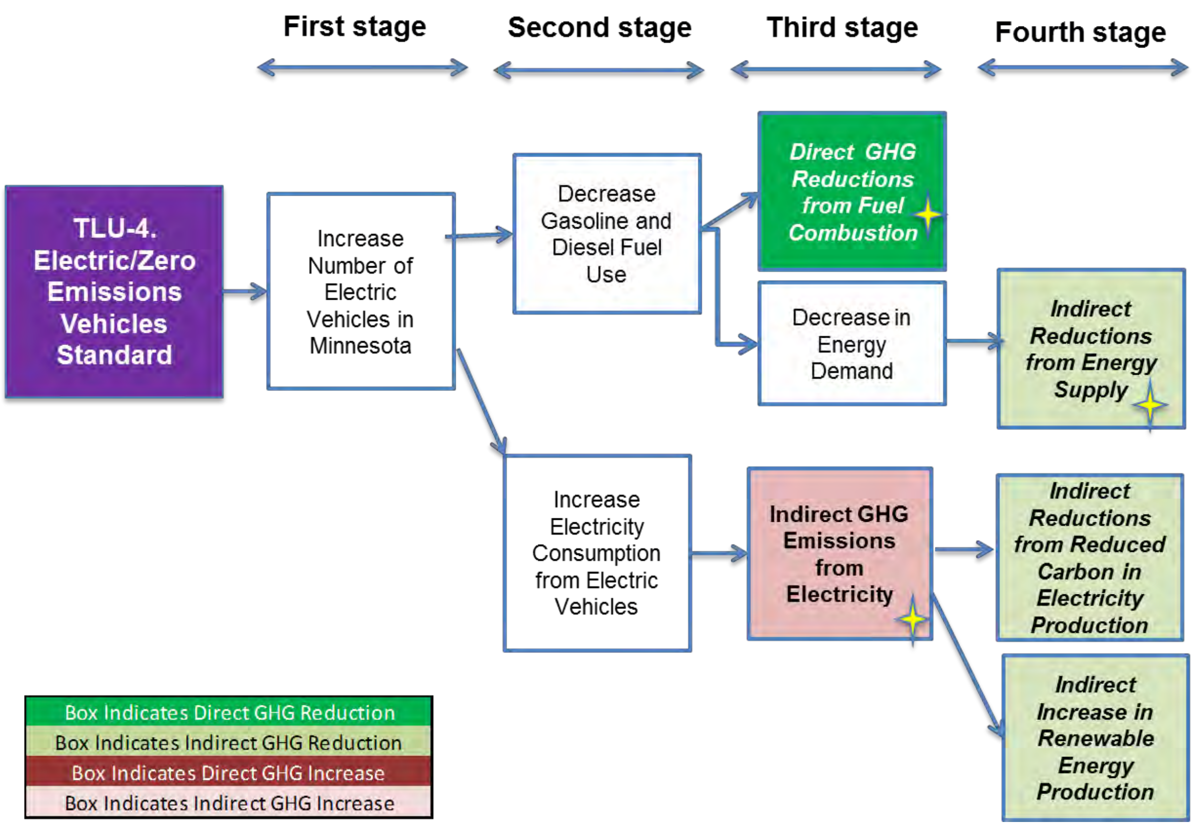
Modeling limits: EVs are an emerging technology with great potential and a lot of unknowns for the role they might play in society. The potential of EVs to reduce GHG emissions is determined by the power generation of the electricity. For instance, electricity generated from coal has much higher emissions than electricity generated from a solar or wind. Integration of EVs into the electric grid represents new demand on the system, how clean the energy is to meet that demand will determine how clean EVs are for the system. Depending on time of day for charging, EVs could even out load demand or increase the intensity of demand peaks. Minnesota and several states are already beginning to design programs around time of day pricing structures to even out demand. At high penetration levels, EVs could be used as storage for the electric grid, where at peak times the system could pull electricity from plugged in vehicles.

As adoption of EVs increases in Minnesota and other parts of the country we will have better information about their integration on systems and we will see what innovations evolve. For this study, much of these considerations were beyond the scope of the modeling work. To capture the full potential of EVs and illustrate the uncertainty that hinges on the power source of generation, we model bookend numbers. We model:

- EVs as new demand that are met with the electricity at the margin, this is 80/20 coal/natural gas in 2015 and going to 50/50 in 2030.
- EVs with 100% renewable energy.

Causal Chain for GHG Reductions

Figure Ap F-34. Causal Chain for TLU-4 GHG Reductions



The causal chain above identifies the main policy option effects and the subsequent GHG impacts. The star symbol identifies significant GHG effects that will be quantified.

Policy Option Design

Adoption of the ZEV Standard would significantly advance the use of electric vehicles, along with an anticipated growth of the charging infrastructure to allow for ease of travel in urban and along high-traffic destination corridors such as tourism routes, while leveraging use of renewable sources of energy, by 2030.

Goals (starting in 2017 and continuing through 2030):

- Achieve 10% or 450,000 registered cumulative penetration of ZEVs registered in Minnesota.
- Installation of Level 2 (240 volt, full charge in 2 to 4 hours) or DC Fast Charger (480 volt, full charge in 15 t0 25 minutes) plug-in public charging stations at increments no greater

than every 50 miles in high population density and high-traffic corridors throughout the state.

- Education and outreach goal to result in powering 50% of the charging stations with renewable electricity production.

Timing: During the 2015 Minnesota Legislative session advance and support either the regulatory Zero Emissions Vehicle Standard.

Parties Involved:

Implementation: State Legislature, Governor's Office, Minnesota Departments of Environmental Quality, Natural Resources, Commerce, MPCA, Department of Public Safety, and electric utilities.

Affected parties: fuel retailers, electric utilities, auto manufacturers, auto dealerships, and consumers.

Other:

This analysis looks at the impact of Minnesota adopting the ZEV portion of the California vehicle emission standards. Adopting only the ZEV requirements is possible because Minnesota has a State Implementation Plan due to two carbon monoxide (CO) maintenance areas. 4.2% is the percentage of ZEV Memorandum of Understanding (MOU) state residents who would have a ZEV under the MOU's 3.3 million goal. The collective target for the ZEV states is to have 3 million ZEVs on the road by 2025. Based upon Minnesota's population in comparison to the other ZEV states – should Minnesota join, it would need 220,000 ZEVs on the road by 2025. This is used as a target for this analysis. For 2026-2030, the number of new vehicles is held at the same number as 2025. Vehicles are also being replaced after ten years, so 2015 vehicles will be replaced in 2026, etc. The total number of EVs and the number of new EVs sold per year are shown in Table Ap F-64 below.

Table Ap F-3.30: EVs Needed in the TLU-4 Analysis

Year	Total # EVs	New EVs Sold Per Year
2015	5,000	5,000
2016	7,300	2,300
2017	10,658	3,358
2018	15,561	4,903
2019	22,719	7,158
2020	33,169	10,451
2021	48,427	15,258
2022	70,703	22,276
2023	103,227	32,524
2024	150,711	47,484
2025	220,038	74,327

Year	Total # EVs	New EVs Sold Per Year
2026	291,666	71,627
2027	362,051	72,685
2028	432,923	74,230
2029	504,505	76,485
2030	577,125	79,778

Implementation Mechanisms

Adoption of the ZEV Standard involves:

- Potential legislative action (subject to state legal counsel review and decisions);
- An optional Governor's Executive Order outlining the program and expectations;
- Adoption of the ZEV states' Memorandum of Understanding.
- The standards approved the U.S. Environmental Protection Agency are already in place. Related rulemaking, organizational support design, and staff assignments would subsequently be undertaken by the MPCA.

Related Policies/Programs in Place and Recent Actions

The following ZEV related policy initiatives were enacted by the 2014 Minnesota State Legislature:

- **Public Fleet Procurement Section:** 1. Minnesota Statutes 2012, section 16C.135, subdivision 3, is amended to read:1.8 Subd. 3. **Vehicle purchases.** Consistent with section 16C.137, subdivision 1, 1.9when purchasing a motor vehicle for the central motor pool or for use by an agency the commissioner or the agency shall purchase a motor vehicle that is capable of being powered by cleaner fuels, or a motor vehicle powered by electricity or by a combination of electricity and liquid fuel if the total life-cycle cost of ownership is less than or comparable that of other vehicles, and if the vehicle is capable of carrying out the purpose for which it is purchased.

  Reporting: the Commissioner of Administration, in collaboration with the Commissioners of the Pollution Control Agency, the Departments of Agriculture, Commerce, Natural Resources, and Transportation, and other state departments must evaluate the goals and directives established in this section, and report their findings to the governor and the appropriate committees of the legislature February 1 of each odd-numbered year. In the report, the committee must make recommendations for new or adjusted goals, directives, or legislative initiatives; in light of the progress the state has made implementing this section and the availability of new or improved technologies.

- **Electric Vehicle Charging Tariff** Sec. 10. [216B.1614] ELECTRIC VEHICLE CHARGING TARIFF. 6.10 Subd. 2. Required tariff. (a) By February 1, 2015, each public utility selling electricity at retail must file with the commission a tariff that allows a customer to purchase electricity solely for the purpose of recharging an electric vehicle. The tariff must: contain either a time-of-day or off-peak rate, as elected by the public utility; offer a customer the option to purchase electricity: from the utility's current mix of energy supply sources; or entirely from renewable energy sources, subject to the conditions established and be made available to the residential customer class.

  Reporting: Each public utility providing a tariff under this section shall periodically report to the commission, as established by the commission and on a form prescribed by the commission, the following information, organized on a per-quarter basis: the number of customers who have arranged to purchase electricity under the tariff; the total amount of electricity sold under the tariff; and other data required by the commission.
- **Energy Policy Goals.** [216C.05 Subd. 2 (2007)] states it is the energy policy goal of the state of Minnesota that the per capita use of fossil fuel as an energy input be reduced by 15 percent by the year 2015, through increased reliance on energy efficiency and renewable energy alternatives.
- **Renewable Electricity Standard. [** 216B.1691 **]** requires the state’s electric utilities to obtain the RPS schedule for Xcel Energy is as follows:
  - 15% by 12/31/2010
  - 18% by 12/31/2012
  - 25% by 12/31/2016
  - 31.5% by 12/31/2020 (including 1.5% solar)
- **Standard for Non-Xcel Public Utilities**: The standard for other public utilities requires that eligible renewable electricity account for 26.5% of retail electricity sales to retail customers in Minnesota by 2025. Of this electricity, 1.5% must be solar photovoltaics by 2020, and 10% of the solar standard must be met with systems of 20 kW or less.
  - 12% by 12/31/2012
  - 17% by 12/31/2016
  - 21.5% by 12/31/2020 (including 1.5% solar)
  - 26.5% by 12/31/2025 (including 1.5% solar)
- **Standard for Non-Public Utilities:** The standard for other Minnesota utilities requires that eligible renewable electricity account for 25% of retail electricity sales to retail customers (and to retail customers of a distribution utility to which the one or more of the utilities provides wholesale service) in Minnesota by 2025. The RPS schedule for other Minnesota utilities is as follows:

- 12% by 12/31/2012
- 17% by 12/31/2016
- 20% by 12/31/2020
- 25% by 12/31/2025

- **Solar Electricity Goal.** H.F. 729 (2013) created a statewide solar goal of 10% of retail electric sales from solar by 2030.
- The Zero Emissions Charging Challenge participants that have **public charging stations powered by solar or wind** include: City of Minneapolis, City of Saint Paul, Hennepin County, Macalester College, Metropolitan Airports Commission (MSP), Ramsey County, Ramsey County Regional Rail Authority, University of Minnesota, Minneapolis Public School (Davis Center), State Capital complex station (corner of Rice and University), Riverside Community College (Albert Lea), City of Austin. As this program expands this list continues to grow.
- Utilities also have programs designed for encouraging **renewables and residential electric vehicle charging** (wind and community solar). Electric vehicles owners report more awareness about sources of electricity and renewable energy use.

Estimated Policy Impacts

Direct Policy Impacts

Table Ap F-3.31: TLU-4 Estimated Net GHG Reductions and Net Costs or Savings

Scenario	2030 In-State GHG reductions ($TgCO_2e$):	2015 – 2030 Total cumulative reductions ($TgCO_2e$):	Net present value of societal costs, 2015 – 2030 ($MM2014):	Cost effectiveness ($2014/$tCO_2e$):
Grid Electricity (0% Renewables) Case	-0.42	-2.0	$3,237	N/A
100% Renewables Case	1.3	6.4	$3,278	$417

Data Sources

- US Department of Energy, Annual Energy Outlook 2014. Can be located online at: http://www.eia.gov/forecasts/aeo/
- Department of Energy, FuelEconomy.gov website. Accessed September 2, 2014. Located online at: http://www.fueleconomy.gov/
- Tessum, Christopher, et al, 2014. "Life cycle air quality impacts of conventional and alternative light-duty transportation in the United States". Proceedings of the National

Academy of Science, December 2014. http://www.pnas.org/content/111/52/18490.full.pdf+html

- *McNeill, Karin, 2014. "Electric Vehicles Cost Less". Drive Electric Vermont, posted January 15, 2014. Located online at:* http://driveelectricvt.com/blog/post/drive-electric-blog/2014/01/15/electric-vehicles-cost-less

Quantification Methods

This analysis focuses on increasing the number of electric vehicles (EVs) in Minnesota, as outlined in Table Ap F-64 above. This target matches Minnesota's portion of the Zero Emissions Vehicles (ZEV) target through 2025. This analysis is focusing exclusively on fully electric vehicles, and does not include any hybrid-electric or plug-in hybrid vehicles. The electric vehicles are assumed to be between mid-sized sedans (for example, the Nissan Leaf) and small SUVs (for example, the Toyota RAV4 EV). The split used in this analysis is 90% electric cars and 10% electric SUVs, based on the breakdown between light cars and trucks in the Annual Energy Outlook 2014 (AEO 2014)'s projected electric vehicle sales for 2015-2030.

While EVs would come in a greater number of vehicle categories, these are the categories which have historically been the most popular for EVs. The analysis estimates the fuel savings based on the typical Vehicle Miles Traveled (VMT) of a light duty vehicle (from the Minnesota I&F). This annual mileage number is divided by the miles per gallon of a sedan and small SUV for the forecast years, which is also estimated in the AEO 2014. The vehicles being displaced are assumed to be entirely gasoline vehicles. This is multiplied by the total number of EVs per year (from Table Ap F-64) to estimate total gasoline savings of these electric vehicles, and these gallons of gasoline are used to estimate metric tons of CO_2e avoided.

Table Ap F-3.32: VMT, MPG, and Gasoline Saved from Electric Vehicles

Year	VMT Per Vehicle	New Mid-Sized Sedans (mpg)	New Small Utility Vehicles (mpg)	Million Gallons of Gasoline Saved	$MtCO_2e$ Saved from Reduced Gasoline
2015	11,788	37.0	30.9	1.6	14,182
2016	11,836	37.2	31.6	2.4	20,741
2017	11,880	39.0	32.1	3.4	29,951
2018	11,939	39.7	32.8	5.0	43,239
2019	12,005	41.1	36.2	7.1	61,966
2020	12,069	42.9	36.8	10.1	88,368
2021	12,126	44.9	37.8	14.4	125,459
2022	12,188	47.4	38.7	20.3	177,274
2023	12,253	49.7	39.7	28.6	249,946
2024	12,314	50.9	41.6	40.5	353,747
2025	12,380	53.3	43.4	58.4	509,847

Year	VMT Per Vehicle	New Mid-Sized Sedans (mpg)	New Small Utility Vehicles (mpg)	Million Gallons of Gasoline Saved	$MtCO_2e$ Saved from Reduced Gasoline
2026	12,449	53.3	43.5	74.1	647,104
2027	12,515	53.3	43.6	91.2	796,007
2028	12,578	53.3	43.7	108.4	946,767
2029	12,636	53.3	43.7	125.9	1,099,169
2030	12,694	53.2	43.7	143.7	1,254,402

GHG emissions from electric vehicles are also calculated in this analysis. The Department of Energy's FuelEconomy.gov website was used to estimate the electricity needed per mile for an EV. The Nissan Leaf was used to estimate the electricity required to power a mid-sized sedan EV (30 kWh per 100 miles). The Toyota RAV4 was used as a stand-in for the small SUV category (44 kWh per 100 miles). These efficiency estimates were then forecast into the future using the Annual Energy Outlook's estimate of Electric Vehicle Efficiency. This models the expected efficiency improvement of EVs between 2015 and 2030 – for example, mid-sized sedans are expected to increase their efficiency to an energy demand of only 25.7 kWh per 100 miles by 2030. These efficiency figures were applied to VMT forecasts to estimate total energy (in MWh) needed to power Minnesota's EV fleet. The MWh required is then increased by an assumption that it is 10% higher than the MWh used, to account for electricity inefficiencies in vehicle charging, based on information from EPA's Fuel Economy.gov website.

The CO_2 emissions from EVs are estimated based on the MWh of electricity needed multiplied by the percentage of electricity that is assumed to be coming from conventional sources, multiplied by the business as usual emissions factor (tons of CO_2e per MWh). This analysis looks at two scenarios, one in which grid electricity is used with 0% renewables set aside for EVS. The second scenario assumes that 100% of electricity that is going towards EVs will be coming from separate generation specifically set aside for EVs from 50% wind and 50% solar PV generation. This can be done a variety of ways, such as through solar charging stations or distributed PV on houses or at the workplace. This analysis assumes that any policy push towards EVs will need to have a component to encourage the use of renewables such as solar PV to power these vehicles.

The difference between the (replaced) gasoline vehicle emissions and the electricity emissions from EVs is the total GHG savings from TLU-4. For the grid electricity (0% renewables) scenario, these calculations are displayed in Table Ap F-67 below. This table also shows upstream emissions savings, which estimate the GHG impact that is occurring outside of Minnesota. This includes the GHG impact of gasoline extraction and refining minus the impact of coal/natural gas extraction for electricity production. In this analysis, the upstream impacts from gasoline are greater than those for electricity, and thus the upstream GHG savings are significant. While Minnesota has significant renewable energy in its electricity mix, the electricity that would need to come online for EV power is expected to be primarily coal. When electricity from coal generation is used to power EVs, the GHG impact is actually negative, which matches what was found in a recent study of EVs for the University of Minnesota (Tessum, 2014).

These same factors are displayed for the 100% renewable scenario in Table Ap F-67, where GHG savings are significant, because all the electricity going towards EVs is coming from wind/solar PV, which are assumed to have zero emissions in this analysis.

Table Ap F-3.33: Electricity GHG Emissions from EVs and Net GHG Savings from TLU-4 in Grid Electricity (0% Renewables) Case

Year	Mid-Sized Sedans (miles per kWh)	Small Utility (miles per kWh)	MWh Required	MWh from Renewables Required	GHG Emissions from Grid Electricity (tCO_2e)	Net GHG Savings from Gasoline minus Electricity (tCO_2e)	Upstream GHG Savings (tCO_2e)
2015	3.7	3.1	17,901	0	16,760	-2,578	2,641
2016	3.7	3.2	26,221	0	24,231	-3,490	3,867
2017	3.7	3.2	38,363	0	35,133	-5,182	5,512
2018	3.8	3.2	56,149	0	51,047	-7,808	7,858
2019	3.8	3.3	82,121	0	74,128	-12,161	10,944
2020	3.8	3.3	119,952	0	107,464	-19,096	15,257
2021	3.8	3.4	175,013	0	153,178	-27,719	21,389
2022	3.9	3.4	255,098	0	220,320	-43,047	29,287
2023	3.9	3.5	372,120	0	318,658	-68,712	39,573
2024	3.9	3.5	543,302	0	458,892	-105,145	54,335
2025	3.9	3.6	812,239	0	670,914	-161,067	77,327
2026	3.9	3.6	1,074,473	0	874,687	-227,583	93,490
2027	3.9	3.6	1,343,040	0	1,075,022	-279,015	113,062
2028	3.9	3.6	1,619,638	0	1,273,234	-326,468	132,957
2029	3.9	3.6	1,906,365	0	1,472,104	-372,934	152,571
2030	3.9	3.6	2,207,734	0	1,672,452	-418,049	172,041
Total						**-2,080,054**	**932,109**

Table Ap F-3.34: Electricity GHG Emissions from EVs and Net GHG Savings from TLU-4 in 100% Renewables Case

Year	Mid-Sized Sedans (miles per kWh)	Small Utility (miles per kWh)	MWh Required	MWh from Renewables Required	GHG Emissions from Grid Electricity (tCO_2e)	Net GHG Savings from Gasoline minus Electricity (tCO_2e)	Upstream GHG Savings (tCO_2e)
2015	3.7	3.1	17,901	17,901	0	14,182	3,407
2016	3.7	3.2	26,221	26,221	0	20,741	5,000
2017	3.7	3.2	38,363	38,363	0	29,951	7,205
2018	3.8	3.2	56,149	56,149	0	43,239	10,382
2019	3.8	3.3	82,121	82,121	0	61,966	14,762
2020	3.8	3.3	119,952	119,952	0	88,368	20,937
2021	3.8	3.4	175,013	175,013	0	125,459	29,613
2022	3.9	3.4	255,098	255,098	0	177,274	41,410
2023	3.9	3.5	372,120	372,120	0	249,946	57,575
2024	3.9	3.5	543,302	543,302	0	353,747	80,719
2025	3.9	3.6	812,239	812,239	0	509,847	115,947
2026	3.9	3.6	1,074,473	1,074,473	0	647,104	144,962
2027	3.9	3.6	1,343,040	1,343,040	0	796,007	177,506
2028	3.9	3.6	1,619,638	1,619,638	0	946,767	210,554
2029	3.9	3.6	1,906,365	1,906,365	0	1,099,169	243,771
2030	3.9	3.6	2,207,734	2,207,734	0	1,254,402	277,410
Total						**6,418,171**	**1,441,159**

The 100% renewables scenario has different costs and GHG impacts associated with it. The scenario assumes 50% wind and 50% solar PV, which requires investment into renewable infrastructure in Minnesota. The costs of PV investment come from the RCII-2 analysis of distributed renewables, and the wind costs come from similar RCII methodologies (although wind was not explicitly included in RCII-2). PV systems are assumed to have a lifetime of 25 years, and the PV costs are estimated to be $3,100 per installed KW, and that PV arrays generate 1,348 kWh of electricity per year for each installed KW of capacity. In contrast, wind systems are assumed to have a lifetime of 20 years, with costs estimated to be $1,600 per installed KW, and that generate 2,367 kWh of electricity per year for each installed KW of capacity. The additional renewables required, and the costs of installing those renewables, is displayed in Table Ap F-69 for Solar PV and Table Ap F-6 for Wind. The grid electricity scenario does not have any of these costs.

Table Ap F-3.35: Cost of Additional PV Installations Required, 100% Renewables Case

Year	MWh from PV Required	Additional PV Capacity Required (MW)	Capital Cost of Installed PV Capacity ($ Million)	O&M Cost of PV Installations ($ Million)
2015	8,950	6.6	$1.5	$0.1
2016	13,111	9.7	$2.1	$0.2
2017	19,182	14.2	$3.1	$0.3
2018	28,075	20.8	$4.6	$0.4
2019	41,061	30.5	$6.7	$0.6
2020	59,976	44.5	$9.8	$0.9
2021	87,506	64.9	$14.3	$1.3
2022	127,549	94.6	$20.8	$1.8
2023	186,060	138.0	$30.4	$2.7
2024	271,651	201.5	$44.3	$3.9
2025	406,120	301.3	$66.3	$5.8
2026	537,236	398.5	$87.7	$7.7
2027	671,520	498.2	$109.6	$9.6
2028	809,819	600.8	$132.1	$11.6
2029	953,182	707.1	$155.5	$13.7
2030	1,103,867	818.9	$180.1	$15.8

Table Ap F-3.36: Cost of Additional Wind Installations Required, 100% Renewables Case

Year	MWh from Wind Required	Additional Wind Capacity Required (MW)	Capital Cost of Installed Wind Capacity ($ Million)	O&M Cost of Wind Installations ($ Million)
2015	8,950	4.02	$0.52	$0.2
2016	13,111	5.88	$0.76	$0.2
2017	19,182	8.61	$1.10	$0.3
2018	28,075	12.60	$1.62	$0.5
2019	41,061	18.42	$2.36	$0.7
2020	59,976	26.90	$3.45	$1.0
2021	87,506	39.27	$5.04	$1.5
2022	127,549	57.24	$7.35	$2.1
2023	186,060	83.50	$10.72	$3.1
2024	271,651	121.90	$15.65	$4.6
2025	406,120	182.15	$23.39	$6.8
2026	537,236	240.91	$30.93	$9.0
2027	671,520	301.40	$38.70	$11.3
2028	809,819	363.22	$46.63	$13.6
2029	953,182	427.52	$54.89	$16.0
2030	1,103,867	495.00	$63.55	$18.6

The costs of TLU-4 are estimated based on the cost differential between a conventional and an electric vehicle, the cost differential between gasoline and electricity needed to power those vehicles and any additional charging infrastructure that will be needed to support EVs. The difference in price between a gasoline powered vehicle and an EV came from AEO 2014. This cost delta is then multiplied by the number of vehicles purchased in each year. The cost differences used are displayed in Table Ap F-71 below. The cost difference between an EV and a gasoline vehicle declines from ~18 thousand dollars in 2015 to ~9 thousand by 2030 based on EIA data.

It is worth noting however, that EIA publishes the Annual Energy Outlook as a BAU trend estimate. In developing this forecast:

- EIA does not assume substantial EV technology improvements.
- EIA assumes that current laws and regulations will be unchanged for the life of the forecast.[12]

[12] Department of Energy . (2014, April). *Annual Energy Outlook 2014.* U.S. Energy Information Administration (EIA). iii. Retrieved from http://www.eia.gov/forecasts/aeo/pdf/0383%282014%29.pdf

- EPA's estimated cost of compliance with increased 2025 fuel economy standards aren't included in EIA's analysis. http://www3.epa.gov/otaq/climate/regs-light-duty.htm
- EIA's estimation of future increases in gasoline cost assumes a conservative rate of change.

Meanwhile, the Obama Administration established the EVs Everywhere Grand Challenge in 2012 with the goal for the U.S. to be the first nation "*to produce plug-in electric vehicles that are as affordable for the average American family as today's gasoline-powered vehicles within the next 10 years*."[13]

EVs Everywhere was adopted as an aggressive but achievable R&D goal and was developed with significant stakeholder input from OEMs (Chrysler, Nissan, Ford, and others), industry, and R&D partnerships. The goal includes ambitious cost reduction targets in four areas: battery R&D; electric drive system R&D; vehicle lightweighting; and advanced climate control technologies. Some specific cost reduction goals include:

- Cutting battery costs from their current $500/kWh to $125/kWh
- Eliminating almost 30% of vehicle weight through lightweighting
- Reducing the cost of electric drive systems from $30/kW to $8/kW

The U.S. is meeting EVs Everywhere Grand Challenge interim targets to date.[14] In order to obtain a more accurate analysis of the TLU-4 option, it is both reasonable and necessary to include the EVs Everywhere goals for cost reductions as adopted by the Department of Energy in the analysis of a ZEV standard as representing not only a possible scenario but a more likely one. The results of the analysis are tabulated alongside the EIA-based findings.

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[13] Department of Energy. (2016). *EV Everywhere About*. Retrieved from Office of Energy Efficiency & Renewable Energy: http://energy.gov/eere/eveverywhere/about-ev-everywhere

[14] U.S. Department of Energy. (2014, January). *EV Everywhere Grand Challenge* . Office of Energy Efficiency & Renewable Energy. 5-7, Retrieved from http://energy.gov/eere/eveverywhere/about-ev-everywhere

Table Ap F-3.37: Initial Per Vehicle Cost Difference between a New Conventional Gasoline and Electric Vehicle

	Mid-Sized Sedan ($ Thousands)			Small Utility Vehicle ($ Thousands)		
Year	New EV Cost	New Conventional Cost	Cost Differential	New EV Cost	New Conventional Cost	Cost Differential
2015	43.0	24.9	18.2	45.0	26.2	18.8
2016	42.8	24.9	18.0	44.7	26.3	18.3
2017	42.6	25.1	17.5	44.4	26.4	18.0
2018	42.3	25.2	17.1	44.0	26.5	17.5
2019	42.0	25.4	16.6	43.1	27.0	16.1
2020	41.5	25.7	15.8	42.6	27.1	15.5
2021	41.0	25.9	15.1	42.0	27.2	14.8
2022	40.4	26.3	14.1	41.4	27.3	14.0
2023	39.9	26.7	13.2	40.7	27.5	13.2
2024	39.3	26.8	12.5	39.9	27.8	12.1
2025	38.7	27.2	11.5	39.2	28.1	11.1
2026	38.2	27.2	11.0	38.7	28.1	10.6
2027	37.7	27.2	10.5	38.3	28.2	10.1
2028	37.3	27.2	10.0	37.9	28.2	9.7
2029	37.0	27.3	9.7	37.6	28.2	9.4
2030	36.7	27.3	9.4	37.3	28.2	9.1

The total vehicle costs are calculated by multiplying the total number of new EVs with the cost differential for each of the two vehicle types. In addition, there is also evidence that a new electric vehicle costs less to maintain than a conventional vehicle. Based on the costs of three conventional and three electric vehicles, we estimate an average savings of $123 per vehicle per year compared for EVs. Vehicle purchase and vehicle maintenance costs are summarized in Table Ap F-72.

Table Ap F-3.38: Additional Vehicle Purchase and Vehicle Maintenance Costs from TLU-4 (costs same for both scenarios)

		Additional Vehicle Costs ($ Million)			Annual Maintenance Savings from EVs ($ million)
Year	New EVs Sold Per Year	Mid-Sized Sedans	Small Utility	Total	
2015	5,000	$82	$9	$91	$0.6
2016	2,300	$37	$4	$41	$0.9
2017	3,358	$53	$6	$59	$1.3
2018	4,903	$75	$9	$84	$1.9
2019	7,158	$107	$12	$118	$2.8
2020	10,451	$149	$16	$165	$4.1
2021	15,258	$207	$23	$230	$5.9
2022	22,276	$283	$31	$314	$8.7
2023	32,524	$387	$43	$430	$12.7
2024	47,484	$533	$57	$591	$18.5
2025	74,327	$770	$82	$853	$27.0
2026	71,627	$707	$76	$783	$35.8
2027	72,685	$685	$73	$758	$44.4
2028	74,230	$671	$72	$743	$53.1
2029	76,485	$668	$72	$739	$61.9
2030	79,778	$678	$73	$750	$70.8

The fuel costs are estimated based on the avoided gasoline costs minus the additional electricity costs. Gasoline cost savings are estimated by multiplying the total gallons of gasoline saved by the $/gallon. Additional electricity costs are estimated from the total MWh needed (beyond that created specifically for this policy option under the renewable energy production) multiplied by the $/MWh.

Tables TLU-4-9 and TLU-4-10 also include the additional infrastructure costs of TLU-4. These costs come in two parts: home charging stations and public charging stations. Home charging stations are where people can plug in their EV while not using it, and typically cost ~ $1,000. Public charging stations are assumed to be add-ons to existing gasoline stations. These are expected to be located along 3 400 mile corridors to northern Minnesota (west, central, and east) and along 9 200 mile corridors south of the metro area and east to west in northern Minnesota, thus requiring 60 stations in all. These level 3 charging stations are phased in on a linear basis between 2015 and 2030, and based on information from ZEF Energy are estimated to cost $70,000 per station ($40,000 for station and $30,000 for installation and service upgrades).

Table Ap F-3.39: Fuel and Infrastructure Costs of TLU-4 Grid Electricity (0% Renewables Case)

Year	Fuel Savings ($ Million)	Electricity Costs ($ Million)	Number of Home Charging Stations Required	Total Costs for Home Charging Stations ($ Million)	Number of Public Charging Stations Required	Total Capital Costs for Charging Stations ($ Million)
2015	$5.6	$2.0	5,000	$5.0	0	$0.0
2016	$8.2	$3.0	2,300	$2.3	4	$0.3
2017	$12.0	$4.4	3,358	$3.4	8	$0.3
2018	$17.4	$6.4	4,903	$4.9	12	$0.3
2019	$25.0	$9.5	7,158	$7.2	16	$0.3
2020	$36.0	$13.9	10,450	$10.5	20	$0.3
2021	$51.3	$20.3	15,258	$15.3	24	$0.3
2022	$73.0	$29.7	22,276	$22.3	28	$0.3
2023	$103.6	$43.5	32,524	$32.5	32	$0.3
2024	$147.5	$63.8	47,484	$47.5	36	$0.3
2025	$213.9	$95.8	69,327	$69.3	40	$0.3
2026	$273.2	$127.2	71,628	$71.6	44	$0.3
2027	$338.1	$159.6	70,385	$70.4	48	$0.3
2028	$404.7	$193.2	70,872	$70.9	52	$0.3
2029	$472.8	$228.3	71,582	$71.6	56	$0.3
2030	$542.9	$265.5	72,620	$72.6	60	$0.3

Table Ap F-3.40: Fuel and Infrastructure Costs of TLU-4 (100% Renewables Case)

Year	Fuel Savings ($ Million)	Electricity Costs ($ Million)	Number of Home Charging Stations Required	Total Costs for Home Charging Stations ($ Million)	Number of Public Charging Stations Required	Total Capital Costs for Charging Stations ($ Million)
2015	$5.6	$0.0	5,000	$5.0	0	$0.0
2016	$8.2	$0.0	2,300	$2.3	4	$0.3
2017	$12.0	$0.0	3,358	$3.4	8	$0.3
2018	$17.4	$0.0	4,903	$4.9	12	$0.3
2019	$25.0	$0.0	7,158	$7.2	16	$0.3
2020	$36.0	$0.0	10,450	$10.5	20	$0.3
2021	$51.3	$0.0	15,258	$15.3	24	$0.3
2022	$73.0	$0.0	22,276	$22.3	28	$0.3
2023	$103.6	$0.0	32,524	$32.5	32	$0.3
2024	$147.5	$0.0	47,484	$47.5	36	$0.3
2025	$213.9	$0.0	69,327	$69.3	40	$0.3
2026	$273.2	$0.0	71,628	$71.6	44	$0.3
2027	$338.1	$0.0	70,385	$70.4	48	$0.3
2028	$404.7	$0.0	70,872	$70.9	52	$0.3
2029	$472.8	$0.0	71,582	$71.6	56	$0.3
2030	$542.9	$0.0	72,620	$72.6	60	$0.3

Total costs (additional vehicle costs – gasoline savings + electricity costs + EV infrastructure costs + renewable energy infrastructure costs) are displayed in Table Ap F-75 and Table Ap F-76 below. These costs are then discounted to 2014 dollars.

Table Ap F-3.41: Total Costs of TLU-4 Grid Electricity 0% Renewable Case ($ Million Dollars)

Year	Net Costs of EV program	Discounted Costs of TLU-4 ($MM2014)
2015	$92.0	$87.7
2016	$37.9	$34.4
2017	$53.6	$46.3
2018	$76.3	$62.8
2019	$107.3	$84.1
2020	$149.7	$111.7
2021	$208.2	$148.0
2022	$284.8	$192.8
2023	$389.8	$251.3
2024	$536.4	$329.3
2025	$777.1	$454.4
2026	$672.9	$374.7
2027	$606.0	$321.4
2028	$549.6	$277.6
2029	$505.0	$242.9
2030	$475.0	$217.6
Total		**$3,237**

Table Ap F-3.42: Total Costs of TLU-4
100% Renewable Case ($ Million Dollars)

Year	Net Costs of EV program	Discounted Costs of TLU-4 ($MM2014)
2015	$92.3	$87.9
2016	$38.2	$34.7
2017	$54.1	$46.7
2018	$76.9	$63.3
2019	$108.2	$84.8
2020	$151.0	$112.6
2021	$210.0	$149.2
2022	$287.3	$194.4
2023	$393.2	$253.5
2024	$541.1	$332.2
2025	$783.7	$458.2
2026	$681.1	$379.2
2027	$615.6	$326.5
2028	$560.3	$283.0
2029	$516.8	$248.6
2030	$487.6	$223.4
Total		**$3,278**

The total costs are higher in the 100% renewable case than they are in the grid electricity case. However, the vehicle costs are the major driver of costs in this policy option, and the total increase in cost of increasing the dedicated PV to 100% is only a small portion of the total (an increase from $3.23 billion in cumulative costs to $3.28 billion over the entire policy option period). However, the GHG impact is significant. Because electricity is now coming entirely from dedicated PV and wind, the total GHG savings increase to more than 6 million tons of CO_2e, whereas in the grid electricity scenario the use of EVs actually increases GHG emissions (which matches what was found in a recent study of EVs for the University of Minnesota (Tessum, 2014). The upstream GHG savings have also increased, because there are no longer any upstream GHG emissions from electricity production.

Key Assumptions

- This analysis assumes that all of the ZEV requirements will be met with entirely electric vehicles, rather than a mix of EVs and PHEVs. If PHEV sales are substituted for some EV sales, then the program emission reductions will be less than estimated here.
- The analysis takes into account the following costs and cost savings:
- Costs – Additional vehicle costs for EVs, capital costs for EV charging stations, additional capital and O&M costs for installing dedicated wind/solar generation for EVs (in the

renewable energy scenario) OR additional electricity costs (in the grid electricity scenario).

- Cost Savings – Reduced gasoline costs from EVs, reduced maintenance costs from EVs compared to conventional vehicles
- Electric vehicles are assumed to be driven the same amount annually as gasoline powered vehicles.
- The analysis assumes that vehicles will last on average 10 years.
- Potential overestimate of fuel efficiency in gasoline cars, which would underestimate greenhouse gas reductions and financial savings from EVs. The fuel economy of gasoline powered vehicles comes from the Annual Energy Outlook 2014, which provides new vehicle fuel economy ratings from EPA. These ratings have often been found to be only achievable under ideal conditions (flat road, constant speed, no heat or air conditioning use). Real world driving conditions often experience efficiencies as much as 20% lower than EPA efficiency listings. No adjustment was included in this analysis to ensure that the EV estimate is a conservative one (actual fuel savings would likely be higher), and because it is unknown if efficiency ratings for EVs are similarly optimistic.
- This analysis does not consider time of day for charging.

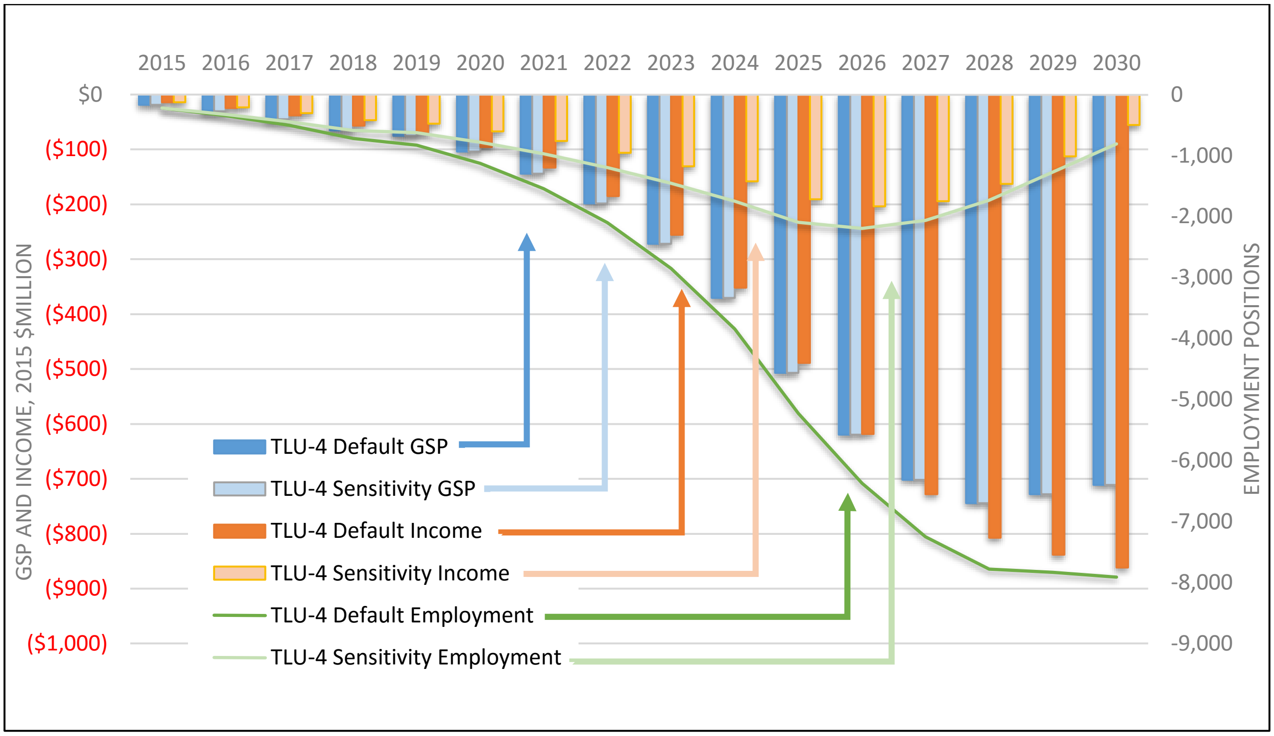
Macroeconomic (Indirect) Policy Impacts

Table Ap F-3.43: TLU-4 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
TLU-4 High EV $	-$711	-$354	-$5,315	-7,910	-3,750	-56,240	-$862	-$370	-$5,551
TLU-4 Low EV $	$140	-$65	-$969	-810	-1,220	-18,300	-$56	-$108	-$1,622

In TLU-4 policy analysis, a sensitivity scenario is also used for analyzing the macroeconomic impacts of the policy. The sensitivity scenario assumes that the EV price will decline during the implementation period, eventually achieving price parity with conventional vehicles, as oppose to relatively higher price of EVs in comparison to conventional vehicles assumed in the default scenario. The comparison of indirect macroeconomic results between these two scenarios is shown in the graph below. The expected negative macroeconomic impacts of this policy are significantly alleviated under the sensitivity (low EV price) scenario.

Figure Ap F-3.35: TLU Policy Impacts of Different Electric-Vehicle Price Assumptions



Notes: "Default" refers to a case where EV prices remain 40-60% higher than conventional vehicles, imposing a large price burden on consumers. "Sensitivity" refers to a case where EV prices start out at 40-60% higher but fall in a linear fashion to no price premium at all in the year 2030.

Graphs below show detail in GSP, employment and personal income impact of the TLU-4 policy.

Figure Ap F-36. TLU-4 Impacts on Gross State Product ($2015 MM)

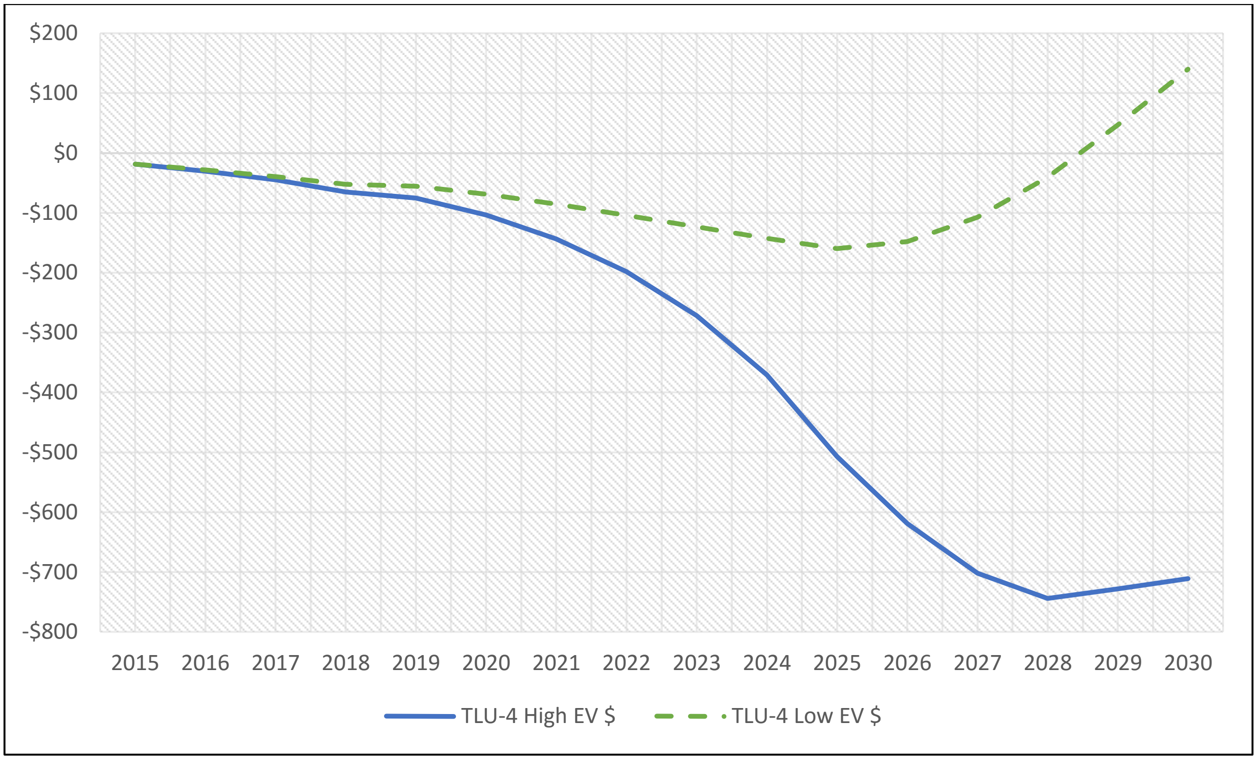


Figure Ap F-37. TLU-4 Impacts on Incomes ($2015 MM)

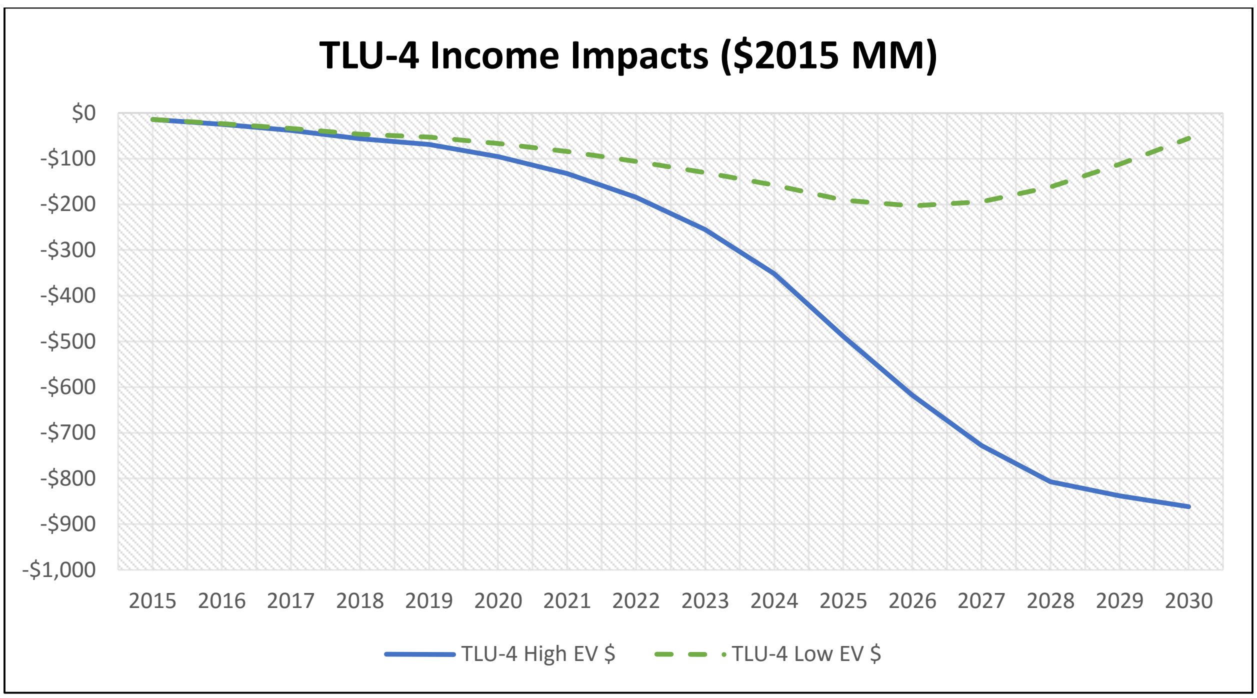
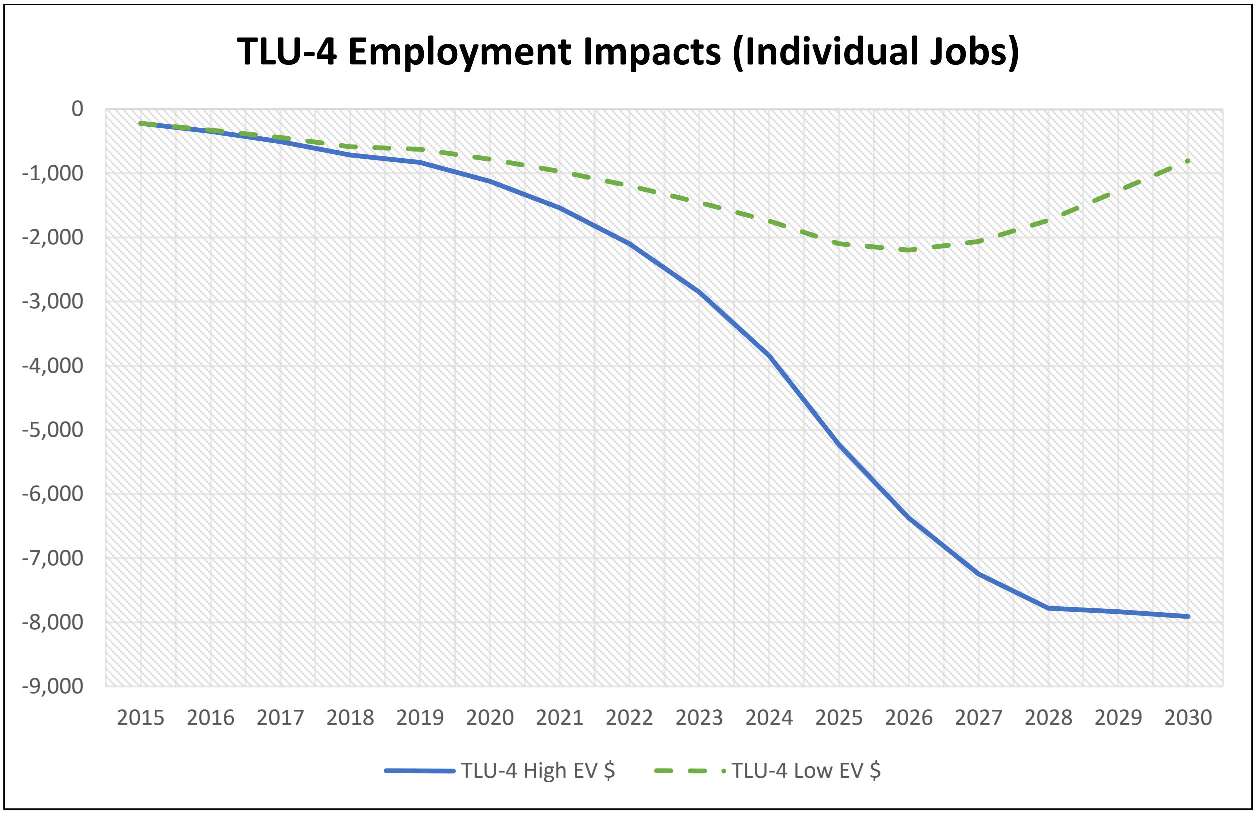
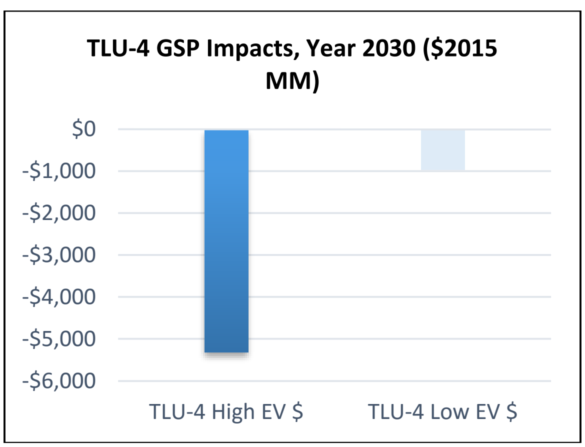
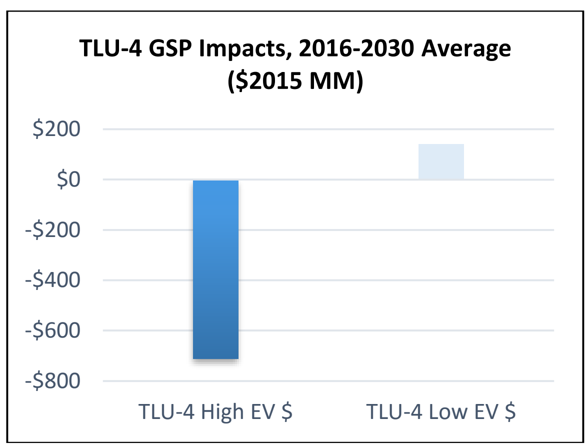


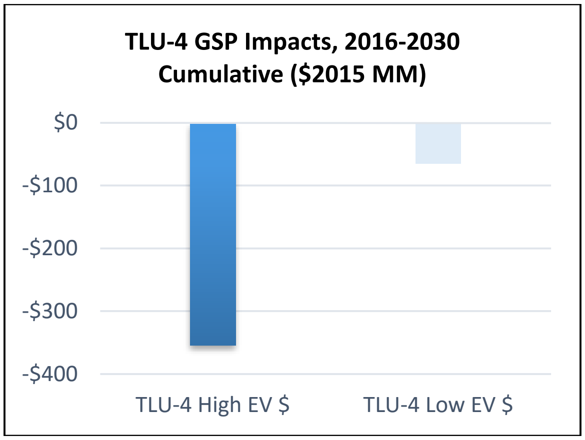
Figure Ap F-38. TLU-4 Impacts on Employment (Individual Jobs)

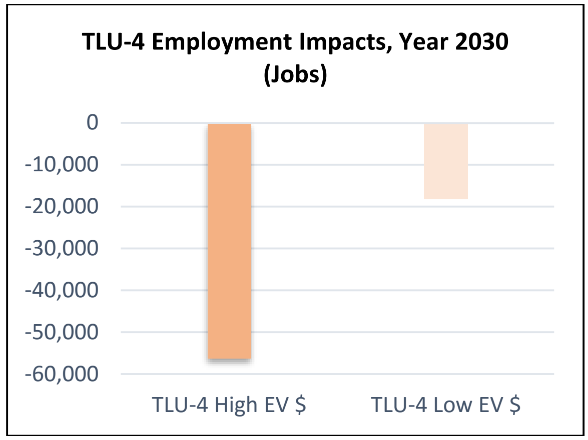


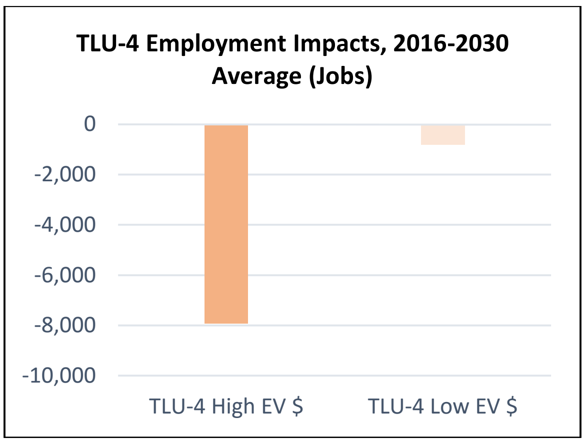
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030). Lighter color indicates the sensitivity scenario.

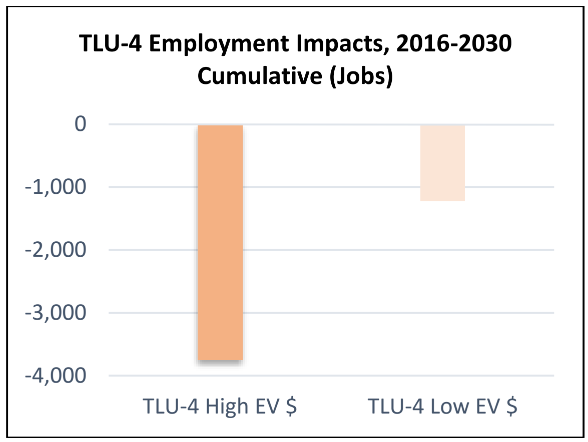


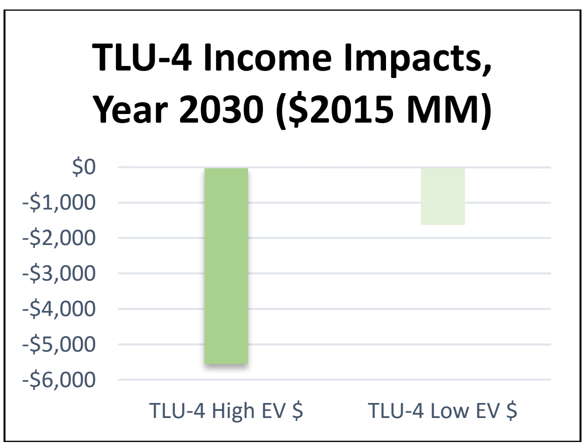


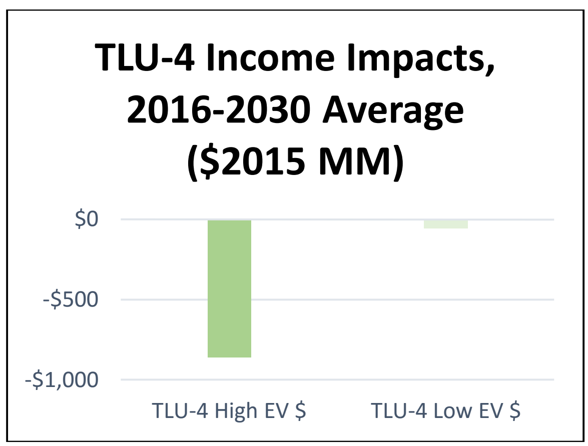

TLU-4 GSP Impacts, 2016-2030 Cumulative ($2015 MM)
$0
-$100
-$200
-$300
-$400
TLU-4 High EV $
TLU-4 Low EV $

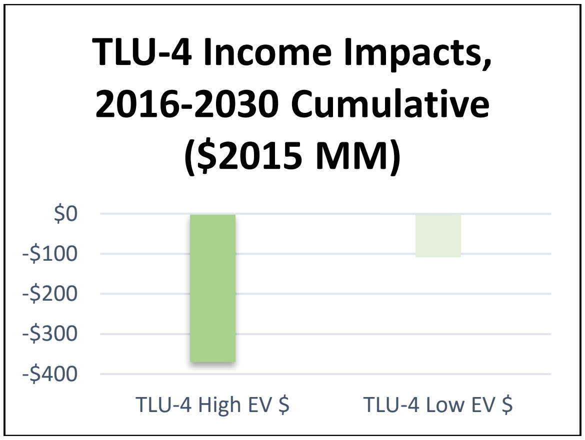

TLU-4 Employment Impacts, Year 2030 (Jobs)
0
-10,000
-20,000
-30,000
-40,000
-50,000
-60,000
TLU-4 High EV $
TLU-4 Low EV $


TLU-4 Employment Impacts, 2016-2030 Average (Jobs)
0
-2,000
-4,000
-6,000
-8,000
-10,000
TLU-4 High EV $
TLU-4 Low EV $


TLU-4 Employment Impacts, 2016-2030 Cumulative (Jobs)
0
-1,000
-2,000
-3,000
-4,000
TLU-4 High EV $
TLU-4 Low EV $


TLU-4 Income Impacts, Year 2030 ($2015 MM)
$0
-$1,000
-$2,000
-$3,000
-$4,000
-$5,000
-$6,000
TLU-4 High EV $
TLU-4 Low EV $


TLU-4 Income Impacts, 2016-2030 Average ($2015 MM)
$0
-$500
-$1,000
TLU-4 High EV $
TLU-4 Low EV $



Principal Drivers of Macroeconomic Changes

The overall sector has many drivers, but a dominant driver comes from the electric-vehicles policy (TLU-4). In that policy, the scenario calls for consumers to shift a substantial number of vehicle purchases from conventional to electric vehicles. Electric vehicles come at a substantial price premium, and this change represents a significant price increase encountered by consumers (which reaches over $700 million by the year 2025).

This vehicle-price increase impact is a crucial driver of economic impacts. CCS conducted sensitivity analyses in which the price premium of electric vehicles was modulated while holding all other inputs constant in order to test its importance. When EV prices fall to parity over time (meaning there is no price premium by 2030), the policy has somewhat positive GSP impacts (reaching $140 million additional GSP per year by 2030, though it is still negative in early years), though it still falls below the baseline on employment and jobs (the prices, while falling, are still higher, and those higher prices reduce spending power around the rest of the economy). When EV prices stay high, however, the policy (and the high prices) pull GSP down by as much as $750 million per year. However, at this price, the policy is unlikely to be effective at driving a change in vehicle choice anyway, and these results should be understood in that context.

Key Uncertainties

Where does the funding come from to support development for infrastructure? Electric utilities, general fund, tax on vehicle registration or exemptions for EV owners, gas tax, Conservation Improvement Program. Under California program adoption, there may be incentives for auto manufacturers to invest in public charging stations.

Additional Benefits and Costs

In addition to GHG reductions, there is economic, energy security, and public health benefits associated with Zero Emission Fleets (ZEV) fleets, for instance:

- Electrification of the vehicle fleet creates new opportunities for electric utilities to employ load management strategies and to improve grid reliability while also resulting in increased electricity sales. While these strategies will take years to implement, there is potential to realize near-term benefits to utilities, consumers, and society.
- Zero emission vehicles, which may generate significantly fewer emissions than gasoline powered vehicles, could significantly reduce emissions if broadly adopted. However, it is critical that the electricity source for these vehicles be considered, as coal-fired power plants that generate electricity do produce significant emissions that can negatively impact health.

Figure Ap F-36. Potential Health Benefits of TLU-4

*Reducing transit-related emissions is likely to reduce the risk for respiratory and cardiovascular illness, cancer, stress, premature birth weight, and premature death in exposed populations.

Feasibility Issues

These policies are technically feasible, and could expect broad and growing consumer support. Electric utilities are primary stakeholders and likely supporters.

Adoption of the regulatory Zero Emissions Vehicle Standard would likely result in resistance from automobile manufacturers and the Minnesota Auto Dealers Association due to the ZEV sales quota and reporting requirements. The implementation and oversight costs to the state would need to be considered.

Chapter XV. Appendix F-4. Agriculture Policy Recommendations

Overview

The tables below provide a summary of the microeconomic analysis of Climate Solutions & Economic Opportunities (CSEO) policies in the Agriculture sector. The first table, Table F-4.1 provides a summary of results on a stand-alone basis, meaning that each policy option was analyzed separately against baseline (business as usual or BAU) conditions. Details on the analysis of each policy option are provided in each of the Policy Option Documents (PODs) that follow within this appendix.

Direct, Stand Alone Economic Impacts

The stand-alone results provide the annual greenhouse gas (GHG) reductions for 2020 and 2030 in teragrams (Tg) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030 (1 Tg is equal to 1 million metric tons). The reductions shown are just those that have been estimated to occur within the State. Additional GHG reductions, typically those associated with upstream emissions in the supply of fuels or materials, have also been estimated and are reported within each of the analyses in each POD.

Also reported in the stand-alone results is the net present value (NPV) of societal costs/savings for each policy option. These are the net costs of implementing each policy option reported in 2014 dollars. The cost effectiveness (CE) estimated for each policy option is also provided. Cost effectiveness is a common metric that denotes the cost/savings for reducing each metric ton (t) of emissions. Note that the CE estimates use the total emission reductions for the policy option (i.e. those occurring both within and outside of the State).

As indicated in Table F-4.1 the combined impacts of Policy AG-4 (Advanced Biofuels Production) and Policy AG-5 addressing biofuel consumption (Existing Biofuel Statute) are provided in the overall results shown for Policy AG-5. In other portions of this appendix and the final CSEO report, these two policies are referred to as the "Biofuels Package". In order to estimate net energy and GHG impacts, the analysis of biofuels production needs to be taken all of the way through consumption of those fuels; so separate reporting of overall policy option impacts is not done (if GHG estimates of biofuel production were provided, these would only indicate an increase in emissions, which would be misleading or confusing to most readers). Implementation of the Biofuels Package will have some overlap with on-road vehicle policies in the Transportation and Land Use (TLU) sector; these will be addressed in the *inter*-sector integration analysis and documented in the final report for the project.

Integrative Adjustments & Overlaps

The second summary table above, Table F-4.2, provides the same values described above after an assessment was made of any policy option interactions or overlaps. In the Agriculture sector, overlaps were identified between the AG-1 policy option addressing nutrient management and policies AG-3 and AG-4. Essentially, implementation of the AG-3 and AG-4 policies will result in conversion of some corn to either perennial cover (AG-3) or other energy crops (AG-4). So the stand-alone reductions and costs estimated for Policy Option AG-1 were adjusted downward to account for a smaller corn production base than is currently expected in the baseline forecast.

As indicated in the Table F-4.2 there could also be some interaction of Policy Option AG-2 with Policy Option AG-1 (i.e. lower nitrogen [N] fertilization requirements achieved via cover cropping); however, the net nitrous oxide (N_2O) emissions impacts related to cover cropping are currently uncertain. Therefore, no adjustments were made relative to this interaction.

Macroeconomic (Indirect) Economic Impacts of Agriculture Policies

Table F-4.3 below provides a summary of the expected impacts of Ag policies on jobs and economic growth during the CSEO planning period. This table focuses on the impact of policies on Gross State Product (the total amount spent on goods and services produced within the state), Employment (the total number of full-time and part-time positions), and Incomes (the total amount earned by households from all possible sources). These metrics represent three valuable indicators of both the overall size of the economy and that economy's structural orientation toward supporting livelihoods and utilizing productive work.

For the purposes of macro-economic analysis of CSEO policies, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software. This particular REMI model is developed specifically for Minnesota, and is developed consistently with the design of models in use by state agency staff within Minnesota for a range of economic analyses. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

The main inputs for macro-economic analysis are microeconomic estimates of direct costs and savings expected from the implementation of individual policy options. These inputs are supplemented with additional data and assumptions necessary to complete the picture of how these costs and savings (as well as price changes, demand and supply changes, and other factors) influence Minnesota's economy. These additional data and assumptions typically regard how various actors around the state (households, businesses and governments) respond to change by changing their own economic activity. A full articulation of the general and policy-specific assumptions made by the macroeconomic analysis team is provided in the Policy Option Documents, contained as appendices to this report.

Table F-4.1 Agriculture Policy Options, Direct Stand-Alone Impacts

Stand-Alone Analysis							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual CO_2e Reductions[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/tCO_2e$
AG-1	Nutrient Management in Agriculture	0.036	0.14	1.1	2.8	($131)	($46)
AG-2	Soil Carbon Management: Increased Use of Cover Crops	0.059	0.49	3.1	3.6	($1,346)	($377)
AG-3	Soil Carbon Management: Increased Conversion of Row Crops to Perennial Crops	0.62	1.6	14	14	($2,104)	($153)
AG-4	Advanced Biofuels Production	*Not Applicable - Results of this supply-side policy option are combined with those from AG-5 (demand-side policy option)*					
AG-5[e]	Existing Biofuel Statute	0.12	0.17	1.8	3.5	$462	$133
Totals		**0.83**	**2.4**	**19**	**24**	**($3,119)**	**($132)**

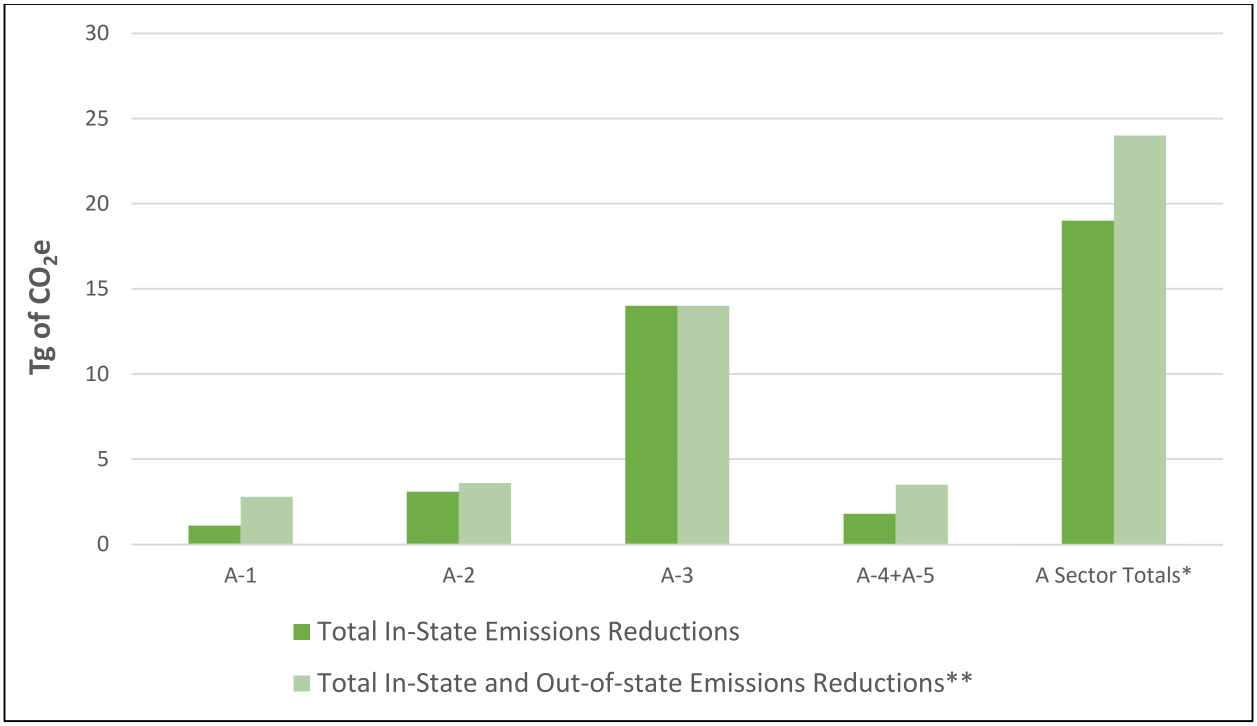
Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] Contains the total net impacts of the AG-4/AG-5 Biofuels Package.

Table F-4.2 Agriculture Policy Options, Intra-Sector Interactions & Overlaps

Intra-Sector Interactions & Overlaps Adjusted Results							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Cost[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$\$/tCO_2e$
AG-1[e]	Nutrient Management in Agriculture	0.035	0.13	1.0	2.7	($127)	($47)
AG-2[f]	Soil Carbon Management: Increased Use of Cover Crops	0.059	0.49	3.1	3.6	($1,346)	($377)
AG-3[g]	Soil Carbon Management: Increased Conversion of Row Crops to Perennial Crops	0.62	1.6	14	14	($2,104)	($153)
AG-4[h]	Advanced Biofuels Production	*Not Applicable*					
AG-5	Existing Biofuel Statute	0.12	0.17	1.8	3.5	$462	$133
Total After Intra-Sector Interactions/ Overlap		**0.83**	**2.4**	**19**	**23**	**($3,115)**	**($133)**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of State. Dollars expressed in $2014.
[e] See AG-2, AG-3, and AG-4 below.
[f] Use of cover crops on 2.25 MMacres of corn by 2030 could reduce N requirements addressed under AG-1. However, net N_2O emissions impacts from cover cropping are uncertain; so no changes were made to AG-1 as a result of implementation of AG-2.
[g] Conversion of 500,000 acres of corn to perennial crops reduces impacts and costs of AG-1.
[h] Diverted corn production to energy beets reduces the impacts and costs of AG-1.

Figure Ap F-4.1 AG Policies GHG Emissions Abatement, 2016-2030



Notes:
* Total in and out-of-state emissions reduction are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Table F-4.3 Macroeconomic (Indirect) Impacts of Agriculture Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	Gross State Product GSP ($2015 Millions)			Employment (Full and Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
AG-1	-$9	-$5	-$73	-360	-200	-2,960	-$22	-$8	-$125
AG-2	-$2	$8	$113	70	230	3,380	$21	$20	$299
AG-3	$23	-$35	-$529	1,170	-490	-7,420	$56	-$32	-$486
AG-4+AG-5	$1,132	$819	$11,469	3,610	3,420	47,820	$539	$398	$5,576
AG Sector Total	**$980**	**$680**	**$10,203**	**810**	**1,490**	**22,300**	**$349**	**$277**	**$4,148**

Notes:
[a] Gross State Production changes in Minnesota. Dollars expressed in $2015.
[b] Total employment changes in Minnesota.
[c] Personal Income changes in Minnesota. Dollars expressed in $2015.
[d] Single final year value. Year 2030 is the final year of analyses in this project.
[e] Average value from the year 2016 to the year 2030. The average value is calculated from the first year of the policy implementation through the year 2030 if implementation of the policy starts after year 2016.
[f] Cumulative value from 2016-2030 time period.

Figure Ap F-4.2 – Average Annual Jobs Impact of Ag Policies, Individually and in Concert

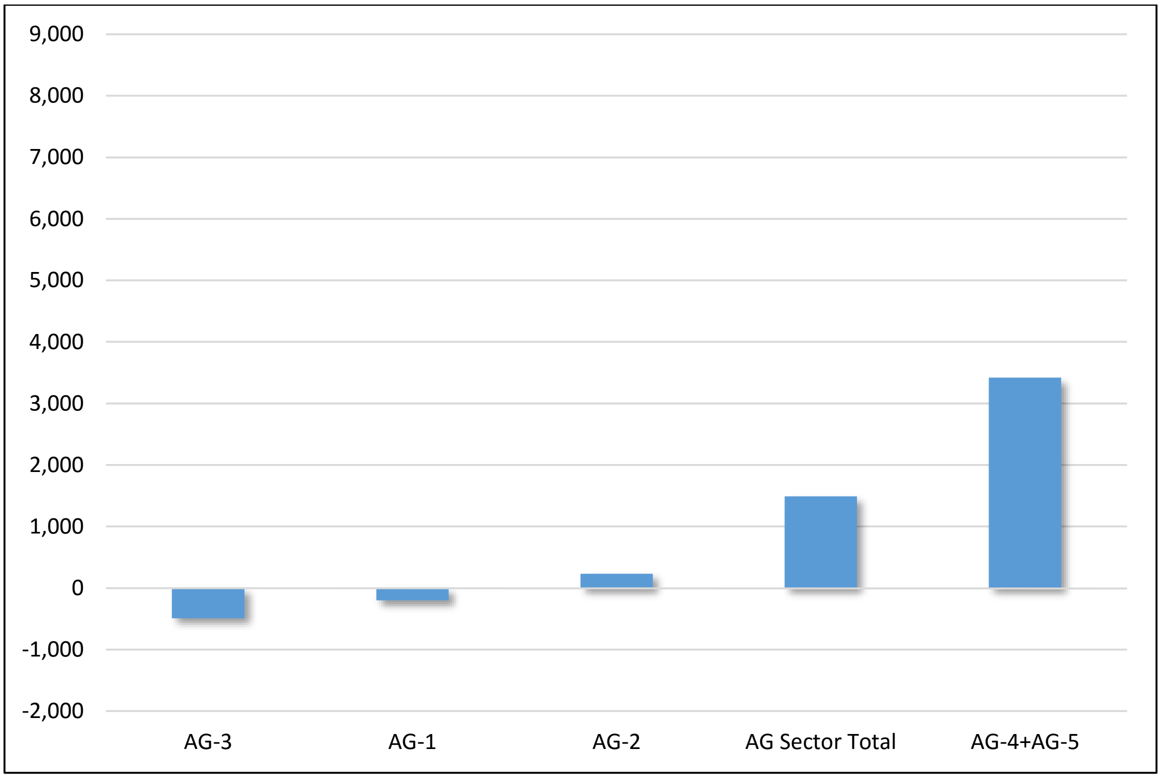
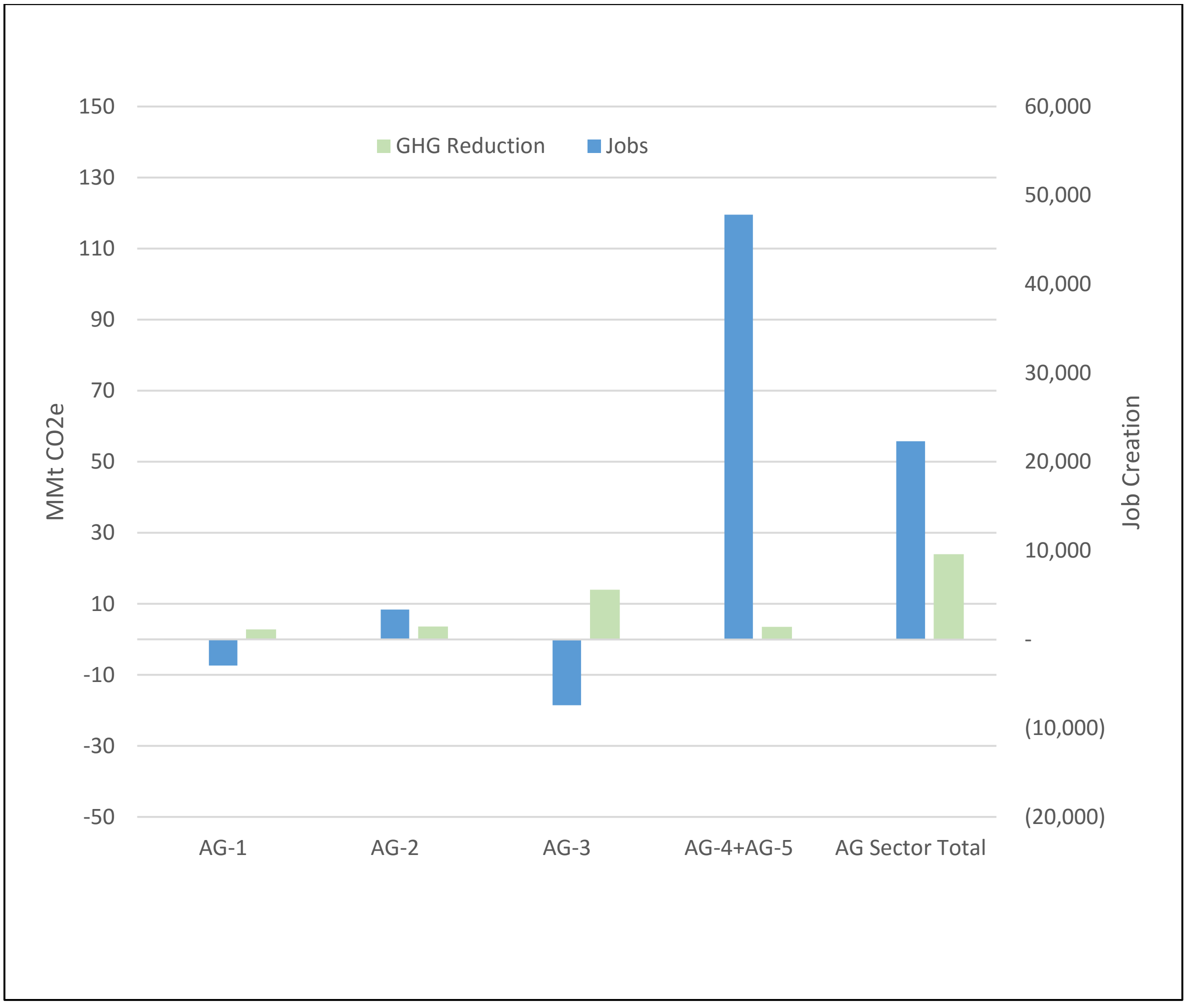


Figure Ap F-4.3 below summarizes a potential for job creation and GHG emissions abatement of Agriculture sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure Ap F-4.3 Ag Jobs and GHG Reduction, 2016-2030



Sector level index

The graphs below express the overall economic impact from each scenario in a single score, and compares those scores. CCS created this single score (a Macroeconomic Impact Index) in order to encapsulate in one measurement the relative macroeconomic impacts (including jobs, GSP and incomes) of each policy. We have found in our own work and in the literature that indexed scores can be helpful to many readers when comparing options with multiple characteristics.

To produce this score, CCS set the results from the absolute best-case scenario (i.e. the implementation of all CSEO policies with all their optimal sensitivities in place) equal to 100, with that scenario's jobs, GSP and incomes impacts weighted equally at one third of the total score. Each policy's jobs, GSP and income impacts are scaled against that measure, and given a total score. The overall score indicates how significant a policy's impact is projected to be. Negative impacts are scaled the same way, except that those impacts are given negative scores and pull down the total score of the policy.

These scores are calculated separately for the final year of the study (2030), the *average* impact over the 2016-2030 period, and the *cumulative* impact of the policies over that period. While each scenario has one line, the relative importance of jobs, income and GSP remain visible as differently-shaded segments of that line.

Figure Ap F-4.4 AG Macroeconomic Impacts, 2030

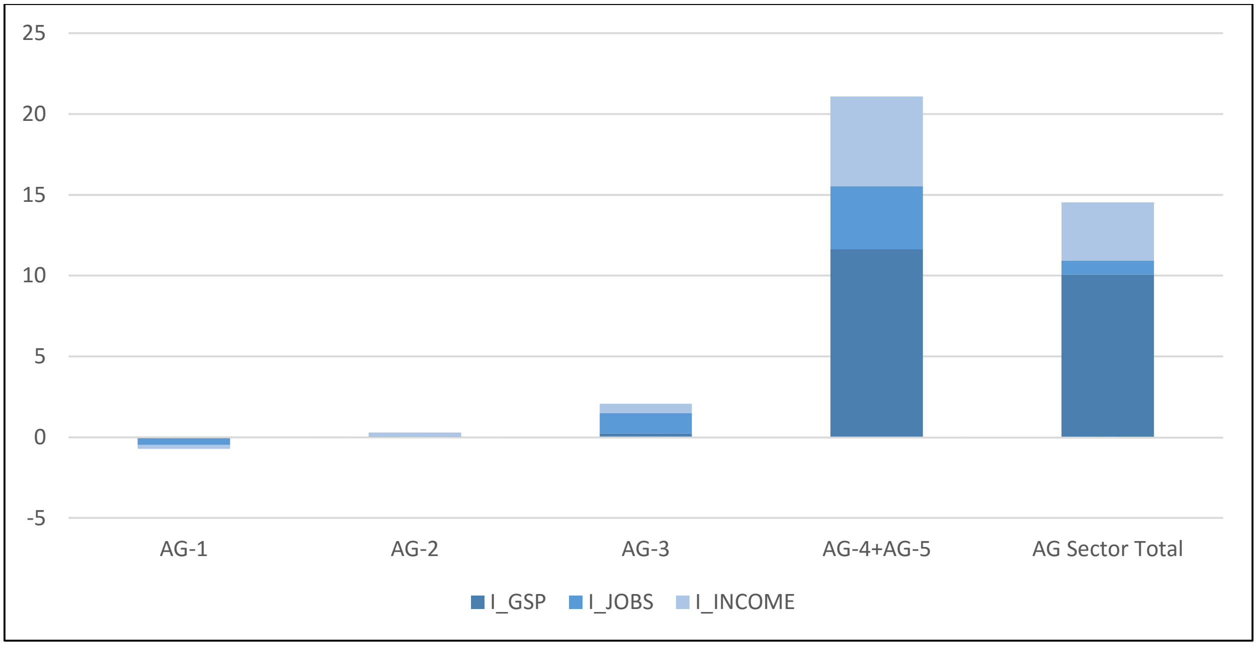


Figure Ap F-4.5 AG Macroeconomic Impacts, 2016-2030, Yearly Average

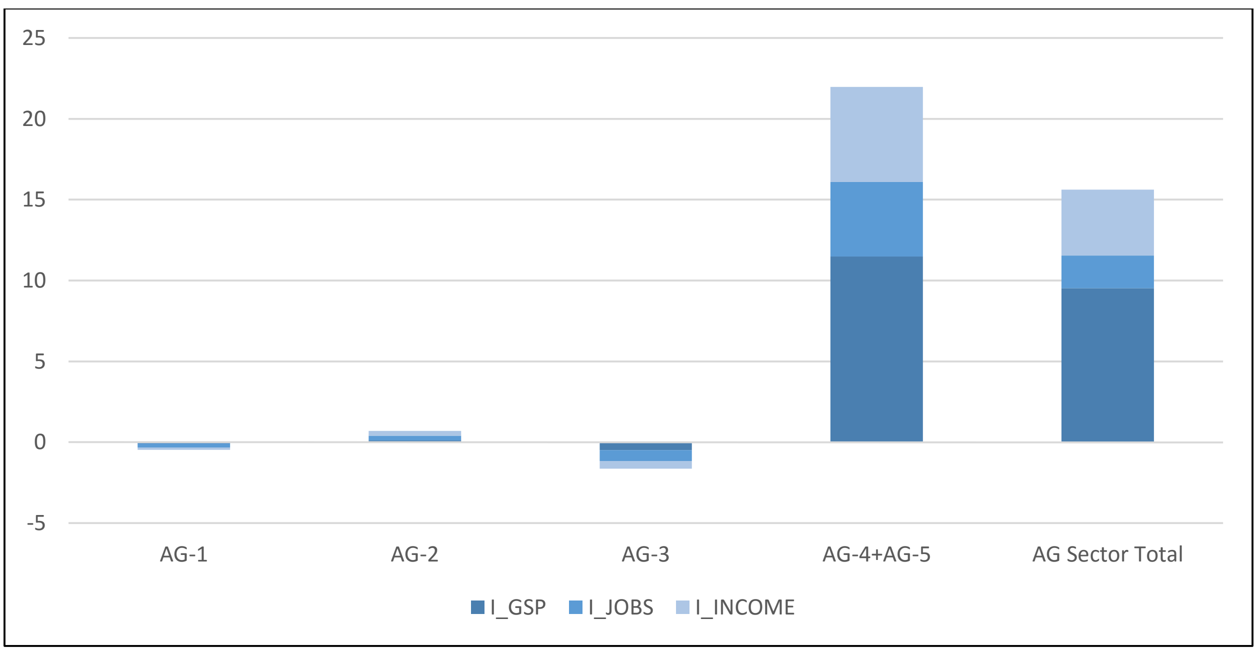
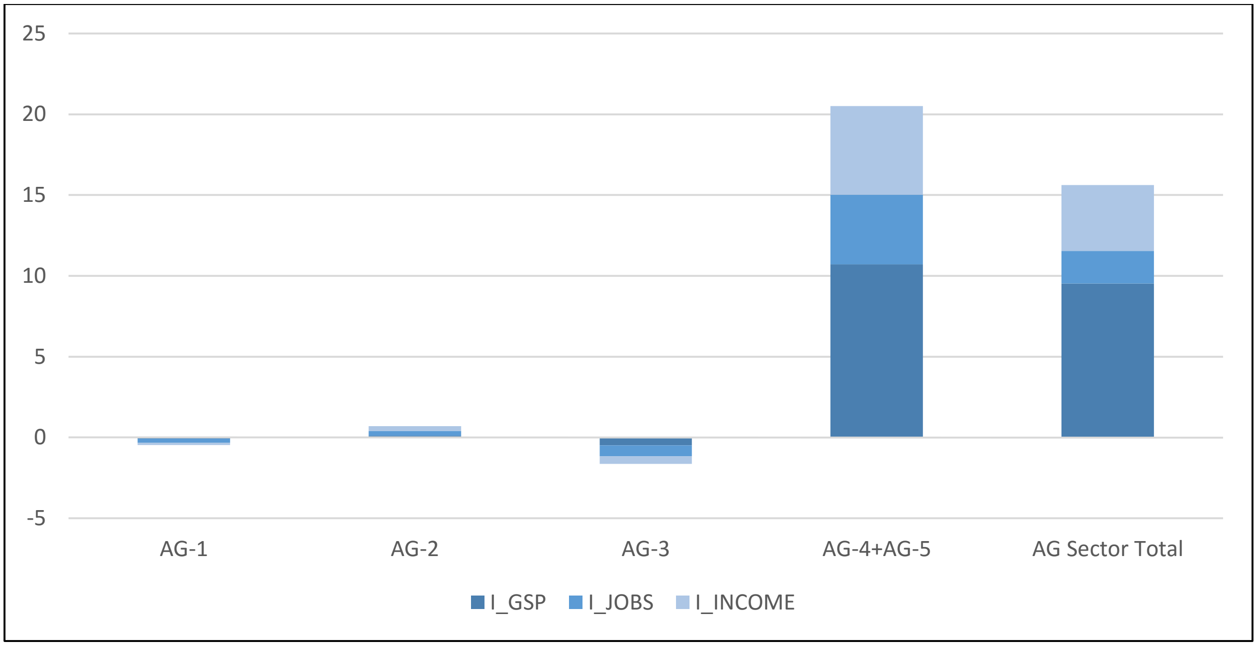


Figure Ap F-4.6 AG Macroeconomic Impacts, 2016-2030, Cumulative



The Agriculture sector generates significant positive impacts – around $1 billion in GSP and nearly two and half times that in income, with a few thousand jobs more than would exist in the state than if these policies were not implemented.

The Agriculture sector impact on Minnesota's economy, according to this analysis, is really the story of the biofuels policy (the combined supply and demand of biofuels from AG-4 and AG-5). While the other policies are effectively neutral in their impacts, driving very small positive or negative shifts over time, the biofuels policies together are responsible for effectively all of the GSP and income gains. They also drive all the employment gains – indeed, the other policies pull the totals slightly down. Graphs and bar charts that follow illustrate the above explained policy effects.

Figure Ap F-4.7 AG GSP Impacts ($2015 MM)

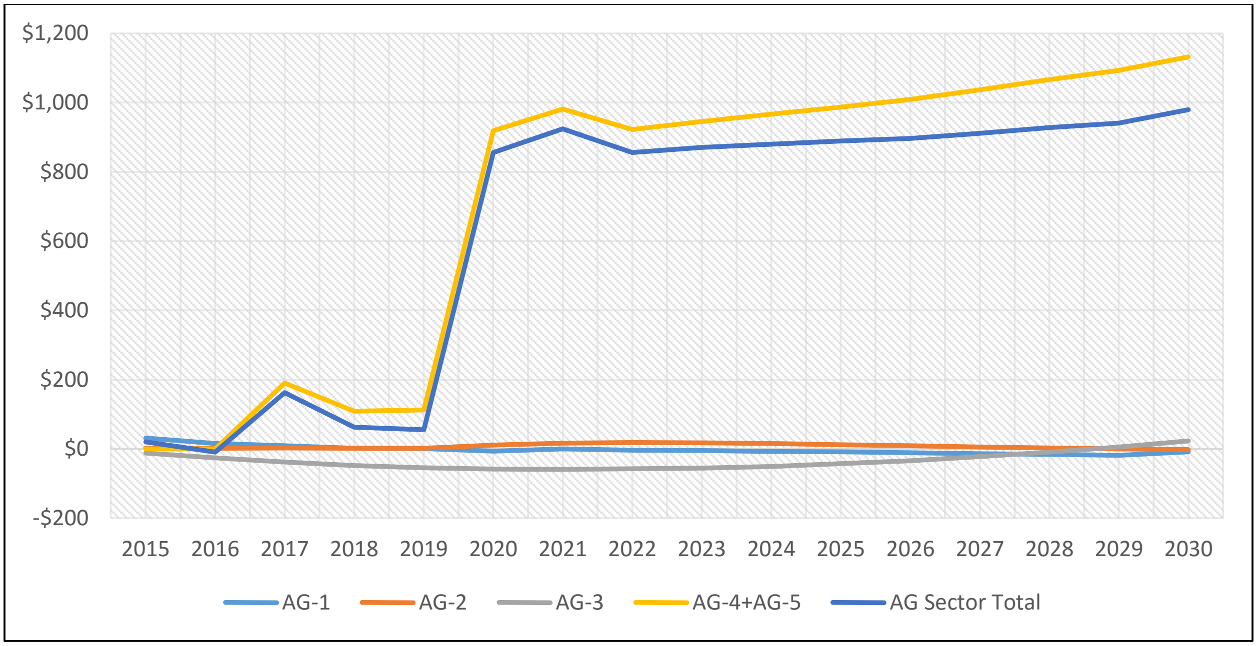


Figure Ap F-4.8 AG Employment Impacts (Individual Jobs)

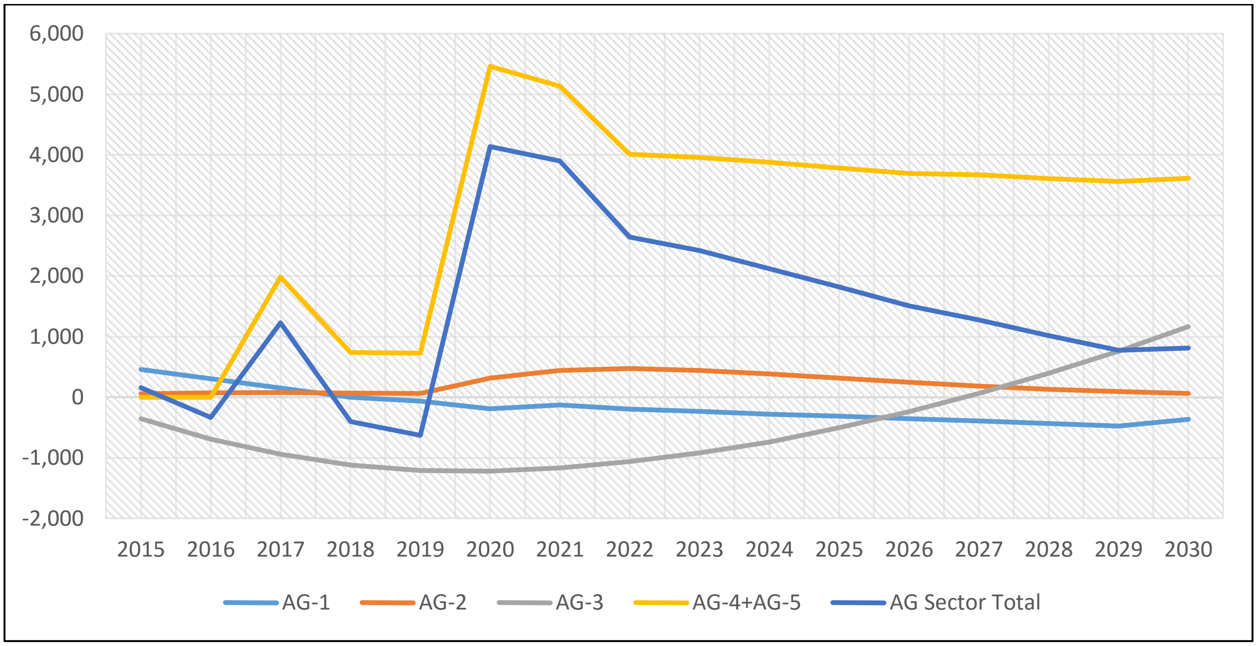
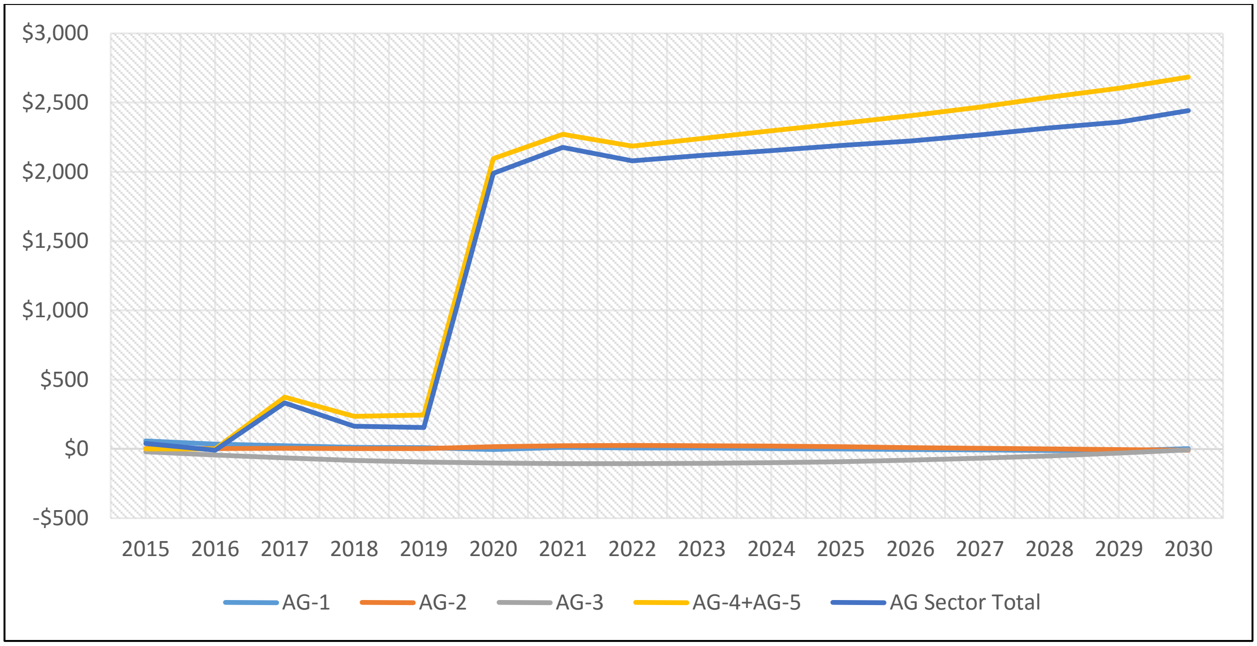


Figure Ap F-4.9 AG Income Impacts ($2015 MM)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and cumulative (2016-2030).

Figure Ap F-4.10 AG GSP Impacts, 2016-2030 Average ($2015 MM)

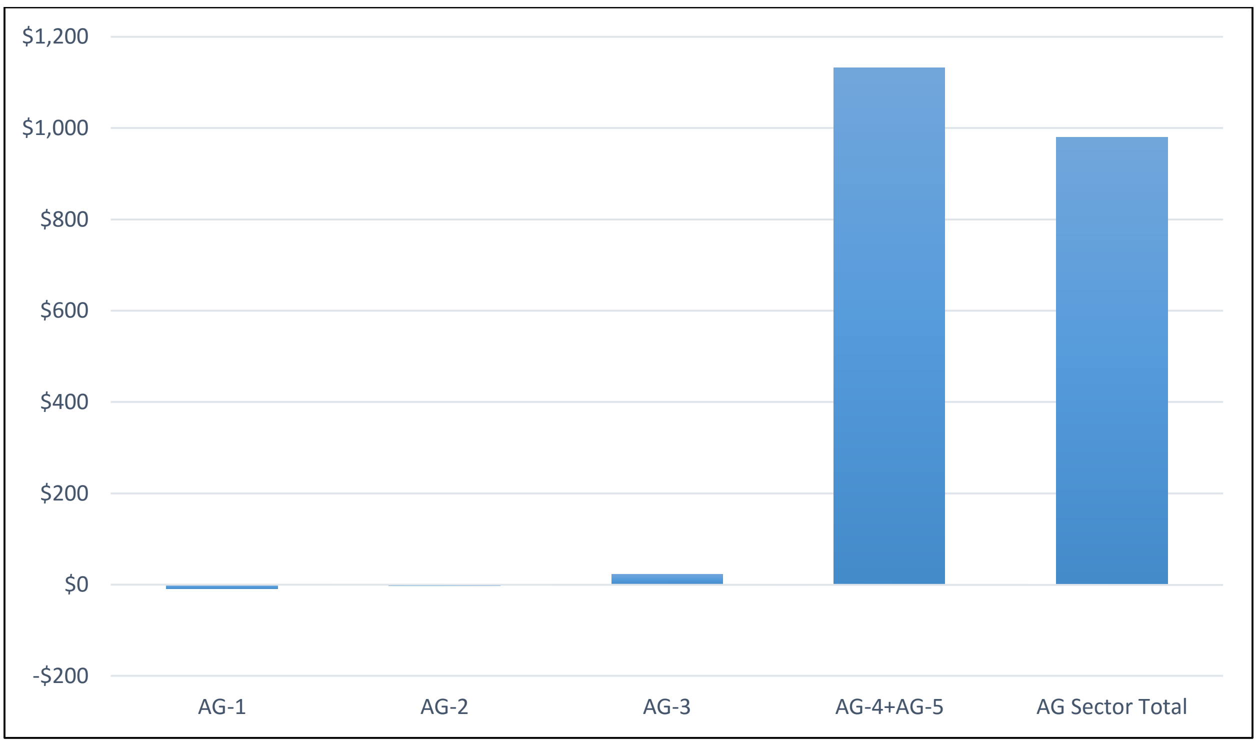


Figure Ap F-4.11 AG GSP Impacts, 2016-2030 Cumulative ($2015 MM)

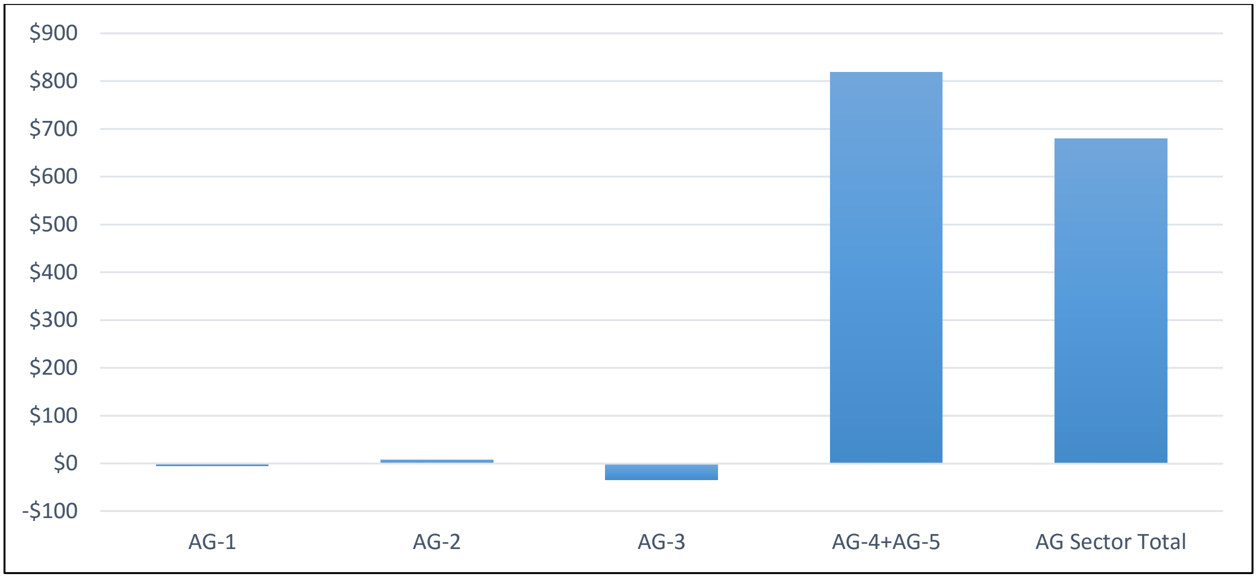


Figure Ap F-4.12 AG GSP Impacts, 2016-2030 Average ($2015 MM)

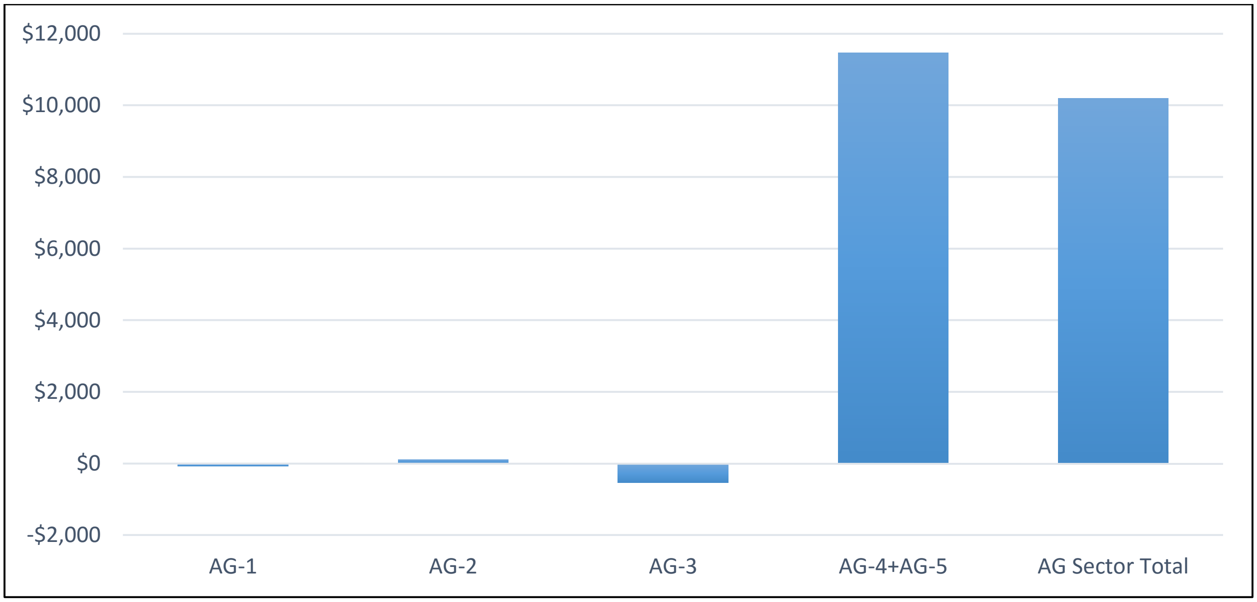


Figure Ap F-4.13 AG Employment Impacts, 2016-2030 Average (Jobs)

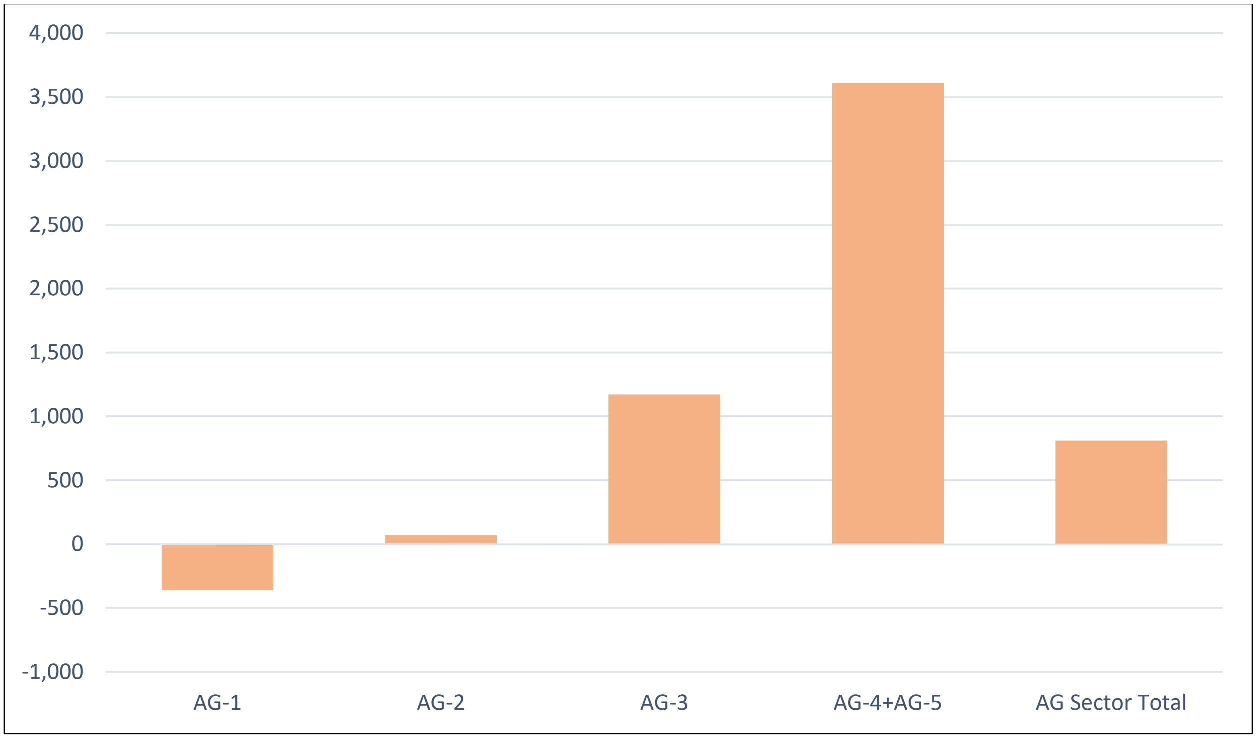


Figure Ap F-4.14 AG Employment Impacts, 2016-2030 Cumulative (Jobs)

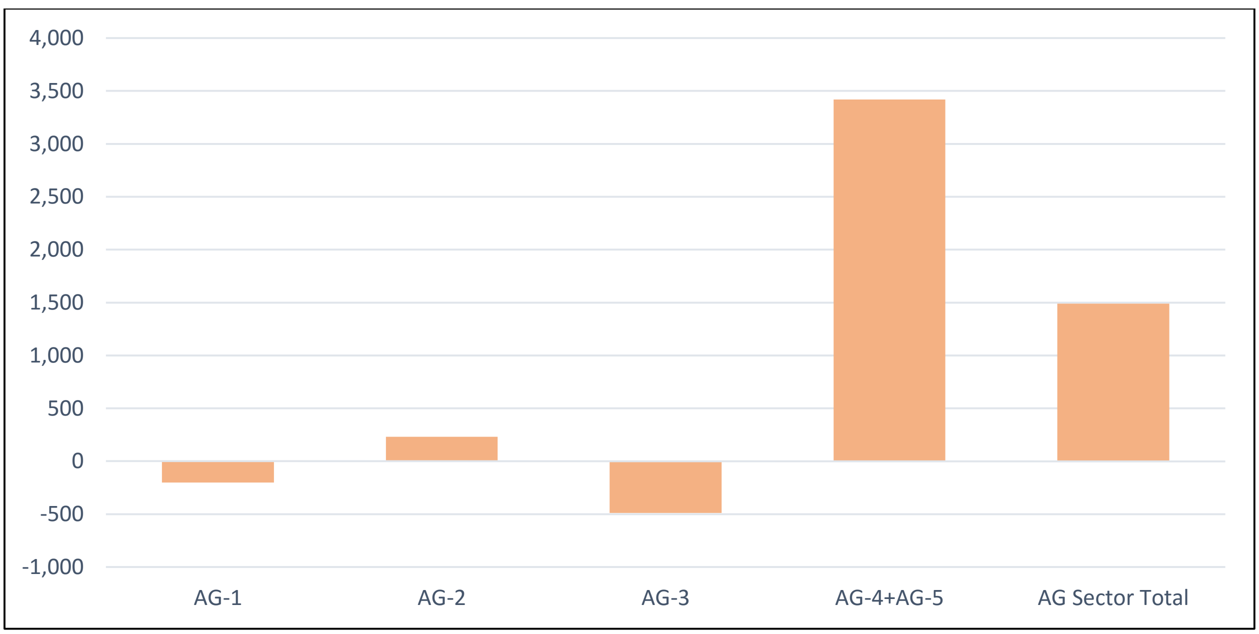


Figure Ap F-4.15 AG Employment Impacts, Year 2030 (Jobs)

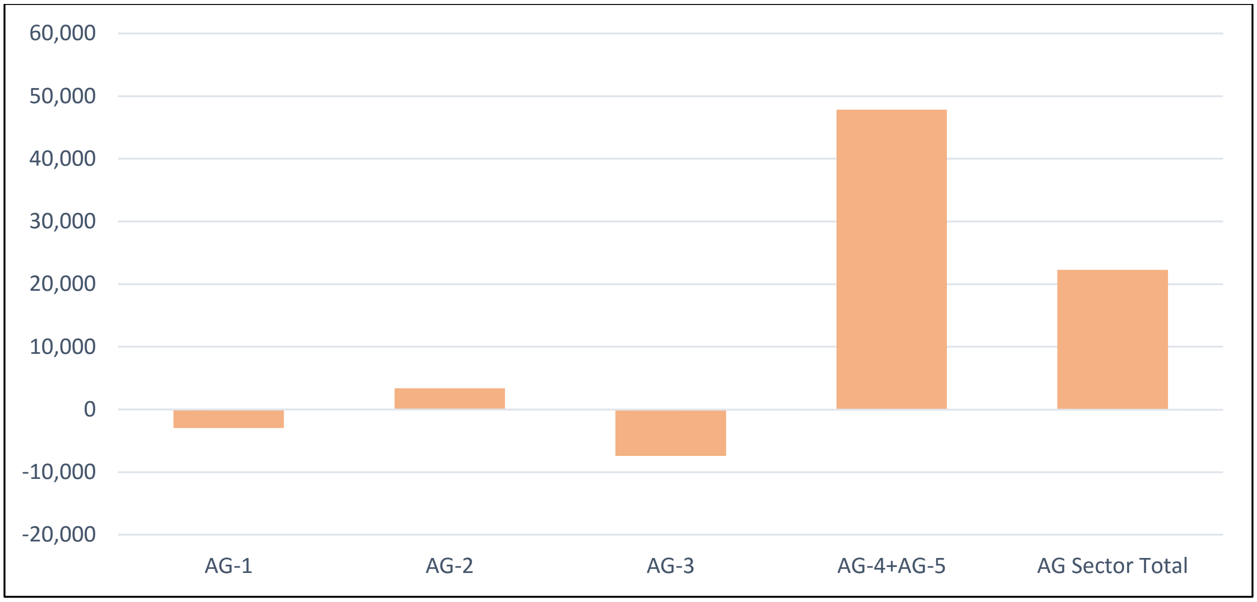


Figure Ap F-4.16 AG Income Impacts, 2016-2030 Average ($2015 MM)

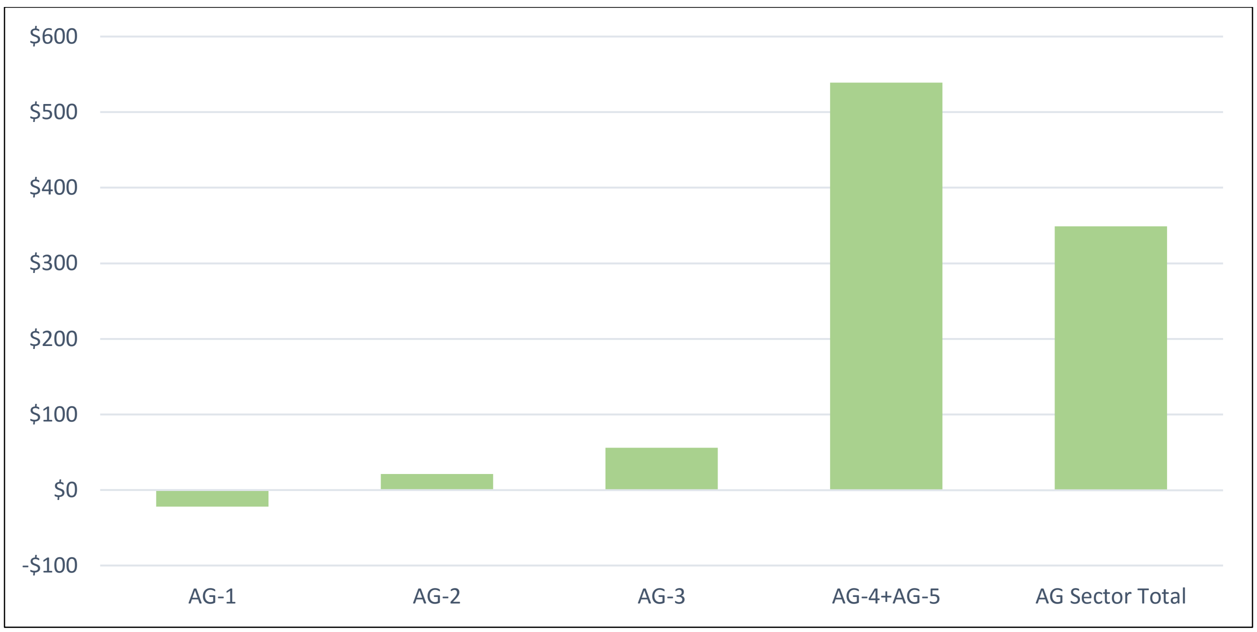


Figure Ap F-4.17 AG Income Impacts, 2016-2030 Cumulative ($2015 MM)

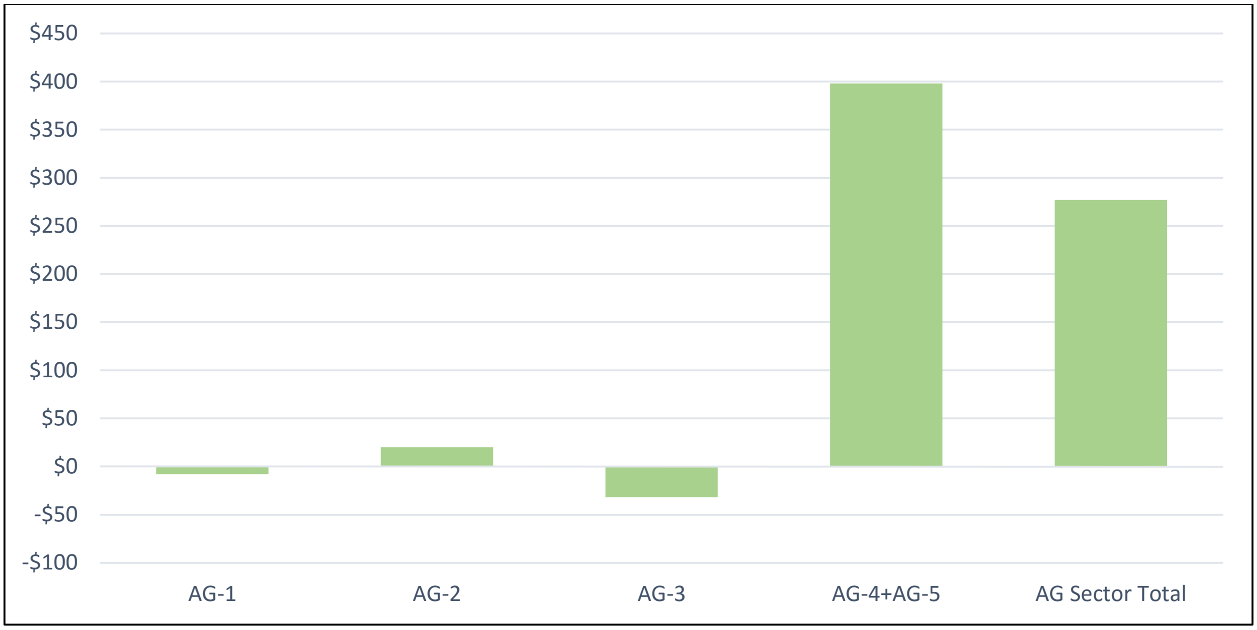
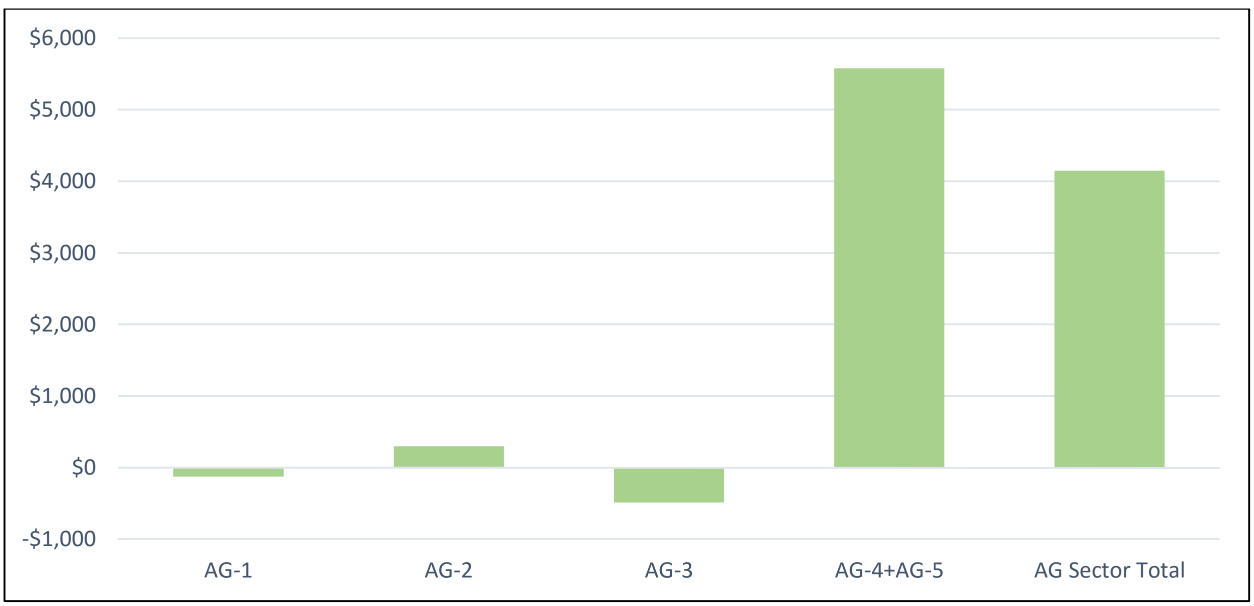


Figure Ap F-4.18 AG Income Impacts, Year 2030 ($2015 MM)



AG-1. Nutrient Management in Agriculture

Policy Option Description

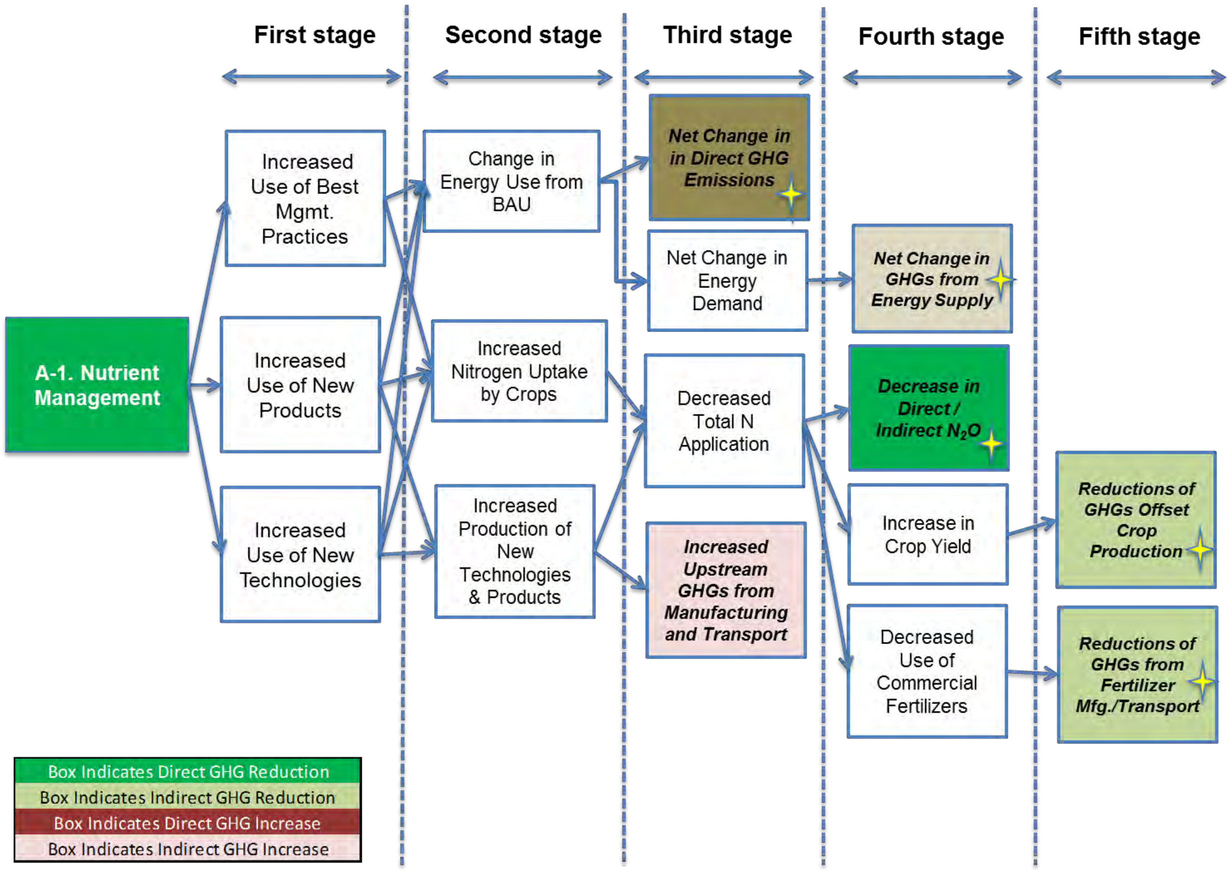
The nitrogen in inorganic and organic fertilizer (manure and plant-based) is the main GHG contributor to nitrous oxide (N_2O) emissions during crop production (N_2O has about 300 times the GHG potential as CO_2). When vegetation does not fully use nitrogen fertilizer, nitrogen can (among other things) leach into groundwater, and/or be emitted into the atmosphere as N_2O. Nitrogen management practices increase efficiency of nitrogen use, reducing nitrate leaching into groundwater and surface water and N_2O emissions. This policy option includes further development, refinement and implementation of nitrogen fertilizer Best Management Practices (BMPs), but also development and use of new technologies. This includes: improved nitrogen fertilizer products and techniques such as the “4Rs”: (Right fertilizer source at the Right rate, at the Right time and in the Right place), as well as precision agriculture materials and methodology (e.g., variable fertilizer rate application, drone use, plant tissue sensors, etc.). The result of changes in the above management practices, products and techniques can be measured using Nitrogen Use Efficiency (NUE). Therefore NUE can be used as a measure of GHG reduction progress.

The reduction in leaching of nitrates to water is a co-benefit of this policy option. Upstream emission reductions associated with nitrogen fertilizer manufacturing and transport are also reduced. While commercial nitrogen fertilizers are not manufactured in Minnesota, the reduced demand will lead to reductions outside of the State’s boundaries.

Causal Chain for GHG Reductions

The GHG causal chain below identifies the main policy option effects and the subsequent GHG impacts. The star symbol identifies significant GHG effects that will be analyzed. Assumptions: the overall amount of organic nitrogen (N) applied to crop fields is not affected by the overall reductions in commercial N application; N application rates will be maintained/optimized to achieve the same yields as expected under BAU conditions; except for use of new products, where an increase in yields are supported by studies in the literature. As discussed in the Estimated GHG Reductions and Net Societal Costs section below, there is still a need to gain an understanding of whether there are significant energy impacts (e.g. diesel fuel consumption) associated with the implementation each BMP (reason why the boxes are currently colored tan).

Figure Ap F-4.19 Causal Chain for AG-1 GHG Reductions



Policy Option Design

Goals: By 2030, increase Nitrogen Use Efficiency (NUE) of Corn by 30% from projected baseline levels. In Minnesota, NUE for corn is used by Minnesota Department of Agriculture (MDA) in the Nitrogen Fertilizer Management Plan.[1]

Timing: Technological progress assumes market availability and adoption by agri-business and farmers. NUE assumes linear progression toward the 2030 goal and will be based on National Agricultural Statistics Service (NASS) production and fertilizer application data.

Parties Involved: Agricultural organizations & individual farmers, agri-business, and the agricultural community; Minnesota Association of Soil and Water Conservation Districts (SWCD), U.S. Department of Agriculture's (USDA's) Natural Resources Conservation Service (NRCS), Minnesota Department of Agriculture (MDA), Board of Water and Soil Resources (BWSR), Department of Natural Resources (DNR), University of Minnesota, USDA's Farm Service Agency (FSA), and conservation organizations.

[1] Nitrogen Fertilizer Management Plan; See draft NFMP, pg 39, since it represents the major nitrogen use crop grown in MN (slightly over 8 mil. acres versus under 3 million for all other nitrogen using crops grown combined – 2013 NASS data).

Other: NUE is a measure of how much of the nitrogen applied is used by the crop. Since corn is the major nitrogen-using crop this is used as the representative crop for this measure. Varying definitions for NUE exist. MDA uses bushel corn per pound of N applied to calculate NUE. This has been done by using N fertilizer sales data (MDA data) & total corn yield (NASS data). Note that this method does not account for soil mineralization, or legume or manure contributions.

In general, any nitrogen management practice that increases NUE should reduce N_2O emissions on a per-acre basis, since less nitrogen is applied to the soil and available to take part in soil denitrification processes. NUE is affected by many factors including adoption of nitrogen fertilizer BMPs, new fertilizer products and technologies, use of the “4Rs”, and adoption of precision agriculture.

This policy option design is based upon increasing NUE, but N_2O emissions can also be reduced by reducing the acreage of crops requiring application of nitrogen fertilizer. Policy Option designs AG-2 (Soil Carbon Management) and FOLU-5 (Conservation on Private Lands) contain goals for reducing row-crop acreage. Corn is the largest sink for N fertilizer used in Minnesota (~70% of N fertilizer used in Minnesota based on MDA personnel conversations). The CSEO crop production baseline assumes growth from around 7.4 million acres of grain corn planted in 2010 to over 7.8 million acres planted in 2030. Conversion of corn acres to low/no nitrogen fertilizer input perennial vegetative cover would most significantly reduce the amount of N fertilizer applied. Each acre of corn taken out of production and converted to grassland would provide a reduction of N input of about 140 lbs/acre (statewide average, N fertilizer applied to corn).[2]

Cover crops are another strategy to reduce N_2O emissions. Cover crops take up, or “scavenge,” nitrogen. Cover crops are included in the AG-2 policy option design.

Implementation Mechanisms

MDA developed the following Implementation Mechanisms with applicable acres for modeling consideration. The modeling of GHG reductions and costs documented in a separate subsection below was conducted just for the nitrification inhibitors and precision agriculture components. That assessment indicated that additional implementation measures would be needed in order to reach the goals of the policy option. MDA believes that carrying out the implementation measures below would achieve the 2030 goal of 30% increase in corn NUE and a corresponding reduction in N_20.

Implementation Measures

[2] (See - MDA 2009 survey data; MDA -2010 survey data –these surveys provide information of N fertilizer type use and timing as well). This policy overlaps with policies AG-2 & FOLU-5 vegetative cover and cover crop factors. Perennial vegetative cover (hay, grazing land, working grasslands, biofuel crops, set-aside, and others that would be low N use vegetation would fit in this category) that replaces corn will in many cases eliminate N fertilizer use on those acres. Cover crops also have the potential to increase NUE through mechanisms such as increased soil storage and change in mineralization, although this will not be quantified in this policy design.

Reduced N fertilizer rate on corn following manure and legume

- MDA survey data has shown that there is an opportunity to reduce N fertilizer application to corn BMP recommendations for years following a legume or manure application.
- It is assumed that this mechanism applies to about 25% of corn acres. (Based on NASS & MDA Surveys – percentage of corn acres with manure applied.)

Potential that commercial N fertilizer use can be reduced by 40 lbs N/ac on 1.5 million acres

- Use of nitrification inhibitors (NI) and urease inhibitors and other N enhancement products - This has limited application; in Minnesota. A large portion of farmers incorporate N fertilizer, and spring apply. NI/urease use would mostly apply to south-central Minnesota, and use on course textured soils. It is estimated (based on MDA records of sales data) that 1.2 M acres of corn currently use Nitrapyrin (N-serve, Instinct). MDA only tracks 2 of these products, so use for all products will be higher. This mechanism could include use of all N enhancement products. Ex: (all nitrapyrin= N-serve, Instinct, DCD=AgrotainPlus, SuperU, Guardian), Urease inhibitors (Agrotain, Nutrisphere etc.) or both, and coated products (ESN).
- Note: Use of inhibitor and microbial products will likely result in decreased N fertilizer rate as well however this is not quantified. (A farmer has a fixed cost for N product, and will balance of cost of N fertilizer≥ cost of inhibitor/microbial product.)
- Note: Also it appears that there is significant industry effort around soil amendment products for microbials. However, this is not included since the efficacy and impact of these new technologies are unknown.

Potential for use of NI/urease products is applicable to 1 million acres.

- Precision agriculture: For this project, this is defined to include in field geographic positioning systems (GPS)/ geographic information system (GIS) technology (Ex. auto-steer) and variable rate fertilizer nitrogen (N) application.
- This mechanism is additive; it will increase incrementally as well as overlap (Ex. GPS and variable rate technology [VRT] is used)
- Increased Use of GPS: Automatic steering to prevent row overlap, and other variability based on site conditions (Hedley, 2014). Research has shown that the use of GPS alone can increase efficiency by five to ten percent. Combine the GPS technology with GIS prescription maps and the efficiency can increase an additional 10 – 20%. Various sources indicate that GPS technology is used by 30-50% of farmers; 50% is assumed.

Potential for N fertilizer reduction of 10% (15lbs/acre using average N application rate of 145lbs/ac.) applies to 3.5 million acres.

- VRT fertilizer application –This can include N fertilizer application based on; soil mapping unit, field conditions (Ex. wetness), fertigation (soil grid sampling in Minnesota), corn variety or other criteria. Agvise Laboratories information indicates 80% of farmers they worked with used soil grid sampling in Minnesota. Fertilizer and Manure Selection and Management Practices Associated with Minnesota's 2010 Corn and Wheat Production publication notes variable rate N application use of 24% use statewide. MDA 2011 Corn Production survey indicates 20-25% may variable rate apply N fertilizer. Assume currently a 50% adoption rate.

Assumed VRT is applied to 4 million corn acres.

- Change from fall to spring application of N: Some research indicates switch for fall to spring N application will reduce N_2O.[3,4] This will apply in limited areas where N fertilizer BMPs do not recommend fall application. Fertilizer and Manure Selection and Management Practices Associated with Minnesota's 2010 Corn and Wheat Production document notes 32% application of some N in fall statewide (mostly MAP & DAP), while ~ 10% fall apply urea.; 18% fall apply AA. The Survey of Nitrogen Fertilizer Use on Corn in Minnesota, by Bierman etal indicates about 32.5% of main N application in fall)

Potential for change from fall to spring application of N applicable to one million acres:

- Tissue/meters & soil N testing: Tissue testing for crop N needs and a reliable soil N test are emerging technologies that may lead to an increase in NUE (In western Minnesota, soil N testing is used). Currently, it is not known if these will prove effective statewide. Assume that one of these technologies (or a combination thereof) will be applied to corn acres (use 7 M). Assume that this will lead to a reduction of N fertilizer application amount. (This could mean an overall reduction in N applied, or increased NUE due to increased plant uptake.)
- This will lead in direct reductions in N applied as well as increase N uptake based on resulting crop needs (better timing –when the crop needs; better placement – at corn roots).
- MDA 2011 Corn Production document notes about 10% of acres use tissue or basal testing, and about 10% use deep N soil test.

Potential for application of tissue/meters & soil N testing on seven million acres:

MDA chose for consideration the implementation mechanisms discussed above because they have the greatest likelihood of increasing NUE, and are actions that can be taken by the state. NUE may also be increased through other means that were not included in this policy option design either because they were deemed less effective than the above mechanisms, or they were actions that would likely be taken by the private sector (e.g., improved plant genetics).

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[3] *Influence of fertilizer nitrogen source and management practice on N_2O emissions from two Black Chernozemic soils* D L Burton, Xinhui Li, C A Grant

[4] *Nitrous oxide emissions from an irrigated soil as affected by fertilizer and straw management* X. Hao, C. Chang, J.M. Carefoot, H.H. Janzen, B.H. Ellert)

Related Policies/Programs in Place and Recent Actions

Existing Programs and funding that address NUE and reducing N_2O emissions.

- Note: None of these programs has reducing N_2O emissions as a stated goal, and may not specify increasing NUE either. These programs goals are to increase water quality, increase nitrogen fertilizer management, increase "conservation cover," etc.; which implicitly provide N_2O reduction as well (though results may vary).
- Note: programs and associated cost related to perennial cover will be done with the AG-2 and FOLU-5 policies.

The Nutrient Management Initiative (NMI) and BMP Challenge work directly with farms to try variable N fertilizer rates and methodologies that will result in an increase in NUE.

Assumed annual Cost $100,000/year (from 2012 budget information – includes federal dollars).

Agriculture Fertilizer Research and Education Council
AFREC[5] funds a broad range of research activities including nitrogen fertilizer related. An annual expenditure of ~$800,000 has been allocated recently. *Assumed $200,000 annually for N related research*

Clean Water Funded research and technical assistance – funds various research activities and on-the-ground studies that promote clean water. Some research/technical assistance nutrient management activities will benefit N_2O as well. Approximately $5 million is available annually ($3M TA, $2.1M research). *Assumed $1 million annually will have a direct relationship to N_2O GHG emissions*.

N Management Education - MDA, University of Minnesota and others annually host and collaborate with; nutrient management related field days, conferences, presentations, and/or provide information (booths, handouts, etc.) to educate farmers and agriculture industry representatives about N management. *Assumed estimated annual cost: $100,000*

Annual N Surveys - MDA conducts surveys of Minnesota farmers' N use and management practices. This is important to track current conditions and progress in increasing NUE. *Assumed estimated annual cost: $100,000*

Others Considered:

The above are programs most likely to indirectly address N_2O emissions. Other public investment not quantified includes:

- MDA Clean Water Fund Activities,
- Significant research and demonstrations are already occurring related to nitrogen fertilizer management, including University of Minnesota research stations, MDA demonstration sites, and information and education activities,

[5] http://www.mda.state.mn.us/chemicals/fertilizers/afrec/researchprojects.aspx

- N fertilizer BMP research and field trials by University of Minnesota & other academic institutions,
- Other technical and financial assistance for nutrient management practices through programs such as USDA Conservation Programs; - (EQIP, CSP, RCPP, CRP, CREP, ACEP) BWSR Grant and Easement Programs, state cost share, and RIM,
- Minnesota Agricultural Water Quality Certification Program (MAWQCP),
- Nitrogen Fertilizer Management Plan,
- Minnesota Nutrient Reduction Strategy,
- MDA cover crop initiatives and research grants (including Clean Water Fund-supported research),
- University of Minnesota Nitrogen Fertilizer BMPs,
- Natural Resources Conservation Service (NRCS) nutrient management programs – technical assistance and cost share,
- Watershed Restoration and Protection Strategy (WRAPS)[6] & Total Maximum Daily Loads (TMDLs), and
- Local initiatives for cover crop adoption, alternative crop development, and nutrient management (e.g., 'Third Crop Initiative" of Blue Earth River Basin Initiative).

Estimated Policy Impacts

Direct Policy Impacts

Table F-4.4 Estimated Net GHG Reductions and Net Costs or Savings

2030 GHG Reductions (Tg CO_2e)	2015 – 2030 Cumulative Reductions (Tg CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ tCO_2e)
0.37	**2.8**	**-$131**	**-$46**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

The GHG reductions summarized above represent full energy-cycle reductions for the policy option, which include reductions of upstream emissions that may occur outside of Minnesota. For comparison, emission reductions that can be specifically allocated to occur within the State are 0.14 Tg CO_2e in 2030 and 1.1 Tg CO_2e cumulatively from 2015 to 2030.

Data Sources

[6] http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/watershed-approach/index.html

Key data sources are referenced within the discussion of Quantification Methods below and include:

- N application reductions for a variety of precision agriculture (PA) approaches: *Greenhouse Gas Mitigation Potential of Agricultural Land Management in the United States, A Synthesis of the Literature*, Technical Working Group on Agricultural Greenhouse Gases (T-AGG) Report, Nicolas Institute for Environmental Policy Solutions, Duke University, January 2012[7].

Quantification Methods

There is not one major item that contributes to NUE, but rather several additive components that result in the NUE metric. There are many factors that contribute to NUE. The research on these various NUE components is variable as to N_2O reductions provided. The approach used in this policy option design was to determine BAU and future conditions in aggregate. The analysis documented here corresponds to an earlier analysis that used only two of the implementation mechanisms described above: precision agriculture (PA) defined as a combination of two technologies, GPS and VRT N application; and the use of NI.

- BMPs that are most applicable to Minnesota, and approximate applicable acres are described under the Implementation Mechanisms section. The first of these is continued State outreach programs aimed at reducing N application following manure application or legumes. MDA estimates that 40 lb. N/acre of synthetic fertilizer can be reduced via this mechanism on 1.5 Minnesota acres. Timing of this mechanism was assumed to be linear beginning in 2015 and reaching its full potential by 2024.
- To estimate GHG reductions of the full suite of implementation mechanisms, the approach used here was to first estimate the amount of N reduction required to meet the requirements of the policy option design (30% NUE increase by 2030). Then, based on these expected N application reductions, the quantity of N_2O reductions was determined using emission factors from the baseline. Literature sources were used to determine the upstream reductions associated with reduced commercial fertilizer demand (e.g. from the T-AGG study). Information from the literature was not clear on the potential net change in diesel consumption associated with application the BMPs analyzed, so it was assumed that no change in diesel consumption was expected between BAU and the Policy Option Scenario.
- New Products: for NI, one literature source suggests an N application reduction of 20%[8]; this fraction was be used along with BAU emission factors to determine N_2O reductions and upstream commercial fertilizer manufacturing/transport reductions. Literature sources (Laboski, 2006) suggest a yield increase of 4-6% using NI. The increase in yield was included within the estimation of net societal costs (described below) for the Policy Option Scenario.

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[7] http://nicholasinstitute.duke.edu/sites/default/files/publications/ni_r_10-04_3rd_edition.pdf.

[8] Laboski (2006) economic analysis of NI on corn; http://www.soils.wisc.edu/extension/wcmc/2006/pap/Laboski1.pdf.

- New Technologies: referred to as Precision Agriculture (PA); assumes some combination of yield monitors (including tractor-mounted geographical information system), soil sampling, and variable rate N application; previous studies (T-AGG) suggest a N application reduction of ~15%. This value was applied to the acres specified for PA and the same baseline N_2O emission factors applied.

Table F-4.5 below provides a summary of the Policy Option Scenario results for N application reductions and the associated N_2O reductions for the policy option.

Net Societal Costs:

The cost elements of the policy option are summarized below:

- BAU avoided costs: through application of policy option mechanisms (e.g. NI application or PA), there can be cases where the change in practice will remove some production cost that would have occurred otherwise. No avoided costs (other than reduced N fertilizer costs) were identified for this analysis.
- All Policy Option Scenario costs are presumed to be incremental to BAU and are some combination of capital, non-fuel operations/maintenance costs, fuel costs, and material costs. Cost reductions for all expected commercial N reductions are based on USDA ERS fertilizer cost data[9]. Fertilizer prices are escalated based on the historical growth in N fertilizer pricing from 2008 to 2012 (0.4%). Note that going back one year to 2007 would have resulted in a much higher growth rate of over nine percent. Based on recent and expected pricing on natural gas (the major feedstock for N fertilizer), the much smaller growth rate appears to be much more in line with expectations.
- Incremental costs of new products (e.g., a cost for the nitrification inhibitor, Nserve) at $7.75/acre (Laboski, 2006) is used, and the corresponding reduction (offset) of commercial fertilizer costs is also calculated.
- Incremental costs of new technologies: studies suggest PA costs of $8-12/acre with about half of these costs associated with enhanced soil sampling.[10] Currently, it is unclear to what extent these new technologies change BAU energy use (so no change in fuel costs is factored into the analysis).

Table F-4.7 provides a summary of the net societal cost results. The estimated cost effectiveness is -$46/t$CO_2$e, indicating a net societal cost savings. A key assumption here is that implementation mechanism #1 (Minnesota technical outreach programs) to farmers is successfully applied and reaches its objectives of N reductions on 1.5 MM acres of corn. Another key assumption is that the estimated program costs (which address all state support for the policy option) are sufficient to successfully achieve the overall policy option goals.

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[9] http://www.ers.usda.gov/Data/FertilizerUse/Tables/Table8.xls.

[10] http://www.cnie.org/NLE/CRSreports/Agriculture/ag-97.cfm;
http://www.plantmanagementnetwork.org/pub/cm/research/2005/precision/;
http://www.cdfa.ca.gov/is/docs/01-0507Plant%2007.pdf.

Table F-4.5 GHG Impacts Summary - BAU Energy & Emissions

Year	Grain Corn N Use Efficiency (NUE) bu/lb N	MN Grain Corn Production bu	Comm. N Applied lb N	N_2O Emissions tCO_2e	Targeted PA/NI Cropland Harvested Acres	Diesel Fuel Use TJ	Diesel Fuel Use tCO_2e
2015	1.37	1,297,029,358	946,736,758	702,060	7,899,083	12,236	853,158
2016	1.41	1,275,475,229	904,592,361	670,607	7,669,725	11,903	829,947
2017	1.45	1,260,682,569	869,436,254	643,760	7,486,239	11,640	811,616
2018	1.50	1,260,761,468	840,507,645	625,200	7,394,495	11,519	803,175
2019	1.54	1,276,289,908	828,759,681	614,529	7,394,495	11,530	803,928
2020	1.59	1,291,818,349	812,464,370	603,858	7,394,495	11,552	805,433
2021	1.61	1,315,456,881	817,053,963	607,604	7,440,367	11,645	811,944
2022	1.63	1,331,081,651	816,614,510	607,604	7,440,367	11,656	812,702
2023	1.65	1,346,706,422	816,185,710	607,604	7,440,367	11,678	814,217
2024	1.67	1,366,051,376	817,994,836	607,604	7,440,367	11,699	815,732
2025	1.68	1,375,528,702	818,767,085	606,534	7,427,261	11,700	815,807
2026	1.70	1,391,125,950	818,309,382	606,534	7,427,261	11,711	816,563
2027	1.72	1,406,723,198	817,862,324	606,534	7,427,261	11,733	818,075
2028	1.74	1,422,320,446	817,425,544	606,534	7,427,261	11,755	819,587
2029	1.76	1,437,917,693	816,998,689	606,534	7,427,261	11,766	820,343
2030	1.78	1,453,514,941	816,581,428	606,534	7,427,261	11,787	821,855
Sum		**21,508,484,141**	**13,376,290,541**	**9,929,635**		**187,511**	**13,074,081**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.6 GHG Impacts Summary - Policy Option Scenario Energy & Emissions

	Policy Option Scenario Energy & Emissions				Net Change			
	Grain Corn N Use Efficiency (NUE)	Increased Grain Corn NUE Over BAU	Commercial N Applied	N_2O Emissions	Change in Commercial N Applied	N_2O Emissions	Net In-State GHG Reductions	Out-of-State GHG Reductions
Year	bu/lb N	%	lbs N	tCO_2e	lbs N	tCO_2e	Tg CO_2e	Tg CO_2e
2015	1.42	3.9%	911,219,164	676,830	(35,517,594)	(25,230)	(0.025)	(0.043)
2016	1.48	4.7%	863,674,993	641,516	(40,917,368)	(29,091)	(0.029)	(0.049)
2017	1.53	5.5%	823,867,840	611,948	(45,568,414)	(31,812)	(0.032)	(0.055)
2018	1.58	5.6%	796,136,315	591,350	(44,371,331)	(33,850)	(0.034)	(0.054)
2019	1.64	6.3%	779,651,746	579,105	(49,107,935)	(35,424)	(0.035)	(0.059)
2020	1.69	6.3%	764,208,678	567,635	(48,255,693)	(36,223)	(0.036)	(0.058)
2021	1.74	8.3%	754,362,244	560,321	(62,691,719)	(47,283)	(0.047)	(0.076)
2022	1.80	10.3%	740,641,916	550,130	(75,972,594)	(57,474)	(0.06)	(0.092)
2023	1.85	12.2%	727,713,402	540,527	(88,472,308)	(67,077)	(0.07)	(0.11)
2024	1.90	14.0%	717,463,958	532,914	(100,530,878)	(74,690)	(0.07)	(0.12)
2025	1.96	16.5%	702,732,554	521,972	(116,034,530)	(84,562)	(0.08)	(0.14)
2026	2.01	18.3%	691,827,109	513,872	(126,482,274)	(92,662)	(0.09)	(0.15)
2027	2.06	20.0%	681,485,902	506,190	(136,376,423)	(100,343)	(0.10)	(0.16)
2028	2.12	21.7%	671,666,248	498,897	(145,759,296)	(107,637)	(0.11)	(0.18)
2029	2.17	23.4%	662,329,661	491,962	(154,669,029)	(114,572)	(0.11)	(0.19)
2030	2.31	30.0%	628,139,560	466,566	(188,441,868)	(139,968)	(0.14)	(0.23)
Sum			**11,917,121,287**	**8,851,734**	**(1,459,169,253)**	**(1,077,901)**	**(1.1)**	**(1.8)**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.7 Net Societal Costs Summary

	Policy Option Scenario Costs (all incremental to BAU)								Net Costs		
Year	Cumulative Precision Ag (PA) Variable Rate Timing (VRT) Use Acres	Cumulative Nitrification Inhibitor (NI) Use Acres	PA Total Annualized Costs MM$	NI Total Annualized Costs MM$	N Fertilizer Savings MM$	NI Yield Increase MM$	MN Program Costs MM$	Federal Incentives MM$	Total Policy Option Costs MM$	Total Discounted Policy Option Costs MM$2014	Cost Effectiveness $2014/tCO₂e
2015	436,835	982,880	$5.2	$9.3	($11)	($15)	$1.5	$0.0	($11)	($10)	
2016	417,615	991,836	$5.0	$10	($13)	($16)	$1.5	$0.0	($13)	($12)	
2017	387,948	974,087	$4.8	$10	($15)	($16)	$1.6	$0.0	($15)	($13)	
2018	278,886	741,582	$3.5	$7.5	($14)	($13)	$1.6	$0.0	($15)	($12)	
2019	254,035	716,742	$3.3	$7.4	($16)	($13)	$1.6	$0.0	($17)	($13)	
2020	157,920	473,759	$2.1	$5.0	($16)	($9.2)	$1.7	$0.0	($16)	($12)	
2021	226,628	829,859	$3.0	$8.9	($21)	($17)	$1.7	$0.0	($24)	($17)	
2022	486,592	986,700	$6.6	$11	($25)	($21)	$1.7	$0.0	($27)	($18)	
2023	910,589	982,770	$13	$11	($29)	($22)	$1.8	$0.0	($26)	($17)	
2024	1,305,643	979,232	$18	$11	($33)	($22)	$1.8	$0.0	($24)	($15)	
2025	2,310,490	974,738	$33	$11	($39)	($23)	$1.8	$0.0	($15)	($8.7)	
2026	2,998,280	963,733	$44	$11	($42)	($23)	$1.9	$0.0	($8.1)	($4.5)	
2027	3,592,117	996,443	$54	$12	($46)	($25)	$1.9	$0.0	($2.7)	($1.4)	
2028	4,199,167	994,540	$64	$12	($49)	($25)	$1.9	$0.0	$3.9	$2.0	
2029	4,818,405	960,631	$75	$12	($52)	($25)	$2.0	$0.0	$12	$5.6	
2030	6,951,111	993,016	$111	$13	($64)	($27)	$2.0	$0.0	$34	$16	

Sum			**$446**	**$162**	**($487)**	**($313)**	**$28**	**$0**	**($164)**	**($131)**	**($46)**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

The estimated cost effectiveness value is -$46/tCO2e reduced. This value is derived by dividing the total cumulative policy option reductions in Table F-4.6 (1.8 teragrams) into the net present value (NPV) of policy option costs (-131 million 2014 dollars) shown in Table Ap F-4,7. These estimated costs are sensitive to the relative amount of N reduction expected from the relatively low cost NI implementation mechanism versus the more expensive PA mechanism. The current estimates show that by limiting the incremental NI use to ~1 million acres total requires nearly 11 million acres of PA to be applied to corn, which exceeds the expected future grain corn area in 2030 (about 7.4 million acres of which about 1.7 million acres are expected to have already adopted some form of PA by 2030). This suggests that other implementation mechanisms will need to be analyzed and applied and/or more NI acreage will be needed. Examples of other implementation mechanisms are provided in the Implementation Mechanisms section above.

Key Assumptions

Key assumptions include the build-up of total N application reductions (and NUE increase) that can be achieved by the practices/technologies envisioned. Individually applied, the methods would be expected to achieve a 10-20% reduction in N application, which would be translated directly into N_2O reductions using baseline emission factors. To achieve the total 30% NUE, these methods would need to be layered over one another (i.e. more than one implementation mechanism may be used on the same acres). Other key assumptions:

- Precision Ag. (PA) techniques (GPS, GIS, soil grid sampling, etc.) would reduce nitrogen fertilizer use 15%.
- Use of nitrification inhibitor products would reduce nitrogen fertilizer use 20%.
- Use of NI products would increase yield 2.9%, while PA techniques would result in zero percent yield increase.
- Use of NI products or PA techniques would not result in a change (increase or decrease) in tillage, planting, or harvesting (i.e. change in ‘in field effort’, fuel use, equipment…).
- N fertilizer prices would increase by 0.4% annually.

Additional background references:

- http://www.usda.gov/oce/climate_change/estimation.htm;
- http://www.usda.gov/oce/climate_change/Quantifying_GHG/USDATB1939_07072014.pdf - start with Chapter 3
- Venterea R.T., A.D. Halvorson, N. Kitchen, M.A. Liebig, M.A. Cavigelli, S.J. Del Grosso, P.P. Motavalli, K.A. Nelson, K.A. Spokas, B.P. Singh, C.E. Stewart, A. Ranaivoson, J. Strock, and H. Collins, Challenges and opportunities for mitigating nitrous oxide emissions from fertilized cropping systems, Frontiers in Ecology and the Environment 2012 10:10, 562-570
- American Carbon Registry (2013), American Carbon Registry Methodology for N2O: Emission Reductions through Changes in Fertilizer Management, Version 2.0., Winrock International, Little Rock, Arkansas.

- Climate Action Reserve (2013), Nitrogen Management Project Protocol, Version 1.1, Los Angeles, CA
- Physiological perspectives of changes over time in maize yield dependency on nitrogen uptake and associated nitrogen efficiencies: A review.- http://www.sciencedirect.com/science/article/pii/S0378429012001013
- Haegele, J.W., K.A. Cook, D.M. Nichols, and F.E. Below. 2013. Changes in nitrogen use traits associated with genetic improvement for grain yield of maize hybrids released in different decades. Crop Sci. 53:1256-1268.
- Abendroth, L.J., R.W. Elmore, M.J. Boyer, and S.K. Marlay. 2011. Corn growth and development. PMR 1009. Iowa State University Extension and Outreach, Ames, Iowa.
- Nitrous oxide emissions in Midwest US maize production vary widely with band-injected N fertilizer rates, timing and nitrapyrin presence. http://iopscience.iop.org/1748-9326/8/3/035031/
- Nitrapyrin Impacts on Maize Yield and Nitrogen Use Efficiency with Spring-Applied Nitrogen: Field Studies vs. Meta-Analysis Comparison. https://www.agronomy.org/publications/aj/abstracts/106/2/753
- Nitrification Kinetics and Nitrous Oxide Emissions when Nitrapyrin is Coapplied with Urea–Ammonium Nitrate - https://dl.sciencesocieties.org/publications/aj/abstracts/105/6/1475
- Nitrogen fertilizer management for nitrous oxide (N_2O) mitigation in intensive corn (Maize) production: an emissions reduction protocol for US Midwest agriculture - http://link.springer.com/article/10.1007%2Fs11027-010-9212-7
- Mulla, D.J. 2013. Twenty five years of remote sensing in precision agriculture: key advances and remaining knowledge gaps. Biosystems Engineering. 114:358-371.
- Hedley, C. 2014. The role of precision agriculture for improved nutrient management on farms. J. Sci. Food and Agric. doi: 10.1002/jsfa.6734.
- David Mulla (Director of the University of Minnesota Precision Agriculture Center http://www.precisionag.umn.edu/); from: http://www.startribune.com/business/259320921.html

Macroeconomic (Indirect) Policy Impacts

Table F-4.8 AG-1 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
AG-1	-$9	-$5	-$73	-360	-200	-2,960	-$22	-$8	-$125

Graphs below show detail in GSP, employment and personal income impact of the AG-1 policy.

Figure Ap F-4.20 AG-1 GSP Impacts ($2015 MM)

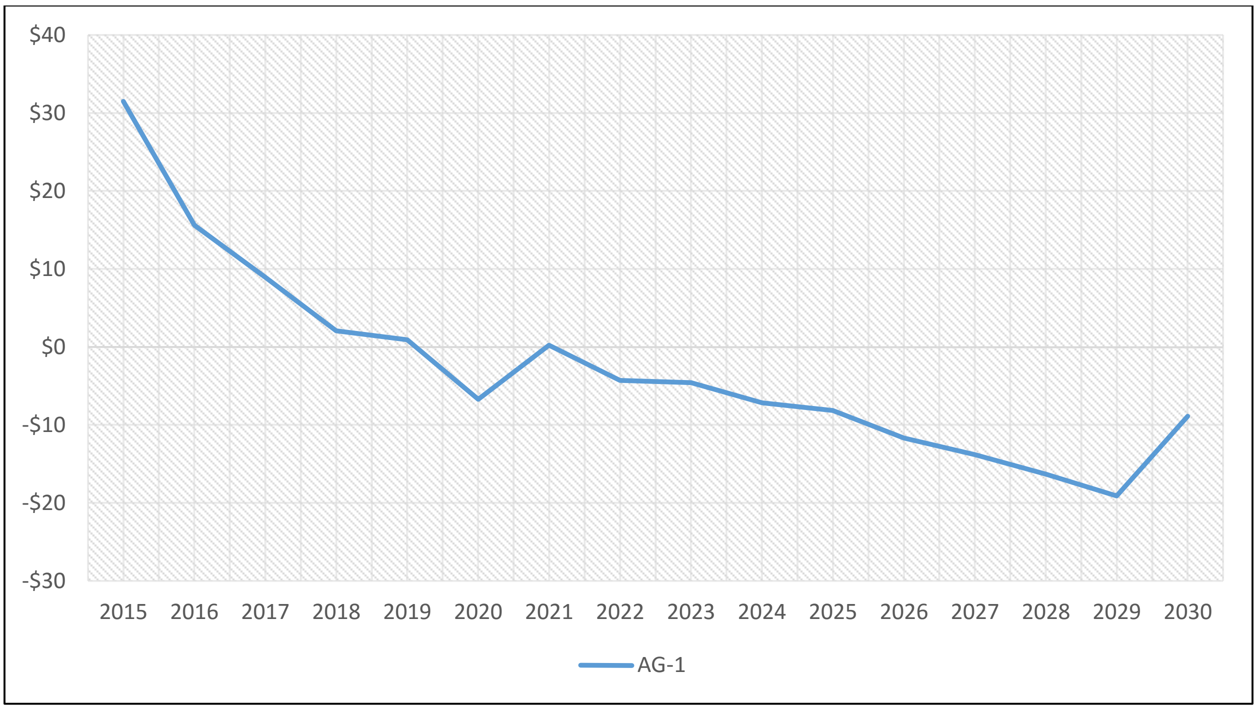


Figure Ap F-4.21 AG-1 Employment Impacts (Individual Jobs)

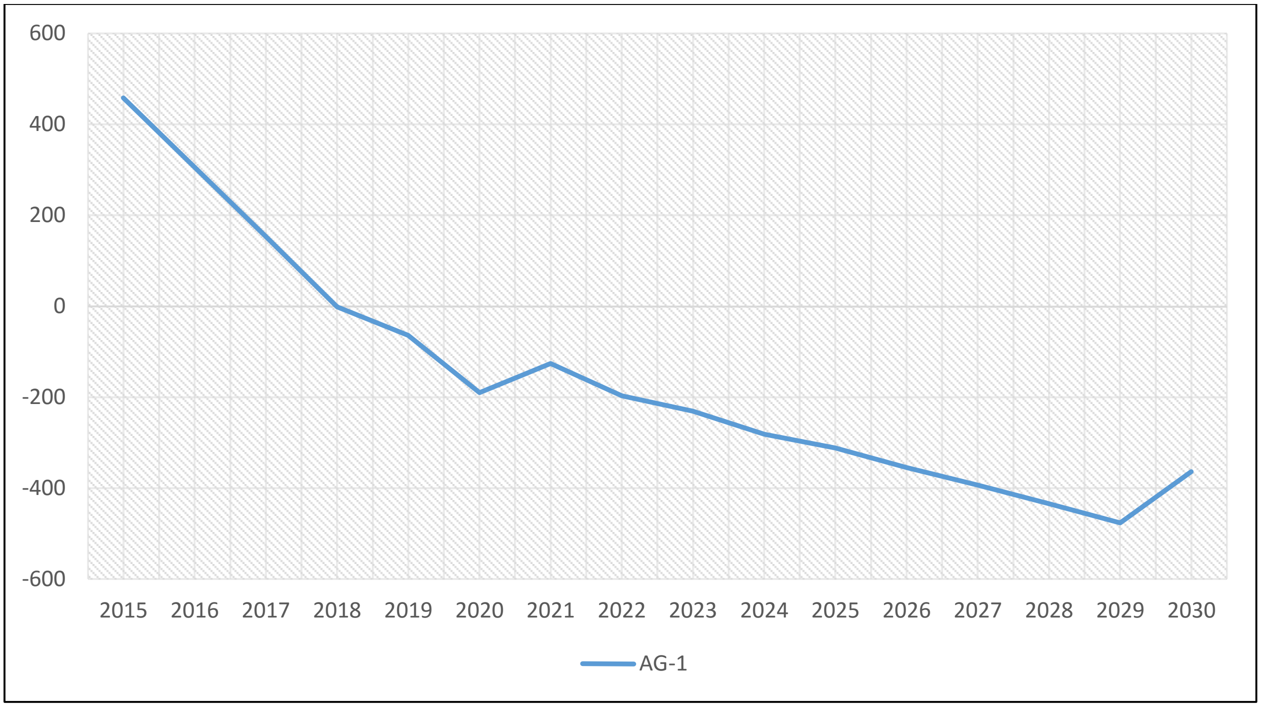
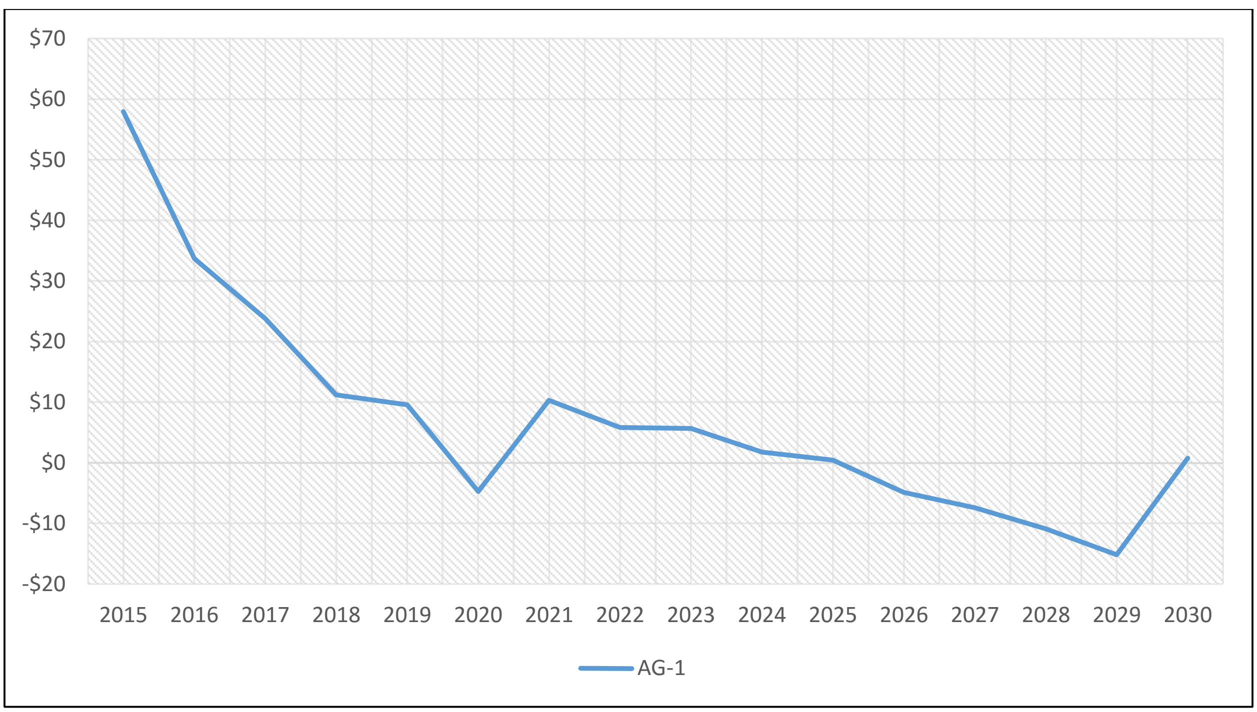
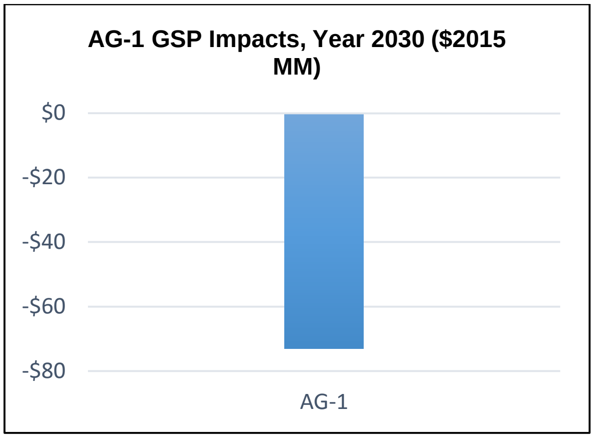
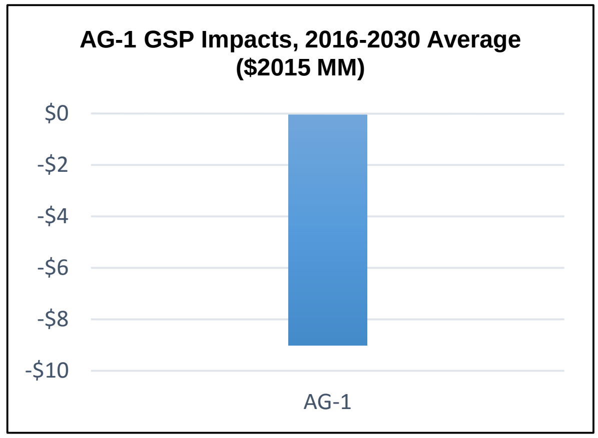
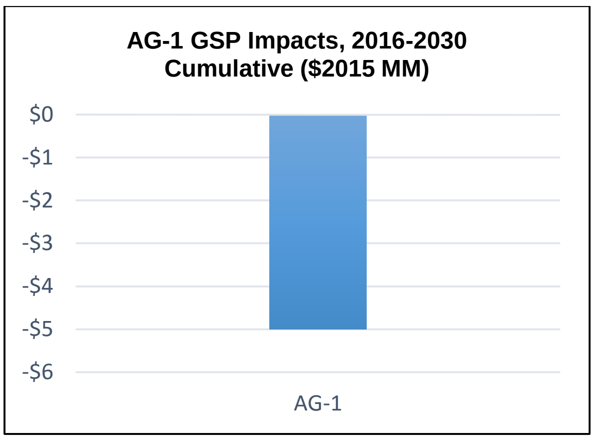


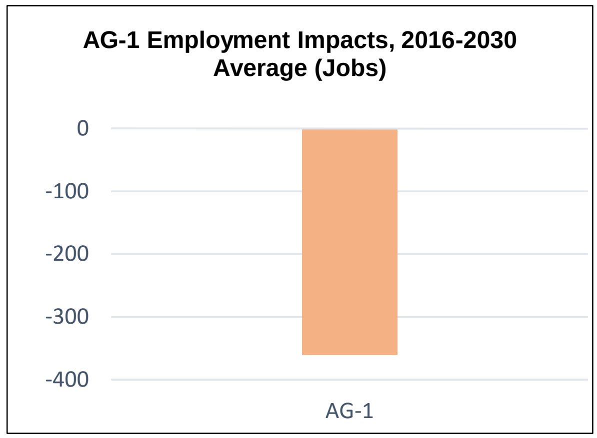
Figure Ap F-4.22 AG-1 Income Impacts ($2015 MM)

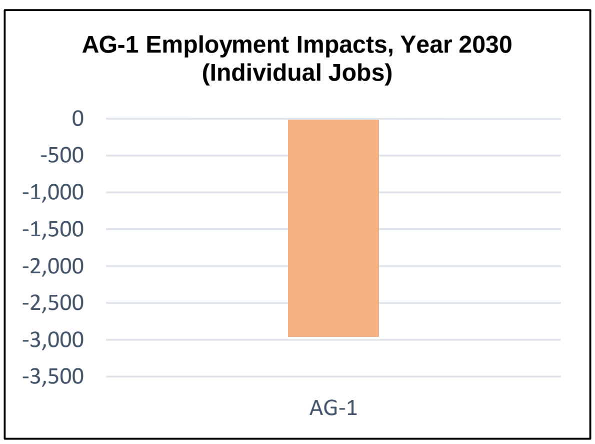


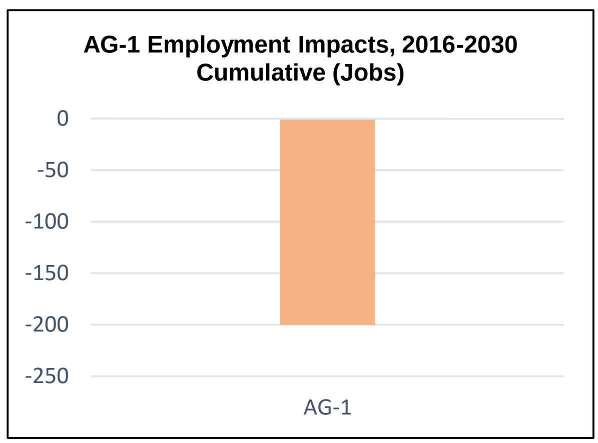

AG-1 GSP Impacts, Year 2030 ($2015 MM)
$0
-$20
-$40
-$60
-$80
AG-1

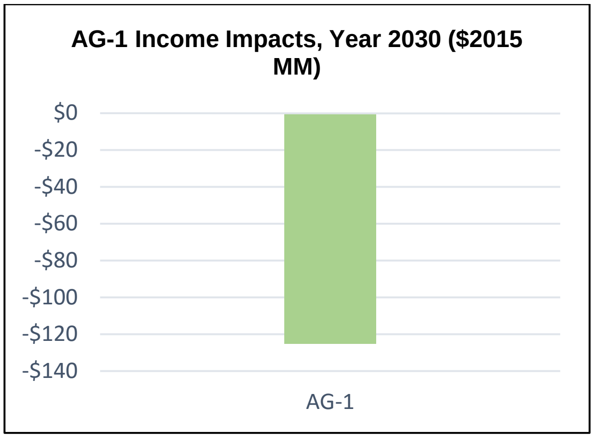

AG-1 GSP Impacts, 2016-2030 Average ($2015 MM)
$0
-$2
-$4
-$6
-$8
-$10
AG-1

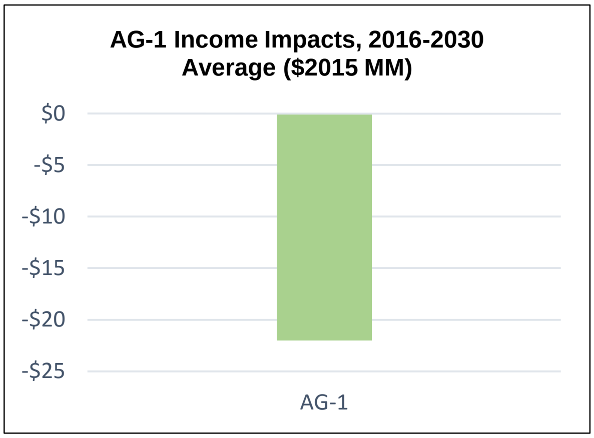

AG-1 GSP Impacts, 2016-2030 Cumulative ($2015 MM)
$0
-$1
-$2
-$3
-$4
-$5
-$6
AG-1

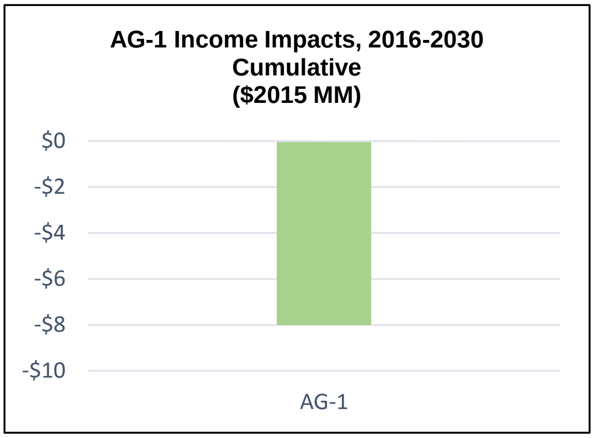

AG-1 Employment Impacts, 2016-2030 Average (Jobs)
0
-100
-200
-300
-400
AG-1


AG-1 Employment Impacts, Year 2030 (Individual Jobs)
0
-500
-1,000
-1,500
-2,000
-2,500
-3,000
-3,500
AG-1


AG-1 Employment Impacts, 2016-2030 Cumulative (Jobs)
0
-50
-100
-150
-200
-250
AG-1







Principal Drivers of Macroeconomic Changes

AG-1 imposes higher costs on farms, all in all, by approximately $100 million by the year 2030. This takes into account the crop-yield increases, which (per the microeconomic analysis) do not appear to pay for the full cost of implementation. The higher costs push down investment, but the direct hiring as part of that cost offsets this impact. Those hires produce consumer spending, which is an effective positive force in economic impacts.

State spending is displacing other existing programs, so its impact directly is positive, but is offset statewide by reductions in spending (and the benefits that produces) in other programs.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For AG-1, which shows immediate positive gains but slowly shows slightly negative impacts, most of the losses are direct – the agriculture sector sheds around two hundred total positions statewide by 2030. The entire rest of the state sees a net shift of about 150 fewer positions.

GSP and incomes shift downward, but very slightly, and the impacts are so small that they are best understood as representing slight negative pressure on economic activity. No particular sector outside of agriculture sees shifts of any significant scale.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the AG-1 policy, important data included:

- Spending by farms to adopt new equipment and software for the management practices involved.
- Additional hiring by farms to implement this more labor-intensive nitrogen-inhibition method.
- A shift in spending – less total spending on fertilizers, but more on nitrogen inhibitors. The chemical sector sees both sides of this shift, and the net cost is positive to farms.

- The sales value of a forecast crop yield increase that should result from this policy.
- Government costs to administer the program and to implement pilot projects.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling

work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.

- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.
- State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

Current N use by crops and associated measure of nitrogen use efficiency; N type, amount; current and future N fertilizer BMP adoption rates; future crops grown & associated N use; N mobility-mass balance/GHG contribution; development and adoption of new technologies and products as well as current adoption of existing precision agriculture.

Additional Benefits and Costs

- Surface and ground water quality benefits due to decreased NO_3 runoff,
- Decreased fertilizer production and associated upstream environmental impacts, and
- New products and technologies may have limited availability and be cost prohibitive.

Feasibility Issues

- Some nitrogen fertilizer products may or will not prove to be value added,
- New technologies may not be feasible for broad adoption if not shown to be cost effective,
- There may be a need for demonstration and/or incentives to induce adoption,
- Federal Farm Bill legislation may have an influence on crops grown and practices adoption, and
- International markets will influence crops grown as well.

Updating, Monitoring and Reporting

In the current Minnesota GHG emission inventory, emissions from fertilizer application are estimated from annual purchases. This will not capture data that can be used to directly evaluate the effectiveness of this policy option. A common current method of measuring nitrogen use efficiency (NUE) is determining the ratio of bushels of corn produced per pound of N fertilizer input. This can be calculated using bulk N fertilizer sales and the average corn yield over all acres grown. Other methodologies to analyze NUE could be explored.

NASS provides annual survey of corn (and all other major crops) grown. The University of Minnesota has established N fertilizer BMPs that are used as the benchmark for BMP adoption. Other Minnesota Plan/Strategies also seek to address information on N use, BMP adoption, other conservation practices (Nitrogen Fertilizer Management Plan, Nutrient Reduction Strategy) and similar monitoring and reporting may be done.

AG-2 & AG-3. Soil Carbon Management in Agriculture

Policy Option Description

Soils contain vast quantities of carbon and are in fact the largest terrestrial carbon pool. On a global scale, the soil carbon pool is about 3 times larger than the atmospheric pool. Carbon levels in soils vary depending on climate, soil parent material, vegetation type, landscape position, and human activities. Human activities significantly influence the size of soil carbon pools.

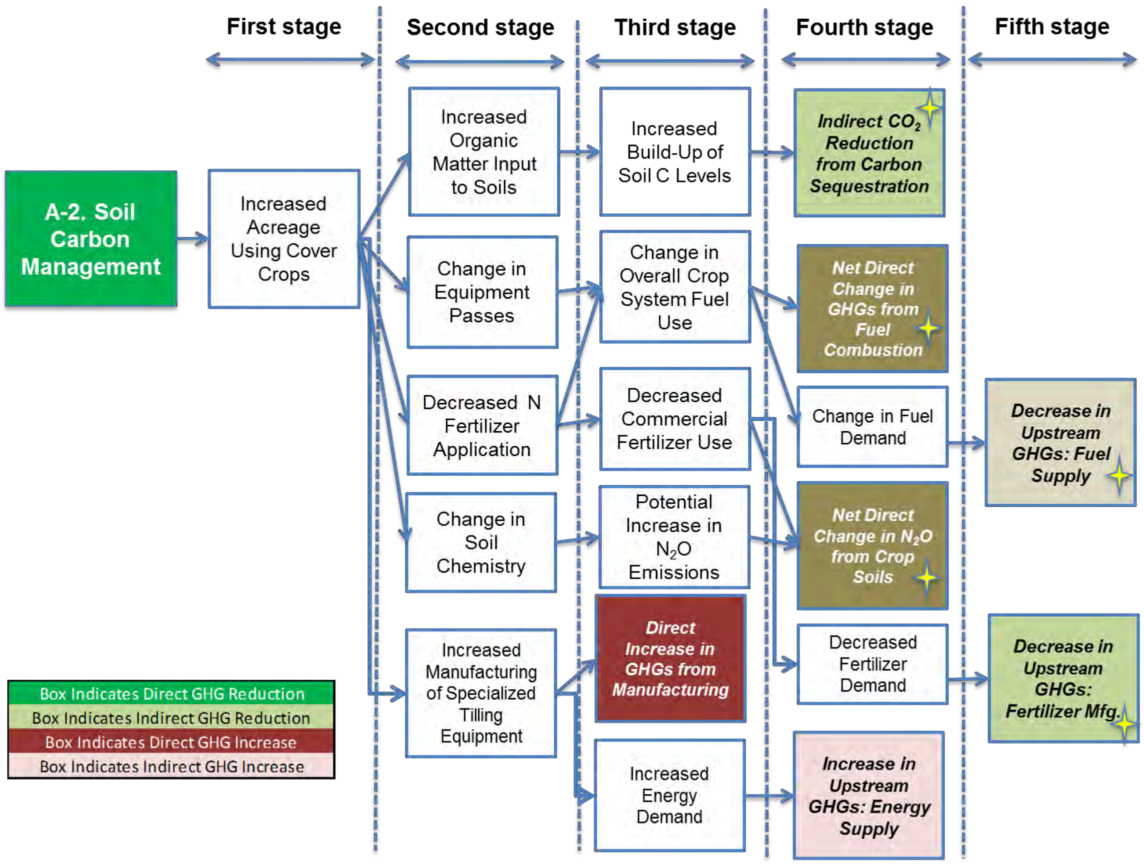
Agricultural soil carbon stocks are increased by diversifying rotations with perennials, minimizing soil disturbance, utilizing manure as a soil amendment, and incorporating cover crops where practicable. These practices are most efficient at sequestering carbon when implemented as a suite of practices rather than stand-alone activities. Minnesota has approximately 19.5 million acres of cropland. Even a modest change in soil carbon content per acre results in a significant total greenhouse gas benefit when considering all agricultural lands in the state.

Logistical, technical, financial and agronomic barriers exist that prevent widespread adoption of cover crop use in traditional corn/soybean systems. New planting technologies, such as robotics and high boy specialized planters (which can efficiently plant cover crop seed below the corn/soybean canopy), may prove to be a dependable and consistent solution for corn and soybean systems in the near future. Information on seeding equipment, establishment and termination techniques needs to be studied and provided to agribusiness and farmers so cover crops have the highest potential for successful establishment. Cover crop seed varieties may need to be developed and sufficient quantities available to meet the new demand. Further research is needed on cover crops' economic cost/benefit and yield effect in major row crop systems. Pilot plots and on-farm demonstrations are needed.

As shown in the causal chains below, two different policies were developed to produce increases in soil carbon levels: AG-2. Increased Use of Cover Crops; and AG-3. Increased Conversion of Row Crops to Perennial Crops. Net costs and benefits have been developed separately for each.

Causal Chains for GHG Reductions

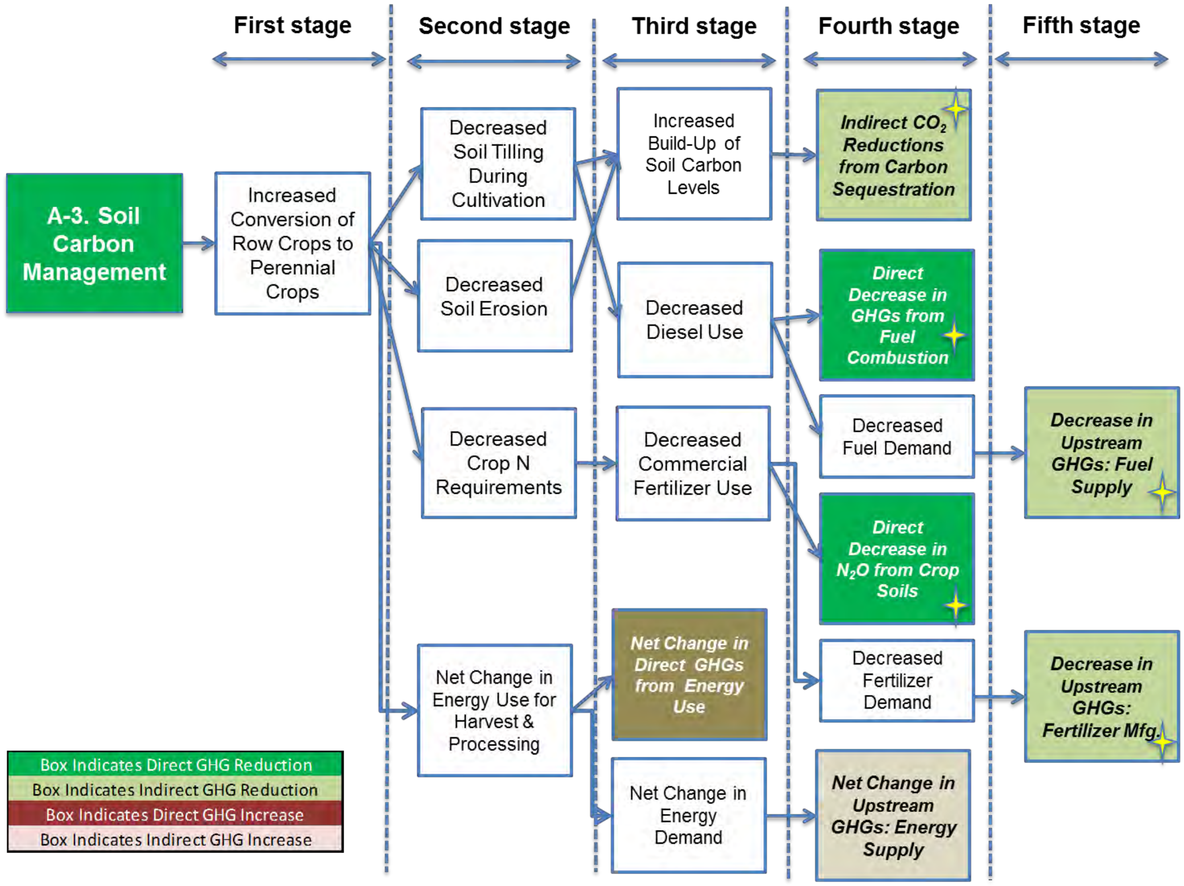
Figure Ap F-4.23 Causal Chain for AG-2 GHG Reductions



The star symbol identifies significant GHG effects for quantification. The tan colored boxes indicate a net change in GHG impacts that could be either positive or negative. The quantification of net benefits detailed in later sections of this document will include an assessment of whether net GHG reductions or emissions are likely to occur as a result of policy option implementation. The increase in GHGs from manufacturing specialized tilling equipment is expected to be small and potentially outside the boundaries of the state. The data required to calculate these reductions would also be difficult to source. For these reasons, these emissions won't be quantified.

Reductions in water use are also a potential benefit with associated energy co-benefits to the extent that groundwater pumping is reduced. There is also a potential for an increase in crop yields associated with higher levels of soil carbon; however, these benefits are not addressed in the quantified results for this policy option. Another benefit associated with cover cropping is a reduction in soil erosion. There is some potential for additional GHG benefits associated with reduced erosion and subsequent oxidation of soil carbon to CO_2; however, more research is needed in this area.

Figure Ap F-4.24 Causal Chain for AG-3 GHG Reductions



The star symbol identifies significant GHG effects for analysis. Reductions in water use are also a potential benefit with associated energy co-benefits to the extent that groundwater pumping is reduced.

Policy Option Design

AG-2. Cover Crop Goals

Cover crops adoption is grouped into cropping systems with high opportunity/high success rate and cropping systems that currently have significant barriers limiting adoption. Targeting 'low-hanging fruit' for early adoption includes: canning crops (some vegetables, sweet corn and peas), corn silage, sugar beets, edible beans, and potatoes. Other 'minor' crops (not significant acres grown) would fall into this category as well. (Numbers below are based on the NASS 2012 State Agriculture Overview).

Overall Goal: Increase cover crop adoption on 5 million acres by 2030.

Policy Option effects to achieve the goal:

Phase I: Cover crop adoption on 500,000 acres of cropland with the highest likelihood of successful implementation. These crops include canning crops, corn silage, edible beans, sugar beets and other fruits and vegetables.

- Fifty percent cover crop adoption on canning crop acreage, approximately 200,000 acres (Vegetables: 227,600, Sweet corn: 106,900, peas: 57,800).
- Thirty percent cover crop adoption on corn silage acreage, approximately 105,000 acres (361,200 total acres).
- Thirty percent cover crop adoption on edible bean acreage, approximately 52,800 (155,200 total acres).
- Thirty percent cover crop adoption on sugar beet acreage, approximately 142,500 acres (480,800 total acres).
- Forty percent cover crop adoption on potato acreage; approximately 20,000 acres (48,200 total acres).

Phase II: Beginning 2020, steady adoption on major row crops by targeting and addressing cover crop implementation barriers. Adoption goal is 4.5 million acres in corn and soybean cropping systems.

Cover Crop Timing: Assume linear growth to achieve all goals by 2030.

Cover Crop Parties Involved: This policy option affects all agricultural producers in the State, agri-business, federal, State and local government, and Soil and Water Conservation Districts.

Cover Crop Other: Cover crop adoption in the major row crops will take more time. Each acre of cover crop adoption in corn production systems potentially increases Nitrogen Use Efficiency by scavenging excess nitrogen or providing nitrogen via legumes. This Nitrogen Use Efficiency benefit overlaps with the goals in AG-1.

AG-3. Perennial Crop Goals

Converting row crops to perennial crops (grasses and legumes) for forage hayland, grazing, or biofuels, increases carbon storage in agricultural soils and biomass. Current market forces do not provide adequate incentives for perennial crop production; and other uses of perennial products are not widely available or do not have significant market penetration (e.g. cellulosic ethanol and biofuels). This policy option includes harvested legume, pasture and hayland, and perennial plantings.[11]

Overall Goals: Increase perennial vegetative cover acreage that can be used for forage, hayland, grazing, or biofuels to 4.6 million acres by 2030. Note: The 2010 Natural Resources Inventory estimates 3.6 million acres of pastureland.

Increase opportunities for grazing livestock on federal, state and conservation organization-owned lands. Multi-purpose land management benefits wildlife, improves habitat

[11] Note that this policy has potential linkage to AG-4 which addresses biofuel production; however, currently, the feedstocks for Policy AG-4 address corn stover and energy beets.

management, and allows for increased livestock production. Increase grazing lands to 50,000 acres by 2030 (there are currently 10,000 acres of grazing lands in Minnesota).

Policy Option Effects to achieve the goal:

- Increase perennial vegetative cover acreage for forage, hayland, grazing, and biofuels by 1 million acres.
- Target environmentally sensitive lands, such as Highly Erodible Lands (HEL) lands for hay and pasture planting.
- Develop markets and/or provide incentives to increase perennial crop production.

Perennial Crop Timing: Assume linear growth to achieve goal by 2030.

Perennial Crop Parties Involved: This policy option affects agricultural producers in the State, agri-business, federal, State and local government, and Soil and Water Conservation Districts.

Perennial Crop Other: Perennial crops have multiple benefits including protection of existing soil carbon stores by reducing (or nearly eliminating) soil erosion, improving water quality, and potentially returning ruminant animals back to the landscape. While both cover crops and perennial crops are vegetative practices used on working lands to mitigate greenhouse gases, their impacts are strikingly different over time. There are multiple reasons why cover crops and perennial crops sequester and store different quantities of carbon. The primary reason is that most cover crops are annual species and don’t produce nearly as much biomass as perennial plants do. The amount of atmospheric carbon that is assimilated and stored in the soil as soil organic matter increases as plant biomass increases. Secondarily, perennial plants also have a much larger and extensive root system than annual cover crops do. Roots contribute significantly to soil organic matter through annual root turnover and sloughing of polysaccharides. Another reason cover crops have a smaller carbon benefit is that they exist within fields that are disturbed or tilled annually. A portion of the carbon sequestered by cover crops is oxidized and lost at carbon dioxide during tillage and planting operations.

Each acre of perennial crops replacing corn reduced Nitrogen fertilizer input and impacts Nitrogen Use Efficiency in AG-1.

Implementation Mechanisms

AG-2 Cover Crops

- Build on NRCS soil health program to develop support and capacity for cover cropping within the universe of agricultural business advisors (NRCS, SWCDs, Extension, MNSCU farm management program, certified crop advisors, farm management companies, etc.). Cost estimate: unknown.
- Support key research into plant material development, and agronomic and economic impacts of cover crops. Document and disseminate the multiple potential benefits of cover crops including increased water storage, increased infiltration, decreased compaction, reduced fertilizer and herbicide inputs, reduced wind and water erosion,

etc. MDA has recently provided funding for cover crop research through the University of Minnesota that will examine:

- Water quality enhancements in corn cropping systems through optimization of cover crop establishment technologies
- Optimizing establishment of corn in cover crops and living mulches to maintain yield while reducing nitrate losses.
- Improvement of field pennycress germplasm for use as a winter annual cover and oilseed crop
- Dual-purpose cover crops and onsite retention of water and nutrients
- Findings from this research should be utilized for cover crop implementation.
- Cost estimate: $12 million.
- The Legislature should appropriate funds for cover crop implementation including establishment, management and technical assistance. MDA and/or BWSR will establish incentive programs for cover crops leveraging NRCS/USDA funding programs with a ramp up (and then down) of state incentive payments to support early adoption and infrastructure development. Cost estimate $5.9 million.
- The Legislature should appropriate funds for pilot plots and on-farm demonstration of new cover-cropping technologies to encourage adoption. Cost estimate: $750,000
- Develop incentive programs to encourage processors to include cover crop requirements in their contracts with farmers. Cost estimate: $100,000
- The State of Minnesota should participate in a carbon market that would ensure adequate oversight, crediting, and insurance of carbon reductions in the Agricultural sector. Cost estimate unknown.

AG-3. Perennial Crops

- Support changes in federal policy option and develop programs at the state level to provide greater incentives for perennial vegetative cover that can be used for forage, hayland, grazing, or biofuels.
- Fund research in multiple areas related to perennial crop production including productivity and quality, and development of multiple uses of perennial crops, including cellulosic biofuels. Cost estimate: $12 million.

Related Policies/Programs in Place and Recent Actions

- Multiple NRCS programs provide funding for cover crop and grazing land practices, including EQIP and CSP. Funds in these programs are limited and additional funding sources are needed to achieve cover crop adoption goals.
- Minnesota Department of Agriculture (MDA) cover crop initiatives and research grants.

- Clean Water Fund accelerated implementation grant (FY14) to Technical Service Area 7 for cover crop technical assistance.

Estimated Policy Impacts

Direct Policy Impacts

Table F-4.9 AG-2 and 3 Estimated Net GHG Reductions and Net Costs or Savings

Policy Option	2030 GHG Reductions (Tg CO_2e)	2015 – 2030 Cumulative Reductions (Tg CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ tCO_2e)
AG-2. Cover Crops	0.57	3.6	($1,346)	($377)
AG-3. Perennial Crops	1.6	14	($2,104)	($153)

Notes:

Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

The GHG reductions summarized above represent full energy-cycle reductions for the policy option, which include reductions of upstream emissions that may occur outside of Minnesota. For comparison, emission reductions that can be specifically allocated to occur within the State for Policy Option AG-2 are 0.49 Tg CO_2e in 2030 and 3.1 Tg CO_2e cumulatively from 2015 to 2030. For Policy Option AG-3, 1.6 Tg CO_2e are estimated to be reduced in-state by 2030 and cumulatively 14 Tg CO_2e from 2015 to 2030.

Data Sources

Key data sources are referenced within the discussion of Quantification Methods below.

Quantification Methods

AG-2. Cover Crops

GHG Reductions:

- *Soil carbon accumulation:* First a schedule for cover crop adoption by crop type was assembled based on the specifications of the policy option design. Incremental carbon gains for use of cover crops were then estimated for all acres covered using a carbon accumulation factor from a University of Minnesota (UMN) study (0.59 tCO_2/acre-yr).[12] Due to the uncertainty in soil carbon permanence, a permanence factor of 0.20 was applied to all soil carbon accumulation estimates.
- *Fuel requirements:* Other than fuel consumption for initial establishment, other net changes to fuel requirements for each cropping system were assumed to be negligible.

[12] UMN 2008 Terrestrial Carbon Study; App. II - 40 g C/m^2-yr mean value with an SD of 22. http://www.wrc.umn.edu/prod/groups/cfans/@pub/@cfans/@wrc/documents/asset/cfans_asset_119302.pdf

Establishment fuel requirements were estimated from the overall cost of cover crop establishment. That cost was presumed to be equal to the low value of the Environmental Quality Incentives Program (EQIP) payment, which in 2014 was $59/acre. Of this value, $28 was presumed to represent seed costs[13]; and for the remaining non-seed costs, one-third was assumed to represent fuel costs. Based on the 2014 average retail price for diesel fuel, the result was 2.0 gallons/acre.

- *Decreased N requirements:* Use of "green manures" (alfalfa, clover, vetch) as cover crops have been shown to produce N inputs (N credits) of 40 or more lb. N/acre annually. A value of 44 lb. N/acre-yr. was applied as an N credit (reduced N application requirement.[14] The decrease in total N requirements was used to estimate the reduction in upstream GHGs from the supply of N fertilizer (by assuming all reductions in N requirements from cover cropping would come from synthetic inputs). As described further under the Key Uncertainties section below, the literature is currently unclear as to the net impact on N_2O emissions; so these were left at BAU levels (i.e. no net change in direct/indirect N_2O emissions from crop soils).

Table F-4.11 below provides a summary of the net GHG impacts assessment. The implementation schedule for each crop is shown first, followed by the BAU energy and emissions associated with BAU cultivation of these crops. Then, the estimated Policy Option Scenario impacts are estimated. Finally, in the "Energy and Emissions Change" columns provide the net results for energy consumption and emissions. "Out of state" emissions refer to the upstream emissions associated with fertilizer and diesel fuel supply (these net impacts can't be presumed to all occur within Minnesota).

Net Societal Costs:

- BAU avoided costs: no BAU operations were found to be avoided through implementation of the policy option (addition of cover crops); so all costs for the policy option were incremental to BAU. These include the fuel and non-fuel costs for establishment. No new equipment costs are expected. Cover crop establishment costs were derived from EQIP cover crop payment costs as mentioned above ($59/acre). Of this seed costs were assumed to be $28/acre (47% of establishment costs). The remaining establishments costs were broken down to fuel and non-fuel costs based on assumptions of one-third of remaining costs being fuel costs (result: 18% of establishment costs were fuel costs; 36% labor and operations and maintenance costs).
- Reductions in synthetic fertilizer costs were included. This assumes that all incremental N additions from use of cover crops would reduce synthetic N requirements. N fertilizer costs for 2014 were $589/ton N, and these were escalated at 0.4%/yr. through the planning period.

[13] Value provided by M. Lennon, MN Bureau of Water & Soil Resources (10/17/2014 personal communication to S. Roe, CCS; value for a basic species mix (single species can run up to $37/acre).

[14] http://www.soils.wisc.edu/extension/wcmc/2009/ppt/Ruark.pdf.

- Minnesota government incentives as described in the Implementation Mechanisms section ($5.9MM total) were applied during the early years of the planning period using a sliding schedule that ends in 2023. Minnesota government program costs as described in the Implementation Mechanisms section ($12.75MM total) were also applied during the same years as the incentives program.
- Federal EQIP payment costs were also included as a net societal cost savings to the State. The low EQIP payment rate was applied ($59/acre in 2014); and the value in each future year through 2020 was trended based on 2009-2014 EQIP payments. The value in 2020 ($75/acre) was then held constant through 2030.
- The final cost component was an assessment of yield impacts associated with cover crops[15]: corn (+9.6%); and soybeans (+11.6%). All other crops were assumed to have no yield impact based on available information. BAU forecasted yields in 2030 for soybeans were estimated at 49.2 bushels/acre (bu./acre) and 196 bu./acre for corn. Price forecasts were based on the USDA long-term price forecasts: in 2030, the price for corn is estimated to be $4.76/bu.; soybean price is estimated to be $11.12/bu.

Table F-4.14 provides a summary of the net societal cost assessment for Policy Option AG-2. Even if the EQIP incentive was removed, the analysis still indicates that implementation of the policy option would result in a net cost savings to society. While not shown in the table, the resulting cost effectiveness would be -$15/t$CO_2$e. This is because the net savings achieved via fertilizer savings and crop yield benefits is greater than the estimated costs for establishment of cover crops.

AG-3. Conversion to Perennial Crops

For analytical purposes, the general conversion scheme assumes that corn and soybeans will be converted to hay/pasture.

GHG Reductions:

Crop conversion targets: policy option design called for 1 MM acres total; this was assumed to be a 50:50 split of corn and soybeans (about 31,250 acres of each converted each year from 2015 to 2030). Based on several studies[16], a sliding scale of sequestration rates were applied to all converted croplands as shown below. For reference, well managed US grazing lands are expected to sequester 0.1 – 0.3 metric tons of carbon per hectare per year (tC/ha-yr.); new grasslands in the US and southern Saskatchewan: 0.5 – 0.6 tC/ha/yr.; and an average of 23 worldwide data points from a National Renewable Energy Labs (NREL) study: 1.0 tC/ha-yr.

Table F-4.10. Assumed Conversion Sequestration Rates

Time after conversion	Sequestration Rate (tC/ha-yr)

[15] 2012-2013 Cover Crop Survey, June 2013 Survey Analysis, Conservation Technology Information Center, North Central Sustainable Research & Education, June 2013.

[16] http://www.fao.org/docrep/007/y5738e/y5738e08.htm; http://www.prairiesoilsandcrops.ca/articles/volume-5-9-screen.pdf; http://www.nrel.colostate.edu/ftp/conant/SLM-proprietary/Conant_et-al_2001.pdf.

Time after conversion	Sequestration Rate (tC/ha-yr)
Year 1 – Year 5	0.57
Year 6	0.49
Year 7	0.42
Year 8	0.35
Year 9	0.27
Year 10 – Year 20	0.20

- As with the policy option analysis for AG-2, a carbon storage permanence factor of 0.2 was applied to all carbon sequestration estimates.
- Fuel use for establishment was assumed to be negligible; therefore the net fuel impact was equal to the BAU fuel consumption for each crop.
- Net N fertilizer application emissions (N_2O) were also determined based on BAU fertilizer use and the expected use for establishing permanent cover.[17]

Table F-4.19, provides a summary of the net energy and GHG impacts. Total in-state GHG reductions were estimated to be 1.6 Tg CO_2e annually by 2030. Additional out-of-state reductions were estimated to be 0.028 Tg CO_2e/yr. (upstream GHGs associated with fertilizer and fuel supply).

Net Societal Costs:

- Establishment costs and incentives: these included seed costs, fuel costs, other costs (labor and operations/maintenance), and government incentives. Similar costing assumptions were applied here as cited above for establishing cover crops.
- Avoided fertilizer and fuel costs: based on net use of N fertilizers and diesel fuel between BAU crop production and permanent cover.
- Change in land use: revenue for the land under the Policy Option Scenario was set at $26/acre (rental value for pasture/grassland).[18] Under BAU land use, the costs for land rental were added to fertilizer, fuel, other production costs, and crop profits to get a total net cost. Fuel and fertilizer use for each crop were taken from the Minnesota BAU crop production forecast. Costs were estimated as described above for Policy Option AG-2. Other production costs were taken from a UMN publication.[19] Corn and soybean

[17] Personal communication, J. Berg, MDA, to S. Roe, CCS, 11/5/2014; 30 lb N/acre at establishment applied to 25% of new acreage.

[18] Average of 2012 and 2013 cash rental rates for MN pasture; http://www.nass.usda.gov/Statistics_by_State/Minnesota/Publications/Prices_Press_Releases/2013/MN%20Cash%20Rent%2012_13.pdf.

[19] Lazarus, 2010 (table 3); costs excluding fertilizer, land rental, and fuel ("miscellaneous" costs assumed as the value for fuel, since fuel was not broken out separately); http://faculty.apec.umn.edu/wlazarus/documents/cropbud.pdf.

profit levels were assumed to remain constant at the average of 2011 and 2012 levels ($197/acre and $211/acre, respectively).[20]

- The Minnesota R&D program cited in the Implementation Mechanisms section ($12MM) was assumed to be spent in a declining schedule through 2023.

Table F-4.18 provides a summary of the net societal cost build-up for the policy option. If the EQIP subsidy is excluded from the net value, the results still show a net cost savings to society (while not shown in the Table, the value would be -$126/t$CO_2$e). While the analysis shows a net societal savings, the high profitability of both corn and soybean production will create challenges for policy option implementation.

[20] Average 2011 and 2012 profit estimates for Heartland Corn and Soybeans; http://landstewardshipproject.org/farmtransitionsvaluingsustainablepracticescornandsoybeanprofitability.

Table F-4.11 Net GHG Impacts for Policy Option AG-2: Cover Cropping

	BAU Energy & Emissions							
Year	**Canning Crops Cumulative Acres**	**Corn Silage Cumulative Acres**	**Edible Beans Cumulative Acres**	**Sugar Beets Cumulative Acres**	**Potatoes Cumulative Acres**	**Grain Corn Cumulative Acres**	**Soybeans Cumulative Acres**	**Total Crops Cumulative Acres**
2015	12,500	6,563	3,300	8,906	1,250	0.00	0.00	32,519
2016	25,000	13,125	6,600	17,813	2,500	0.00	0.00	65,038
2017	37,500	19,688	9,900	26,719	3,750	0.00	0.00	97,556
2018	50,000	26,250	13,200	35,625	5,000	0.00	0.00	130,075
2019	62,500	32,813	16,500	44,531	6,250	0.00	0.00	162,594
2020	75,000	39,375	19,800	53,438	7,500	204,545	204,545	604,203
2021	87,500	45,938	23,100	62,344	8,750	409,091	409,091	1,045,813
2022	100,000	52,500	26,400	71,250	10,000	613,636	613,636	1,487,423
2023	112,500	59,063	29,700	80,156	11,250	818,182	818,182	1,929,032
2024	125,000	65,625	33,000	89,063	12,500	1,022,727	1,022,727	2,370,642
2025	137,500	72,188	36,300	97,969	13,750	1,227,273	1,227,273	2,812,252
2026	150,000	78,750	39,600	106,875	15,000	1,431,818	1,431,818	3,253,861
2027	162,500	85,313	42,900	115,781	16,250	1,636,364	1,636,364	3,695,471
2028	175,000	91,875	46,200	124,688	17,500	1,840,909	1,840,909	4,137,081
2029	187,500	98,438	49,500	133,594	18,750	2,045,455	2,045,455	4,578,690
2030	200,000	105,000	52,800	142,500	20,000	2,250,000	2,250,000	5,020,300
Sum	**200,000**	**105,000**	**52,800**	**142,500**	**20,000**	**2,250,000**	**2,250,000**	**5,020,300**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.12 Net GHG Impacts for Policy Option AG-2: Cover Cropping (continued)

Year	BAU Energy & Emissions					Policy Option Scenario Energy & Emissions				
	Total N Additions (t N)	Total N_2O Emissions (tCO_2e)	Diesel Fuel Use (TJ)	Diesel Fuel Emissions (tCO_2e)	Total BAU Emissions (tCO_2e)	Soil C Sequestration (tCO_2)	Total N Additions (t N)	Total N_2O Emissions (tCO_2e)	Diesel Fuel Use (TJ)	Diesel Fuel Emissions (tCO_2e)
2015	4,274	69,986	49	3,416	73,402	3,837	3,757	69,986	58	4,078
2016	8,693	142,348	98	6,842	149,190	7,674	7,644	142,348	117	8,168
2017	13,257	217,084	147	10,280	227,364	11,512	11,661	217,084	176	12,268
2018	17,966	294,196	197	13,729	307,925	15,349	15,807	294,196	235	16,380
2019	22,820	373,683	246	17,175	390,858	19,186	20,084	373,683	294	20,488
2020	56,657	927,759	845	58,915	986,674	71,296	49,840	927,759	1,022	71,228
2021	90,752	1,486,070	1,444	100,708	1,586,777	123,406	79,817	1,486,070	1,750	122,020
2022	125,205	2,050,248	2,043	142,467	2,192,715	175,516	110,115	2,050,248	2,478	172,780
2023	159,954	2,619,260	2,644	184,342	2,803,602	227,626	140,671	2,619,260	3,208	223,654
2024	195,140	3,195,443	3,247	226,377	3,421,819	279,736	171,612	3,195,443	3,940	274,689
2025	231,667	3,793,568	3,849	268,378	4,061,947	331,846	203,884	3,793,568	4,671	325,690
2026	268,059	4,389,489	4,450	310,251	4,699,741	383,956	235,970	4,389,489	5,401	376,563
2027	304,884	4,992,506	5,053	352,335	5,344,841	436,066	268,451	4,992,506	6,133	427,646
2028	342,136	5,602,516	5,658	394,471	5,996,987	488,176	301,322	5,602,516	6,867	478,782
2029	379,810	6,219,423	6,259	436,408	6,655,831	540,285	334,576	6,219,423	7,597	529,718
2030	417,899	6,843,136	6,865	478,626	7,321,762	592,395	368,208	6,843,136	8,332	580,936
	2,639,173	43,216,715	6,865	478,626	7,321,762	3,707,861	2,323,420	43,216,715	52,279	3,645,088

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.13 Net GHG Impacts for Policy Option AG-2: Cover Cropping (continued)

	Energy & Emissions Change			
	Diesel Fuel	Change in N Additions	Net In-State GHG Change	Out-of-State GHG Change
Year	TJ	t N	Tg CO_2e	Tg CO_2e
2015	10	(517)	(0.003)	(0.0009)
2016	19	(1,049)	(0.006)	(0.0019)
2017	29	(1,596)	(0.010)	(0.003)
2018	38	(2,159)	(0.013)	(0.004)
2019	48	(2,737)	(0.016)	(0.005)
2020	177	(6,817)	(0.06)	(0.011)
2021	306	(10,934)	(0.10)	(0.018)
2022	435	(15,090)	(0.15)	(0.024)
2023	564	(19,283)	(0.19)	(0.031)
2024	693	(23,528)	(0.23)	(0.037)
2025	822	(27,783)	(0.27)	(0.044)
2026	951	(32,089)	(0.32)	(0.051)
2027	1,080	(36,433)	(0.36)	(0.058)
2028	1,209	(40,814)	(0.40)	(0.064)
2029	1,338	(45,234)	(0.45)	(0.071)
2030	1,467	(49,691)	(0.49)	(0.078)
	9,184	**(315,753)**	**(3.1)**	**(0.50)**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.14 Net Societal Costs for Policy Option AG-2: Cover Cropping

	Policy Option Scenario Costs									
	Establishment Fuel Costs	**Fertilizer Cost**	**Seed/Other Materials Application**	**Establishment O&M Costs**	**MN Gov. Incentives**	**MN Gov. Program Costs**	**US Government Incentives**	**Yield Impacts: Corn**	**Yield Impacts: Soybeans**	**Yield Impacts: Other Crops**
Year	**MM$**	**MM$**	**MM$**	**MM$**	**MM$**	**MM$**	**MM$**	**MM$**	**MM$**	**MM$**
2015	$0.22	($0.31)	$0.81	$0.62	$0.89	$1.91	($1.7)	$0.00	$0.00	$0.00
2016	$0.45	($0.62)	$1.8	$1.3	$0.89	$1.91	($3.7)	$0.00	$0.00	$0.00
2017	$0.68	($1.0)	$2.8	$2.1	$0.89	$1.91	($6.0)	$0.00	$0.00	$0.00
2018	$0.91	($1.3)	$4.0	$3.1	$0.59	$1.28	($8.6)	$0.00	$0.00	$0.00
2019	$1.14	($1.6)	$5.4	$4.1	$0.59	$1.28	($11)	$0.00	$0.00	$0.00
2020	$4.3	($4.1)	$21	$16	$0.59	$1.28	($45)	($13)	($11)	$0.00
2021	$7.5	($6.6)	$37	$28	$0.59	$1.28	($78)	($27)	($22)	$0.00
2022	$10.7	($9.2)	$52	$40	$0.59	$1.28	($111)	($43)	($34)	$0.00
2023	$14.0	($12)	$68	$51	$0.30	$0.64	($144)	($60)	($46)	$0.00
2024	$17	($14)	$83	$63	$0.00	$0.00	($177)	($76)	($59)	$0.00
2025	$21	($17)	$99	$75	$0.00	$0.00	($210)	($94)	($72)	$0.00
2026	$24	($20)	$114	$87	$0.00	$0.00	($244)	($113)	($85)	$0.00
2027	$28	($23)	$130	$98	$0.00	$0.00	($277)	($134)	($99)	$0.00
2028	$31	($25)	$145	$110	$0.00	$0.00	($310)	($155)	($113)	$0.00
2029	$35	($28)	$161	$122	$0.00	$0.00	($343)	($177)	($128)	$0.00
2030	$38	($31)	$176	$133	$0.00	$0.00	($376)	($201)	($143)	$0.00
	$233	**($195)**	**$1,102**	**$834**	**$6**	**$13**	**($2,347)**	**($1,094)**	**($812)**	**$0.00**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.15 Net Societal Costs for Policy Option AG-2: Cover Cropping (continued)

Year	Total Policy Option Costs MM$	Total Discounted Policy Option Costs MM$2014	Cost Effectiveness $2014/tCO2e
2015	$2.2	$2.1	
2016	$1.5	$1.4	
2017	$0.8	$0.7	
2018	($0.9)	($0.8)	
2019	($1.8)	($1.4)	
2020	($34)	($25)	
2021	($68)	($48)	
2022	($104)	($70)	
2023	($142)	($92)	
2024	($181)	($111)	
2025	($220)	($129)	
2026	($261)	($145)	
2027	($304)	($161)	
2028	($348)	($176)	
2029	($394)	($189)	
2030	($441)	($202)	
	($2,494)	**($1,346)**	**($377)**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.16 Net GHG Impacts for Policy Option AG-3: Conversion to Perennial Crops

Year	BAU Energy & Emissions										
	Converted Corn Cumulative Acres	Converted Soybeans Cumulative Acres	Converted Corn - N Additions t N	Converted Soybeans - N Additions t N	Converted Corn N_2O Emissions t $C0_2e$	Converted Soybeans N_2O Emissions t $C0_2e$	Converted Corn Diesel Consumption TJ Diesel	Converted Soybeans Diesel Consumption TJ Diesel	Converted Corn Diesel Consumption tCO_2e	Converted Soybeans Diesel Consumption tCO_2e	Total In-State BAU GHGs tCO2e
2015	31,250	31,250	3,651	760	59,780	12,441	48	35	3,375	2,459	78,056
2016	62,500	62,500	7,248	1,595	118,693	26,124	97	70	6,763	4,912	156,492
2017	93,750	93,750	10,793	2,493	176,738	40,816	146	106	10,164	7,358	235,076
2018	125,000	125,000	14,285	3,440	233,916	56,330	195	141	13,577	9,798	313,622
2019	156,250	156,250	17,724	4,367	290,226	71,503	244	175	16,987	12,232	390,948
2020	187,500	187,500	21,109	5,319	345,668	87,099	293	210	20,423	14,659	467,850
2021	218,750	218,750	24,707	6,187	404,579	101,310	342	245	23,872	17,080	546,840
2022	250,000	250,000	28,327	7,090	463,861	116,099	392	280	27,307	19,494	626,762
2023	281,250	281,250	31,970	7,988	523,515	130,799	441	314	30,778	21,902	706,994
2024	312,500	312,500	35,664	8,899	584,004	145,715	491	349	34,261	24,336	788,316
2025	343,750	343,750	39,324	10,151	643,936	166,217	542	383	37,757	26,735	874,645
2026	375,000	375,000	43,035	11,219	704,704	183,715	591	418	41,228	29,127	958,773
2027	406,250	406,250	46,769	12,307	765,842	201,533	642	452	44,746	31,513	1,043,634
2028	437,500	437,500	50,525	13,414	827,352	219,656	692	486	48,277	33,892	1,129,178
2029	468,750	468,750	54,304	14,539	889,234	238,071	743	520	51,774	36,265	1,215,344
2030	500,000	500,000	58,106	15,680	951,487	256,766	794	554	55,327	38,632	1,302,211
Sum			**487,541**	**125,446**	**7,983,536**	**2,054,194**	**6,692**	**4,739**	**466,618**	**330,393**	**10,834,741**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.17 Net GHG Impacts for Policy Option AG-3: Conversion to Perennial Crops (continued)

	Policy Option Scenario Energy & Emissions				
Year	Forage/Hayland /Pasture Cumulative Acres	Forage/Hayland/ Pasture: N Requirements t N	Forage/Hayland/ Pasture: N2O Emissions tCO_2e	Forage/Hayland /Pasture: Carbon Sequestration tCO_2	Forage/Hayland/ Pasture: Permanent C Storage tCO_2
2015	62,500	213	3,485	(129,479)	(25,896)
2016	125,000	213	3,485	(258,958)	(51,792)
2017	187,500	213	3,485	(388,438)	(77,688)
2018	250,000	213	3,485	(517,917)	(103,583)
2019	312,500	213	3,485	(647,396)	(129,479)
2020	375,000	213	3,485	(760,146)	(152,029)
2021	437,500	213	3,485	(856,167)	(171,233)
2022	500,000	213	3,485	(935,458)	(187,092)
2023	562,500	213	3,485	(998,021)	(199,604)
2024	625,000	213	3,485	(1,043,854)	(208,771)
2025	687,500	213	3,485	(1,089,688)	(217,938)
2026	750,000	213	3,485	(1,135,521)	(227,104)
2027	812,500	213	3,485	(1,181,354)	(236,271)
2028	875,000	213	3,485	(1,227,188)	(245,438)
2029	937,500	213	3,485	(1,273,021)	(254,604)
2030	1,000,000	213	3,485	(1,318,854)	(263,771)
		3,405	**55,757**	**(13,761,458)**	**(2,752,292)**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.18 Net GHG Impacts for Policy Option AG-3: Conversion to Perennial Crops (continued)

Year	Energy & Emissions Change			
	Diesel Energy Use TJ Diesel	N Fertilizer Use t N	Net In-State GHG Reductions Tg CO_2e	Out-of-State GHG Reductions Tg CO_2e
2015	(84)	(4,198)	(0.10)	(0.002)
2016	(167)	(8,631)	(0.20)	(0.003)
2017	(251)	(13,073)	(0.31)	(0.005)
2018	(335)	(17,512)	(0.41)	(0.007)
2019	(419)	(21,877)	(0.52)	(0.009)
2020	(503)	(26,216)	(0.62)	(0.010)
2021	(587)	(30,681)	(0.71)	(0.012)
2022	(671)	(35,204)	(0.81)	(0.014)
2023	(756)	(39,745)	(0.90)	(0.015)
2024	(840)	(44,350)	(0.99)	(0.017)
2025	(925)	(49,262)	(1.09)	(0.019)
2026	(1,009)	(54,041)	(1.2)	(0.021)
2027	(1,094)	(58,863)	(1.3)	(0.023)
2028	(1,178)	(63,726)	(1.4)	(0.024)
2029	(1,263)	(68,630)	(1.5)	(0.026)
2030	(1,348)	(73,573)	(1.6)	(0.028)
	(11,431)	**(609,582)**	**(14)**	**(0.23)**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.19 Net Societal Costs for Policy Option AG-3: Conversion to Perennial Cover

Year	BAU Costs							
	N Fertilizer Costs	Diesel Fuel Costs	Corn Non-Fuel/ Fert Production Costs	Soybean Non-Fuel/ Fert. Production Costs	Corn Land Rental Cost	Soybeans Land Rental Cost	Corn Profit	Soybeans Profit
	MM$	MM$	MM$	MM$	MM$	MM$	MM$	MM$
2015	$2.7	$2.0	$11	$7.0	$5.1	$5.1	($6.2)	($6.6)
2016	$5.7	$3.9	$22	$14	$10	$10	($12)	($13)
2017	$8.6	$6.0	$33	$21	$15	$15	($18)	($20)
2018	$12	$8.0	$44	$28	$20	$20	($25)	($26)
2019	$14	$10	$55	$35	$26	$26	($31)	($33)
2020	$17	$12	$66	$42	$31	$31	($37)	($40)
2021	$20	$14	$77	$49	$36	$36	($43)	($46)
2022	$24	$17	$88	$56	$41	$41	($49)	($53)
2023	$27	$19	$99	$63	$46	$46	($55)	($59)
2024	$30	$21	$110	$70	$51	$51	($62)	($66)
2025	$33	$23	$121	$77	$56	$56	($68)	($73)
2026	$37	$26	$132	$84	$61	$61	($74)	($79)
2027	$40	$28	$143	$91	$66	$66	($80)	($86)
2028	$44	$30	$154	$98	$72	$72	($86)	($92)
2029	$47	$33	$165	$105	$77	$77	($92)	($99)
2030	$51	$35	$176	$112	$82	$82	($99)	($106)
Sum	**$413**	**$287**	**$1,496**	**$952**	**$695**	**$695**	**($837)**	**($897)**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.20 Net Societal Costs for Policy Option AG-3: Conversion to Perennial Cover (continued)

Year	Policy Option Scenario Costs								
	Initial Conversion Costs: Seed MM$	Initial Conversion Costs: Non-Seed/Non-Fuel MM$	Initial Conversion Costs: Fuel MM$	Initial Conversion Costs: Fertilizer MM$	Hay/Pasture Revenue MM$	Federal Gov't Subsidy MM$	State Gov't Subsidy MM$	State Gov't R&D Program Costs MM$	Total Policy Option Scenario Costs MM$
2015	$1.7	$1.18	$0.58	$0.13	$0.0	($3.3)	$0.00	$1.8	$2.1
2016	$1.7	$1.18	$0.58	$0.13	($1.6)	($7.2)	$0.00	$1.8	($3.4)
2017	$1.7	$1.18	$0.58	$0.13	($3.3)	($12)	$0.00	$1.8	($9.5)
2018	$1.7	$1.18	$0.58	$0.13	($4.9)	($17)	$0.00	$1.2	($17)
2019	$1.7	$1.18	$0.58	$0.13	($6.6)	($22)	$0.00	$1.2	($24)
2020	$1.7	$1.18	$0.58	$0.13	($8.2)	($28)	$0.00	$1.2	($31)
2021	$1.7	$1.18	$0.58	$0.13	($9.8)	($33)	$0.00	$1.2	($38)
2022	$1.7	$1.18	$0.58	$0.13	($11)	($37)	$0.00	$1.2	($44)
2023	$1.7	$1.18	$0.58	$0.13	($13)	($42)	$0.00	$0.6	($51)
2024	$1.7	$1.18	$0.58	$0.13	($15)	($47)	$0.00	$0.0	($58)
2025	$1.7	$1.18	$0.58	$0.13	($16)	($51)	$0.00	$0.0	($64)
2026	$1.7	$1.18	$0.58	$0.13	($18)	($56)	$0.00	$0.0	($71)
2027	$1.7	$1.18	$0.58	$0.13	($20)	($61)	$0.00	$0.0	($77)
2028	$1.7	$1.18	$0.58	$0.13	($21)	($65)	$0.00	$0.0	($83)
2029	$1.7	$1.18	$0.58	$0.13	($23)	($70)	$0.00	$0.0	($89)
2030	$1.7	$1.18	$0.58	$0.13	($25)	($75)	$0.00	$0.0	($96)
Sum	**$28**	**$19**	**$9.3**	**$2.1**	**($197)**	**($627)**	**$0**	**$12**	**($754)**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.21 Net Societal Costs for Policy Option AG-3: Conversion to Perennial Cover (continued)

Year	Net Costs		
	Total Policy Option Costs MM$	Total Discounted Policy Option Costs MM$2014	Cost Effectiveness $2014/tCO₂e
2015	($18)	($17)	
2016	($44)	($40)	
2017	($70)	($61)	
2018	($98)	($81)	
2019	($126)	($98)	
2020	($154)	($115)	
2021	($181)	($129)	
2022	($208)	($141)	
2023	($236)	($152)	
2024	($264)	($162)	
2025	($291)	($170)	
2026	($318)	($177)	
2027	($346)	($184)	
2028	($374)	($189)	
2029	($401)	($193)	
2030	($429)	($197)	
Sum	**($3,558)**	**($2,104)**	**($153)**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Macroeconomic (Indirect) Policy Impacts

Tables below provides a summary of the expected impacts of Ag-2 policy on jobs and economic growth during the CSEO planning period.

Table F-4.22 AG-2 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
AG-2	-$2	$8	$113	70	230	3,380	$21	$20	$299

Table F-4.23 AG-3 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
AG-3	$23	-$35	-$529	1,170	-490	-7,420	$56	-$32	-$486

Graphs below show detail in GSP, employment and personal income impacts of Ag-2 policy.

Figure Ap F-4.25 AG-2 GSP Impacts ($2015 MM)

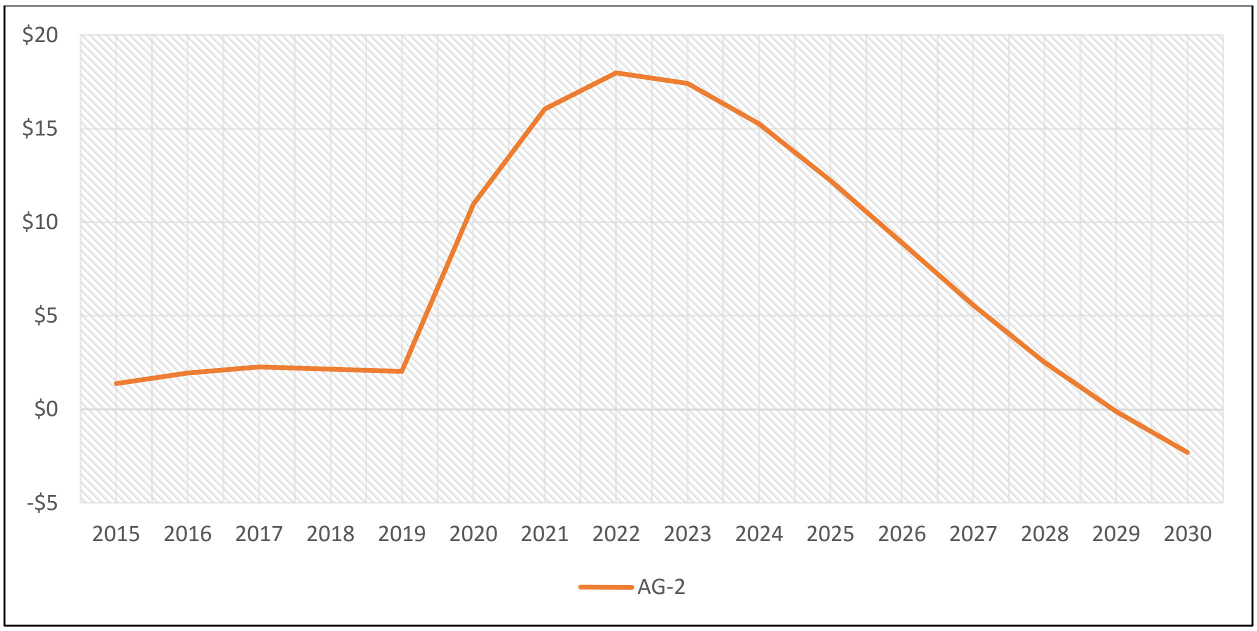


Figure Ap F-4.26 AG-2 Employment Impacts (Individual Jobs)

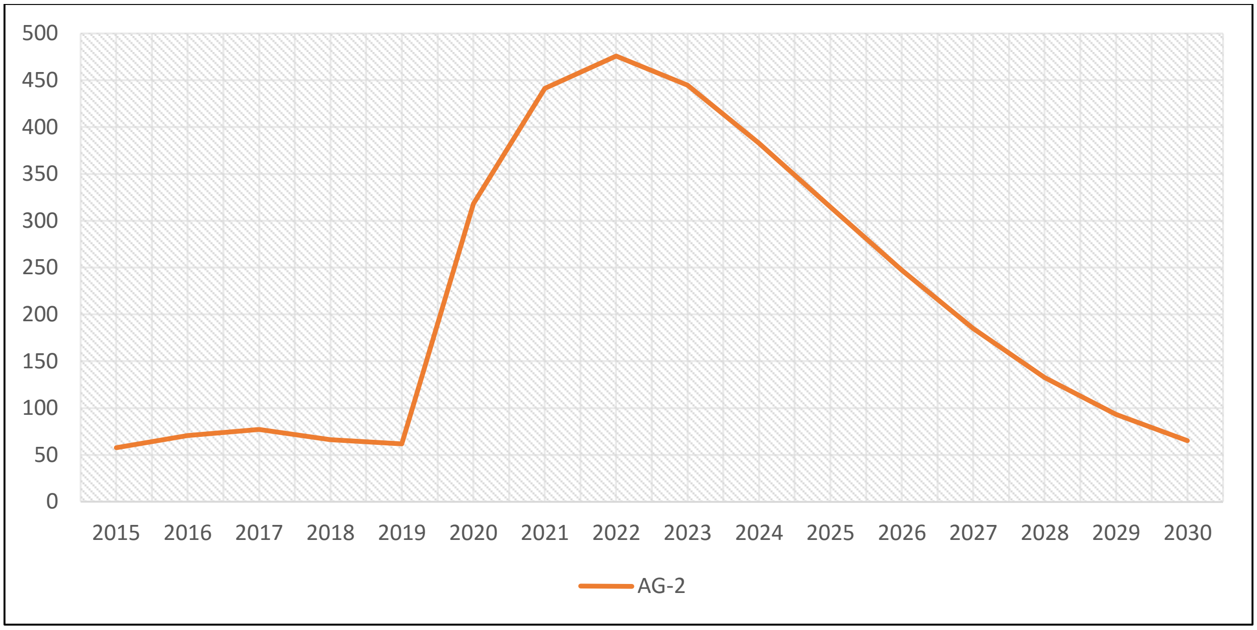
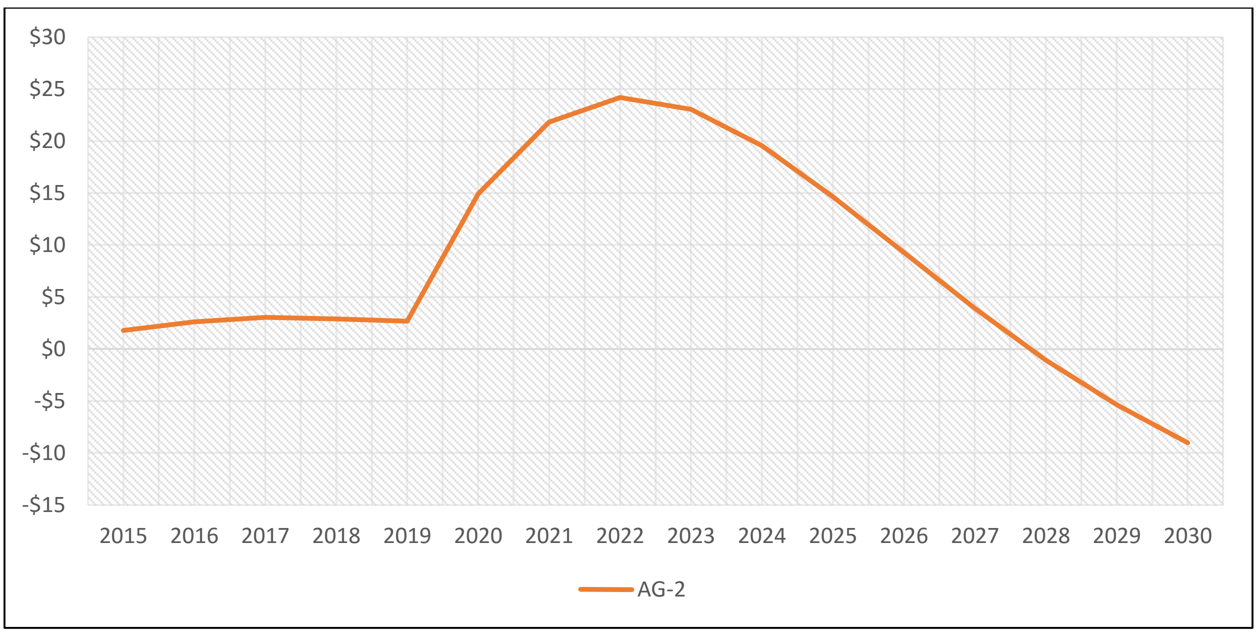
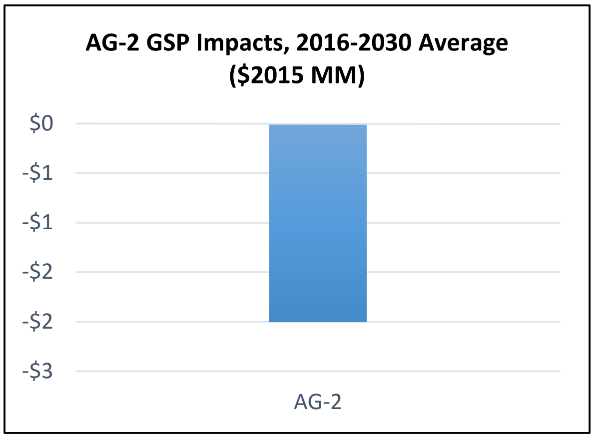
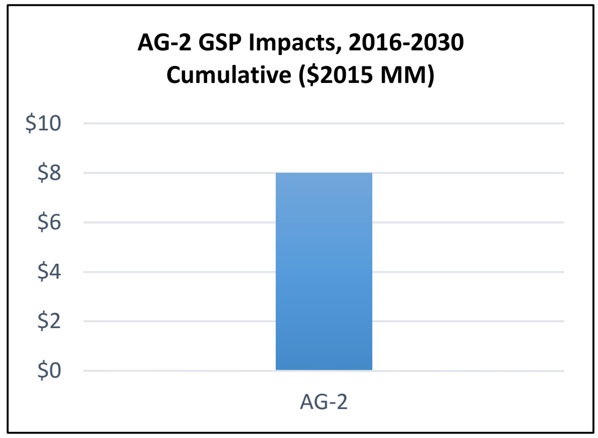


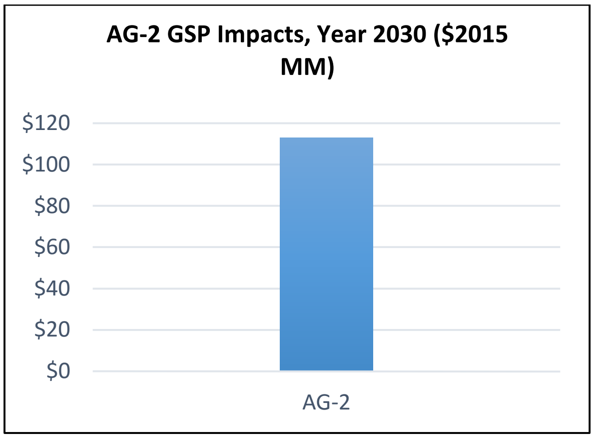
Figure Ap F-4.27 AG-2 Income Impacts ($2015 MM)

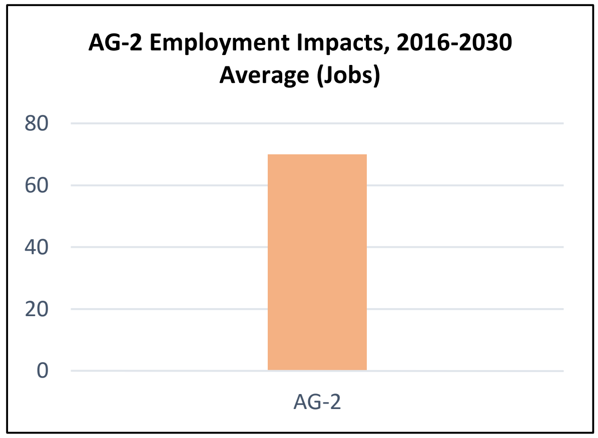


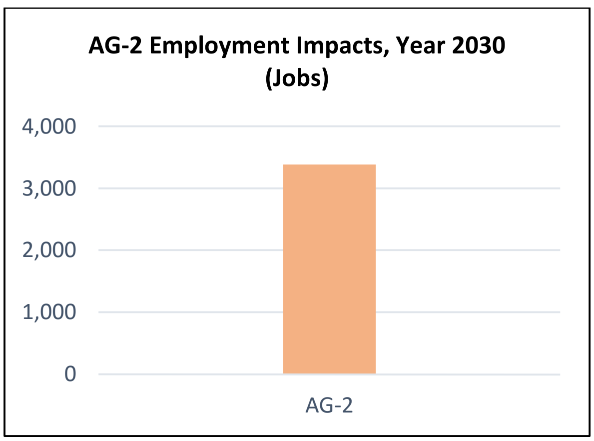
Bar charts below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030) for Ag-2 policy.

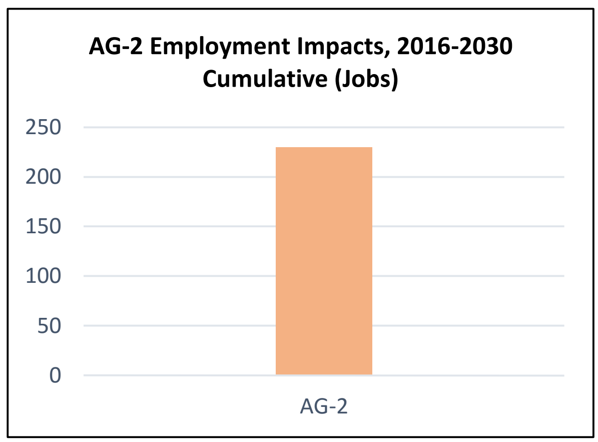

AG-2 GSP Impacts, 2016-2030 Average ($2015 MM)
$0
-$1
-$1
-$2
-$2
-$3
AG-2

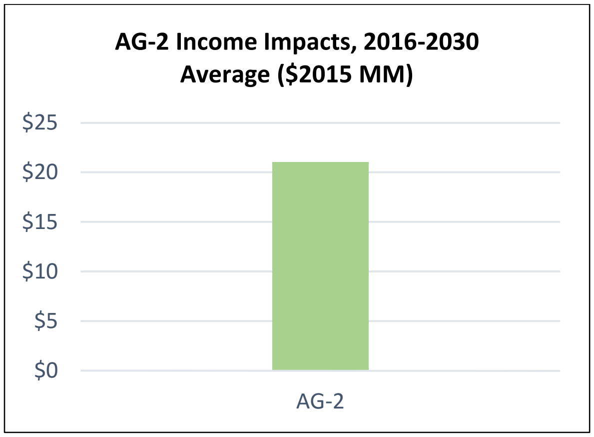

AG-2 GSP Impacts, 2016-2030 Cumulative ($2015 MM)
$10
$8
$6
$4
$2
$0
AG-2

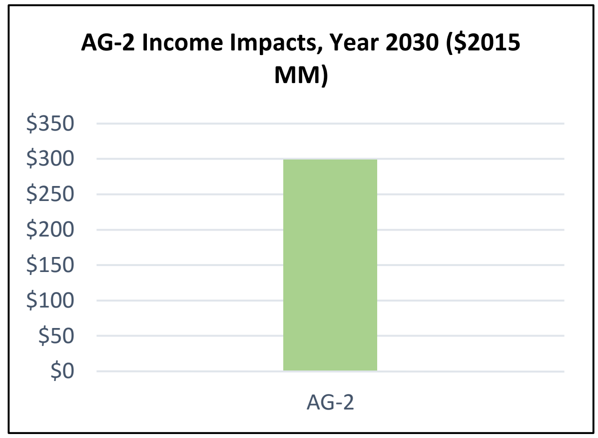

AG-2 GSP Impacts, Year 2030 ($2015 MM)
$120
$100
$80
$60
$40
$20
$0
AG-2

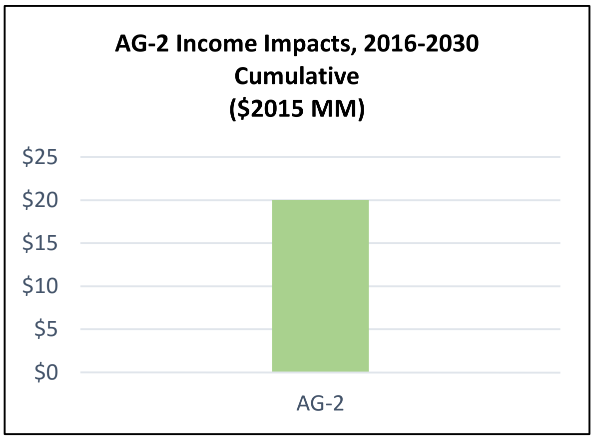

AG-2 Employment Impacts, 2016-2030 Average (Jobs)
80
60
40
20
0
AG-2


AG-2 Employment Impacts, Year 2030 (Jobs)
4,000
3,000
2,000
1,000
0
AG-2


AG-2 Employment Impacts, 2016-2030 Cumulative (Jobs)
250
200
150
100
50
0
AG-2







Principal Drivers of Macroeconomic Changes

AG-2, like AG-1, imposes net higher costs on farms, all in all, by approximately $200 million by the year 2030. The higher costs push down investment, but the direct hiring as the largest of that cost offsets this impact. Those hires produce consumer spending, which is an effective positive force in economic impacts.

State spending follows the same profile as the farm spending, as it is directed mostly to program implementation and to pilot programs. It is displacing other existing programs, so its impact directly is positive, but is offset statewide by reductions in spending (and the benefits that produces) in other programs.

Overall employment is slightly positive – fewer than 500 additional new positions, and as a result, incomes rise slightly in response. GSP change is neutral, with neither significant positive nor significant negative impacts.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For AG-2, the direct hiring by the agriculture sector to implement this policy drives the policy upward, and constitutes the vast majority of the small shift in employment upward. No other sector shows significant effects.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the AG-2 policy, important data included:

- Spending by farms on fuels, seed, equipment, and additional labor to implement the policy.
- Savings by farms on fertilizer. These savings reach approximately $30 million statewide, which is only about 10-15% of the cost of the program.
- Additional hiring by farms to implement this more labor-intensive nitrogen-inhibition method.

- A shift in spending – less total spending on fertilizers, but more on nitrogen inhibitors. The chemical sector sees both sides of this shift, and the net cost is positive to farms.
- Government costs to administer the program and to implement pilot projects.

<u>Quantification Methods</u>

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

<u>Key Assumptions</u>

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus

allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.

- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.
- State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Graphs below show detail in GSP, employment and personal income impacts of AG-3 policy.

Figure Ap F-4.28 AG-3 GSP Impacts ($2015 MM

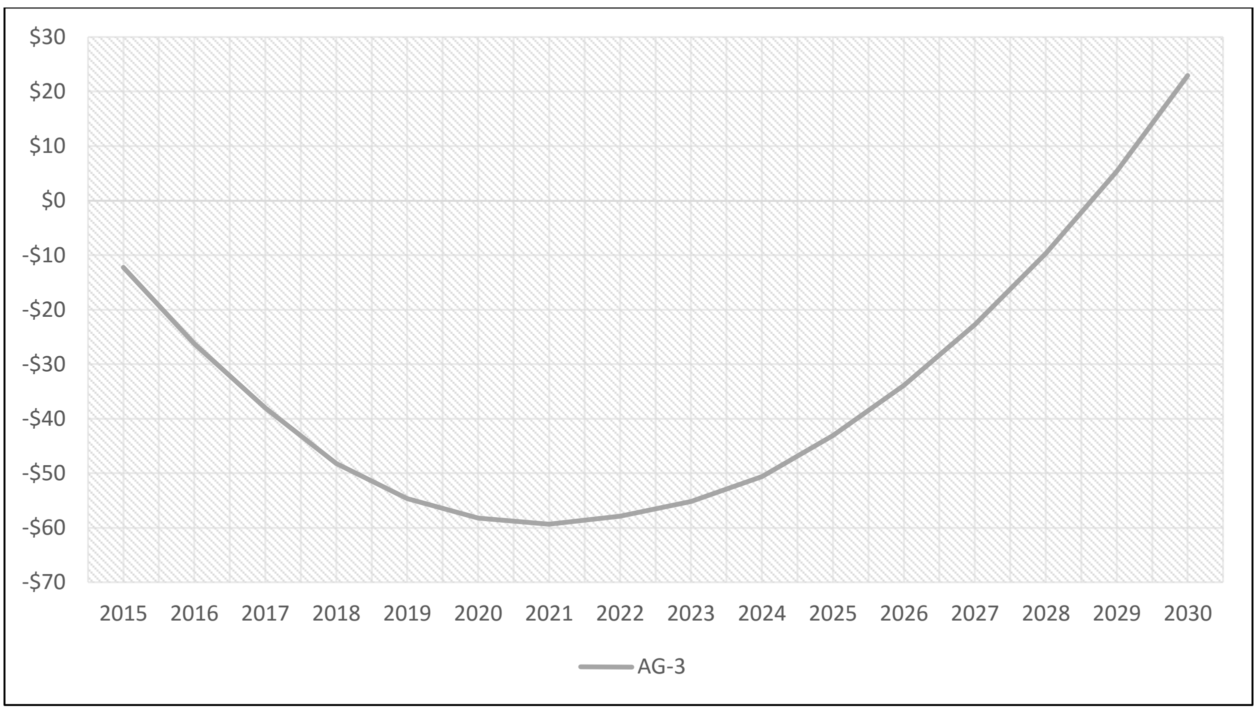


Figure Ap F-4.29 AG-3 Employment Impacts (Individual Jobs)

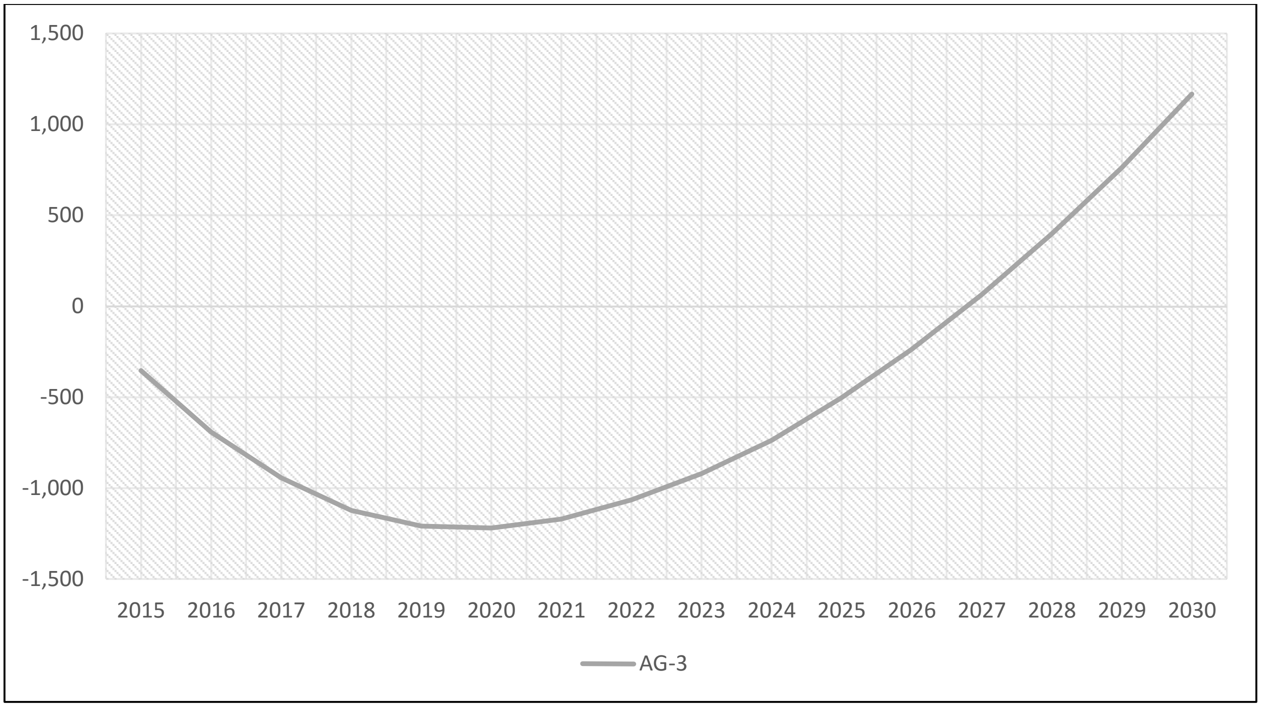
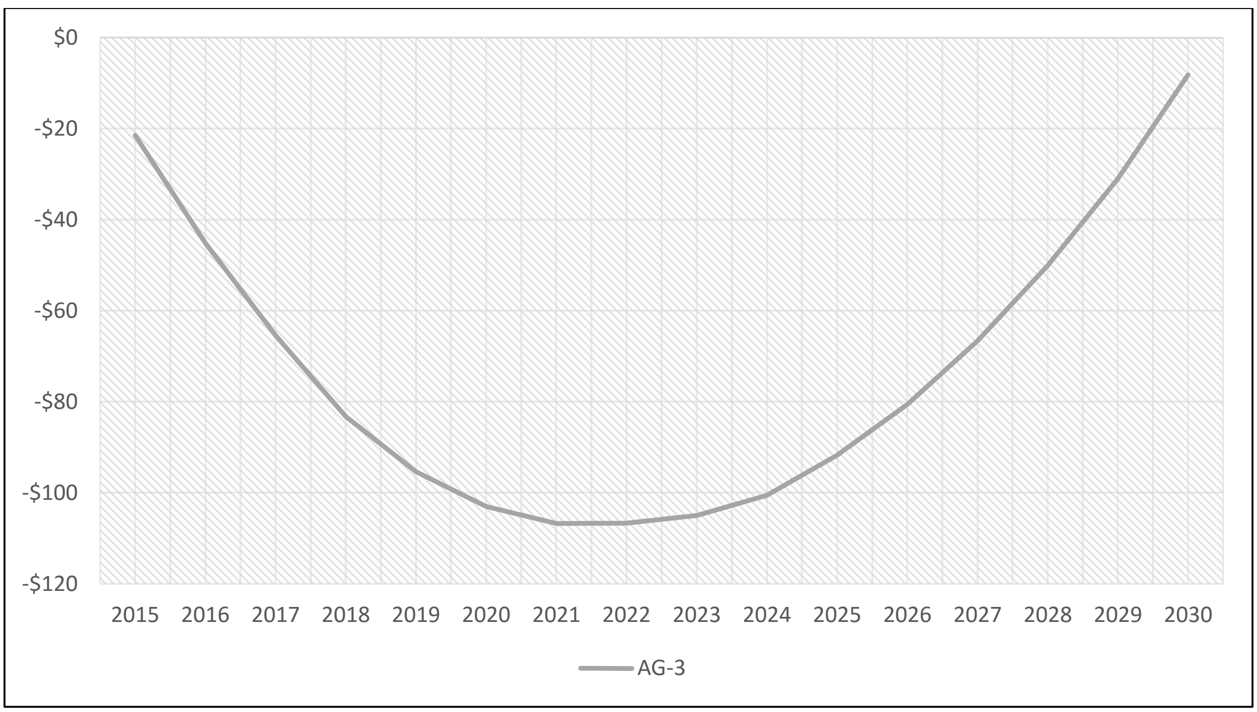
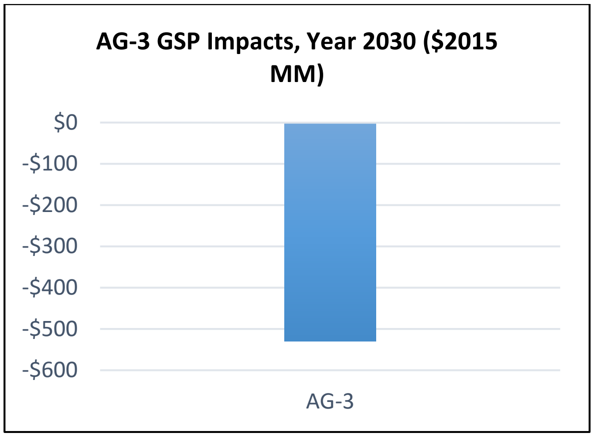
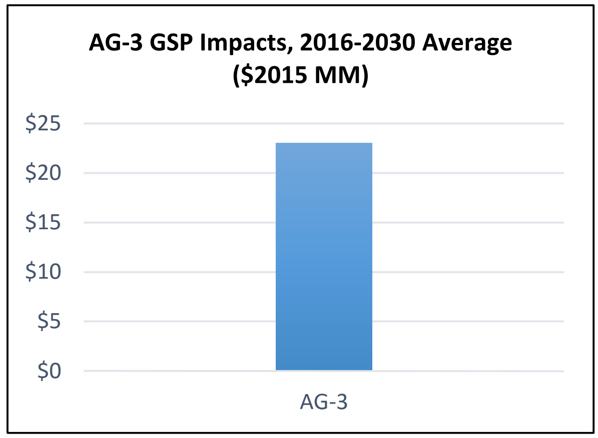


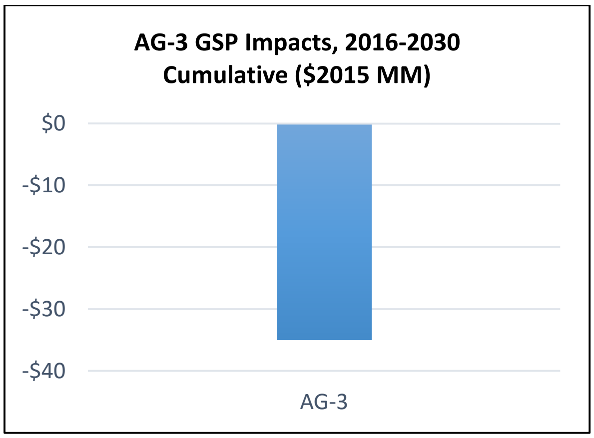
Figure Ap F-4.30 AG-3 Income Impacts ($2015 MM)

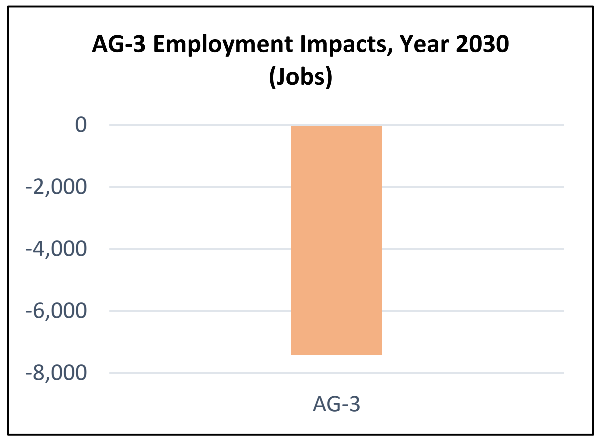


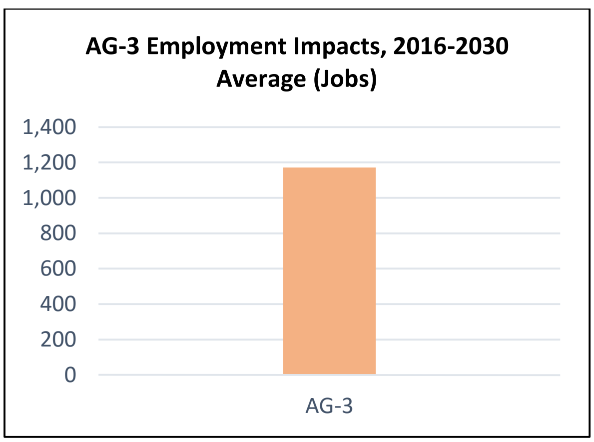
Bar charts below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030) for Ag-3 policy.

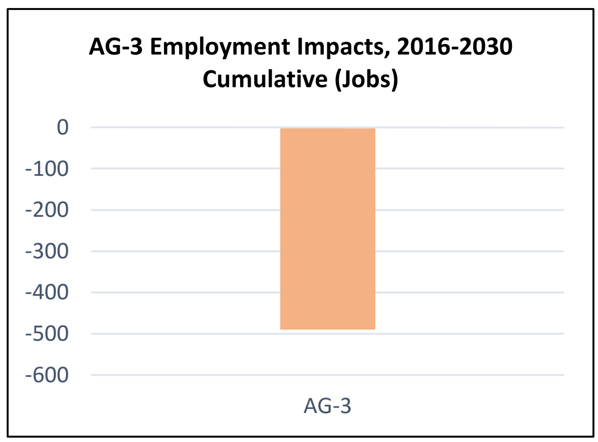

AG-3 GSP Impacts, Year 2030 ($2015 MM)
$0
-$100
-$200
-$300
-$400
-$500
-$600
AG-3

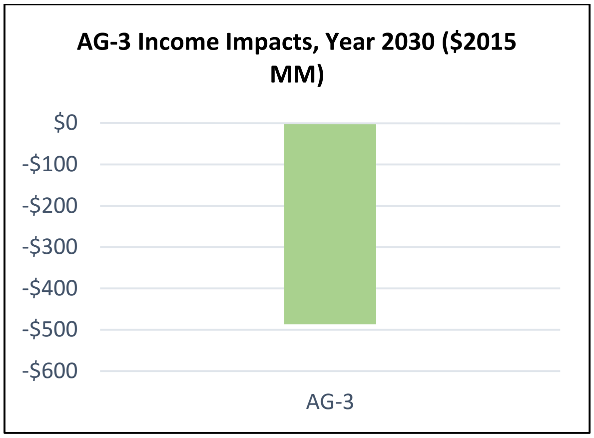

AG-3 GSP Impacts, 2016-2030 Average ($2015 MM)
$25
$20
$15
$10
$5
$0
AG-3

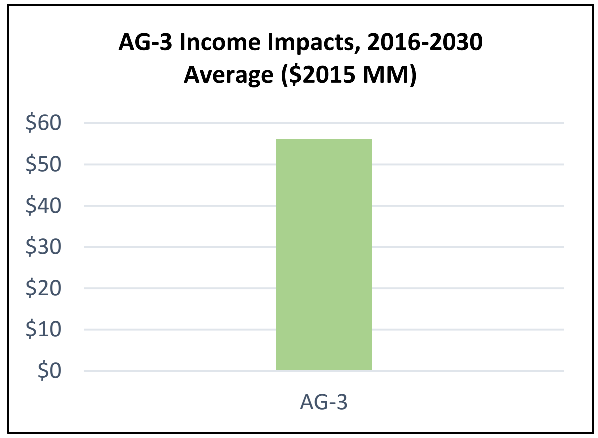

AG-3 GSP Impacts, 2016-2030 Cumulative ($2015 MM)
$0
-$10
-$20
-$30
-$40
AG-3

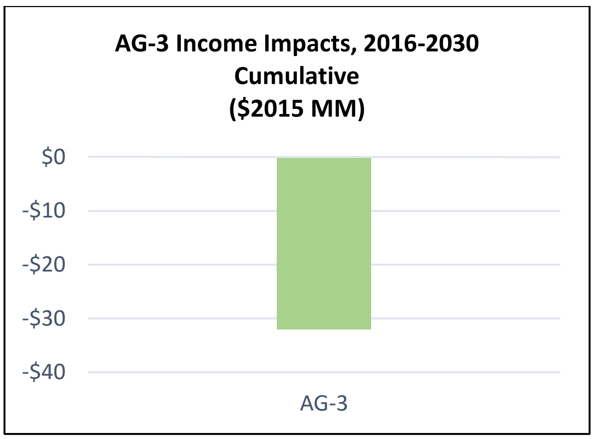

AG-3 Employment Impacts, Year 2030 (Jobs)
0
-2,000
-4,000
-6,000
-8,000
AG-3


AG-3 Employment Impacts, 2016-2030 Average (Jobs)
1,400
1,200
1,000
800
600
400
200
0
AG-3


AG-3 Employment Impacts, 2016-2030 Cumulative (Jobs)
0
-100
-200
-300
-400
-500
-600
AG-3







Principal Drivers of Policy Impact on the Broader Economy

AG-3 has an interesting forecast, in that the policy appears to apply a slight downward pressure on the economy for a dozen years, during which employment, incomes and GSP all fall slightly below neutral. However, as the lower production costs take hold and farms adjust slowly to this cost (through a combination of reduced prices and expanded operations), the sector – and the entire economy – sees a return to neutral and an upward trend in all three indicators from around 2021 to 2030. So the policy is initially dampening to the economy, but over the long term shows the potential to be slightly positive.

The major driver is the voluntary reduction in total activity in the sector – less-expensive farming mechanisms are applied to grow crops that sell for less, and fewer inputs of all sorts are required to make this happen.

However, the lower cost of production shows up in these models as an expansive force, allowing farms to expand slightly and lower prices. These two forces counteract the initial reduction in scale of economic activity that defines this policy.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For AG-3, however, the impacts are primarily felt directly in the agriculture sector. It sheds economic activity through the first few years, employing over 100 fewer people statewide by the early 2020s, but rebounds back to being the only sector with significant positive (though still small) gains by 2030.

Key Uncertainties

Key uncertainties in managing soil carbon using cover crops are related to impacts on N_2O emissions, commercial fertilizer application rates, and changes in diesel fuel consumption. The literature is mixed on the N_2O emissions consequences of cover cropping. Some studies seem to suggest that cover cropping increases N_2O emissions, rather than decreases them.[21] Basche and Miguez concluded: Cover crops have the potential to increase or decrease nitrous oxide emissions, depending upon the N fertilization level, soil pH, period of measurement and type of cover crop (grass or legume). In some instances, the reported N_2O emissions increase can be large enough to offset completely any emissions reduction from increased soil organic carbon (SOC) accumulation.[22]

N_2O formation in soils is generally favored by high soil organic carbon and increased soil wetness. The presence of cover crops encourages both of these conditions. Target crop yields and nitrogen crediting for cover crops influence commercial fertilizer application rates. Leguminous cover crops provide a source of nitrogen to the following cash crop and reduce the need for synthetic nitrogen fertilizer application. Currently there is no consensus on the best method to credit cover crops nitrogen contribution. Also, it is unknown whether the majority of farmers count the credit and adjust commercial Nitrogen application accordingly. Decreased crop nitrogen needs reduce commercial fertilizer use when per acre yields are constant or declining. When yields increase, it is possible that per acre nitrogen applications could remain constant or increase, depending on how the yield target changes. This is a function of how returns per acre are perceived by the producer to have changed as a result of increased nutrient use efficiency (NUE) (stemming from the use of cover crops).

Fuel costs and fuel savings for cover crop establishment and termination will vary depending on establishment and termination methods. Cover cropping is often done in combination with reduced tillage. Fuel is saved when switch from conventional tillage to reduced tillage. Fuel use increases if additional field passes are need to establish or terminate cover crops. However new technologies exist allowing farmers to seed cover crops while simultaneously side dressing nitrogen, spraying herbicide or applying manure. In this case, no additional fuel is consumed. There is no one size fits all approach for cover management and it is difficult to pin down generalized estimates.

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[21] In reviewing the published literature (about 25 studies, about 100 data points) Basche and Miguez (2012) found that in about 60% of the studies cover cropping increased N_2O emissions and decreased them in about 40%. A. Basche and F. Miguez, 'Do Cover Crops Increase or Decrease Nitrous Oxide Emissions? A Meta-Analysis,' http://www.sustainablecorn.org/Publications/Posters_docs/2012/Cover-Crops-and-N20-emissions_Basche.pdf

[22] S. Peterson, et al., 'Tillage Effects on N_2O Emissions as Influenced by a Winter Cover Crop,' Soil Biology and Biochemistry, 30 (2011): 1-9.

Key uncertainties in managing soil carbon using perennial cover include cattle herd expansion and subsequent methane and N_2O emissions. A one-million-acre increase in forage acreages, if all in alfalfa and other hay, would increase total hay acres in the state by about 50%. Increased production of forages would lower cattle feed costs, leading to some herd expansion. An increase in methane emissions from ruminant flatulence and methane and N_2O emissions from manure storage and land application then might be expected. The impact of a one million acre expansion of forages on feed costs and livestock populations is challenging to estimate. An 20% expansion in the state cattle herd results in a one half million CO_2e ton annual increase in emissions. However, the expansion of the in-state cattle herd could also be viewed as off-setting the need for higher cattle herds out of state with potentially higher GHG emissions per unit of production. Additional emissions associated with energy use in the livestock sector also would be likely.

The persistence of added soil organic carbon is uncertain and dependent on maintaining land management practices over long periods of time (many decades). An estimate of soil organic carbon persistence is necessary to translate the estimated storage into tons of CO_2 equivalence. For the purposes of this policy option analysis, a soil organic carbon permanence factor of 0.2 was applied to estimate the amount of carbon stored permanently.

Additional Benefits and Costs

Cover Crop Co-benefits: Reduced soil erosion and sedimentation, increased water storage on the landscape due to increased soil organic matter (SOM) content, improved nutrient cycling, and improved water quality. Many practices that sequester soil carbon also buffer the landscape and protect against extreme weather events associated with climate change.

Cover Crop Costs: Some producers may purchase specialized equipment for planting cover crop seeds into standing crops like corn.

Perennial Crop Co-benefits: Reduced soil erosion and sedimentation, improved water quality, wildlife habitat, increased water storage on the landscape due to increased SOM content, and provides resiliency to extreme weather events associated with climate change. Increasing perennial grass acreage in Minnesota has the potential of returning grazing animals to the landscape. Managed grazing by ruminant animals is an effective method of managing perennial landscapes of grasses and legumes (i.e., helps prevent overgrowth by trees and shrubs), and improves vegetative health (increasing carbon uptake) by distributing manure on the landscape. Through physical and chemical processes, manure is incorporated into the soil and a portion is converted to soil organic matter.

Some additional benefits include: reduced soil erosion and sedimentation; reduced nitrogen run-off and leaching and attendant water quality impacts; improved weed control; improved soil physical properties and, potentially, long-term yields. For conversion to perennial cover, trickle through benefits of expanded meat and dairy commodities production might represent an additional benefit that might be considered.

Climate Change Adaptation Benefits: Managing carbon in agricultural soils provides community resiliency and ecosystem co-benefits such as:

- Increasing water availability and reducing drought impacts by holding more water in the soil profile,
- Improving resistance to agricultural pests by utilizing cover crops to enhance bio-control with beneficial insects,
- Improving surface and ground water quality by reducing runoff from agricultural fields and reducing erosion, sedimentation and nutrient export, and
- Increasing resilience of agricultural production by maximizing plant available water in the soil, reducing soil temperatures and evapotranspiration, improving nutrient cycling, and reducing pest outbreaks.

Potential Health Impacts

The two primary soil carbon management practices that the Minnesota CSEO policies address include incorporating cover crops where practical and diversifying annual cover-crop rotations with perennials. Incorporating cover crops may result in a decrease in nitrogen fertilizer use. Switching annual cover crop rotations with perennials could result in reduced use of fossil fuels and subsequent particle pollution emissions due to less tilling and crop management. Perennial vegetation and cover crops may reduce the need for herbicides and pesticides and prevent soil erosion, protecting water quality.[23]

The primary health impacts of soil carbon management (primarily perennial vegetation) will result from reductions in nitrate (NO_3) concentrations, as well as other agricultural chemicals, in drinking water (see policy option AG-1); reduced exposure to particle pollution; and reduced exposure of farmers to pesticides and herbicides. Reduced exposure to particle pollution may reduce exacerbations of respiratory and cardiovascular diseases, such as asthma, allergies, and chronic obstructive pulmonary disease (COPD), as well as cancer mortality in exposed populations (EPA[24]; Kappos[25]; Pope 2002, Pope 2000[26]; Bernard[27]). If not handled and used

[23] Sustainable Agriculture Research & Education (SARE). 2012. Benefits of Cover Crops (website). Accessed October 23, 2014. http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Benefits-of-Cover-Crops.

[24] U.S. Environmental Protection Agency. Coal. http://www.epa.gov/cleanenergy/energy-and-you/affect/coal.html, Updated August 2014.

[25] Kappos et al. Health effects of particles in ambient air. International Journal of Hygiene and Environmental Health. Volume 207, Issue 4, 2004, Pages 399–407.

[26] Pope CA III, Burnett RT, Thun MJ, Calle EE, Krewski D, Ito K and Thurston GD. 2002. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. JAMA. Vol. 287 (9): 1132-41.

Pope CA III. 2000. Epidemiology of fine particulate air pollution and human health: biologic mechanisms and who’s at risk? Environ Health Perspect; 108:Supple 4:713-23.

[27] Bernard SM, Samet JM, Grambsch A, Ebi KL, Romieu I. 2001. The potential impacts of climate variability and change on air pollution-related health effects in the United States. Environmental Health Perspectives Vol 109, Supplement 2, pp 199-209.

properly, exposure to agricultural chemicals (including pesticides and herbicides) may result in both acute and chronic health effects, including acute and chronic neurotoxicity (insecticides, fungicides, fumigants), lung damage (paraquat), chemical burns (anhydrous ammonia), hematopoietic cancers, immunologic abnormalities and adverse reproductive and developmental effects (Weisenburger[28]; Alvanaja et al.[29]). The potential reduction of agrichemical use through the introduction of perennial vegetation and cover crops may reduce farmers' exposure and related health outcomes.

Feasibility Issues

Cover Crops: Cover crop adoption on short season crops has few barriers. However, cover crop adoption in traditional corn/bean system has many barriers. These barriers are:

- A short window of opportunity for establishment,
- Consistent establishment and field coverage,
- Issues and uncertainties regarding crop insurance and USDA Risk Management Agency,
- A potential shortage of cover crop seed, this is especially true if practice adoption is swift,
- Cover crops viewed as an 'unproven' practice by some producers and therefore a reluctance to try, and
- Stable, long-term policy option commitment is needed to incentivize perennial crop practices. At this point it is unknown if the State will develop long-term policies for cover crops.

Perennial Crops:

- Markets may not be ready for an influx of perennial products,
- Reluctance of farmers to convert cash crop land to perennials plantings because of lost opportunity cost, and
- Stable, long-term policy option commitment is needed to incentivize perennial crop practices. At this point it is unknown if the State will develop long-term policies for cover crops and perennial crops.

[28] Weisenburger D. 1993. Human health effects of agrichemical use. Human Pathology. Volume 24, Issue 6, June 1993, Pages 571–576. DOI: 10.1016/0046-8177(93)90234-8.

[29] Alavanja M, Hoppin J, Kamel F. 2004. Health Effects of Chronic Pesticide Exposure: Caner and Neurotoxicity. Annual Review of Public Health. Vol. 25: 155-197 (Volume publication date April 2004). DOI: 10.1146/annurev.publhealth.25.101802.123020.

Updating, Monitoring and Reporting

The current Minnesota GHG emission inventory does not include soil carbon storage, except for forest soil; carbon storage in forests is not included in the state emission total but presented separately. Carbon emissions from histosol cultivation and soil erosion and oxidation are represented with placeholder estimates because of limited information. The current inventory methods will not be able to evaluate this policy option. Significant data collection and inventory modification would be necessary.

AG-4. Advanced Biofuels Production

Policy Option Description

Production based incentives to support commercial development of advanced biofuels in Minnesota. Advanced biofuel would be sourced primarily from Minnesota biomass feedstocks from agricultural or forestry sources, or the organic content of municipal solid waste. Fuels made from biological materials tend to have lower energy-cycle emissions[30] as compared to fossil-based sources, and thus their use provides net greenhouse gas reductions.

Production based incentives to support commercial development of advanced biofuels in Minnesota are proposed. Proposed legislation for this initiative was introduced in 2014, HF 2456 and SF2101, are expected to return for consideration in 2015. Advanced biofuel (as defined in the legislation, which uses the definition in public law of improving greenhouse gas emissions over the fossil fuel it replaces by 50% or better – this would not include current technology for ethanol or biodiesel) would be sourced primarily from Minnesota biomass feedstocks (at least 80%) from agricultural or forestry sources, or the organic content of municipal solid waste. Fuels made from biological materials tend to have lower energy-cycle emissions as compared to fossil-based sources, and thus their use provides net greenhouse gas reductions.

Hand-in-hand with this policy option is Policy Option AG-5 which focuses on biofuel consumption within the state. In many cases installation of infrastructure for storage and delivery of higher biofuels blends must also be accomplished in order to ensure a marketplace for the fuels, especially ethanol-blended gasoline with ethanol content greater than 10% by volume, as current regulation requires, being incentivized in this policy option. A second option would be to require gasoline dispensing locations to upgrade their equipment to a specific, reasonable priced ethanol blend level as the infrastructure turns over into the future.

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[30] *Energy-cycle emissions* as defined for this project include the upstream emissions associated with the production of fuels and materials. Using gasoline and diesel fuels as examples, the energy-cycle emissions would include the GHG emissions for petroleum extraction, transport, processing, and distribution, as well as those from the combustion of the fuel itself. CCS differentiates energy-cycle from life-cycle based accounting.
Lifecycle emissions involves a cradle-to-grave view of GHG emissions associated with the use of a fuel or product. Such an assessment includes the extraction and transport of raw materials, manufacture, packaging, freight, usage and finally disposal. It also includes the emissions from construction of all facilities within the value chain. Using the previous example, that would include construction of the extraction well (and its components), transport pipelines/ships, refineries, gasoline stations, vehicles, etc.

Causal Chain for GHG Reductions

Figure Ap F-4.31 Causal Chain for AG-4 GHG Reductions

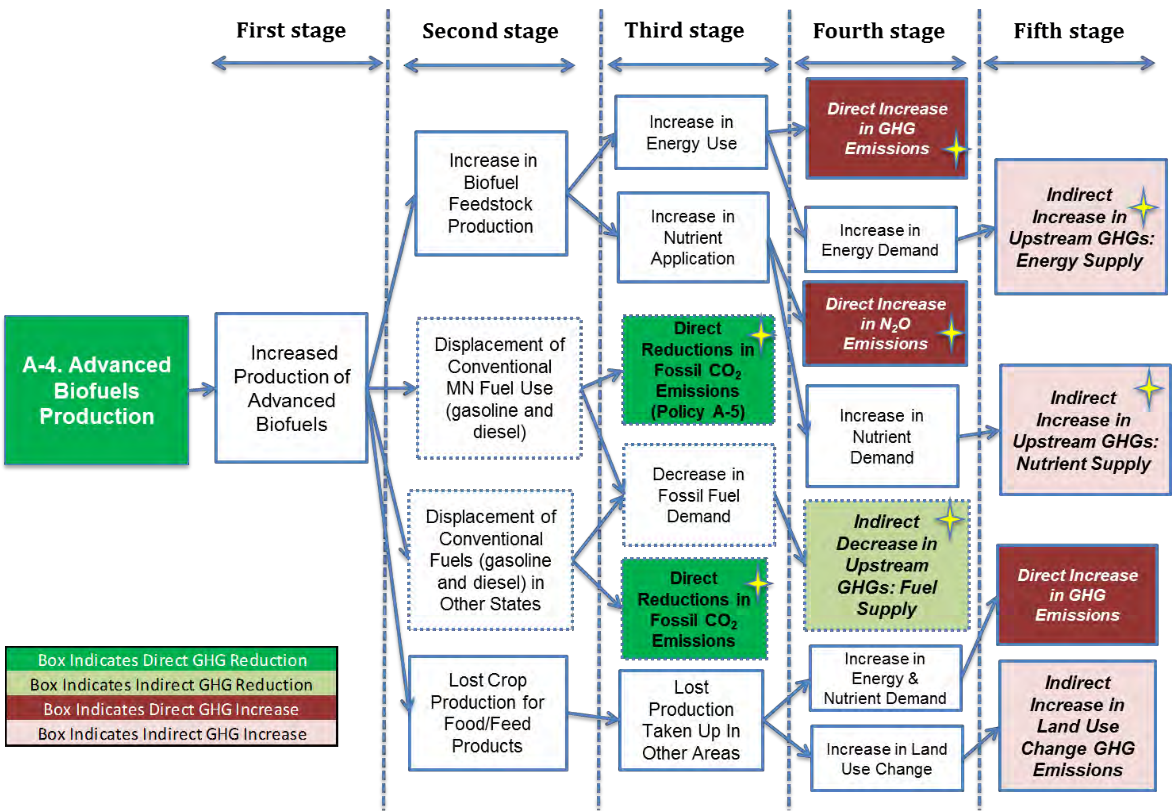
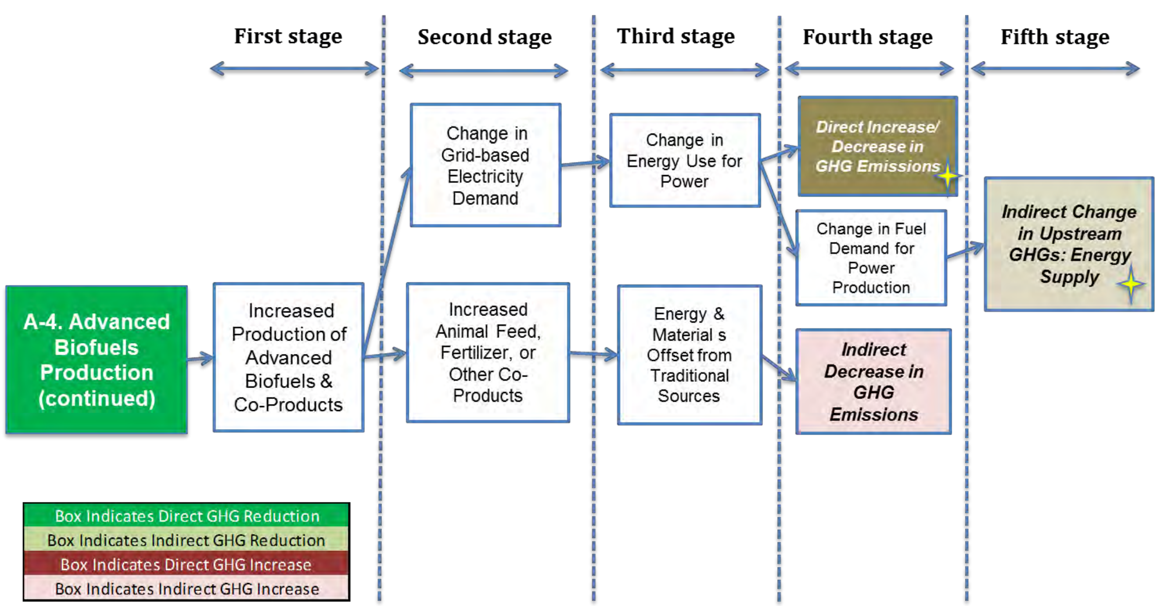


Figure Ap F-4.32 Causal Chain for AG-4 GHG Reductions (continued)



The star symbol identifies significant GHG effects that will be quantified. For this policy option, the analysis will center on developing estimates of the volumes of advanced biofuels produced in the State during each year, their associated carbon content, and their production costs. These results will be used as input to the analysis of Policy Option AG-5 addressing increased biofuels consumption in order to determine the full GHG benefits and costs for in-state biofuels production and use (the dotted lines around the fossil fuel displacement boxes indicate these displacement effects). All of the quantified GHG effects for this policy option analysis will be used to develop the advanced biofuel carbon content for use in the AG-5 analysis.

As shown in the causal chain above, with any biofuels or bio-products production policy option, there is a potential for dis-benefits from lost crop production capacity for food and feed. These include emissions from indirect land use change (e.g. lands in grassland or forest cover are converted to make up for lost food/feed production in Minnesota or elsewhere). These dis-benefits won't be quantified in this policy option analysis; however, the policy option goals and implementation methods were designed to minimize their potential (i.e. by minimizing the loss in crop production capacity in Minnesota). There are also additional co-benefits associated with the co-products from advanced biofuels production. These could include: renewable power production sold to the grid from the excess electricity produced from certain types of biofuels plants (e.g. cellulosic ethanol), animal feed, fertilizer, or other co-products. This policy option analysis will provide an accounting for any excess power production, but will not include any accounting of the additional co-products benefits due to data availability and the likely significance of these in terms of net GHG reductions.

Policy Option Design

Goals: Advanced biofuel production goals:

- 150 million gallons produced from 2015 - 2020
- 500 million gallons by 2025
- 875 million gallons by 2030

Timing: If policy option is passed in 2015, eligible projects could begin production for eligible payments beginning on July 1, 2015. Assume two year time horizon before the first plant is operating with production total of 25 million gallons of starch-based advance ethanol per year; assume five years until the first cellulosic plant of 25 million gallons per year capacity.

Parties Involved: State of Minnesota Department of Agriculture, as the implementer.
Other affected parties include: advanced biofuel producers; refiners, to meet renewable fuel standard (RFS) blending requirements under the RFS; corn (if advanced biofuel is butanol) and beet producers; cellulosic feedstock suppliers and producers; cellulosic sugar producers.

Other: The national goal through the Renewable Fuel Standards is 58% of renewable fuels are advanced biofuels by 2022, totaling 21 billion gallons blended into the transportation fuel supply by that time.

The goal for the Minnesota incentive program is $15 million in producer payments annually, which would equate to a range of 7,124,875 - 14,245,014 MMBtu, depending on what portion of the payments is at the lower (starch-based advanced biofuel) or higher (cellulosic-based advanced biofuel) levels. This is the equivalent of a range of 92,500,000 - 185,000,000 ethanol equivalent gallons of biofuel per year. For this policy option we will use ethanol for all calculations with the assumption that other biofuels, such as butanol or drop-in renewable hydrocarbon replacement fuels, could translate into the policy option on a MMBtu basis.

Implementation Mechanisms

The policy option also creates a loan program for capital expenditures needed to build the production facilities. Production incentive payments would be based on the total BTU content of the fuel produced. Payments for cellulosic-based fuel production would be more than for corn starch/other readily available sugar production, currently proposed at $2.1053/MMBtu and $1.053/MMBtu respectively. Total payments in any one year would not exceed $15,000,000 and total payments to any individual producer would not exceed 2,850,000 MMBTU of biofuel production per year. The 2,850,000 MMBtu of production equates to just over 37 million gallons of ethanol-equivalent fuel in production (77,000 Btu/gallon) and $3-6 million based on the type of feedstock being used to produce the biofuel.

Minnesota built a first generation ethanol industry using a producer payment policy option. Over the course of a 10-year program the state spent approximately $450 million to support the development of ethanol plants. Today, the ethanol industry supports 12,600 jobs and generates over $5 billion annually in economic activity. Passage of a production incentive payment program for advanced biofuels would make Minnesota a world-class location for building commercial-scale production facilities. The incentive can be used to help leverage private investment for facility construction. The production incentive approach also helps to protect state investment using taxpayer dollars since no payments are made until production occurs. This type of policy option also has the advantage of removing government from the role of evaluating technology. Projects that cross the finish line are rewarded for their success.

Biobutanol as a transportation fuel made from corn starch would qualify if it improves greenhouse gas emissions compared to gasoline by at least 50%. Considerations will have to be made for ethanol plants that received producer payments for ethanol production (and hence were built to some degree with the payments and the promise of the payments).

Concerns need to be addressed on the sourcing of biomass feedstocks so that the collection is done in an environmentally appropriate way. Incentives could be tied to land management practices.

Legislation:

- Incentive payments ($15 million per year maximum totals for all producers and 2,850,000 MMBtu of biofuel production per year maximum per producer).
- Capital equipment loans.

Related Policies/Programs in Place and Recent Actions

- AG-5, Existing Biofuel Statute, incentivizing the use of the advanced biofuel produced in the state.
- Next Gen Energy Board grant program.
- Bio-economy Coalition of Minnesota.
- Minnesota Governor's Association Academy grant: develop clean energy economy.

Estimated Policy Impacts

Direct Policy Impacts

Table F-4.24 AG-4 Estimated Net GHG Reductions and Net Costs or Savings

	2030 GHG Reductions (short tons CO_2e)	2015 – 2030 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ ton CO_2e)
	See Policy Option AG-5	*See Policy Option AG-5*	*See Policy Option AG-5*	*See Policy Option AG-5*

Note: Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

For this policy option, the analysis will center on developing estimates of the volumes of advanced biofuels produced in the State during each year, their associated carbon content, and their production costs. These results will be used as input to the analysis of Policy Option AG-5 addressing increased biofuels consumption in order to determine the full energy-cycle GHG benefits and costs for in-state biofuels production and use. Any in-state biofuel production that is not expected to be taken up by the state fleet will be assumed to displace gasoline use outside of the state, and these indirect GHG reductions will be reflected in the combined AG-4/AG-5 Biofuels Package.

Although this policy option does not dictate any specific advanced biofuel production method, some method(s) needs to be specified in order to develop estimates of net energy/GHG impacts and societal costs. For the purposes of analysis, the two methods selected for analysis are: cellulosic ethanol production using corn stover as feedstock; and ethanol from energy beets:

- Energy Beets: Production capacity of 25 MMgal/yr. installed by 2016; and 50 MMgal/yr. installed by 2021;
- Cellulosic Ethanol: 25 MMgal production capacity installed by 2020.

<u>Data Sources</u>

- Literature review of current capital and operations costs and energy requirements for cellulosic ethanol and energy beet ethanol production.
- Contacts with industry sources.
- Additional sources include: relevant and available fuel pathways in ANL's GREET Model (for BAU gasoline displacement).

References are footnoted, as applicable below.

Quantification Methods

Energy Impacts and Carbon Content of Advanced Biofuels (Ethanol)

- Quantify biofuel production schedule based on policy option design.
- Quantify the GHG emissions (carbon content) of ethanol feedstocks.
- Data on energy use and N additions taken from the Minnesota BAU inventory and forecast; energy beet acreage is assumed to come from diverted corn production.
- Potential soil carbon impacts of removal of corn stover: the analysis assumes a limitation of 1 ton/acre (20%), which industry sources indicate is a safe level to avoid net losses.[31] BAU stover management assumes 100% is left on the field. Removal at this level is also assumed to not require additional N application as a result of lower crop residue N input. As a result, impacts on future corn yields are also presumed to be negligible.
- Energy beet yield is 21 ton/acre[32]; energy and GHG impacts are presumed to be similar to sugar beets. Baseline data for sugar beet production used to estimate those for energy beets, except for commercial N application (76 lb. N/acre), which was taken from same USDA study footnoted below.
- Energy requirements of stover harvest and transport: 0.10 gal diesel/acre; this value was derived from the total delivered costs for feedstock ($50/ton) and the assumption that one-third of this cost was attributable to diesel fuel.
- Quantify net plant energy and feedstock requirements based on policy option design, industry contacts and literature review.
- Cellulosic ethanol: 79 gal ethanol/dry ton stover; 149 kWh excess electrical power for the electrical grid.[33]

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[31] Personal communication, S. Hartig, Poet-DSM, with S. Roe, CCS, September 10, 2014. By comparison, N. Clark of DuPont stated that their feedstock sources remove 2 tons/acre (person communication with S. Roe, CCS, September 2014).

[32] Value for sugar beets grown in Red River Valley from USDA; *Characteristics and Production Costs of U.S. Sugarbeet Farms*, 2004, http://www.ers.usda.gov/media/943070/sb974-8.pdf.

[33] Based on a model facility in this 2011 National Renewable Energy Labs study: http://www.nrel.gov/docs/fy11osti/47764.pdf.

- Energy beets: 81 lb. beets/gal ethanol,[34] fuel requirements: 1.52 GJ/metric ton beet; electricity: 30 kWh/metric ton beets.[35]
- Quantify feedstock supply carbon content based on sourcing assumptions for advanced ethanol.
- Quantify GHG emissions for each advanced biofuel pathway based on net energy and non-energy impacts of biofuel plants and feedstock production and transport.
- Calculate net carbon content of each biofuel. Production volumes and carbon contents are then used as input to the analysis of Policy Option AG-5.

Table Ap F-93 provides a summary of the net energy and GHG impacts of policy option AG-4, including the resulting carbon content of ethanol produced from the presumed fuel pathways (50 MMgal beet ethanol; 25 MMgal cellulosic ethanol). Results can be summarized as follows:

- 2030 C content of advanced ethanol produced: 48.4 tCO_2e/TJ. This is an improvement of 45% over gasoline (88.2 tCO_2e/TJ). Greater relative production volumes of cellulosic ethanol as compared to beet ethanol would push the advanced ethanol carbon content down further for the policy option, as cellulosic ethanol production has a lower fossil energy requirement.
- BAU C content of conventional (corn-based) ethanol in Minnesota was found to be 60.2 tCO_2e/TJ, which is 32% cleaner than conventional gasoline.
- For both advanced and conventional ethanol, the improvement over gasoline could be somewhat higher than reported here. The current assumption for BAU gasoline is based on a US national average mix; whereas, Minnesota sources much of its petroleum from Canadian tar sands, which are expected to produce higher embedded energy and emissions than conventional petroleum derived fuel products.

Net Societal Costs:

- All cost components were assumed to be incremental to BAU (e.g. no costs were avoided as a result of implementing the policy option). For societal costs, the change in production costs and revenue between BAU corn production and Policy Option Scenario energy beet production was not factored in to the analysis.
- Quantify initial investment costs based on literature review of capital costs for plant construction and industry contacts. Annualize these initial investments:
- Energy beet plants: $5.04/gal ethanol capacity;[36]
- Cellulosic ethanol plants: $9.25/gal ethanol capacity:[37]

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[34] USDA, 2006. http://www.usda.gov/oce/reports/energy/EthanolSugarFeasibilityReport3.pdf; fuel requirements: $0.01003/lb sugar x 14.18 lb sugar/gal ETOH; App. Table 12; electricity: $0.00283/lb sugar x 14.18 lb sugar/gal ETOH; App. Table 12.

[35] S. Libsack, Independent Consultant, personal communication to S. Roe, CCS, September 12, 2014.

[36] Personal communication, S. Libsack, Independent Consultant, to S. Roe, CCS, September 12, 2014.

- All plants assumed to be financed at 8.0% over 10 years with 50% equity share coming from corporate sources located out of Minnesota.
- Quantify non-energy O&M costs based on lit review and industry contacts; feedstock costs based on lit review or data from Minnesota agencies:
- Energy beets: non-energy O&M: variable = $1.68/metric ton beet, fixed = $7.11 metric ton beet (both in $2011), also 0.052 t beet pellet co-product/t beet[38]; value of pellets = $220/t beet.[39]
- Cellulosic ethanol: variable O&M = $2.15/gal; fixed O&M = $0.35/gal.[40]
- Quantify net energy costs based on energy impacts quantified above, wholesale fuel costs, avoided electricity costs, Minnesota production tax credit (assume the credit stated under the Implementation Mechanisms section, $0.16/gal, would be paid to all production targeted by the policy option), and Federal Renewable Identification Number (RIN) value ($0.54/gal based on the current value at time of policy option analysis).
- Derive net costs per gallon of biofuel produced to serve as input to Policy Option AG-5.

As shown in Table Ap F-94, ethanol production costs for the policy option were ranged from $1.71/gal in 2017 to $2.86/gal in 2029.

All biofuel supply from AG-4 will be incentivized for sale and use in-state within Policy Option AG-5. Therefore, the results of the AG-4 analysis will include: volumes of biofuel produced; carbon content of biofuel; and production costs. These results will serve as input to the AG-5 analysis to determine net GHG impacts and societal costs for the full Biofuels Package.

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[37] Average of values provided by DuPont and Poet-DSM. Poet-DSM indicated that costs could come down further into the $8-9/gal capacity range with the next phase of installations.

[38] Personal communication, S. Libsack, Independent Consultant, to S. Roe, CCS, September, 12, 2014.

[39] Internet search in September 2014 found pricing from $220-$225/t on min. 20 t order (Alibaba.com).

[40] Based on the mid-point of the range provided by Poet-DSM of total O&M and a break-down of these costs based on the NREL model facility study cited above.

Table F-4.25 Production Volumes and Carbon Content

	BAU Energy & Emissions						
Year	Advanced Biofuels Production MMgal	Cumulative Acres of Corn Stover Needed Acres	Energy Use: Corn Stover Mgmt. TJ Diesel	Non-Energy GHGs: Corn Stover Mgmt. tCO_2e	Cumulative Corn Diverted to Beets Acres	Non-Energy GHGs from Diverted Corn tCO_2e	Energy Use: Corn Acres for Beet Production TJ Diesel
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2016	0.00	0.00	0.00	0.00	47,976	96,912	75.7
2017	0.00	0.00	0.00	0.00	47,976	97,392	75.7
2018	0.00	0.00	0.00	0.00	47,976	96,432	82.6
2019	0.00	316,456	0.00	153,491	47,976	96,432	75.7
2020	0.00	316,456	0.00	155,372	95,952	191,905	151.4
2021	0.00	316,456	0.00	157,252	95,952	191,905	151.4
2022	0.00	316,456	0.00	159,132	95,952	190,945	165.1
2023	0.00	316,456	0.00	161,013	95,952	189,986	151.4
2024	0.00	316,456	0.00	163,363	95,952	189,986	165.1
2025	0.00	316,456	0.00	164,774	95,952	189,026	151.4
2026	0.00	316,456	0.00	166,654	95,952	189,986	151.4
2027	0.00	316,456	0.00	168,535	95,952	189,986	165.1
2028	0.00	316,456	0.00	170,415	95,952	190,945	151.4
2029	0.00	316,456	0.00	172,295	95,952	190,945	165.1
2030	0.00	316,456	0.00	174,176	95,952	191,905	151.4
Sum	**0.00**	**316,456**	**0.00**	**1,966,472**	**95,952**	**2,484,687**	**2,030**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.26 Production Volumes and Carbon Content

	BAU Energy & Emissions						
Year	Advanced Biofuels Production MMgal	Cumulative Acres of Corn Stover Needed Acres	Energy Use: Corn Stover Mgmt. TJ Diesel	Non-Energy GHGs: Corn Stover Mgmt. tCO_2e	Cumulative Corn Diverted to Beets Acres	Non-Energy GHGs from Diverted Corn tCO_2e	Energy Use: Corn Acres for Beet Production TJ Diesel
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2016	0.00	0.00	0.00	0.00	47,976	96,912	75.7
2017	0.00	0.00	0.00	0.00	47,976	97,392	75.7
2018	0.00	0.00	0.00	0.00	47,976	96,432	82.6
2019	0.00	316,456	0.00	153,491	47,976	96,432	75.7
2020	0.00	316,456	0.00	155,372	95,952	191,905	151.4
2021	0.00	316,456	0.00	157,252	95,952	191,905	151.4
2022	0.00	316,456	0.00	159,132	95,952	190,945	165.1
2023	0.00	316,456	0.00	161,013	95,952	189,986	151.4
2024	0.00	316,456	0.00	163,363	95,952	189,986	165.1
2025	0.00	316,456	0.00	164,774	95,952	189,026	151.4
2026	0.00	316,456	0.00	166,654	95,952	189,986	151.4
2027	0.00	316,456	0.00	168,535	95,952	189,986	165.1
2028	0.00	316,456	0.00	170,415	95,952	190,945	151.4
2029	0.00	316,456	0.00	172,295	95,952	190,945	165.1
2030	0.00	316,456	0.00	174,176	95,952	191,905	151.4
Sum	**0.00**	**316,456**	**0.00**	**1,966,472**	**95,952**	**2,484,687**	**2,030**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.27 Production Volumes and Carbon Content (continued)

Year	Policy Option Scenario Energy & Emissions											
	Beet Ethanol Production MMgal	Cellulosic Ethanol Production MMgal	Energy: Corn Stover Mgmt. TJ Diesel	Non-Energy GHGs: Corn Stover Mgmt. tCO_2e	Energy Use: Beet Cultivation TJ (Diesel)	Non-Energy GHGs: Beet Cultivation tCO_2e	Cellulosic ETOH Prod. Energy Use TJ Biomass	Cellulosic ETOH Prod. Excess Energy TJ Natural Gas	Cellulosic ETOH Prod. GHGs tCO_2e	Beet ETOH Energy Reqs. TJ (Natural Gas)	Beet ETOH Energy Reqs. MWh	Beet ETOH Production GHGs tCO_2e
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
2016	0.00	0.00	6.3	0.00	130	151,308	0.00	0.00	0.00	0	0	0
2017	25.0	0.00	6.3	0.00	130	151,308	0.00	0.00	0.00	1,261	24,898	63,277
2018	25.0	0.00	6.3	0.00	130	151,308	0.00	0.00	0.00	1,261	24,898	63,277
2019	25.0	0.00	6.3	122,793	130	151,308	0.00	0.00	0.00	1,261	24,898	63,277
2020	25.0	25.0	12.7	124,297	260	302,617	5,219	(294)	10,020	1,261	24,898	63,277
2021	50.0	25.0	12.7	125,802	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2022	50.0	25.0	12.7	127,306	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2023	50.0	25.0	12.7	128,810	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2024	50.0	25.0	12.7	130,691	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2025	50.0	25.0	12.7	131,819	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2026	50.0	25.0	12.7	133,323	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2027	50.0	25.0	12.7	134,828	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2028	50.0	25.0	12.7	136,332	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2029	50.0	25.0	12.7	137,836	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
2030	50.0	25.0	12.7	139,341	260	302,617	5,219	(294)	10,020	2,522	49,796	126,554
	600	**275**	**165**	**1,573,178**	**3,382**	**3,934,016**	**57,404**	**(3,234)**	**110,215**	**30,269**	**597,556**	**1,518,644**

Note: Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.28 Production Volumes and Carbon Content (continued)

Year	Energy & Emissions Change								
	Energy Use	Energy Use	Energy Use	Energy Use	Non-Energy GHGs	Net In-State GHGs	Out-of-State GHGs	ETOH Carbon Content	ETOH Carbon Content
	TJ Diesel	TJ Natural Gas	MWh	TJ Biomass	tCO_2e	Tg CO_2e	Tg CO_2e	g CO_2e/gal	tCO_2e/TJ
2015	0.00	0	0	0	0	0.000	0.000	0	0.0
2016	61	0	0	0	54,396	0.059	0.001	0	0.0
2017	61	1,261	24,898	0	53,917	0.145	0.024	6,772	84.1
2018	54	1,261	24,898	0	54,876	0.146	0.024	6,778	84.2
2019	61	1,261	24,898	0	24,178	0.115	0.024	5,571	69.2
2020	121	967	24,898	5,219	79,638	0.170	0.020	3,810	47.3
2021	121	2,228	49,796	5,219	79,261	0.256	0.043	3,987	49.5
2022	108	2,228	49,796	5,219	79,845	0.255	0.043	3,975	49.4
2023	121	2,228	49,796	5,219	80,428	0.257	0.043	3,999	49.7
2024	108	2,228	49,796	5,219	79,958	0.255	0.042	3,972	49.3
2025	121	2,228	49,796	5,219	80,636	0.257	0.043	3,991	49.6
2026	121	2,228	49,796	5,219	79,300	0.255	0.042	3,967	49.3
2027	108	2,228	49,796	5,219	78,924	0.253	0.042	3,937	48.9
2028	121	2,228	49,796	5,219	77,588	0.253	0.042	3,930	48.8
2029	108	2,228	49,796	5,219	77,212	0.251	0.042	3,902	48.5
2030	121	2,228	49,796	5,219	75,877	0.250	0.042	3,895	48.4
	1,517	**27,035**	**597,556**	**57,404**	**1,056,035**	**3.18**	**0.52**		

Note: Each policy analysis was done over a fifteen-year planning horizon. While implementation of each policy is not expected occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.29 Net Production Costs

Year	Beet ETOH Initial Investments MM$	Cellulosic ETOH Initial Investments MM$	Annualized Capital: Beet ETOH MM$	Annualized Capital: Cellulosic ETOH MM$	Cellulosic ETOH Feedstock/ Energy MM$	Cellulosic ETOH: Excess Energy Value MM$	Beet ETOH Feedstock MM$	Beet ETOH Natural Gas MM$	Beet ETOH Electricity MM$	Cellulosic ETOH Non-Energy O&M MM$
2015	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2016	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2017	$126	$0.0	$9.4	$0.0	$0.0	$0.0	$39	$6.2	$1.9	$0.0
2018	$0.0	$0.0	$9.4	$0.0	$0.0	$0.0	$40	$6.4	$1.9	$0.0
2019	$0.0	$0.0	$9.4	$0.0	$0.0	$0.0	$40	$6.5	$2.0	$0.0
2020	$0.0	$231	$9.4	$17	$18	($1.6)	$41	$6.7	$2.0	$70
2021	$126	$0.0	$19	$17	$18	($1.6)	$84	$14	$4.1	$72
2022	$0.0	$0.0	$19	$17	$19	($1.6)	$86	$14	$4.2	$73
2023	$0.0	$0.0	$19	$17	$19	($1.7)	$87	$14	$4.3	$75
2024	$0.0	$0.0	$19	$17	$19	($1.7)	$89	$15	$4.4	$76
2025	$0.0	$0.0	$19	$17	$20	($1.8)	$91	$15	$4.4	$78
2026	$0.0	$0.0	$19	$17	$20	($1.8)	$93	$15	$4.5	$79
2027	$0.0	$0.0	$9.4	$17	$20	($1.8)	$95	$16	$4.6	$81
2028	$0.0	$0.0	$9.4	$17	$21	($1.9)	$97	$16	$4.7	$82
2029	$0.0	$0.0	$9.4	$17	$21	($1.9)	$98	$17	$4.9	$84
2030	$0.0	$0.0	$9.4	$0.0	$22	($2.0)	$100	$17	$5.0	$86
	$252	**$231**	**$188**	**$172**	**$217**	**($19)**	**$1,080**	**$178**	**$53**	**$856**

Note: Each policy analysis was done over a fifteen-year planning horizon. While implementation of each policy is not expected occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.30 Net Production Costs (continued)

Year	Beet ETOH Non-Energy O&M MM$	Cellulosic ETOH Co-Product Value MM$	Cellulosic ETOH Federal Production Tax Credit MM$	Cellulosic ETOH RIN Value MM$	Beet ETOH Co-Product Value MM$	Beet ETOH Federal Production Tax Credit MM$	Beet ETOH RIN Value MM$	Cellulosic ETOH: MN Production Credit MM$	Beet ETOH: MN Production Credit MM$
2015	$0.0	$0.0	$0.00	0.00	$0.0	$0.0	$0.0	$0.0	$0.0
2016	$0.0	$0.0	$0.00	0.00	$0.0	$0.0	$0.0	$0.0	$0.0
2017	$8.1	$0.0	$0.00	0.00	($10)	$0.0	($13)	$0.0	$2.0
2018	$8.3	$0.0	$0.00	(12)	($10)	$0.0	($13)	$0.0	$2.0
2019	$8.5	$0.0	$0.00	(12)	($11)	$0.0	($13)	$0.0	$2.0
2020	$8.6	$0.0	$0.00	(12)	($11)	$0.0	($13)	$4.0	$2.0
2021	$18	$0.0	$0.00	(12)	($22)	$0.0	($27)	$4.0	$4.0
2022	$18	$0.0	$0.00	(12)	($22)	$0.0	($27)	$4.0	$4.0
2023	$18	$0.0	$0.00	(12)	($23)	$0.0	($27)	$4.0	$4.0
2024	$19	$0.0	$0.00	(12)	($23)	$0.0	($27)	$4.0	$4.0
2025	$19	$0.0	$0.00	(12)	($24)	$0.0	($27)	$4.0	$4.0
2026	$19	$0.0	$0.00	(12)	($24)	$0.0	($27)	$4.0	$4.0
2027	$20	$0.0	$0.00	(12)	($25)	$0.0	($27)	$4.0	$4.0
2028	$20	$0.0	$0.00	(12)	($25)	$0.0	($27)	$4.0	$4.0
2029	$21	$0.0	$0.00	(12)	($26)	$0.0	($27)	$4.0	$4.0
2030	$21	$0.0	$0.00	(12)	($26)	$0.0	($27)	$4.0	$4.0
	$227	**$0.00**	**$0.00**	**(150)**	**($282)**	**$0.0**	**($323)**	**$44**	**$48**

Note: Each policy analysis was done over a fifteen-year planning horizon. While implementation of each policy is not expected occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.31 Net Production Costs (continued)

Year	Net Costs			
	Total Policy Option Costs	Total Discounted Policy Option Costs	Cost Effectiveness	ETOH Production Costs
	MM$	MM$2014	$2014/t$CO_2$e	$/gal ETOH
2015	$0	$0.00	Cost Effectiveness is shown under Policy Option AG-5 to capture the complete production and use of advanced ethanol.	$0.00
2016	$0	$0.00		$0.00
2017	$43	$37		$1.71
2018	$32	$27		$1.29
2019	$33	$26		$1.33
2020	$142	$106		$2.84
2021	$192	$136		$2.55
2022	$195	$132		$2.60
2023	$199	$128		$2.66
2024	$203	$125		$2.71
2025	$207	$121		$2.76
2026	$211	$118		$2.82
2027	$206	$109		$2.75
2028	$210	$106		$2.80
2029	$215	$103		$2.86
2030	$202	$92		$2.69
	$2,290	**$1,367**		

Note: Each policy analysis was done over a fifteen-year planning horizon. While implementation of each policy is not expected occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Key Assumptions

- Advanced biofuel production was modeled as advanced forms of ethanol. This is not to assume that ethanol would necessarily be the advanced biofuel of choice in the period of 2015-2030. Data is, however, readily available for both starch-based advanced ethanol and cellulosic ethanol.
- Opening of first 25 million gallon per year (MMgal/yr) starch-based ethanol plant is 2017, and second plant 25 MMgal/yr plant in 2021. A 25 MMgal/yr cellulosic plant opening in 2020 is used for modeling cellulosic production.
- Energy beets are modeled as the feedstock for the starch-based ethanol plants.
- Cellulosic ethanol produced from corn stover is the model for cellulosic production.
- No federal blending credit for ethanol is in place currently, so none is expected outside provisions of the Renewable Fuel Standard Renewable Identification Number, to offset the costs of advanced ethanol production.

Macroeconomic (Indirect) Policy Impacts

Macroeconomic implications of AG-4 policy were evaluated in combination with AG-5 policy, as a package. Macroeconomic analysis assumed a scenario in which these two policies are simultaneously implemented, and their combined impacts on state employment, personal income and GSP were assessed.

The results of these analysis, as well as more detailed discussion about the macroeconomic drivers and assumptions, is provided under AG-5 Macroeconomic (indirect) impact section latter in this appendix.

Key Uncertainties

- Timeline with which cellulosic biofuel production can be installed without supporting grant/loan money from the federal government and the state.
- Determination of feedstocks or methods to be used to harvest cellulosic biomass.
- Need for cellulosic sugar producer intermediary companies.

Additional Benefits and Costs

- Job creation (construction, maintenance, project design, manufacturing, delivery of new feedstock to plant, etc.).
- Increased local property tax from facility creation or expansion.

Feasibility Issues

At this point in time, it appears that Minnesota legislation will be adopted that includes advanced biofuel producer payments. Potential results of the legislation would be development of:

- Biochemical and cellulosic companies that have production capacity;
- Production facilities likely to be located near wood resources; and
- Facilities located in the Minnesota Iron Range regions supported by the Iron Range Resources and Rehabilitation Board (IRRRB). This is another avenue that will assist these fledgling companies with financing.

Other interest has also been shown for value-added projects that involve agricultural byproducts, such as sugar beet tailings, that would have the production of advanced biofuel as a product.

Projects such as those modeled in this report will take longer to take hold in Minnesota than in other states. Large grants enabled the first large scale cellulosic ethanol production to roll out in other states, and a producer payment such as the one modeled for this report (the same that is in the legislation) is unlikely to incentivize plant production in and of itself. The scale of such large projects (20 mgy) will occur first in the other states where these plants have already been constructed and have begun ramping up production.

Part of the 2015 biofuels bill involves the inclusion of perennials and cover crops into the feedstock mix when harvesting agricultural residue. Projects that would be built under this law would be different that the first three large-scale cellulosic plants that have been built and will begin production by the end of this year. They would also be different than what was modeled in this report.

In the meantime, a gradual rollout of advanced biofuel production should be seen within the state as the economics of these projects allows for their construction. The producer payment will help make the economics of these projects more favorable and will likely tip the decision to add these technologies and facilities.

If anything is certain, it is that the future should be friendly to low-carbon fuels and their development. As these fuels produce more and more benefits relative to their petroleum-based counterparts, we will see society move toward them, however slowly.

Updating, Monitoring and Reporting

With the likely passage of a biofuels production incentive in the 2015 legislative session, there will be updating, monitoring, and reporting of any projects that will be created and deployed. The results of the production incentive will be plainly evident.

As projects roll out, companies will be reporting their production and the amount and type of feedstock used. Funding will be on a two-year basis. The program is, however, scheduled to last through 2035 with companies allowed to participate for a period of 10 years. Data used to model plants in this report is likely to change quickly as technology improves, and assumptions made for this policy option analysis will need to be updated based on what comes to pass as plants being to take shape and begin production.

AG-5. In-State Biofuel Consumption

Policy Option Description

The current Minnesota Statute 239.7911 has the following goals for in-state liquid biofuels consumption: replace gasoline with: 14% by 2015, 18% by 2017, 25% by 2020, and 30% by 2025. However, Minnesota is not on track to meet these goals and further policy option to support deployment of infrastructure and vehicles is needed. Additionally, more research and development is needed to design appropriate engines and to bring advanced biofuels to the market in a cost competitive way. Note the linkage of this biofuel consumption policy option with Policy Option AG-4 which addresses in-state advanced biofuels production. This policy option should address known distribution issues and actions needed to assure that the in-state vehicle fleet is capable of consuming the biofuels at the target levels specified in state law and in AG-4 addressing advanced biofuels production.

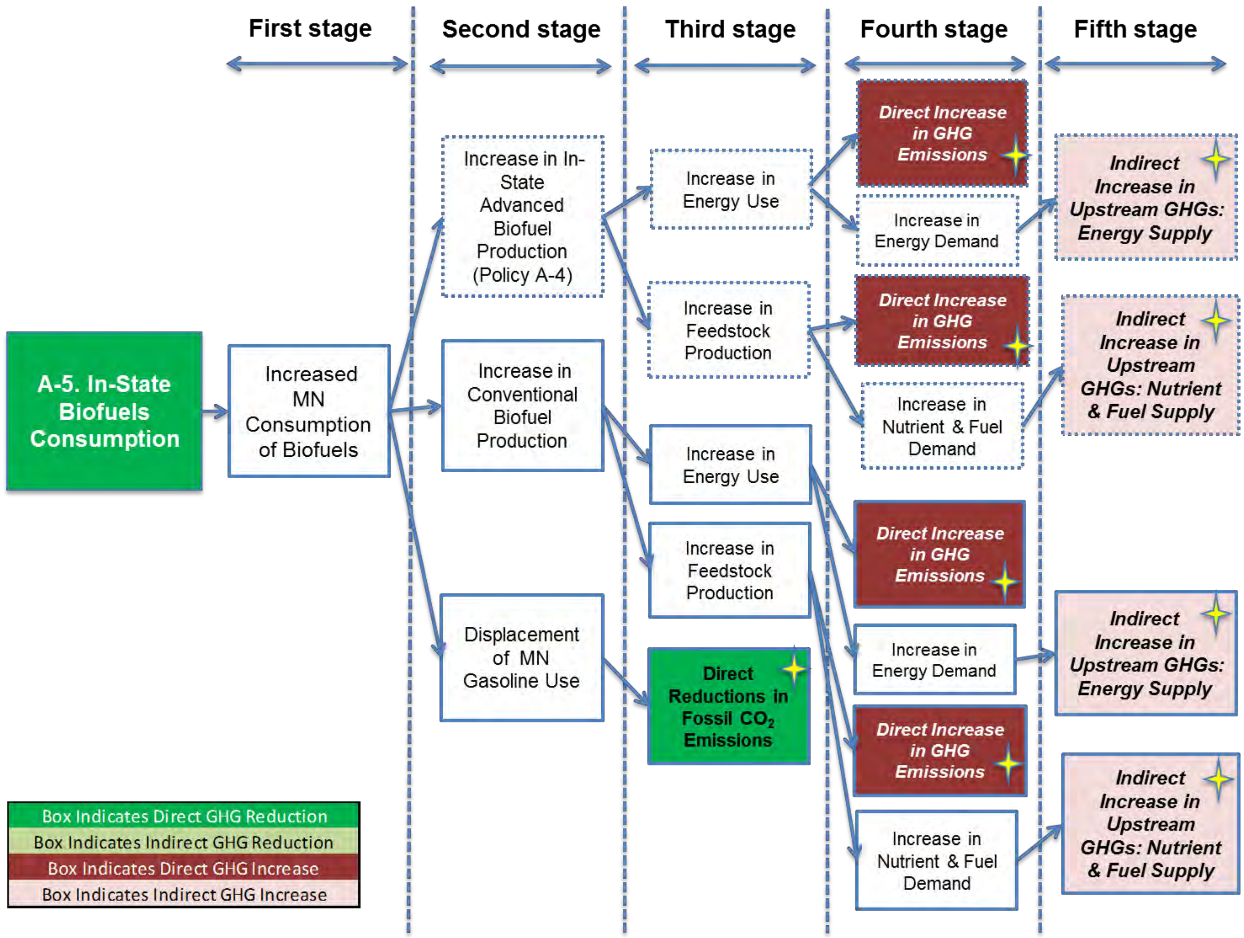
Actions to support these existing goals would include incentives that have as their goal the improvement of the entire infrastructure for delivery of gasoline-blended fuels to a higher level biofuel standard. The expectation is that the statewide infrastructure will need to turnover to compatibility with a higher-level biofuel content requirement which will be necessary to pave the way for the sale of higher blends of biofuel.

The opportunity exists within this policy option to incentivize biofuel blended spark-ignition engine fuels that are not just using advanced biofuel, but also advanced biofuel blends that would have higher octane content and allow for higher efficiency in an engine that is designed to take advantage of that property. Greenhouse gases would therefore be reduced by petroleum displacement, higher efficiency/higher miles-per-gallon vehicles that would use less fuel in total, and with the added fuel component having at least a 50% increase in life-cycle greenhouse gas benefits over straight gasoline as measured by the EPA in its RFS 2 methods.

To simplify this policy option, advanced ethanol has been used as the advance biofuel for all modeling. This does not preclude the use of other biofuels, such as biobutanol or drop-in renewable gasoline, which will also bring with them properties different from ethanol but perhaps advantageous in other properties (energy content, compatibility with existing storage/dispensing infrastructure, etc.).

Causal Chain for GHG Reductions

Figure Ap F-4.33 Causal Chain for AG-5 GHG Reductions



The star symbol identifies significant GHG effects that are quantified. The net energy and emissions impacts of increased in-state advanced biofuel production were quantified under Policy Option AG-4. The net energy/emissions impacts of the consumption of advanced biofuels biofuels produced as a result of Policy Option AG-4 are quantified under this policy option, which provides a full accounting of both production and consumption of advanced biofuels. While the AG-4/AG-5 “biofuels package” is not meant to specify the exact biofuels to be promoted in the State, for the purposes of policy option analysis, the advanced fuel pathways considered in the initial AG-4 analysis are cellulosic ethanol production from corn stover and energy beets. Consumption of this advanced ethanol leads to both direct and indirect GHG reductions (direct fossil CO_2 emissions displaced from gasoline; and indirect reductions associated with lower energy and process emissions for the advanced biofuels.

Policy Option Design

Goals:

- Offer a $0.05 per gallon tax incentive to retailers selling E15 in state with one third of the ethanol content in the blend covered by ethanol that qualifies as advanced biofuel (this would be the ethanol content above the E10 level).
- Offer a $0.15 cent per gallon tax incentive to retailers selling E30 or greater ethanol blends with the portion of ethanol above and beyond E10 coming from ethanol that qualifies as an advanced biofuel.
- Require all new infrastructures installed in the state used for the storage and dispensing of higher ethanol blends be compatible with E30 in order to prepare for a future of high biofuel/higher octane content gasoline.

Timing: See "Statutory Goals" above as a guideline only. The in-state biofuels production goals from AG-4 will be used to gauge what amount of advanced bioethanol will be available for use within the state as part of this incentive. Those cumulative production numbers were estimated by the Great Plains Institute to be:

- 150 million gallons by 2020
- 300 million gallons by 2025
- 600 million gallons by 2030

The cumulative production values from AG-4 are in-line with these values, but are slightly higher (125 MMgal by 2020; 500 MMgal by 2025; and 875 MMgal by 2030). In Great Plain's proposed legislation (on behalf of the Bioeconomy Coalition) in the regular legislative session of 2014 numbers used for production goals were $30 million per year for all producers in the state. At this production level and given the incentives they specified in the legislation of $1.053/MMBtu for starch-based advanced biofuel and $2.1053/MMBtu for cellulosic-based advanced biofuel, a range of 187,250,337 gallons (if all production was cellulosic ethanol at 76,100 Btu/gallon) gallons to 374,376,196 (if all production was starch-based advanced biofuel biofuel) would exist. This is much higher production than estimated from the most recent goals above that were submitted.

*Note: Gasoline usage in 2013 was estimated at 2,517,351,045 gallons by the Minnesota Department of Revenue, with approximately 10% of that volume, or 251,735,105 gallons coming from corn-starch ethanol. Assuming gasoline usage as flat into the future, E15 would require an additional 125,867,552 gallons of advanced ethanol and E30 would require an additional 503,470,209 gallons should all of the gasoline supply be blended with those percentages.

Discussion: Two main factors exist to drive a higher ethanol content in the national gasoline engine fleet: RFS2 volumes, which are exclusively increases in advanced and cellulosic biofuel after the year 2015; and the 2025 Corporate Average Fuel Economy (CAFE) standard requirement of an average mile per gallon for a light duty fleet vehicle of 54.5. According to the NACS document *The Future of Fuels 2012*, with full implementation of the RFS by 2022, the program that was enacted in 2007 has “the mandated volume (of biofuel) expected to represent 20-25% of the motor fuels consumption (by 2022)”; and if “the new CAFE standards do reduce the demand for petroleum by 36% in 2025, then the mandated renewable fuel volume would represent 34.1-39.6% of motor fuels consumption.” It further says that “clearly, a substantial volume of fuel will have to be blended with greater than 10% ethanol to meet the standard . . . a percentage of fuel volume blended at E15 or beyond must enter the market if the RFS is to be successfully implemented.”

One of the solutions to these policy option goals is a higher efficiency engine that requires higher octane fuel with a research octane number (RON) rating of 98. An E25-30 blend would be the least expensive fuel that could be used to meet this octane level. Changes to the storage and dispensing infrastructure need to be implemented in policy option to clear the way for this fuel availability, and for the vehicles that would use that fuel. The cost to begin upgrading to an E25 blend is said to be relatively minimal, as low as an extra $1,000 above an E10-compatible dispenser, and this could be required by the state in its effort to reduce petroleum use. Incentives and grant programs to support infrastructure turnover would of course be helpful in the change, but will not be covered in this policy option.

Parties Involved: State legislature, state departments of Environmental Quality, Agriculture, Natural Resources, fuel providers, agricultural producers, utilities, and auto companies.

Implementation Mechanisms

The state recommends a variety of actions to stimulate the production and use of renewable, low-carbon fuels within the state. These include:

- Establish a Next-Generation Renewable Fuels Feedstock Program,
- Create a Green Fuels Retailers Program for sales of E15 and E30 (or greater) using advanced biofuel for the blend volume that exceeds 10% ethanol. (State agencies of Minnesota’s fleet will, whenever possible, adopt the use of vehicles that can run on an E25/30 blend as the vehicles become available. This would include E25/30 hybrid and E25/30 electric vehicles, as well as straight E25/30 higher efficiency (better fuel mileage) vehicles, and
- Require that updates and replacements of petroleum fuel dispensing sites be done to be compatible with at least E25 ethanol volume.

Related Policies/Programs in Place and Recent Actions

The current Minnesota Statute 239.7911 has the following requirements for in-state biofuels consumption to replace gasoline with:

- 14% biofuel by 2015
- 18% by 2017
- 25% by 2020
- 30% by 2025.

Estimated Policy Impacts

Table F-4.32 AG-5 Estimated Net GHG Reductions and Net Costs or Savings

2030 GHG Reductions (Tg CO_2e)	2015 – 2030 Cumulative Reductions (Tg CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ tCO_2e)
0.32	**3.5**	**$462**	**$133**

Note: Each policy analysis was done over a 15 year planning horizon. While implementation of each policy is not expected occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

The reductions in the summary table address those that would occur in-state, as well as some reductions for the upstream fuel cycle that occur out of state (e.g. petroleum extraction, transport and processing). The in-state reductions (direct tail-pipe reductions for displacement of gasoline with biofuels) are 0.17 Tg CO_2e in 2030 and 1.8 Tg CO_2e on a cumulative basis.

Data Sources: These are described and cited in more detail below, but include: baseline (BAU) gasoline consumption for the state; additional biofuel distribution infrastructure requirements and costs; number of additional higher ethanol content vehicles (engines/fuel systems) required for the fleet; incremental costs of vehicles requiring higher ethanol content gasoline; advanced biofuel production volumes, carbon content, and costs from the AG-4 Policy Option Analysis; energy-cycle carbon content for conventional gasoline (ANL GREET model).

Quantification Methods

GHG reductions:

- *BAU energy and emissions*: Since no advanced ethanol production and subsequent consumption are included in the baseline, these values are zero.
- *For the Policy Option Scenario*: The advanced ethanol produced in AG-4 is presumed to be consumed within the state during the year in which it is produced, which offsets gasoline use.
- Direct emissions of N_2O and CH_4 from ethanol combustion are quantified using standard emission factors; CO_2 from advanced ethanol combustion is considered to be carbon neutral.

- *Upstream GHGs from advanced ethanol*: Calculated from the production volume and carbon content in each year as calculated from the AG-4 analysis.
- *Offset gasoline emissions*: First, calculate the equivalent amount of gasoline displaced by ethanol (a gallon of ethanol has 66% of the energy that a gallon of gasoline has). On the other hand, optimized vehicle engines are expected to get a performance boost of about 17% on a gallon equivalent basis.[41] Multiply the equivalent amount of gasoline displaced by the GHG emission factors from the baseline.
- *Calculate the upstream GHG reductions from offset gasoline*: Using emission factors from ANL's GREET Model for conventional US gasoline.[42]

Table Ap F-96 provides a summary of the net energy and GHG impacts for Policy Option AG-5.

Net Societal Costs:

- *BAU costs avoided by the policy option*: These correspond to the cost of gasoline that is offset through the use of advanced ethanol. The volume of gasoline avoided (as determined above) is multiplied by the CSEO project BAU wholesale gasoline forecasted price in each future year.
- Policy Option Scenario costs:
- *Cost of advanced ethanol use*: Using the volumes and production cost estimates derived from Policy Option AG-4;
- *Add infrastructure "put through" costs*: Covers additional in-state trucking from plants to rack locations[43];
- *Add state fuel incentives*: from the AG-5 Policy Option Design, $0.05/gal for E15 blended gasoline; and $0.15/gal for E30 or greater blends. Assume 50% of total advanced ethanol consumption is blended into E15 and 50% into E30 or greater.
- *Consider the need for incremental costs for vehicles required to meet the consumption needs of the policy option*: $983/vehicle for higher performance engines optimized for using higher ethanol blends.[44] From another viewpoint, these vehicle costs will already be required as manufacturers comply with the Federal CAFE standards, and so cannot be attributed to Policy Option AG-5.

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[41] Energy content difference plus ETOH performance boost. Energy content of gasoline = 115,640 Btu/gal; ethanol = 76,330 Btu/gal. 2013 Fuel Freedom White Paper indicates a 17.2% performance boost for FFVs optimized to use ethanol on a gallon of gasoline equivalent basis: http://www.fuelfreedom.org/whitepaper/is-the-gasoline-gallon-equivalent-an-accurate-measure-of-mileage-for-ethanol-and-methanol-fuel-blends/.

[42] https://greet.es.anl.gov/.

[43] 2015 value based on current $0.030/gal to $0.035/gal range provided by Patrick Griffin-Boyle at RPMG, personal communication with S. Roe, CCS, 10/21/2014. Escalated each year at the rate of inflation.

[44] Cost total breaks down as: $78 for variable valve actuation + $268 for stoichiometric gasoline direct injection + $556 for turbocharging/down-sizing. Mid-point of range selected. NHTSA, *Corporate Average Fuel Economy for MY 2017-MY 2025 Passenger Cars and Light Trucks, Federal Regulatory Impact Analysis*, Table V-121.

- *Consider the need for incremental fuel dispensing costs*: New storage tanks and dispensers that are compliant with higher ethanol blends. A total cost was estimated using an assumption that half of the existing gasoline stations in the State would need to install a new 2 nozzle dispenser with a new 15,000 gallon storage tank.[45] As with the vehicle costs above, it could be argued that this infrastructure will be required to comply with the combination of Federal CAFÉ and Renewable Fuel Standard (RFS2) Programs, and therefore the costs should not be attributed to Policy Option AG-5.

Table Ap F-97 provides a summary of the net societal cost analysis. The cost effectiveness value shown ($133/t$CO_2$e) excludes the vehicle and fuel dispensing infrastructure costs noted above. If those costs are included, the cost effectiveness value increases to $228/t$CO_2$e.

<u>Key Assumptions</u>

- The advanced ethanol incentivized by this policy option is the advanced ethanol produced in Policy Option AG-4.
- All ethanol produced in Policy Option AG-4 will be used within the State of Minnesota.
- Half of the advanced ethanol produced will be blended into E15, and the other half into E30 or higher blends. Vehicles and dispensing facilities will be available to consume the advanced biofuel produced by Policy Option AG-4.
- 2030 business-as-usual carbon content of gasoline = 88.2 tCO_2e/TJ; business-as-usual carbon content of corn ethanol = 60.2 tCO_2e/TJ; Advanced ethanol improvement over business-as-usual ethanol = 20%.

[45] In 2011, there were 2,147 gasoline stations in MN; this value was held constant through the planning period. EPA estimated the cost for dispenser and storage at $154,000 each installed; EPA RFS2 Final RIA, Feb 2010, http://www.epa.gov/otaq/renewablefuels/420r10006.pdf.

Table F-4.33 Net GHG and Energy Impacts

Year	Policy Option Scenario Energy & Emissions						Net Change	
	Additional Advanced Biofuel Ethanol 1,000 Gallons	Direct GHGs: Ethanol Combustion $TgCO_2e$	Additional Upstream ETOH GHG Emissions $TgCO_2e$	Gasoline Offset by ETOH 1,000 Gallons	Gasoline Offset: Direct GHGs $TgCO_2e$	Gasoline Offset: Upstream GHGs $TgCO_2e$	Net In-State GHG Reductions Tg CO_2e	Out-of-State GHG Reductions Tg CO_2e
2015	0.00	0.0000	0.00	0	0.00	0.00	0.00	0.00
2016	0.00	0.0000	0.00	0	0.00	0.00	0.00	0.00
2017	25,000	0.0048	0.17	(19,340)	(0.16)	(0.048)	0.015	(0.048)
2018	25,000	0.0048	0.17	(19,340)	(0.16)	(0.048)	0.015	(0.048)
2019	25,000	0.0048	0.14	(19,340)	(0.16)	(0.048)	(0.015)	(0.048)
2020	50,000	0.010	0.19	(38,680)	(0.32)	(0.097)	(0.12)	(0.10)
2021	75,000	0.014	0.30	(58,020)	(0.48)	(0.15)	(0.16)	(0.15)
2022	75,000	0.014	0.30	(58,020)	(0.48)	(0.15)	(0.16)	(0.15)
2023	75,000	0.014	0.30	(58,020)	(0.48)	(0.15)	(0.16)	(0.15)
2024	75,000	0.014	0.30	(58,020)	(0.48)	(0.15)	(0.16)	(0.15)
2025	75,000	0.014	0.30	(58,020)	(0.48)	(0.15)	(0.16)	(0.15)
2026	75,000	0.014	0.30	(58,020)	(0.48)	(0.15)	(0.16)	(0.15)
2027	75,000	0.014	0.30	(58,020)	(0.48)	(0.15)	(0.17)	(0.15)
2028	75,000	0.014	0.29	(58,020)	(0.48)	(0.15)	(0.17)	(0.15)
2029	75,000	0.014	0.29	(58,020)	(0.48)	(0.15)	(0.17)	(0.15)
2030	75,000	0.014	0.29	(58,020)	(0.48)	(0.15)	(0.17)	(0.15)
	875,000	**0.17**	**3.6**	**(676,899)**	**(5.6)**	**(1.8)**	**(1.8)**	**(1.7)**

Note: Each policy analysis was done over a fifteen-year planning horizon. While implementation of each policy is not expected occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Table F-4.34 Net Societal Costs

	BAU Costs	Policy Option Scenario Costs					Net Costs		
Year	Avoided Gasoline Use MM$	Advanced Ethanol Use MM$	Infrastructure "Put Through" Costs MM$	Infrastructure Dispensing Costs MM$	MN Gov't Fuel Incentives MM$	Incremental Vehicle Costs MM$	Total Policy Option Costs MM$	Total Discounted Policy Option Costs MM$2014	Cost Effectiveness $2014/tCO₂e
2015	$0.00	$0	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
2016	$0.00	$0	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
2017	$53	$43	$0.86	$40	$10	$67	$0.91	$0.79	
2018	$53	$32	$0.88	$0.78	$10	$1.3	($10)	($8.0)	
2019	$53	$33	$0.90	$2.7	$10	$4.4	($8.9)	($7.0)	
2020	$107	$142	$1.8	$46	$21	$77	$58	$43	
2021	$161	$192	$2.8	$49	$31	$82	$65	$46	
2022	$161	$195	$2.9	$4.5	$31	$7.5	$68	$46	
2023	$162	$199	$2.9	$4.8	$31	$8.0	$72	$46	
2024	$162	$203	$3.0	$4.9	$31	$8.1	$75	$46	
2025	$162	$207	$3.0	$7.0	$31	$12	$79	$46	
2026	$163	$211	$3.1	$0.0	$31	$0.00	$83	$46	
2027	$163	$206	$3.2	$0.0	$31	$0.02	$77	$41	
2028	$163	$210	$3.2	$0.0	$31	$0.00	$81	$41	
2029	$164	$215	$3.3	$0.0	$31	$0.00	$86	$41	
2030	$164	$202	$3.3	$5.6	$31	$9.2	$72	$33	
Sum	$1,891	$2,290	$35	$167	$365	$275	$799	$462	$133

Note: Each policy analysis was done over a fifteen-year planning horizon. While implementation of each policy is not expected occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Macroeconomic (Indirect) Policy Impacts for both A4 and AG-5 Policies

Table F-4.35 AG-4+AG-5 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
AG-4+AG-5	$1,132	$819	$11,469	3,610	3,420	47,820	$539	$398	$5,576

Graphs below show detail in GSP, employment and personal income impact of the AG-4+AG-5 policy.

Figure Ap F-4.34 AG-4+AG-5 GSP Impacts ($2015 MM)

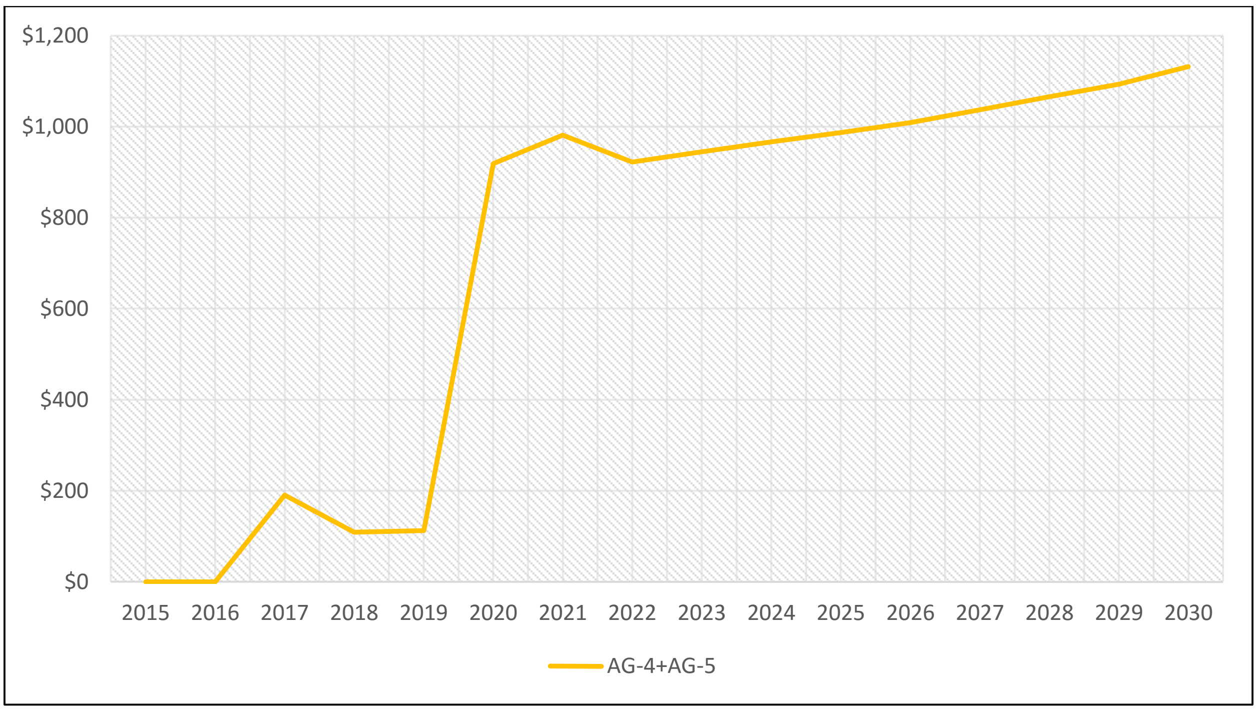


Figure Ap F-4.35 AG-4+AG-5 Employment Impacts (Individual Jobs)

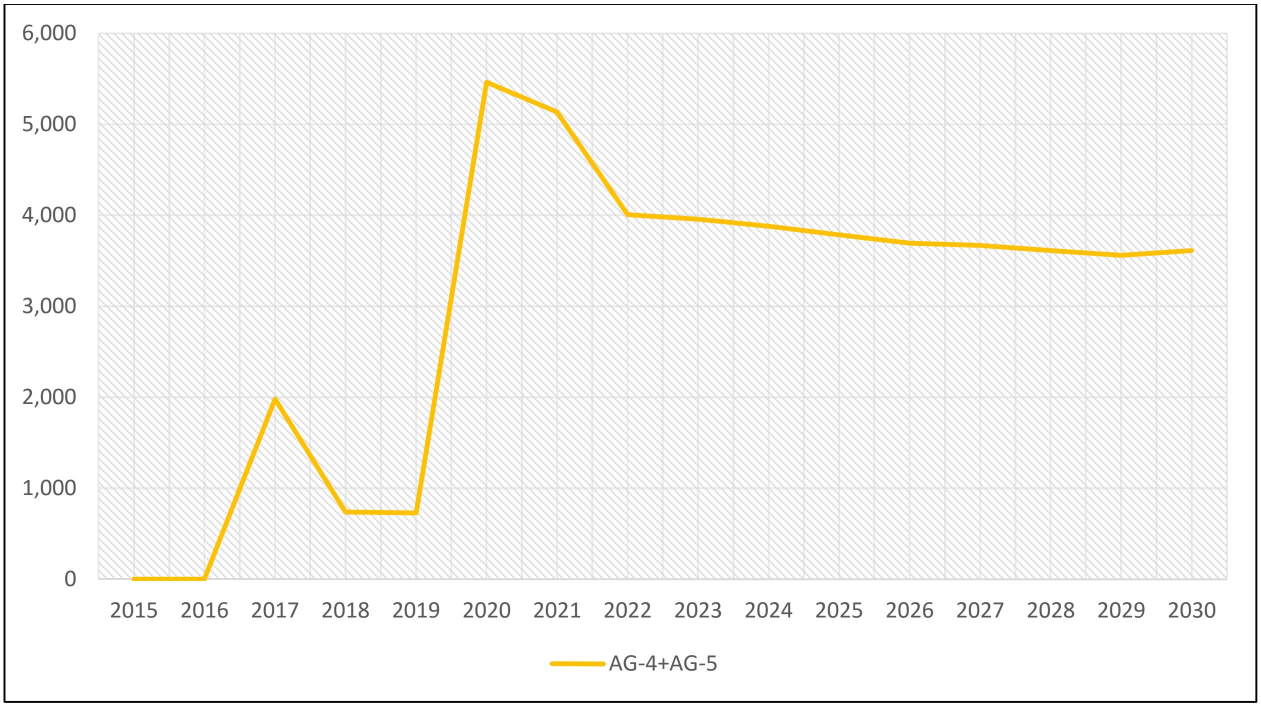
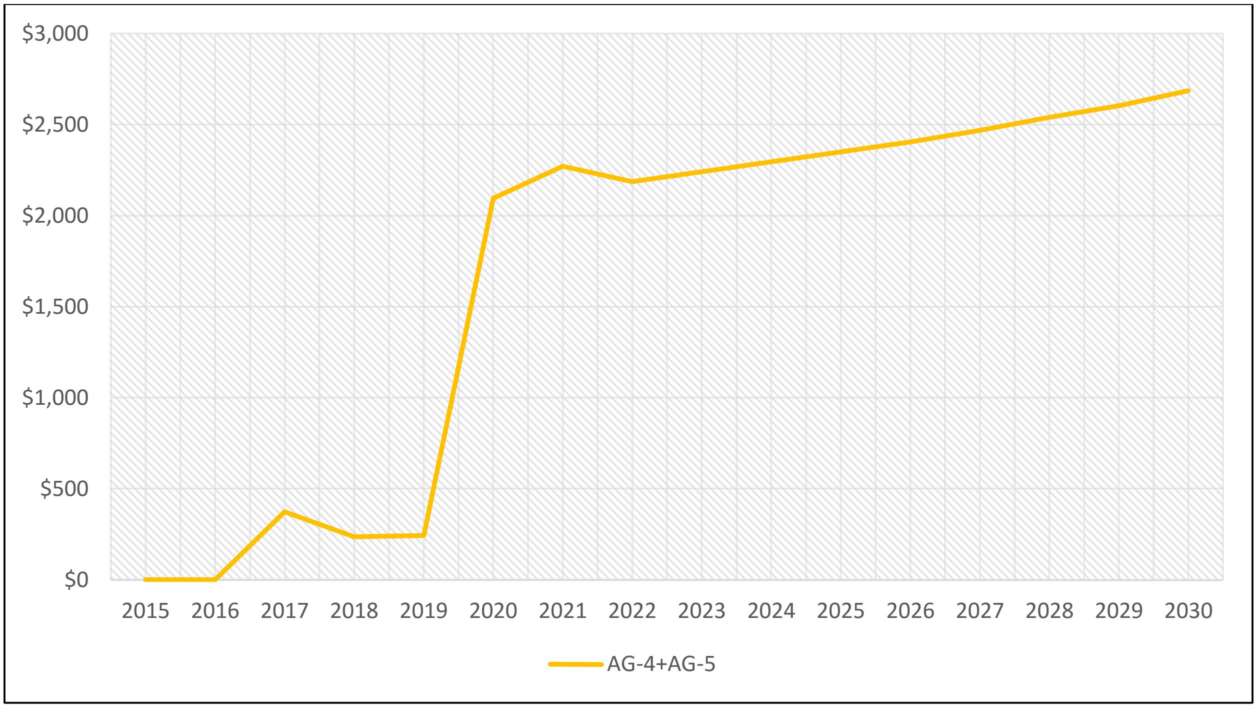
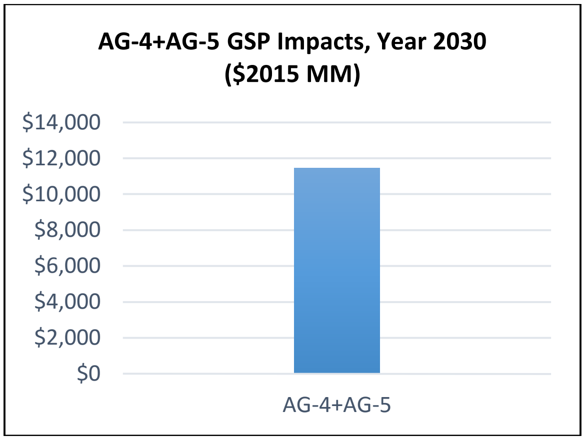
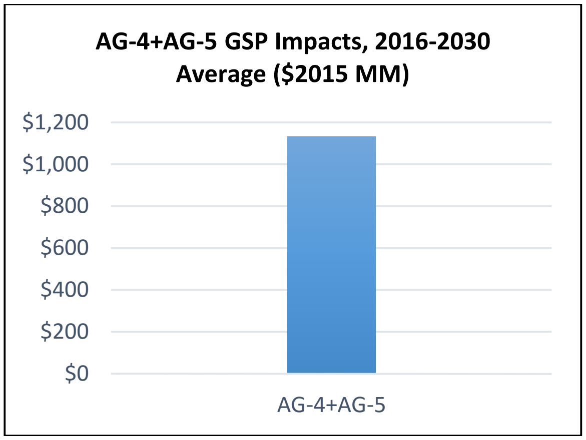


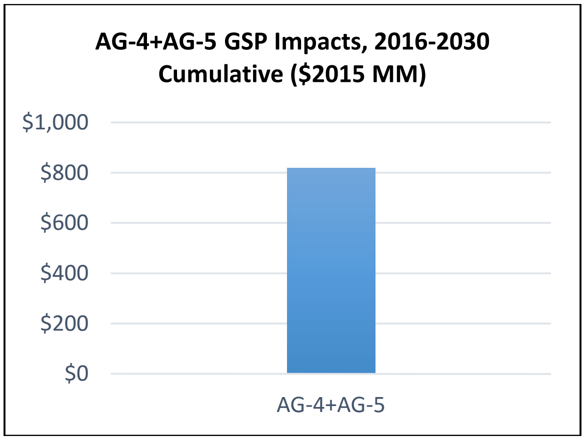
Figure Ap F-4.36 AG-4+AG-5 Income Impacts ($2015 MM)

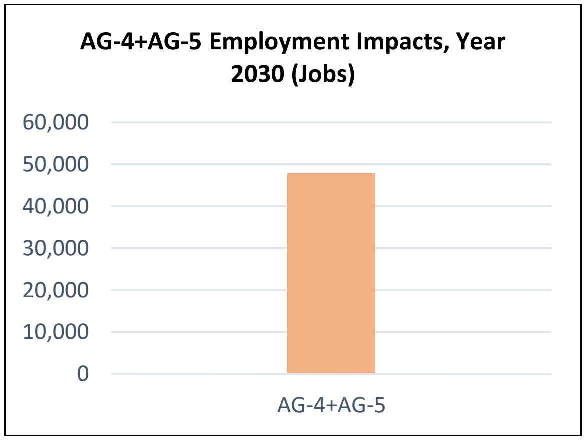


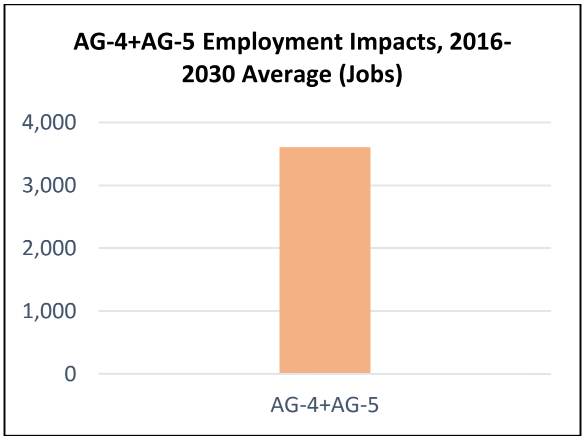
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030). Light color means sensitivity scenarios.

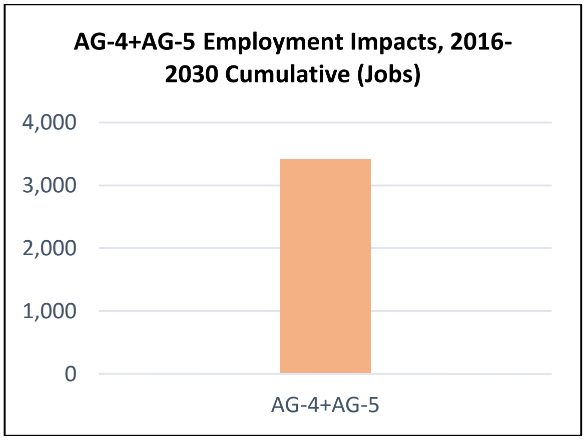


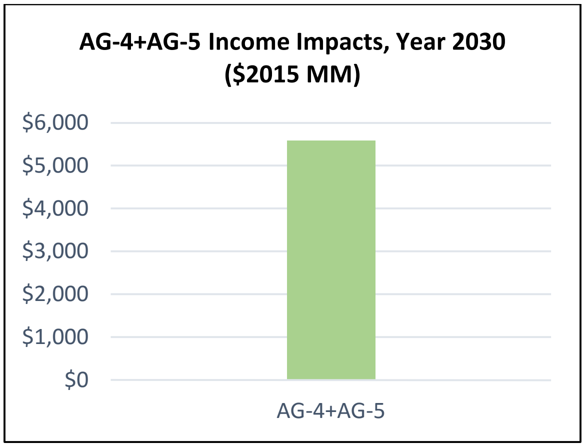


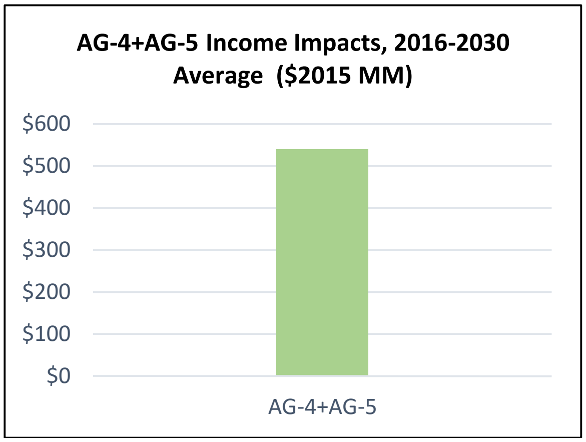


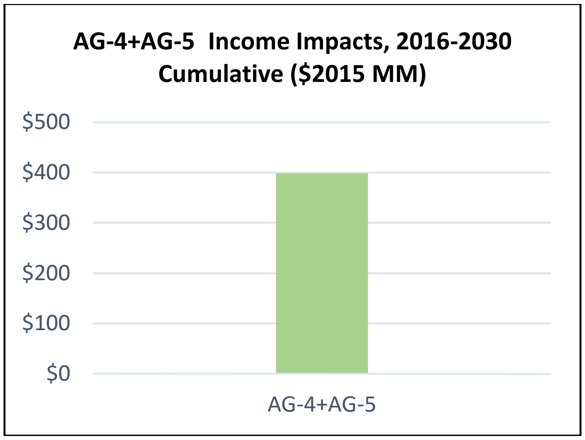












Principal Drivers of Macroeconomic Changes

This policy pair (the supply and demand of biofuels) shows positive impacts, occurring primarily outside the metro area. The major positive drivers of these impacts are:

- The construction of biofuels plants in 2017, 2020 and 2021. These produce the often-seen spikes in economic activity and employment associated with short bursts of intensive construction activity. They total approximately $490 million of total spending, but their positive impact disappears as soon as projects are complete.
- Additional labor spending by the industry producing biofuels. This drives an annual volume that reaches approximately $100 million in 2030 (in nominal dollars) of new direct income to employees working in manufacturing of biofuels. The number of people employed directly would be in the range of 1,000 to 1,500.

There are negative drivers as well, though smaller in scale:

- Consumers are projected to face additional fuel costs every year as biofuels displace petroleum fuels. These additional costs, which take money out of their spending on all other categories of consumption, reach as high as $50 million per year by the year 2030 (in nominal dollars).

- However, this additional fuel spending is going to a product that is domestically produced. So while the consumer is burdened, the beneficiary of that burden is entirely within the state. This offsets to a significant degree any loss to the economy.
- The same is true of state spending. The state is a consumer of these fuels under this scenario, and pays more, thus reducing other spending. However, because the vendor is domestic, the price impact is moderated.

Sectors of Economy Most Affected by the Policy

Economic impacts from policies run around the economy, affecting sectors that are sometimes far from the direct target of a policy.

For AG-4 and AG-5, positive gains most impact construction and chemical manufacturing (the sector into which biofuels manufacturing falls). Consumer prosperity is also improved, which we see through increases in indirect sectors such as health care and retail sales.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.

- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

Further research and development is needed to:

- Develop automobiles that meet future CAFE standards, with one way to do this being the development of engines requiring a higher octane content that could be satisfied by an E25/30 fuel (higher octane allows for more efficient, smaller engines).
- Bring advanced biofuels into higher levels of production at cost effective rates. There is uncertainty on when innovations and breakthroughs occur.
- Further, compatible infrastructure is needed to comply with EPA regulations for compatibility of materials for the storage and dispensing of ethanol blended fuels greater than 10%.

- Advanced ethanol improvement over gasoline should be 50% or greater; however, the production capacity mix in the current AG-4 analysis (50 MMgal energy beets: 25 MMgal/cellulosic) falls just short of that (45% improvement by 2030); however, as noted the baseline gasoline carbon content in Minnesota is likely higher than the value used in this initial CSEO analysis (based on average US conventional gasoline). Still, future work on the Biofuels Package should consider a set of slightly higher goals for cellulosic ethanol production capacity (a larger plant or more than one plant) and take a closer look at energy beet ethanol to assure that it would meet the requirements for an advanced ethanol production method per Federal definitions.
- Minor differences exist between the baseline crop production forecast used as an input to the AG-4/AG-5 analysis and a later revised version of that forecast produced by Minnesota Pollution Control Agency (MPCA). Revision of these inputs to match the MPCA values is not expected to produce a significant change to the estimated impacts.

Additional Benefits and Costs

Biofuels burn cleaner and displace fossil fuels in combustion engines. This will impact air quality, benefiting human health. See Policy Option AG-4 for more details on ethanol and air quality.

Feasibility Issues

Infrastructure is the main obstacle to vehicle feasibility and development. If the fuel cannot be stored and dispensed it cannot be offered for sale and vehicle will not have the option to use them. A turnover of infrastructure to ethanol compatibility is a necessary step in the process outlined above.

Chapter XVI. Appendix F-5.Forestry and Other Land Use Policy Option Documents

Overview

The tables below provide a summary of the microeconomic analysis of Climate Solutions & Economic Opportunities (CSEO) policies in the Forestry and Other Land Use (FOLU) sector. The first table provides a summary of results on a stand-alone basis, meaning that each policy option was analyzed separately against baseline (business as usual or BAU) conditions. Details on the analysis of each policy option are provided in each of the Policy Option Documents (PODs) that follow within this appendix.

The stand-alone results provide the annual greenhouse gas (GHG) reductions for 2020 and 2030 in teragrams (Tg) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030 (1 Tg is equal to 1 million metric tons). The reductions shown are just those that have been estimated to occur within the state. Additional GHG reductions, typically those associated with upstream emissions in the supply of fuels or materials, have also been estimated and are reported within each of the analyses in each POD.

Also reported in the stand-alone results is the net present value (NPV) of societal costs/savings for each policy option. These are the net costs of implementing each policy option reported in 2014 dollars. The cost effectiveness (CE) estimated for each policy option is also provided. Cost effectiveness is a common metric that denotes the cost/savings for reducing each metric ton (t) of emissions. Note that the CE estimates use the total emission reductions for the policy option (i.e. those occurring both within and outside of the state).

As indicated in the first summary table, the full benefits of FOLU policies are only realized when considering the full life-span of new trees. For this reason, the costs and benefits of FOLU policies were estimated out to the year 2085. The cumulative emission reductions, NPV, and cost effectiveness for the 2015-2085 period are shown in the notes field for each policy option.

Integrative Adjustments & Overlaps

The second summary table above provides the same values described above after an assessment was made of any policy option interactions or overlaps. There were no interactions of overlaps identified between the FOLU policies; therefore, the values in the second table equal those in the first table.

Macroeconomic (Indirect) Economic Impacts

Table F-5.3 below provides a summary of the expected impacts of FOLU policies on jobs and economic growth during the CSEO planning period. This table focuses on the impact of policies on Gross State Product (the total amount spent on goods and services produced within the state), Employment (the total number of full-time and part-time positions), and Incomes (the total amount earned by households from all possible sources). These metrics represent three valuable indicators of both the overall size of the economy and that economy's structural orientation toward supporting livelihoods and utilizing productive work.

For the purposes of macro-economic analysis of CSEO policies, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software. This particular REMI model is developed specifically for Minnesota, and is developed consistently with the design of models in use by state agency staff within Minnesota for a range of economic analyses. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

The main inputs for macro-economic analysis are microeconomic estimates of direct costs and savings expected from the implementation of individual policy options. These inputs are supplemented with additional data and assumptions necessary to complete the picture of how these costs and savings (as well as price changes, demand and supply changes, and other factors) influence Minnesota's economy. These additional data and assumptions typically regard how various actors around the state (households, businesses and governments) respond to change by changing their own economic activity. A full articulation of the general and policy-specific assumptions made by the macroeconomic analysis team is provided in the Policy Option Documents, contained as appendices to this report.

Table F-5.1 FOLU Policy Options, Direct Stand-Alone Impacts

Stand-Alone Analysis							
		GHG Reductions				Costs	
Policy Option ID	Policy Option Title	Annual CO_2e Reductions[a] 2020 Tg	Annual CO_2e Reductions[a] 2030 Tg	2030 Cumulative[a] $TgCO_2e$	2030 Cumulative[b] $TgCO_2e$	Net Costs[c] 2015-2030 $Million	Cost Effectiveness[d] $/tCO_2e$
FOLU-1	Protect Peatlands and Wetlands	*Not Quantified*					
FOLU-2[e]	Manage for Highly Productive Forests - Intermediate Stand Treatments	*Not Applicable*					
FOLU-3[f]	Urban Forests: Maintenance and Expansion 40% Canopy Goal	0.086	0.49	3.2	3.2	$1,806	$568
FOLU-4[g]	Tree Planting: Forest Ecosystems	1.4	1.9	30	34	$187	$5.6

FOLU-5[h]	Conservation on Private Lands	0.14	0.34	3.0	3.0	$1,261	$421
Totals		**1.6**	**2.7**	**36**	**40**	**$3,254**	**$81**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] Net emissions were found to be positive for this policy option; therefore, no cost effectiveness could be calculated.
[f] Full benefits are realized when considering the full life-span of planted trees. 2015-2085 Cumulative Reduction = 67 $TgCO_2e$; NPV = $2,208; 2085 CE = $33
[g] Full benefits are realized when considering the full life-span of planted trees. 2015-2085 Cumulative Reduction = 108 TgCO2e; NPV = $183; 2085 CE = $1.76
[h] Full benefits are realized when considering the full life-span of planted trees. 2015-2085 Cumulative Reduction = 25 TgCO2e; NPV = $1,304; 2085 CE = $53
Note: Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

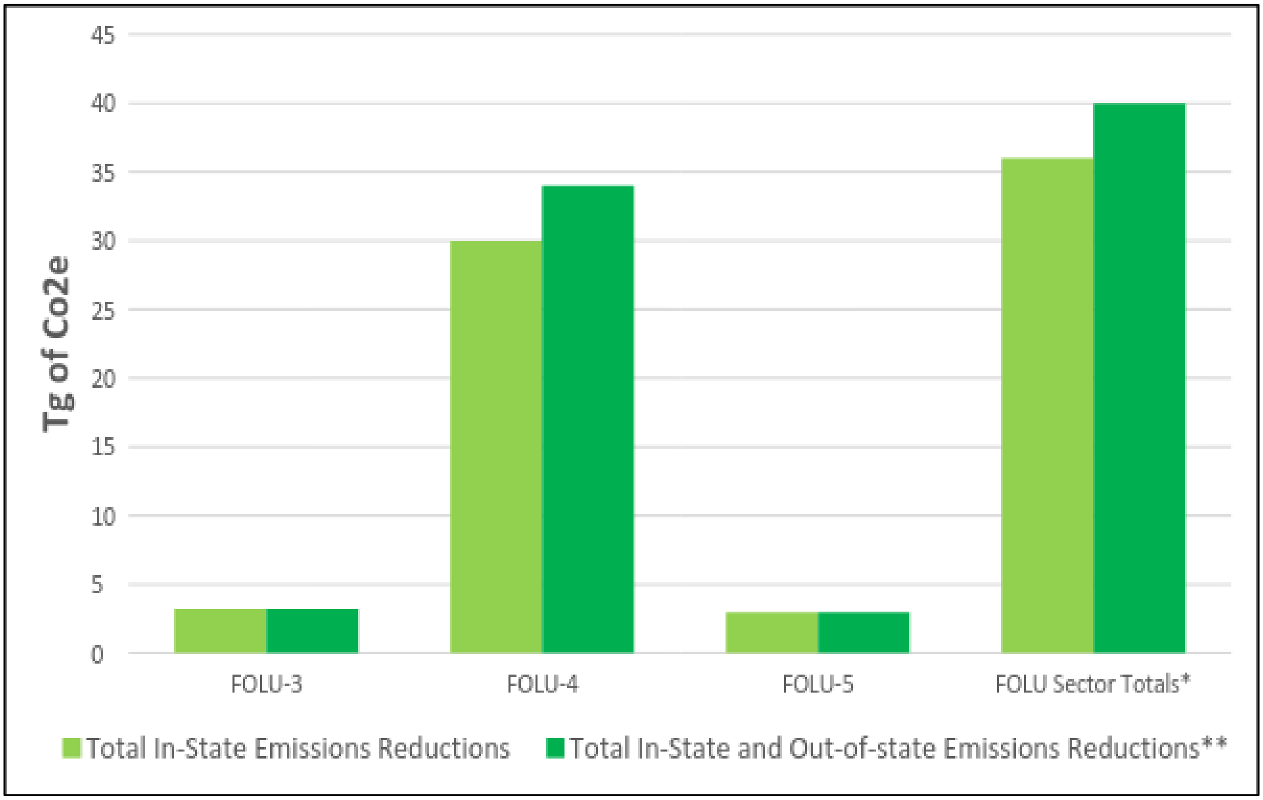
Table F-5.2 FOLU Policy Options, Intra-Sector Interactions

Intra-Sector Interactions & Overlaps Adjusted Results							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual[a]		2030 Cumulative[a]	2030 Cumulative[b]	Net Cost[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$\$/tCO_2e$
FOLU-2.	Manage for Highly Productive Forests - Intermediate Stand Treatments	Not Applicable					
FOLU-3.	Urban Forests: Maintenance and Expansion 40% Canopy Goal	0.086	0.49	3.2	3.2	$1,806	$568
FOLU-4.	Tree Planting: Forest Ecosystems	1.4	1.9	30	34	$187	$6
FOLU-5.	Conservation on Private Lands	0.1	0.3	3.0	3.0	$1,261	$421
Total After Intra-Sector Interactions /Overlap		**1.6**	**2.7**	**36**	**40**	**$3,254**	**$81**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).

[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.

Figure F-5.1 FOLU Policies GHG Emissions Abatement, 2016-2030



Notes:
* All Policies Total's comprise emissions reductions achieved by all the FOLU options combined.
** Total in and out-of-state emissions reductions are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Table F-5.3 Macroeconomic (Indirect) Impacts of FOLU Policies

Macroeconomic (Indirect) Impacts Results									
Scenario	Gross State Product GSP ($2015 Millions)			Employment (Full and Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulativ e (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
FOLU-3	$382	$366	$5,495	4,420	4,180	62,670	$463	$361	$5,409
FOLU-4	-$10	-$15	-$232	-130	-210	-3,160	-$14	-$19	-$283

FOLU-5 with farms losing income (FOLU-5 low income)	-$114	-$87	-$1,301	-1,350	-1,060	-15,900	-$3	$67	$1,010
FOLU-5 with farms keeping income (FOLU-5 keep income)	-$75	-$59	-$883	-920	-720	-10,750	$117	$144	$2,157
FOLU Sector Total With Farms Losing Income (FOLU Sector Total Low Income)	**$258**	**$264**	**$3,961**	**2,940**	**2,910**	**43,610**	**$446**	**$409**	**$6,135**
FOLU Sector Total with Farms Keeping Income (FOLU Sector Total Keep Income)	**$294**	**$290**	**$4,345**	**3,340**	**3,220**	**48,340**	**$567**	**$486**	**$7,292**

The graph below articulates the relative scale of job-producing potential of the FOLU policies. In this analysis, we considered two alternative scenarios for FOLU-5, in which private landowners put land out of use for forestry easements funded by the state and federal governments. In the default scenario, this land is assumed to be unproductive before the easements are obtained. In the "low income" or "lost income" scenario, that land is assumed to be marginal, but farmed and productive, and its coverage by an easement creates a loss in income to offset the gain in income from the easement. This alternative affects not only the results of FOLU-5 but also the FOLU sector's overall results.

Figure F-5.3 – Average Annual Jobs Impact of FOLU Policies, Individually and in Concert

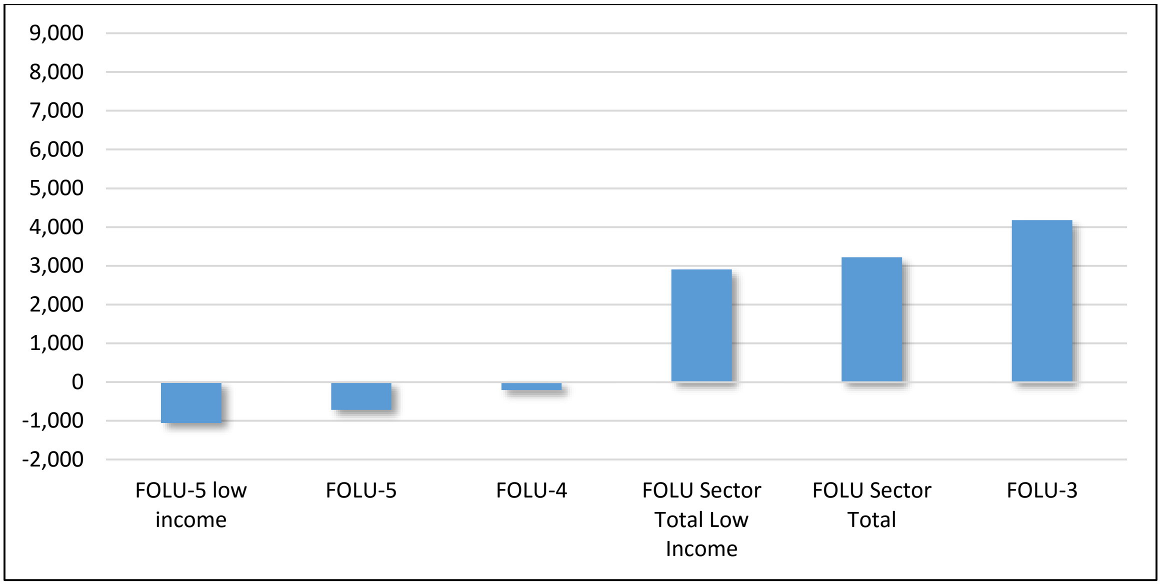
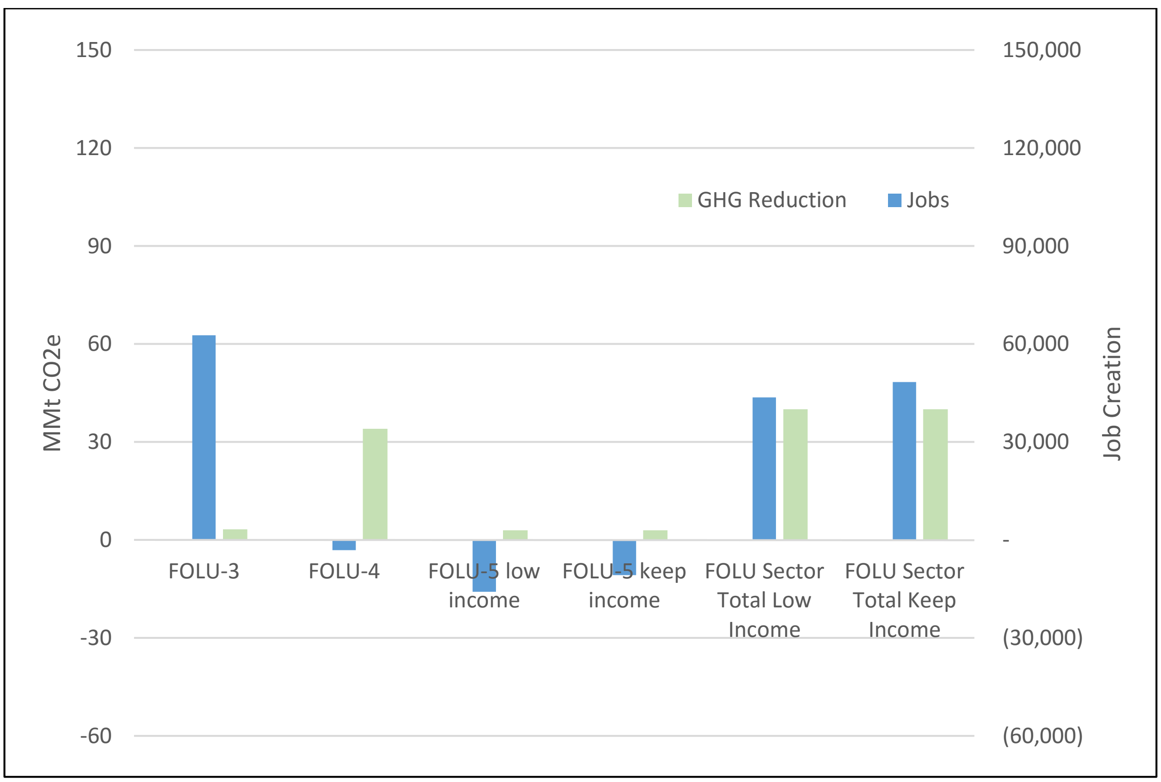


Figure Ap F-5.2 below summarizes a potential for job creation and GHG emissions abatement of FOLU sector policies on the same graph. This allows for a simultaneous assessment of performance of individual options against two crucial environmental and economic indicators.

Figure F-5.4 – Cumulative Jobs and Emissions Impacts of FOLU Policies



Macroeconomic index

The graphs below express the overall economic impact from each scenario in a single score, and compares those scores. CCS created this single score (a Macroeconomic Impact Index) in order to encapsulate in one measurement the relative macroeconomic impacts (including jobs, GSP and incomes) of each policy. We have found in our own work and in the literature that indexed scores can be helpful to many readers when comparing options with multiple characteristics.

To produce this score, CCS set the results from the absolute best-case scenario (i.e. the implementation of all CSEO policies with all their optimal sensitivities in place) equal to 100, with that scenario's jobs, GSP and incomes impacts weighted equally at one third of the total score. Each policy's jobs, GSP and income impacts are scaled against that measure, and given a total score. The overall score indicates how significant a policy's impact is projected to be. Negative impacts are scaled the same way, except that those impacts are given negative scores and pull down the total score of the policy.

These scores are calculated separately for the final year of the study (2030), the *average* impact over the 2016-2030 period, and the *cumulative* impact of the policies over that period. While each scenario has one line, the relative importance of jobs, income and GSP remain visible as differently-shaded segments of that line.

Figure F-5.5 FOLU Macroeconomic Impacts, 2030

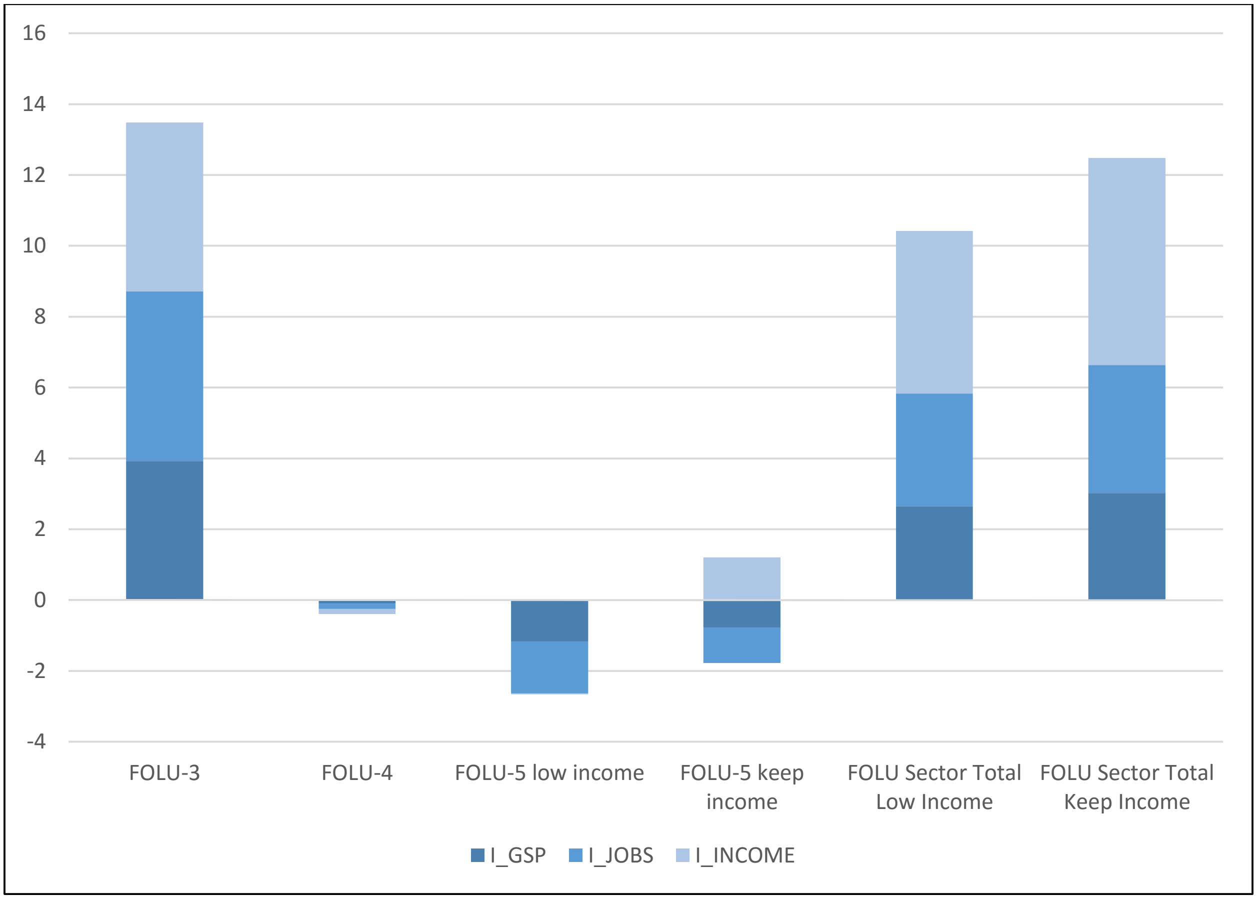


Figure Ap F-5.6 FOLU Macroeconomic Impacts, 2016-2030, Yearly Average

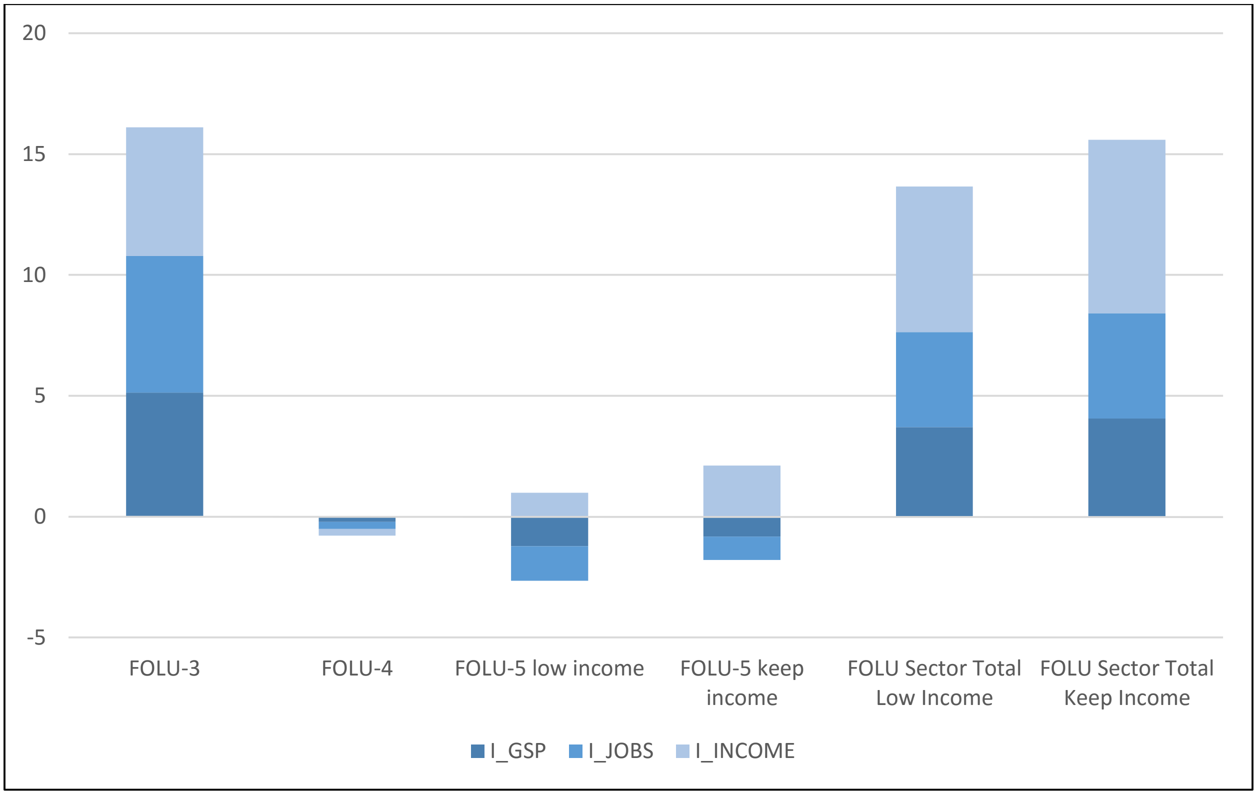
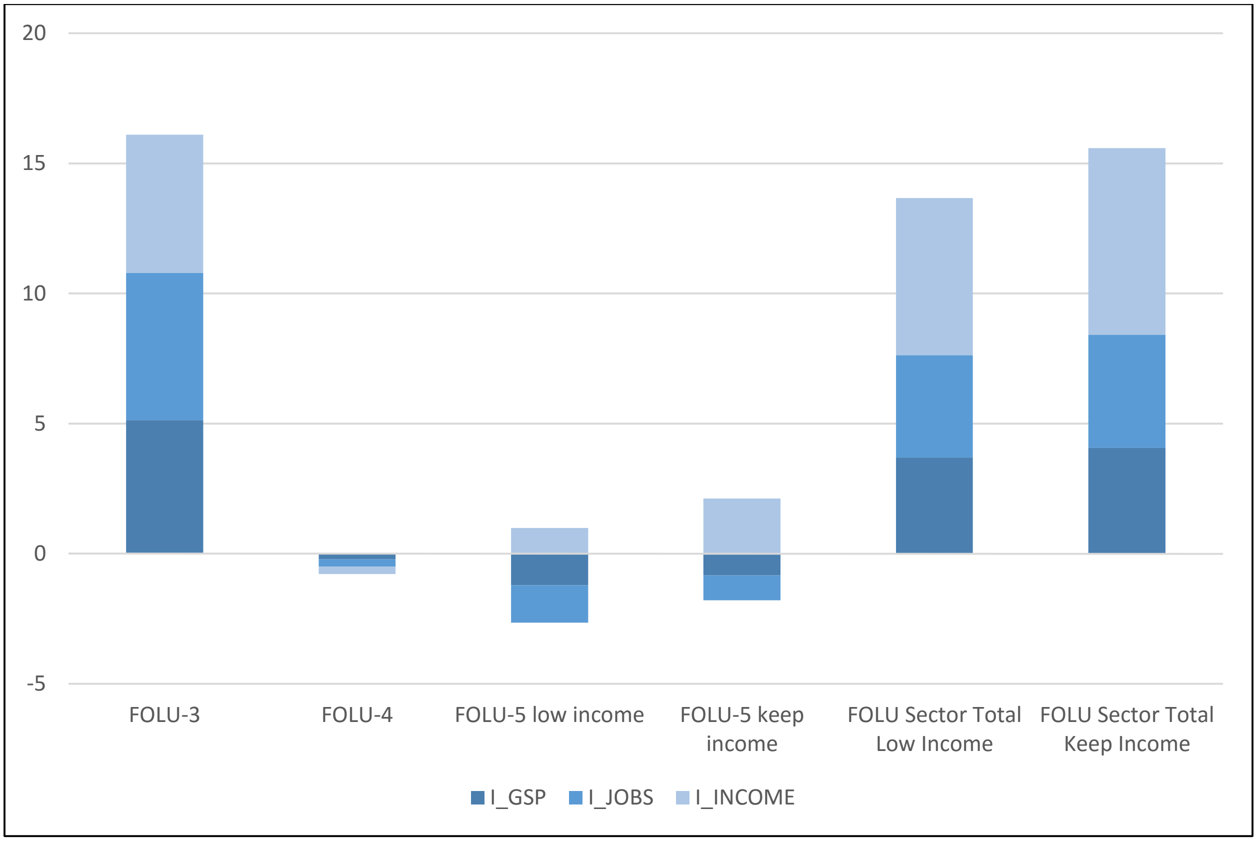


Figure Ap F-5.7 FOLU Macroeconomic Impacts, 2016-2030, Cumulative



The FOLU sector generates significant positive impacts – around $250 million in GSP and nearly $350 million in income, with 3,500 jobs more than would exist in the state by 2030 than if these policies were not implemented.

The sector impact on Minnesota's economy, according to this analysis, is really the story of the policy focused on community forest development (FOLU-3). While the other policies are small in their overall impacts, and somewhat negative in terms of job creation, the community forests policy generates significant growth through the year 2025 in all three metrics, and lifts the overall sector up to a total of 4,500 additional positions, and nearly $500 million in overall economic activity (both in GSP and in Incomes). FOLU-4 reduces total employment, incomes and GSP (by less than $100 million). FOLU-5 is slightly positive with regard to income creation, but reduces GSP and jobs as the state bears the burden of funding the program.

Graphs below show the trend of FOLU policy macroeconomic impacts during the year 2015 to 2030.

Figure Ap F-5.8 FOLU GSP Impacts ($2015 MM)

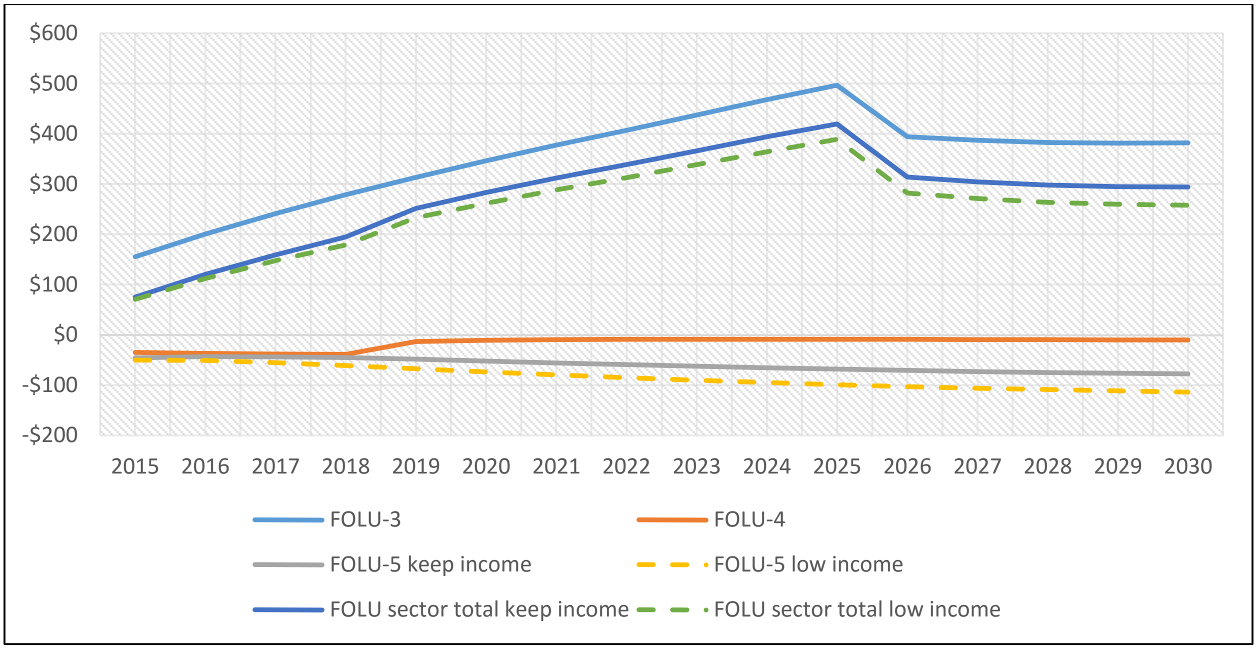


Figure Ap F-5.9 FOLU Income Impacts ($2015 MM)

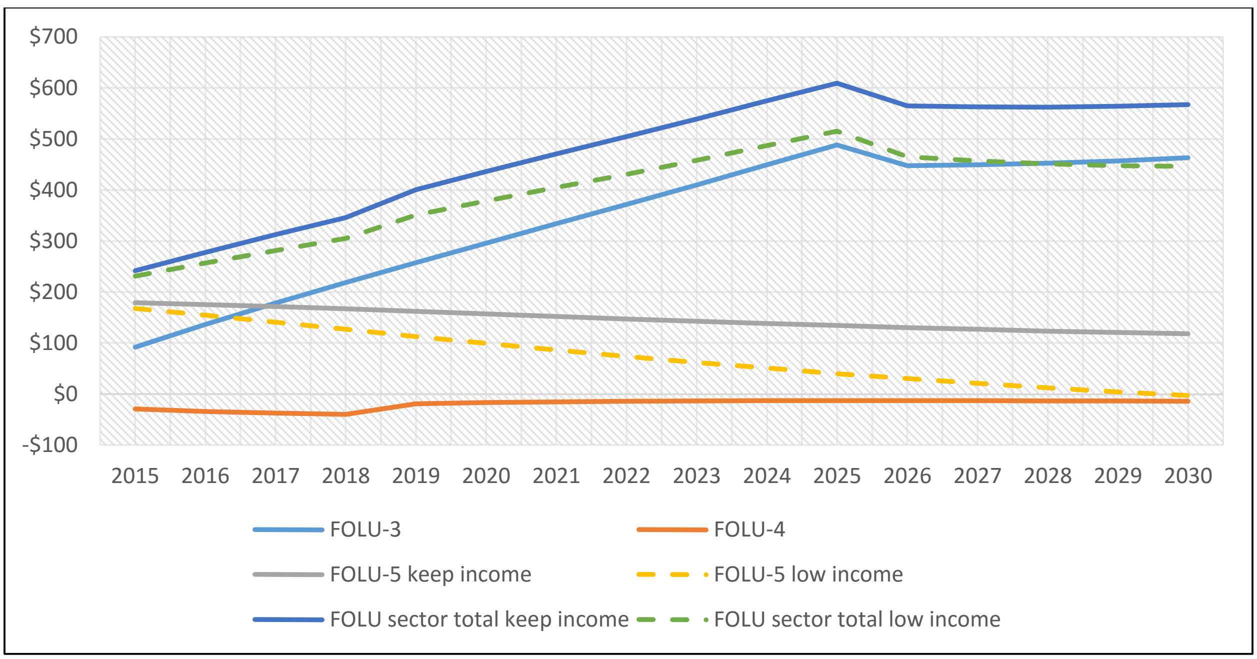
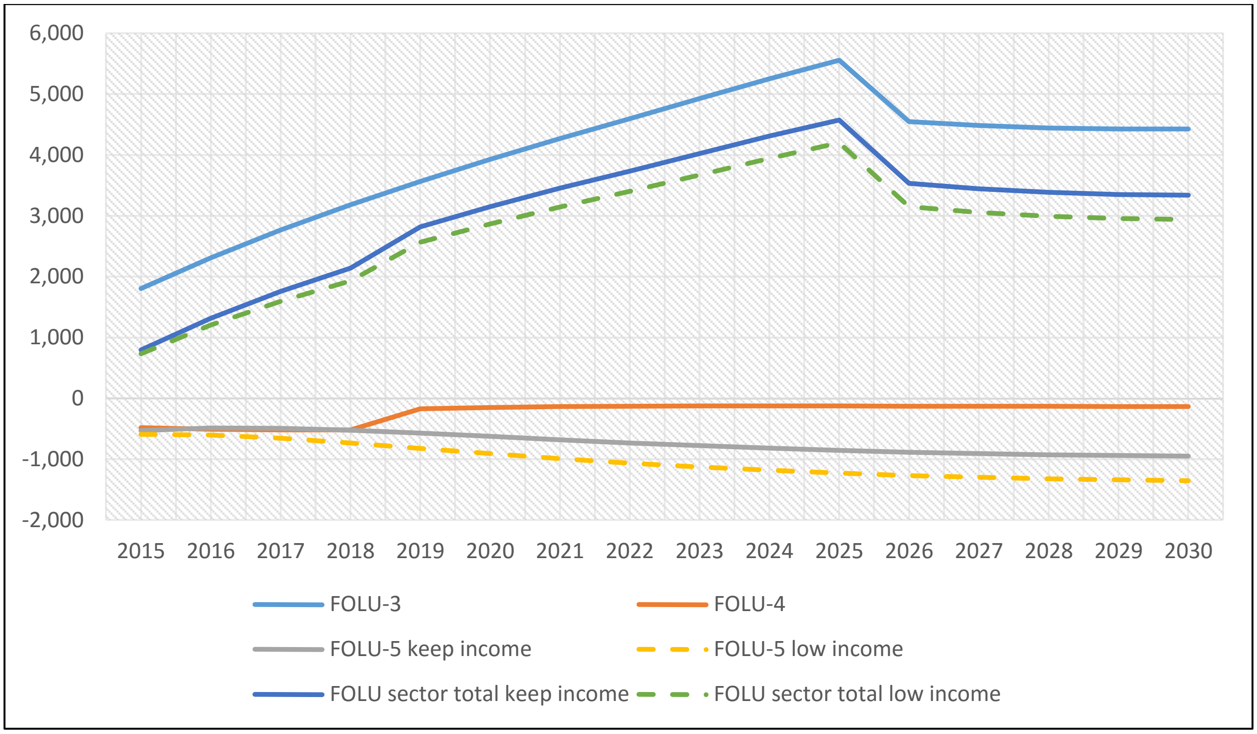


Figure Ap F-5.10 FOLU Employment Impacts (Individual Jobs)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030). Light color indicates sensitivity scenarios.

Figure Ap F-5.11 FOLU GSP Impacts, 2016-2030 Average ($2015 MM)

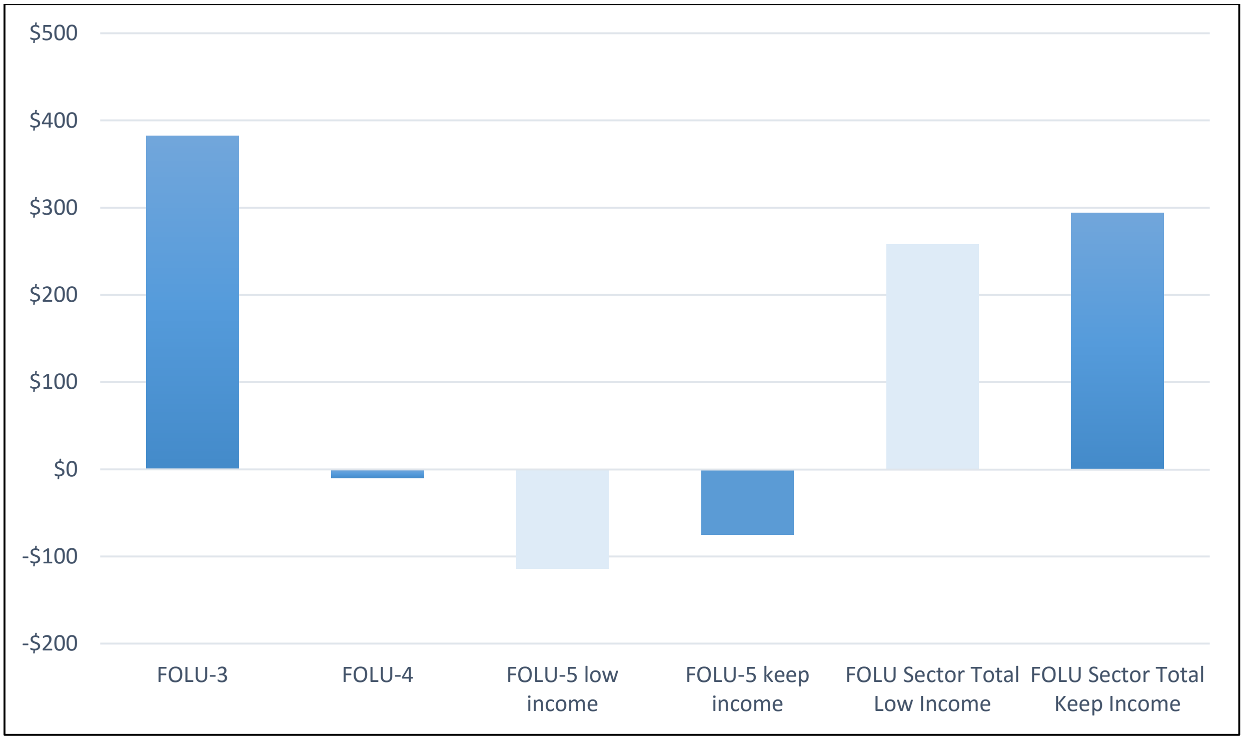


Figure Ap F-5.12 FOLU GSP Impacts, 2016-2030 Cumulative ($2015 MM)

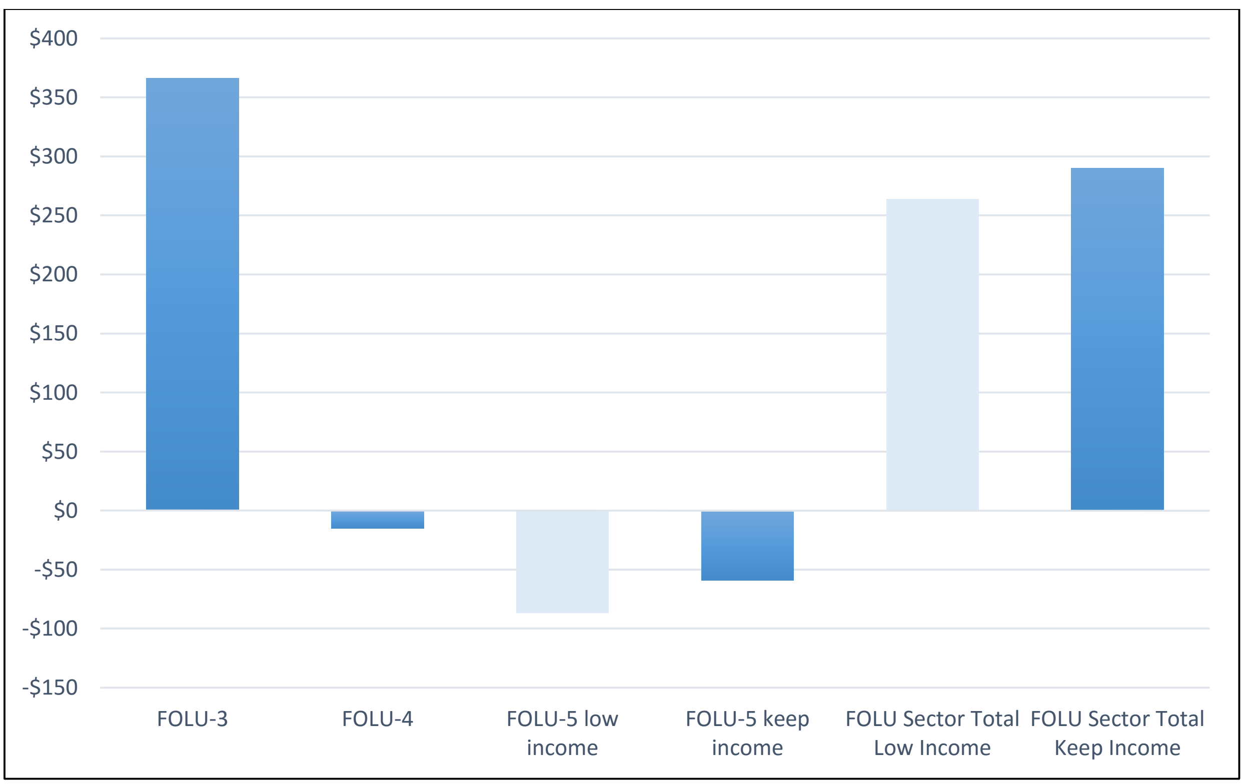


Figure Ap F-5.13 FOLU GSP Impacts, Year 2030 ($2015 MM)

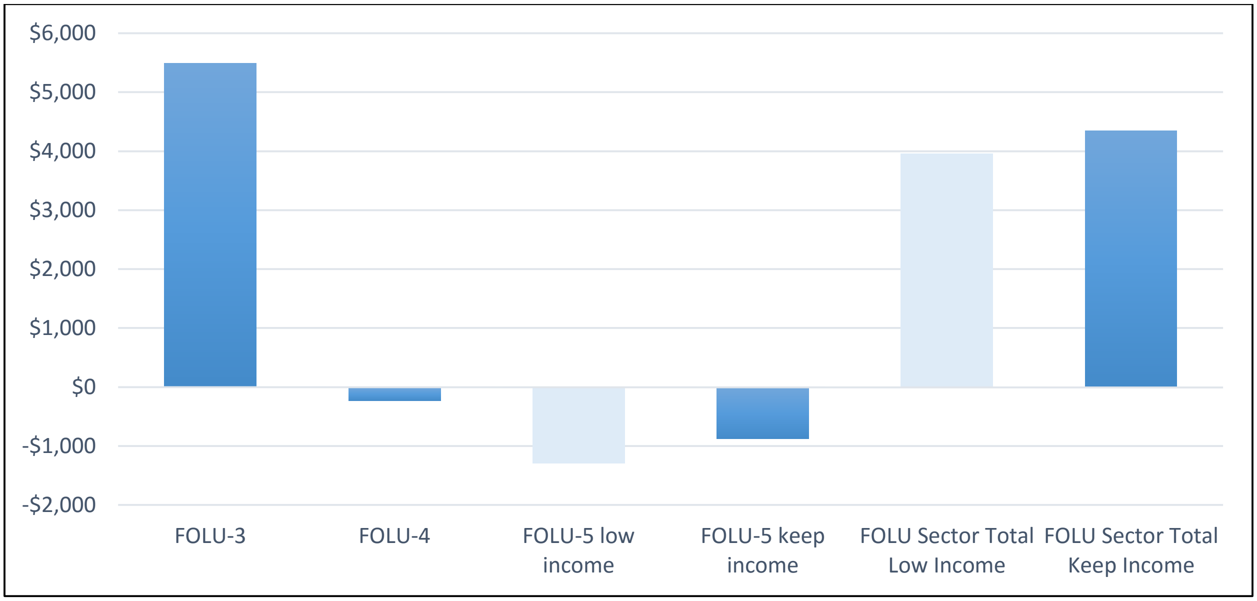


Figure Ap F-5.14 FOLU Employment Impacts, 2016-2030 Average (Jobs)

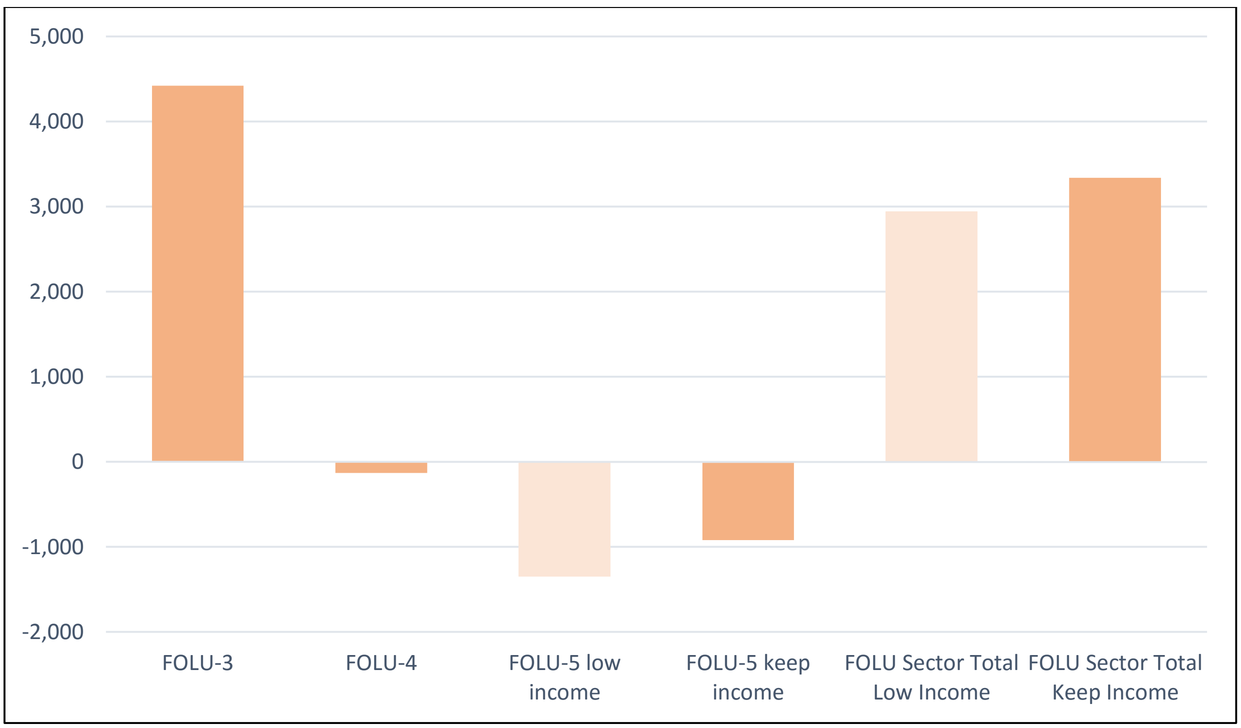


Figure Ap F-5.15 FOLU Employment Impacts, 2016-2030 Cumulative (Jobs)

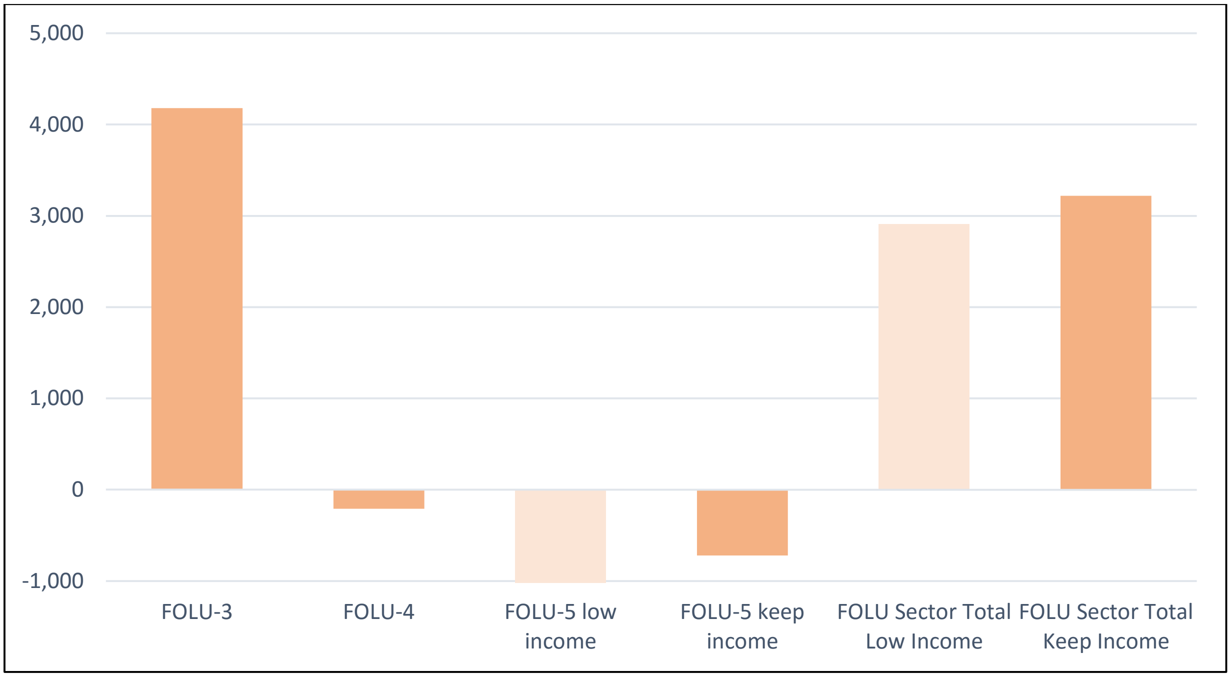


Figure Ap F-5.16 FOLU Employment Impacts, Year 2030 (Jobs)

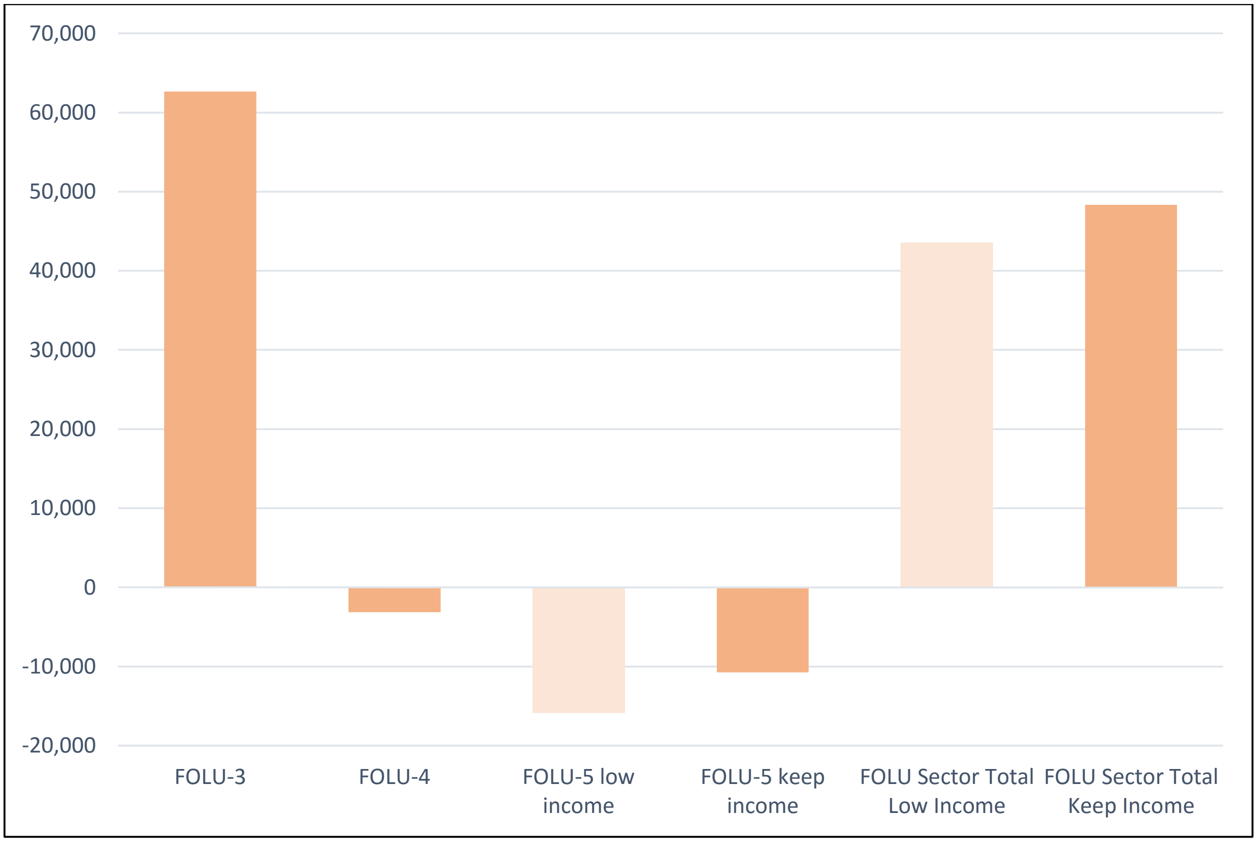


Figure Ap F-5.17 FOLU Income Impacts, 2016-2030 Average ($2015 MM)

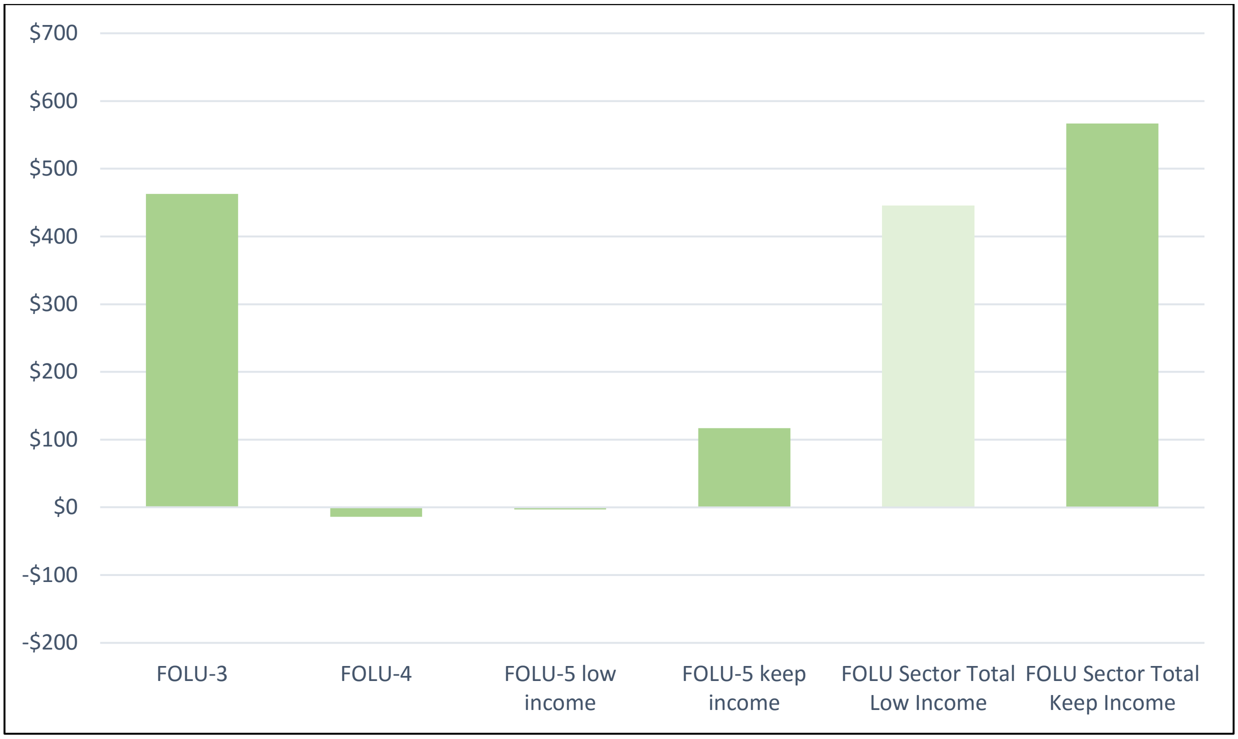
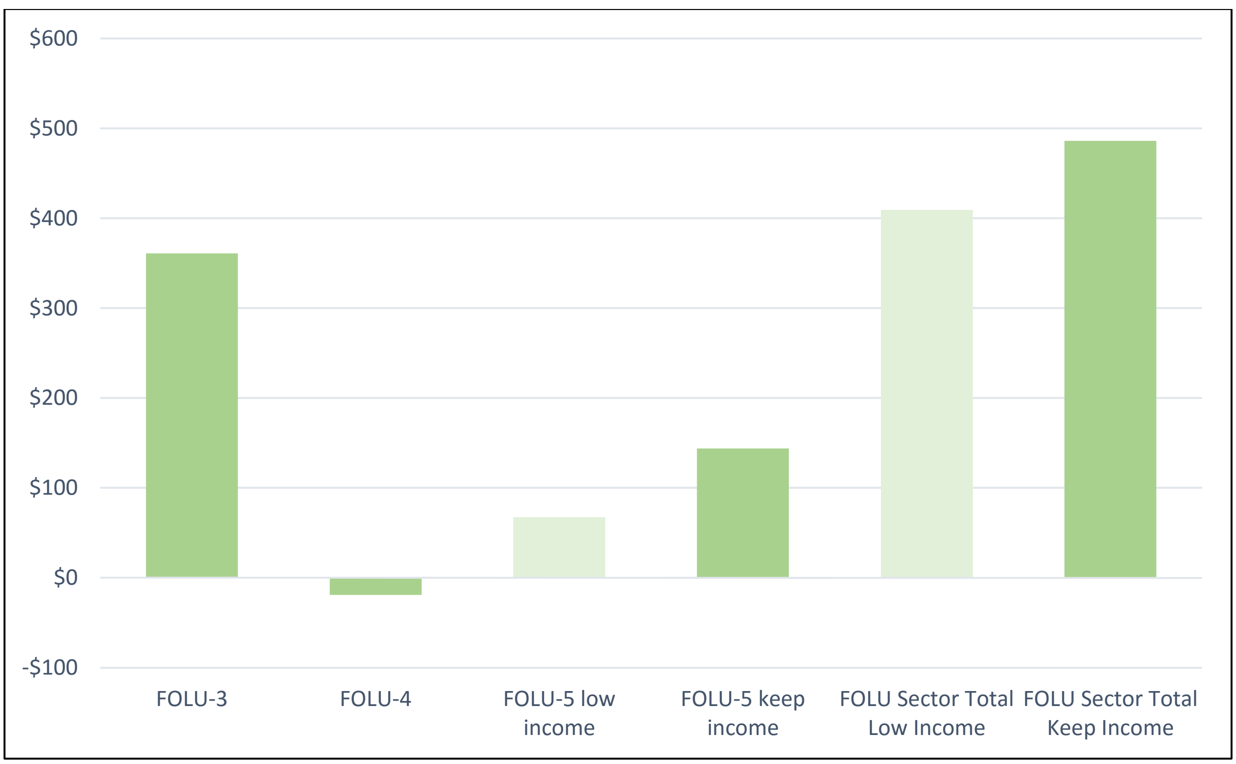


Figure Ap F-5.18 FOLU Income Impacts, 2016-2030 Cumulative ($2015 MM)



FOLU-3. Community Forests

Policy Option Description

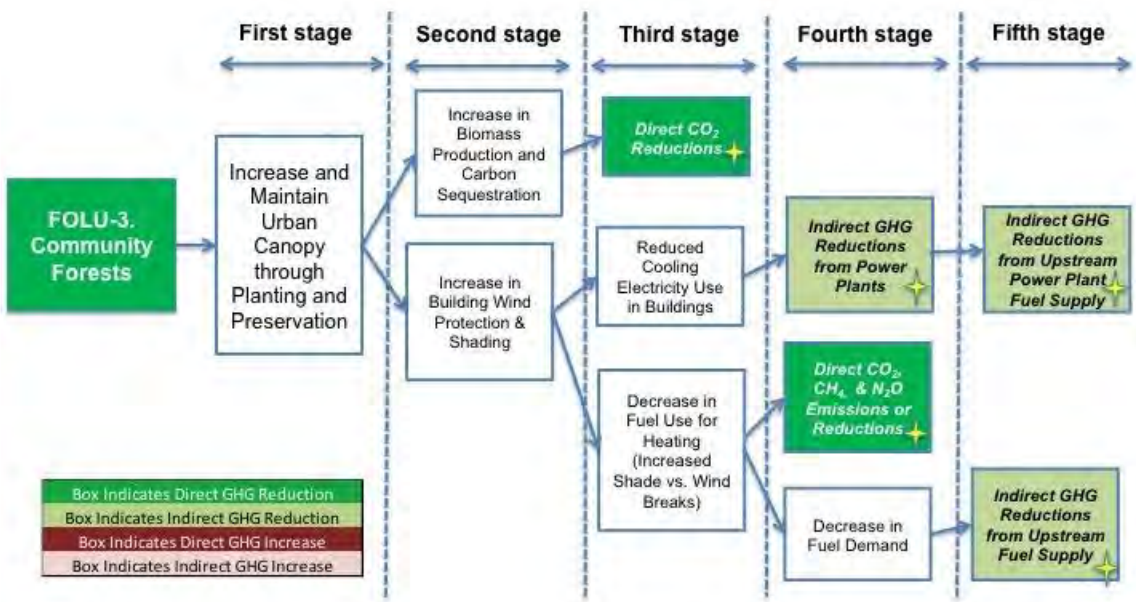
This policy option would strengthen community forests across the state by:

- Increasing the overall tree canopy cover of community forests to 40% by 2050, with discrete goals for residential, commercial/industrial, and other land use types.
- Achieving no net loss of tree canopy cover by 2035.

It has long been recognized that trees conserve energy by providing shade and windbreaks. Recent and ongoing scientific evidence also recognizes that community trees provide substantial benefits for air and water quality. Specific to this policy option, trees sequester carbon. Trees also provide numerous other economic, environmental, and public health benefits.

Causal Chain for GHG Reductions

Figure Ap F-5.19 Causal Chain for FOLU-3 GHG Reductions



The causal chain above identifies the main policy option effects and the subsequent GHG impacts. The star symbol identifies significant GHG effects that will be quantified.

- "First stage" refers to the direct physical impacts of the policy option, namely an increase in overall tree canopy through maintenance and planting.
- In the "Second stage," community forests will grow in size and volume, resulting in increased biomass production and wind protection and shading of buildings.

- The “Third stage” includes direct CO_2 reductions as a result of expansion and growth of community forests. This stage also includes reductions in electricity and heating fuel consumption resulting from the increased shading and wind protection.
- The “Fourth stage” reductions in GHGs resulting from reduced electricity use to cool buildings and fuel use for heating, as well as the reduced demand resulting from reductions in consumption.
- The “Fifth stage” refers to reductions of indirect upstream GHGs from electricity and heating fuel use.

Policy Option Design

The proposed policy option is designed to reverse the decline in community forests and achieve a preferred overall tree canopy cover for Minnesota communities. This will be accomplished through increased tree maintenance and planting.

The policy option design is anchored by a set of best practices in community forestry which includes proper planting and proper maintenance. Proper planting involves considerations of site design, site preparation, soil suitability, planting depth, and species and size diversity. Proper maintenance involves timely and regular pruning of new and existing trees, planning and inventorying, and employing preparedness measures for invasive species including integrated pest management approaches.

Goals:

This policy option is framed around three goals:

- By 2050, all Minnesota cities/towns will have at least 40% overall tree canopy cover, with discrete goals for residential, commercial/industrial, and other land use types.
- By 2035, all Minnesota cities/towns will achieve no net loss of overall tree canopy cover, using DNR’s 2010 Rapid Assessment as a baseline. This will be achieved primarily through preservation of canopy cover and secondarily through tree planting. *Goal is strategic in nature, and represents a key milestone toward achievement of the 2050 goal. It is a non-GHG quantified goal*.
- By 2035, 350 Minnesota communities will have implemented inventory base management plans. Similarly, this goal is strategic in nature and represents a key milestone toward achievement of the 2050 goal. This is a non-GHG quantified goal.

Timing:

Increased tree maintenance activities will begin in Year 1 and will be ongoing until 2050. An ambitious tree planting initiative will begin and be ongoing from Year 1 until 2025 so that new trees will have mature canopies by 2050. These efforts (increased maintenance and ambitious planting) will achieve the 40% canopy goal by 2050, resulting in projected GHG emissions and numerous other co-benefits.

Parties Involved:

Implementation of this policy option will occur at the local government level with support and involvement from state government and other parties. Collaborators for maintenance and plantings include federal, state, regional, and local governmental agencies, academic and research institutions, and non-governmental and private sector organizations. In order to achieve overall tree canopy cover goals, planting on residential and privately owned land will be necessary.

Other:

Community trees can sequester more carbon than individual trees in non-urban forests because the more open structure of the growing environment allows individual trees to intercept more light and grow faster. In addition, individual urban trees, on average, contain approximately four times more carbon than individual trees in forest stands.[1] Unfortunately, when trees are stressed, they can lose their normal ability to absorb CO_2. In contrast, healthy, vigorous, growing trees will absorb more CO_2 than will trees that are diseased or otherwise stressed.[2]

Substantial numbers of ash trees are found in community forests across Minnesota. The timeline included in this policy option includes the projected mortality of 100% of the ash population in community forests.

This policy option design does not include the removal of ash or stump grinding because this is presumed to be necessary, regardless of whether or not this policy option is advanced.

Community forests provide significant adaptation and other co-benefits such as improving air quality, providing natural habitat, mitigating temperature extremes, and improving soil health. Trees also contribute toward the aesthetics of communities, including increasing property values and positively impacting the physical and mental well-being of residents. While the value of many of these contributions can be calculated using existing software, they are outside the scope of the policy option and are not quantified or included in this analysis, but should be considered in the overall ROI calculations for investments in urban forests.

When these other benefits are lost due to the declining state of community forests, vulnerable populations including low-income individuals, children, and the elderly experience disproportionate impacts.

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[1] Nowak, David, and Daniel Crane. "Carbon Storage and Sequestration by Urban Trees in the USA." Environmental Pollution 116 (2002): p. 385 Accessed on web June 2, 2014.

[2] Urban Forest Project Protocol, Climate Action Reserve. Version 1.1, March 2010, p. 47, accessed online 5/29/14.

Implementation Mechanisms

Existing Infrastructure

This policy option recognizes the current value of existing community forests throughout more than 800 Minnesota cities and towns, which provide an estimated 20% overall tree canopy cover. Since full benefits begin to accrue once a tree reaches maturity (25 to 30 years), maintaining the base tree canopy cover in Minnesota communities is an essential implementation strategy.

Formal Adoption of Goals

A key first step is to formally adopt the goals proposed in this policy option. This could be accomplished statutorily through legislation, Governor's executive order, or some other related mechanism.

State Technical and Financial Assistance to Communities

Community forestry activities will be carried out at the local level. Many Minnesota communities will face challenges in securing adequate resources to carry out necessary activities. Recognizing the important role that individual cities, towns and communities play in maintaining and improving community forests, the state and other supporting institutions and organizations will need to provide increased and sustained assistance from a mix of funding sources including forestry and environmental funds, stormwater utility fees, energy conservation funding, habitat and natural heritage resources, state and local bond funds, and disaster preparedness funding. It is likely that corporate and philanthropic resources will need to be secured to help with community forestry needs and reach overall canopy goals, especially on non-public, non-residential lands.

The substantial additional funding required to implement this policy option will support increased technical and financial assistance, detection and management of pests and diseases, and research on innovations and emerging best practices.

Data Collection

To guide implementation of this policy option, new and improved data around community forestry will be necessary. This data is in the form of tree inventories (tracking the species, location, condition, and size of a given tree), aerial canopy assessments, and other best practices for forestry data management. This data and related analysis will be used to track the progress of the stated goals.

Related Policies/Programs in Place and Recent Actions

Policies related to community forestry in Minnesota statutes place emphasis on terrestrial invasive pest detection, quarantine, and management. These responsibilities are shared between the departments of Agriculture and Natural Resources.

Few statewide community forestry programs are currently in place. Like other states, DNR receives a modest annual USDA Forest Service grant. It is used to fund one staff person and provide pass-through dollars to the University of Minnesota Department of Forest Resources.

As a result of the Clean Air Dialogue in 2009, community forestry is recommended as an approach to mitigate the urban heat island effect and improve air quality. Additionally, community forestry has been identified as a practical climate adaptation strategy in the November 2013 report of the state's interagency climate adaptation team, "Adapting to Climate Change in Minnesota."

Estimated Policy Impacts

Direct Policy Impacts

Table F-5.4 FOLU-3 Estimated Net GHG Reductions and Net Costs or Savings for 40% Canopy Goal

2030 GHG Reductions (short tons CO_2e)	2015 – 2030 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ ton CO_2e)
0.49	3.4	$1,806	$568

Recognizing the anticipated lifespan of existing and newly planted trees, costs and benefits of this policy option are quantified over a time period extending to 2085

Table F-5.5 Estimated FOLU-3 Net GHG Reductions and Net Costs or Savings (2015-2085) for 40% Canopy Goal

2085 GHG Reductions (short tons CO_2e)	2015 – 2085 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2085 ($2014)	2085 Cost Effectiveness ($2014/ ton CO_2e)
0.14	67	$2,208	$33

In addition to the 40% canopy goal, GHG reductions and costs were estimated for the goals of 50%, 30%, and 20%. The results for these differing goals are shown below.

Table F-5.6 Estimated FOLU-3 Net GHG Reductions and Net Costs or Savings (2015-2030 and 2015-2085) – Other Canopy Goals

Canopy Goal	2030 GHG Reductions (short tons CO_2e)	2015 – 2030 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ ton CO_2e)
50%	0.69	4.5	$2,567	$565

Table F-5.7 Estimated FOLU-3 Net GHG Reductions and Net Costs or Savings (2015-2085) for 40% Canopy Goal

2085 GHG Reductions (short tons CO_2e)	2015 – 2085 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2085 ($2014)	2085 Cost Effectiveness ($2014/ ton CO_2e)
0.14	67	$2,208	$33

In addition to the 40% canopy goal, GHG reductions and costs were estimated for the goals of 50%, 30%, and 20%. The results for these differing goals are shown below.

Table F-5.8 Estimated FOLU-3 Net GHG Reductions and Net Costs or Savings (2015-2030 and 2015-2085) – Other Canopy Goals

Canopy Goal	2030 GHG Reductions (short tons CO_2e)	2015 – 2030 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ ton CO_2e)
50%	0.69	4.5	$2,567	$565
30%	0.28	1.8	$1,045	$576
20%	0.069	0.45	$284	$629
Canopy Goal	**2085 GHG Reductions (short tons CO_2e)**	**2015 – 2085 Cumulative Reductions (short tons CO_2e)**	**Net Present Value of Societal Costs, 2015 – 2085 ($2014)**	**Cost Effectiveness ($2014/ ton CO_2e)**
50%	0.20	96	$3,066	$32
30%	0.079	38	$1,350	$35
20%	0.020	9.5	$492	$52

Data Sources

The following data sources were used to quantify costs and benefits for this policy option:

- Data from the National Land Cover Database (NLCD) was used to establish the total Urban/Developed area for the state.
- Minnesota DNR Community Tree Survey 2012 was used to determine the baseline tree species diversity in cities and towns.
- University of Minnesota Department of Forest Resources was consulted in establishing the baseline average community forest canopy cover.
- The 2002 study, "Carbon Storage and Sequestration by Urban Trees in the USA," by David Nowak and Daniel Crane, was used to estimate carbon sequestration by community trees.
- The 2012 study, "Tree and Impervious Cover Change in U.S. Cities," by Nowak and Greenfield, was used to identify BAU average annual canopy loss.
- Guidance from the Minnesota Pollution Control Agency, Department of Natural Resources, and University of Minnesota Department of Forest Resources was used to establish areal coverage of average mature community trees, as well as estimated percents for new plantings in "municipal core," "peri-urban strategic," and "peri-urban other" areas.
- The USDA Forest Service's Midwest Community Tree Guide was consulted for tree installation & maintenance costs and energy impacts.
- The USDA Forest Service's iTree software was used to develop the Minneapolis model which was used to estimate statewide stormwater benefits.

Quantification Methods

Net GHG Benefits:

The number of trees planted in the urban core, strategic suburban, and other suburban areas was estimated based on statewide urban area, current and desired urban canopy coverage, and estimated areal coverage of each tree.

The total number of trees needed to increase canopy was divided equally among the planting years (2015-2025).

To maintain canopy, new trees were assumed to be planted to replace all of those lost to emerald ash borer (EAB) and those lost through normal BAU mortality.

All urban ash trees were assumed to be killed by EAB between 2015 and 2031, giving an estimate of 8 km^2 of canopy lost annually, based on data from the Minnesota DNR Community

Tree Survey[3] showing that ash trees comprise 20% of total trees. New trees only provide a fraction of the carbon sequestration and heating/cooling benefits of a mature tree. The fractions for these benefits for tree age ranges were developed based on data in the United States Forest Service (USFS) Midwest Urban Tree Guide. Trees were assumed to be lost to EAB in both the BAU and policy option scenarios; however, in the policy option scenario these trees are assumed to be replaced with new trees, which take time to reach full maturity and provide the same benefits as lost mature trees.

In addition to trees planted to expand and maintain canopy, this policy option is intended to mitigate the further loss of canopy due to inadequate maintenance. An estimate of 0.3% per year of canopy loss, based on a recent study of tree cover lost in US cities[4], was used to estimate BAU losses of heating, cooling, and stormwater runoff savings. Under the policy option scenario, these losses are not realized.

Societal Benefits and Costs:

Several important societal benefits have been deemed to be indirect to this policy option and therefore not quantified in the cost-benefit analysis. Examples include air quality improvements, mitigation of urban heat island effect, as well as public health benefits.

Costs associated with tree planting and maintenance activities were estimated based on the number of trees planted each year and the costs indicated above under Data Sources.

Savings from reduced electricity and natural gas use and savings from reduced stormwater runoff were estimated for each year based on the age range fractions described above under Net GHG Benefits. Stormwater savings result from the reduction in runoff that has to be handled by water treatment plants. It was assumed that most suburban areas do not have combined sewers that receive stormwater runoff; therefore, these savings were applied to trees in the urban core only.

Under the BAU, lost savings from reductions in canopy due to EAB and inadequate maintenance were estimated, assuming loss of mature trees. BAU losses also assume that 50% of current ash trees are in strategic suburban areas (areas providing shading and wind breaks), based on agency guidance.

BAU maintenance was estimated to be 40% of needed maintenance to mitigate further loss of canopy (based on current maintenance frequency of once every 10 years compared to preferred frequency of once every four years).

Lost cost savings under BAU are subtracted from the policy option scenario costs to give net costs.

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[3] Minnesota DNR Community Tree Survey, State of Minnesota, Department of Natural Resources, 2012. http://archive.leg.state.mn.us/docs/2012/other/120339.pdf

[4] Nowak and Greenfield, 2012. Tree and Impervious Cover Change in U.S. Cities, Urban Forestry & Urban Greening 11 (2012) 21-31. http://www.itreetools.org/Canopy/resources/Tree_and_Impervious_Cover_change_in_US_Cities_Nowak_Greenfield.pdf

Key Assumptions:

Key assumptions used in the quantification of benefits and costs are described above under Net GHG Benefits and Societal Costs. Other key assumptions include:

- One hundred percent ash mortality due to EAB,
- Tree maturity is reached when a tree is 25 to 30 years old,
- All newly planted trees survive to maturity (currently 30-50% die before full maturity), and
- Projected expansion of urban land use is 201 km^2 (from 4,071 km^2 in 2011 to 4,272 km^2) by 2035.

Macroeconomic (Indirect) Policy Impacts

Table below summarizes impacts of FOLU 3 option on GSP, employment and income earned in the state. Impacts of a sensitivity scenario are also evaluated.

Table F-5.9 Macroeconomic (Indirect) Economic Impacts

Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
FOLU-3	$382	$366	$5,495	4,420	4,180	62,670	$463	$361	$5,409

Figure F-5.20 FOLU-3 GSP Impacts ($2015 MM)

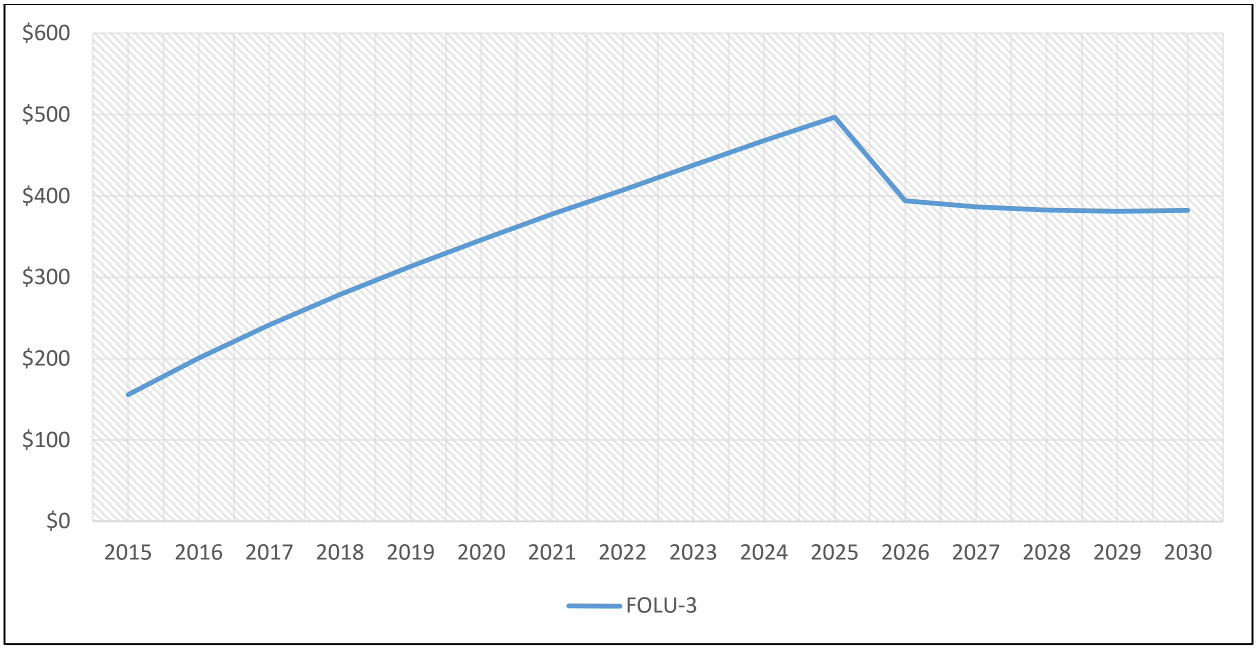


Figure F-5.21 FOLU-3 Income Impacts ($2015 MM)

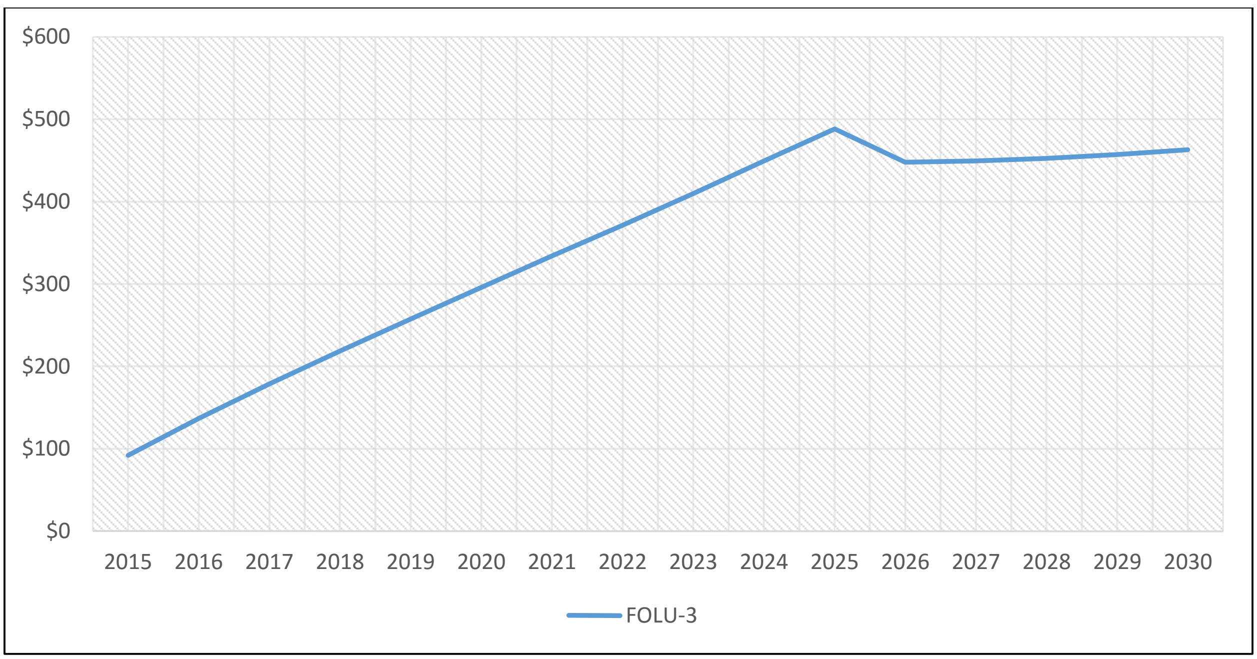
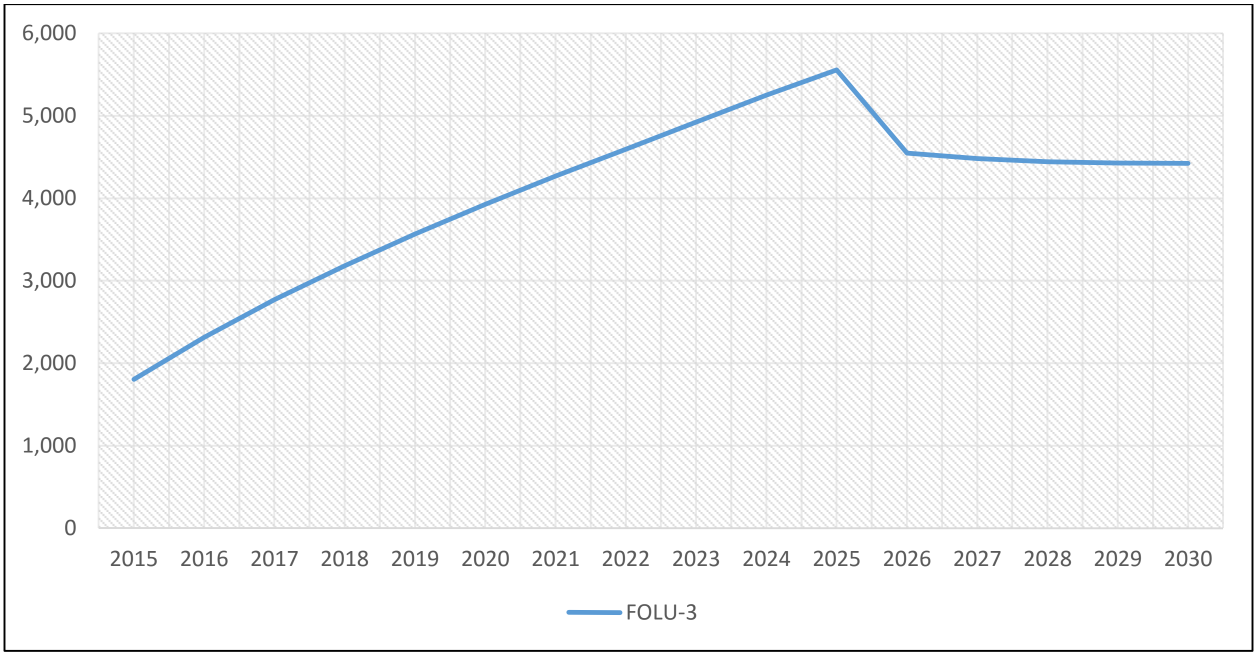


Figure F-5.22 FOLU-3 Employment Impacts (Individual Jobs)



Principal Drivers of Macroeconomic Changes

A major driver of positive macro-economic implications in this policy is the state government spending on strengthening and increasing the tree canopy cover of community forests. This spending is almost entirely on labor to carry out the forestry work. As a result of that spending, there is a constant increase in employment, both in the metro area and the rest of the state. This kind of direct employment has significant indirect impacts as those employees spend their money around the economy.

Another positive macro-economic driver is the energy savings achieved by the policy, due to the reduction in electricity demand for cooling that grows over the entire modeling period.

The state is expected to achieve significant storm water management savings by implementing this policy. Bigger absorption and transpiration of water by expanded community forests reduces the need for storm water management spending.

The state does, however, cut back on other spending in order to fund this effort, and that reduction serves as a downward pressure on GDP, incomes and total employment.

This policy suddenly reduces its government investment in tree-planting after 2025, cutting a $350 million annual expenditure to a $40 million annual expenditure, and this shift drives the abrupt downward shift of the impacts starting in 2026.

<u>Data Sources</u>

- Local government spending, primarily in the metro area, on urban forestry efforts. This steadily rises through the period of analysis to reach approximately $175 million per year in 2030.

- Savings by governments, businesses and households on electricity as a result of shade trees.

- Government savings, reaching as much as $25 million, on storm water management.

<u>Key Assumptions</u>

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers’ cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses

spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Quantifications Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis
- These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Uncertainties

Key uncertainties associated with this analysis include:

- The impacts of ash tree mortality as it relates specifically to how much shading and windbreaks these trees currently provide.
- BAU estimates of canopy loss due to inadequate maintenance was based on a national study on current trends in urban canopy. It is uncertain whether Minnesota's annual estimated tree loss parallels national averages.
- In addition to cost savings from reductions in stormwater runoff, there would also be a reduction in electricity usage by water treatment plants. This electricity savings was not quantified in this analysis.
- There is some uncertainty associated with the level of maintenance spending necessary to establish and maintain new urban canopy. The sensitivity of total costs and cost effectiveness to changes in maintenance costs was investigated by increasing and decreasing the maintenance costs by 20%. As shown in the table below, a 20% over-

estimate or under-estimate in maintenance costs only changes the calculated total costs and cost effectiveness of the policy option by 6.5%.

Table F-5.10 . Impact of Change in Maintenance Costs on FOLU-3 Results

Change in Maintenance Costs	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ ton CO_2e)
Increased by 20%	$1,974	$571
Original Values	$1,852	$536
Decreased by 20%	$1,730	$500

Additional Benefits and Costs

Significant benefits beyond GHG reductions exist for community tree canopy expansion.

Community forests improve or increase:

- Air quality,
- Quality and quantity of ground and surface waters,
- Extreme weather resilience,
- Use of multi-modal as well as non-motorized ways of commuting and travelling and healthy living behaviors,
- Biodiversity/wildlife habitat, and
- Property values.

Community forests also reduce:

- Urban heat island impacts,
- Flooding,
- Soil erosion,
- Impacts of drought, and
- The need for other infrastructure improvements.

Additionally, activities necessary to achieve the policy option goals will create jobs.

Feasibility Issues

Broad Political Support

Community forestry enjoys broad political support from state and local government officials, citizens, and private and nonprofit stakeholders in Minnesota. The potential for political opposition is low.

Established Best Practices

Best practices for community forestry such as tree planting, tree maintenance, tree inventory, and tree inspection are well established and demonstrated to be feasible. Additionally, there is an existing private sector workforce in place that could grow to support these efforts.

Community Forestry Resources Historically Limited

The feasibility of relying on federal resources for implementing this policy option is low. Federal resources for community forestry activities in Minnesota are estimated at $250,000 per year. State resources for community forestry activities are presently limited and would require a substantial increase to achieve the targeted goals proposed in this policy option.

Other potential obstacles include the low priority placed on community forestry by state government. The relative priority level placed on community forestry is gradually increasing in light of broader recognition of the numerous environmental, economic, and societal benefits associated with community forests.

Clock is ticking

Without decisive and concerted efforts to stem the decline of community forests and increase planting activities, the barriers and challenges faced in achieving the proposed policy option goals will become higher.

Updating, Monitoring and Reporting

Baseline measures of tree canopy cover and tree inventories are important data sets that require periodic updates.

This policy option should be updated to utilize ongoing developments in available tools and technology used to quantify benefits of community forests.

If this policy option is advanced, additional reporting requirements will be necessary including tracking of outputs, outcomes, and expenditures.

FOLU-4. Tree Planting: Forest Ecosystems

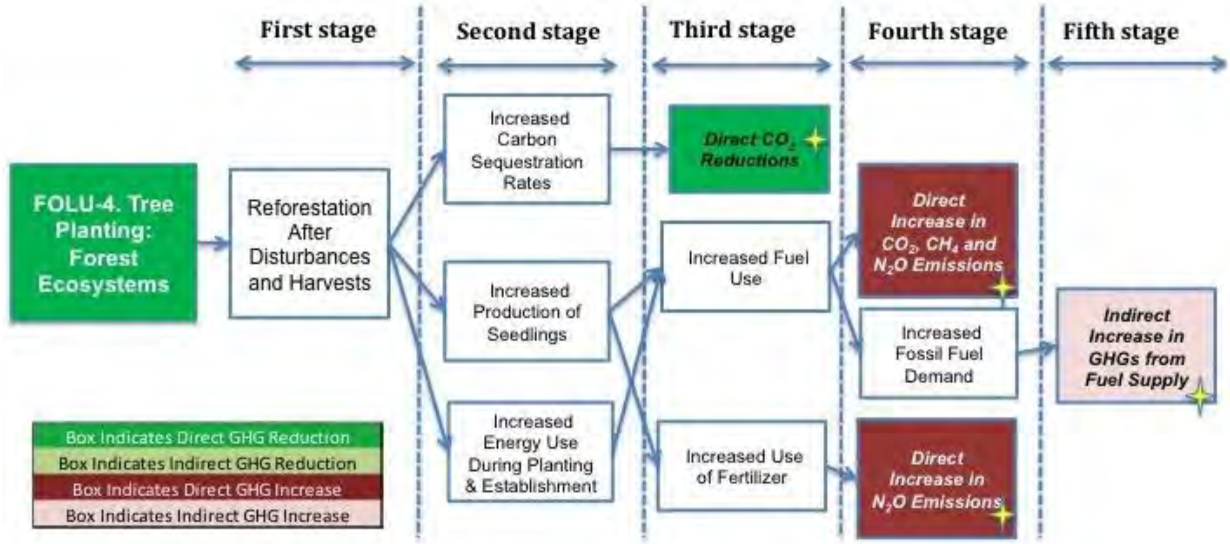
Policy Option Description

Minnesota forests contain about 1.6 million metric tons of carbon and over the past ten years have accumulated carbon at the rate of about 0.66 metric tons per acre per year (Forest Inventory and Analysis 2009-2013 Evalidator report for Minnesota). Although disturbances, such as blowdowns, fire, pest and disease outbreaks, are common, natural features of forest ecosystems, they release large amounts of carbon and reduce the rate at which the state's forest as a whole removes carbon from the atmosphere. With anticipated changes in climate, the frequency and intensity of landscape-level forest disturbance (tens to a few hundreds of thousands of acres) in Minnesota will likely increase. Since younger forests accumulate carbon more quickly than older forests do, re-establishing forests without delay on disturbed sites helps maintain high levels of carbon sequestration.

Dedicated resources are needed to ensure timely restoration of carbon sequestration following large disturbances on state, county, and private lands. DNR meets legislative requirements for routine post-harvest reforestation using a combination of funds allocated biennially by the legislature. Large-scale natural disturbances, however, are exceptions: following such disturbances, the areas in need of reforestation are typically many times larger than the largest harvest sites, the plant communities to be restored are more diverse, and the site preparation required is usually extensive. Without additional funding to address these disturbances, reforestation of such areas is delayed and carbon uptake is reduced or delayed, or staff and other resources are diverted from equally essential, but more routine, management activities.

Causal Chain for GHG Reductions

Figure F-5.23 Causal Chain for FOLU-4 GHG Reductions



The causal chain above identifies the main policy option effects and the subsequent GHG impacts. The star symbol identifies significant GHG effects that will be quantified. The increase in emissions for sourcing planting feedstocks and for planting and establishment activities are not considered to be significant.

Policy Option Design

Goals:

- Ensure that reforestation efforts (natural regeneration monitoring, site preparation, seeding or planting, and protection) are underway within one year of disturbance on state, county, and private non-industrial forestlands.
- Ensure that planned timber harvest and other management activities continue in accordance with sub-section forest resource management plans and that post-harvest reforestation is initiated within one year of harvest.

Timing: This policy option can be implemented immediately.

Parties Involved: This policy option applies primarily to public forestland managers (MN DNR, county land departments) but private, non-industrial forest landowners and national forests will also be affected. Consulting foresters and tree nurseries will also be involved.

Implementation Mechanisms

- Anticipate reoccurring landscape level disturbances by maintaining $2 million in a fund reserved for reforestation on state, county, and private lands following large-scale natural disturbance.

- Align funding for post-harvest reforestation and associated protection practices with planned harvest levels.

Related Policies/Programs in Place and Recent Actions

This policy option contributes to meeting the goals of FOLU-2 (Manage for Highly Productive Forests).

This policy option supplements existing budgeting processes and policies that ensure reforestation of harvested state lands within one year of harvest.

Estimated Policy Impacts

Direct Policy Impacts

Table F-5.11 FOLU-4 Estimated Net GHG Reductions and Net Costs or Savings

2030 GHG Reductions (short tons CO_2e)	2015 – 2030 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ ton CO_2e)
1.9	30	$187	$5.6

For Forestry Policies, full policy option benefits are only realized when considering the full lifetime of planted or preserved trees. Therefore, cost and benefits of FOLU policies were quantified over a longer time period (2015-2085) as shown in the table below.

Table F-5.12 Estimated FOLU-4 Net GHG Reductions and Net Costs or Savings (2015-2085)

2085 GHG Reductions (short tons CO_2e)	2015 – 2085 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2085 ($2014)	Cost Effectiveness ($2014/ ton CO_2e)
0.67	104	$183	$1.8

The policy option was estimated to produce almost 250,000 TJ of biomass fuel, offset 23.4 $TgCO_2e$, over between 2015 and 2030, as shown below. The first few years show more biomass production than later years, because of the lag in reforestation/land clearing in the BAU case, which considers only disturbances happening in 2015 and later.

Table F-5.13 Biomass Fuel and Fossil Fuel Offsets

Year	Biomass Fuel (TJ)	Fossil Fuel Offset ($TgCO_2e$)
2015	36,960	-2.69
2016	37,004	-2.69

2017	37,049	-2.70
2018	37,093	-2.70
2019	8,309	-1.06
2020	8,319	-1.06
2021	8,329	-1.06
2022	8,339	-1.05
2023	8,349	-1.05
2024	8,359	-1.05
2025	8,369	-1.05
2026	8,379	-1.05
2027	8,389	-1.05
2028	8,399	-1.05
2029	8,409	-1.05
2030	8,419	-1.05
Total	248,474	-23.4

Data Sources

Current data on forest area and forest carbon density by stand age for Minnesota forests was obtained from the Forest Inventory Data Online web-application[5]. The area of forest land affected by fire, wind damage, and pest and disease were obtained from the 2013 DNR Forest Health Report.[6] Estimates of the annual increase in extent of disturbance were obtained from the baseline Inventory and Forecast. The model variables in the table below were set based on MN DNR guidance.

[5] Forest Inventory Data Online web-application version: FIDO 1.5.1.05b, http://apps.fs.fed.us/fia/fido/index.html.

[6] Minnesota Department of Natural Resources. 2013 Forest Health Report. http://files.dnr.state.mn.us/assistance/backyard/treecare/forest_health/annualreports/2013annualReport.pdf

Table F-5.14 Variables Used in Modeling

Model Variables	Fraction
Fraction of Area Requiring Reforestation	
Fire	55%
Wind	55%
Pest/Disease	30%
Reforestation Method	
Seeding	50%
Planting	50%
Fraction of Reforested Area Requiring Site Prep.	
Fire	0%
Wind	100%
Pest/Disease	100%
Fate of Removed Residue	
Fuel	50%
Fiber	50%

<u>Quantification Methods</u>

GHG Benefits:

Based on input from MN DNR, BAU reforestation following large scale disturbance was assumed to happen on 100% of public land and 50% of private land, but with a delay of five years. In the policy option, scenario 100% of land needing reforestation is reforested within one year. Carbon sequestered by reforested land and emissions associated with seedling production and site preparation was estimated for both the BAU and policy option scenarios, with net emissions estimated as the policy option scenario emissions minus the BAU scenario emissions.

The areas replanted and reseeded each year were estimated based on the disturbance area for each year and the model variables listed in the table above. The amount of carbon sequestered by the reforested land was estimated based on the acreage and stand age of each reforested area. Emissions associated with seedling production (fossil fuel and fertilizer usage) were estimated based on the area replanted and emission factors from a 2006 study of life-cycle emissions from forestry operations[7]. Emissions associated with site preparation (felling,

[7] Sonne, 2006. Greenhouse Gas Emissions from Forestry Operations: A Life Cycle Assessment. http://www.lanecounty.org/departments/pw/lmd/landuse/documents/lane%20county%20land%20use%20task%20force/jim%20just_greenhouse%20gas%20emissions%20from%20forestry%20operations.pdf

skidding, loading) were estimated based on the area needing site preparation (estimated using the model variables in the table above) and a diesel fuel consumption factor of 0.41 gallon per ton of wood.[8] For wood coming from site preparation, it was assumed that 70% of residue was removed from the forest, and 50% of that wood would be used for fuel, with the other half going to fiber.

Societal Costs:

As with GHG Benefits, costs were estimated for both the BAU and policy option scenarios using the assumptions for extent and timing of reforestation described above, with net emissions estimated as the policy option scenario emissions minus the BAU scenario emissions. Costs were estimated for seeding, planting, and site preparation based on the costs shown in the table below set based on Minnesota Agency guidance. Minnesota forests were assumed to be 64% hardwood and 36% softwood, based on FIA data. Revenue for salvaged wood was also estimated based on stumpage from the 2012 Minnesota's Forest Resources report and the assumption that salvage wood brings in 45% the revenue of other wood. Also, the value of incremental value of the timber planted during reforestation were estimated based on forest sequestration rates, developed from FIA data, and the same stumpage values reference above (adjusted for inflation) starting at 35 years in the future, the assumed age for harvest. Costs associated with preparing wood for biomass usage (chipping) were taken from the EPA Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis.[9]

Table F-5.15 Costs Used in Modeling

Activity	Costs per acre
Seeding Costs	$35/acre
Planting Costs (softwood)	$190/acre
Planting Costs (hardwood)	$270/acre
Site Preparation Costs	$100/acre

Key Assumptions

While the design of this policy option does not include demand-side implementation mechanisms for biomass usage, increased biomass usage from this policy option is assumed to result in incremental residential heating reductions (propane). Other key assumptions are discussed above under GHG Benefits and Societal Costs.

[8] Timmons and Mejía, 2010. Biomass Energy from Wood Chips: Diesel Fuel Dependence? Biomass and Bioenergy 34 (2010) 1419-1425.
http://www.academia.edu/4582400/Biomass_energy_from_wood_chips_Diesel_fuel_dependence

[9] EPA, Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis, Table 4.1-6, http://www.epa.gov/otaq/renewablefuels/420r10006.pdf

Macroeconomic (Indirect) Policy Impacts

Table below summarizes impacts of FOLU 4 option on GSP, employment and income earned in the state.

Table F-5.16 Macroeconomic (Indirect) Impacts

Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
FOLU-4	-$10	-$15	-$232	-130	-210	-3,160	-$14	-$19	-$283

Figure F-5.24 FOLU-4 GSP Impacts ($2015 MM)

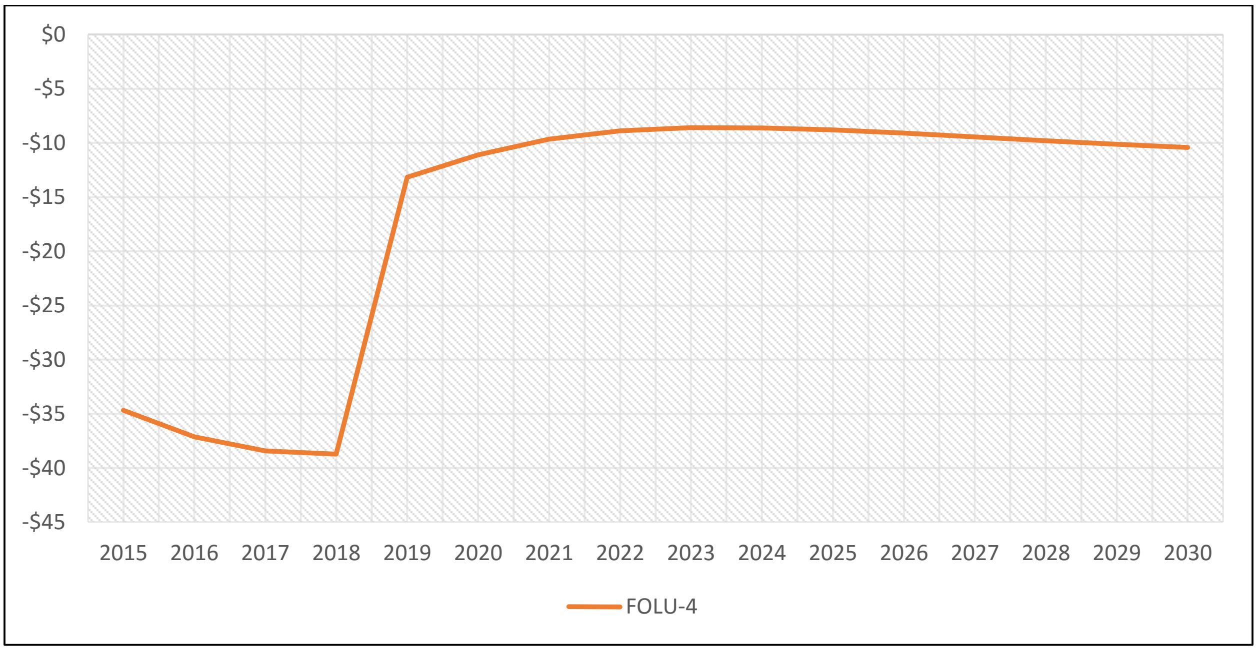


Figure F-5.25 FOLU-4 Income Impacts ($2015 MM)

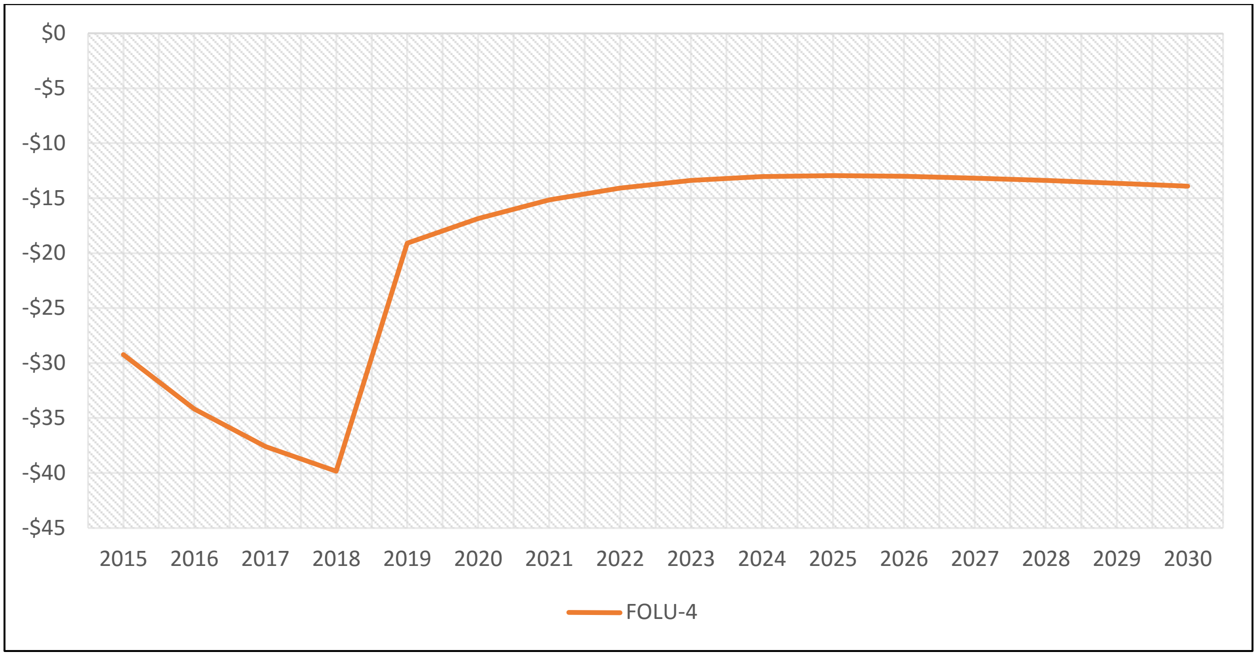
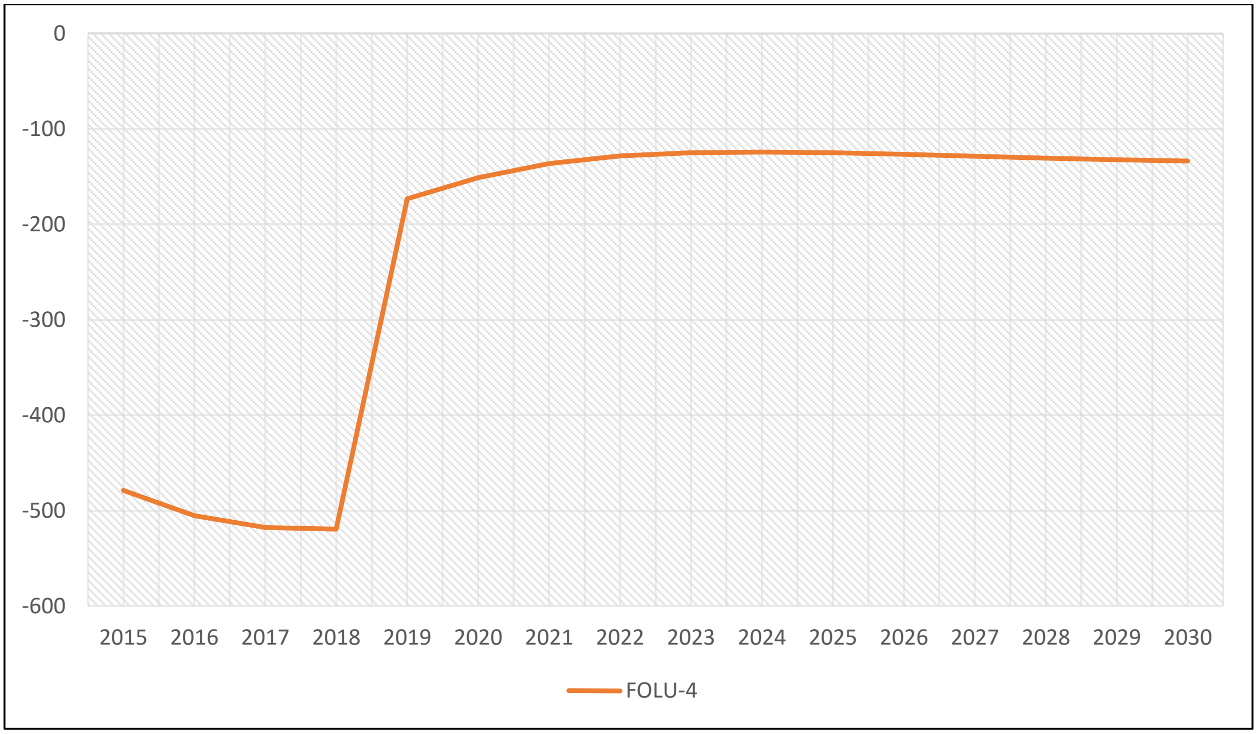


Figure F-5.26 FOLU-4 Employment Impacts (Individual Jobs)



Principle Drives of Macroeconomic Changes

- This policy has relatively small effects on the state economy in comparison to the rest of FOLU policies.
- This policy is characterized almost entirely by streams of state government spending in the forestry and transportation sectors. These drive new activity, output and labor into these sectors, but must be paid for by reducing other government spending, and so these benefits are significantly offset.
- The policy does produce a burst of additional revenue to public and private landowners from higher sales of timber, which will add to GDP directly as well as creating new spending power for both individual landowners and the government. This spending power also enters the economy as new GDP (which is calculated by summing total spending by governments, consumers and businesses).

Data Sources

- Costs to state government agencies associated with public and private lands reforestation efforts funded by state government funds.
- Revenue resulting from an increase in managed timber sales.
- State spending on transportation of biomass as part of forestry and managed logging efforts.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.

- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

<u>Quantifications Methods</u>

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Uncertainties

This analysis estimates the area of disturbance that requires reforestation using data on disturbances in the recent past. Under most climate change scenarios, however, increases in the frequency and intensity of weather-related disturbances will result in much more area that requires reforestation.

While the biomass produced as a result of this policy option was assumed to replace residential propane, this policy option does not contain a mechanism for directing the biomass produced as a result of this policy option to a particular use or sector (i.e., propane to wood stove conversion). Because of this lack of demand-side implementation mechanisms, the fate of this biomass fuel is uncertain.

Additional Benefits and Costs

The risk of catastrophic wildfire is much higher following large disturbances in which trees are uprooted or killed but left standing. Timely removal of fuel loads and reestablishment of growing stock reduces the risk that lives or property will be lost.

Soils from which vegetation has been removed by fire and soils that have been disturbed as trees are uprooted are more susceptible to wind and water erosion than undisturbed soils. Trees that have been defoliated by pests or diseases intercept less rainfall and don't moderate the erosive effects of heavy downpours as effectively as healthy trees. Re-establishing forest vegetation following such disturbances helps protect those soils and helps minimize sediment and nutrient accumulation in surface waters.

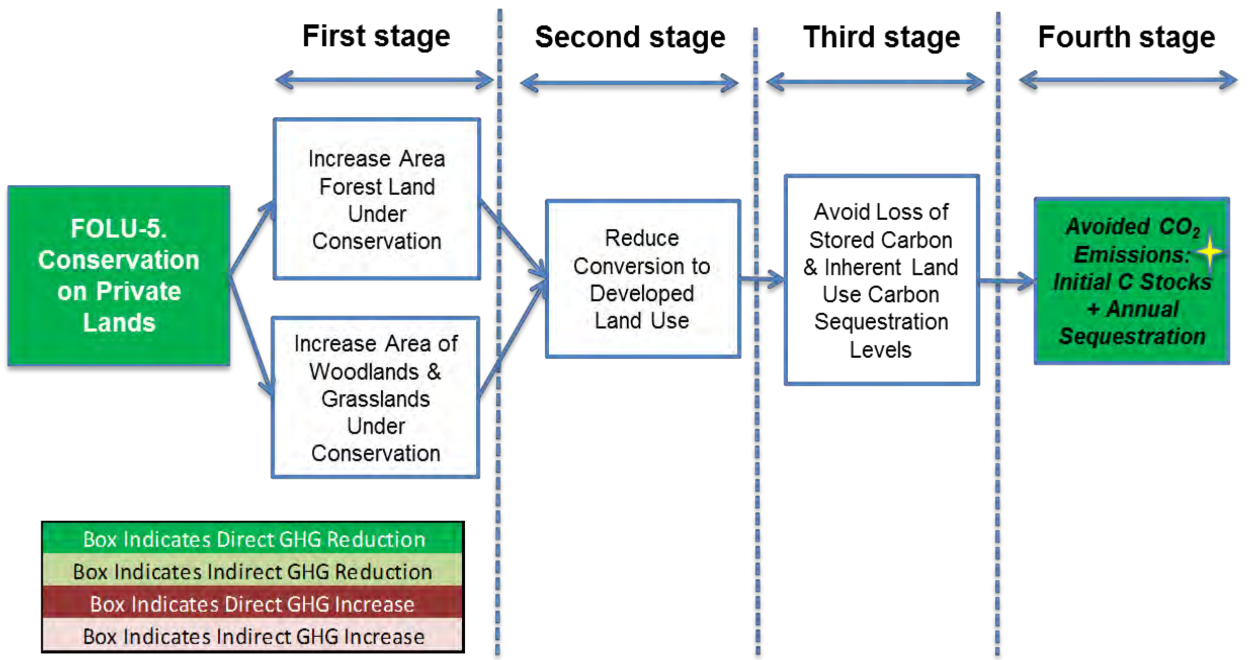
FOLU-5. Conservation on Private Lands

Policy Option Description

Permanent vegetative covers in natural ecosystems and agricultural systems sequester more carbon than do annual cropping systems. Restoring and protecting perennial vegetation (prairie, wetland, forest, hay, and pasture) will increase carbon sequestration in soils and plant biomass. In addition, restoring wetlands will improve water quality and reduce flooding. Protecting forests sustain their ability to sequester carbon while preventing large emissions associated with forest loss.

Causal Chain for GHG Reductions

Figure Ap F-5.27 Causal Chain for FOLU-5 GHG Reductions



The causal chain above identifies the main policy option effects and the subsequent GHG impacts. The star symbol identifies significant GHG effects that will be quantified.

Policy Option Design

The policy option will deploy conventional conservation tools to restore native vegetation and protect land with permanent vegetative cover from urban and agricultural development. Land protection will mirror the Minnesota Prairie Conservation Plan and target the protection of 1.5 million acres of agricultural land and 500,000 acres of forest land. Forest land will be protected through permanent conservation easements under the Minnesota Forests for the Future

Program. Grassland and wetland habitat will be restored and using a range of federal and state conservation tools and funding. These tools include: conservation easements, such as State RIM, Prairie Bank, USF&WS wetlands easements, USDA Agricultural Conservation Easement (Wetlands Reserve Easement and Grasslands Reserve Easement), as well as fee title acquisitions by MN DNR, USF&WS and the Nature Conservancy. They will also include shorter term contracts programs such as the USDA Conservation Reserve Program. Federal funding opportunities such as the Conservation Reserve Enhancement program will be utilized to the fullest extent possible. Working grass lands strategies are of growing importance. Conservation programs such as GRE will continue to provide for on-going grazing and haying, and traditional conservation programs are integrating more grazing and haying to support enhanced grassland management.

Funding for the projects will be approximately 50% federal and 50% state.

Goals:

- **Forest Conservation:** Permanent conservation easements on an additional 500,000 acres of forestland.
- **Grasslands and Wetlands Conservation:** Restore and/or protect an additional 1.2 million acres of grasslands and wetlands from development via conservation easements or other less permanent protection strategies and tools.
    - Native Prairie Protection:
        - Fee title 30,000 acres
        - Easement 75,000 acres
    - Other Existing Grassland /Wetland Protection (2:1 grassland to wetland acreage)
        - Fee title 210,000 acres
        - Easement 400,000 acres (includes working lands easements)
    - Grassland/Wetland Restoration from Ag Land (3:1 grassland to wetland acreage)
        - Fee title: 50,000 acres
        - Easement: 125,000
        - Contract (CRP) 500,000 acres
- It is anticipated that approximately 30% of the land area protected or restored will be available for forage production through grazing or haying.

Timing: Implementation will be on a linear basis from now through 2034, with the expiration of the Minnesota Legacy Amendment.

Parties Involved: A wide range of parties will be involved. Forest for the Future easements will involve non-industrial private forest land owners, industrial forest land owners, forestry consultants and forest products industries. Parties involved in grasslands and wetland conservation will include individual land owners and farm operators, conservation agencies, agriculture agencies, and farm groups.

Implementation Mechanisms

Continue implementation of the Minnesota Forests for the Future Plan:

- Resolve ancillary policy option issues such as property tax treatment of easement lands and Sustainable Forestry Incentive Act (SFIA) program.
- Utilize state funding sources to leverage federal programs to secure permanent conservation easements.

Protect 1.2 million acres of grasslands and wetlands:

- Implement strategies outlined in the Minnesota Prairie Plan to reach protection goals:
    - Use a mix of permanent (fee title and easement acquisition) and mid-term (CRP contracts) land protection and restoration tools.
    - Funding Leverage; use Lessard-Sams Outdoor Heritage Fund, Minnesotan Environmental and Natural Resource Trust Fund and State Bonding to maximize Minnesota share of federal farm bill programs resources as well as other federal resources such as the Prairie Pothole Joint Venture.
    - Integrate working lands conservation strategies, including managed haying and grazing in land retirement programs, to ensure that grass based agriculture remains viable in the state of Minnesota.
    - Utilize strategic targeting and precision conservation tools to maximize the benefits of land retirements, restoration and protection efforts including targeting soil types most appropriate for greenhouse gas management.
    - Continue Farm Bill Assistance program efforts to drive targeted outreach, promotion and enrollment of private land into the most appropriate conservation programs.
- Invest in research and development of markets for perennial crops that provide multiple environmental benefits in order to enhance the economic sustainability of increased grassland.

Related Policies/Programs in Place and Recent Actions

This policy option connects directly to A-2 (enhancing soil carbon), specifically perennial crop retention and expansion.

There is a suite of traditional conservation programs run through state and federal agencies with the goal of conserving natural and conservation lands. Conservation partners have aligned long term efforts in Western and Southern Minnesota through the Minnesota Prairie Plan. The

Minnesota Forests for the Future initiative provides similar landscape scale direction for the conservation of forest cover.

The key funding mechanisms were established in the Minnesota Constitution through the Clean Water Land and Legacy Amendment as well as through the creation of the Environment and Natural Resources Trust Fund. These dramatically expand resources beyond those traditionally invested such as license fees, bonding, general fund appropriation, USDA conservation programs, and federal aid for fish and wildlife management.

Minnesota programs, such as RIM and Prairie Bank easements, complement and support federal programs such as CRP and NRCS and US Fish and Wildlife Service conservation easements.

Estimated policy Impacts

Direct Policy Impacts

Table F-5.17 FOLU-5 Estimated Net GHG Reductions and Net Costs or Savings

2030 GHG Reductions (short tons CO_2e):	2015 – 2030 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2030 ($2014):	Cost Effectiveness ($2014/ ton CO_2e):
0.34	3.0	$1,261	$421

For Forestry Policies, full policy option benefits are only realized when considering the full lifetime of planted or preserved trees. Therefore, cost and benefits of FOLU policies were quantified over a longer time period (2015-2085).

Table F-5.18 FOLU-5 Estimated Net GHG Reductions and Net Costs or Savings (2015-2085)

2085 GHG Reductions (short tons CO_2e):	2015 – 2085 Cumulative Reductions (short tons CO_2e)	Net Present Value of Societal Costs, 2015 – 2085 ($2014):	2085 Cost Effectiveness ($2014/ ton CO_2e):
0.39	25	$1,304	$53

Data Sources

The sequestration rate for forests (1.00 Mg C/acre) was estimated from FIA data for Minnesota forests obtained from the Forest Inventory Data Online (FIDO) tool. [10] Sequestration rates for grassland, peatland, and prairie pothole lands were obtained from a 2008 report on terrestrial

[10] Forest Inventory Data Online web-application version: FIDO 1.5.1.05b, http://apps.fs.fed.us/fia/fido/index.html.

carbon sequestration in Minnesota.[11] Emission factors for wetland methane were developed as part of the Inventory and Forecast based on recent wetland methane studies.

Quantification Methods

Net emission reductions for this policy option were estimated as the total policy option scenario emissions/reductions minus the BAU scenario emissions/reductions. BAU scenario emissions include the lost carbon sequestration on forestland, grassland, and wetlands that are lost to development and lost methane emissions from lost wetlands. Policy option scenario emissions/reductions include carbon sequestration from restored grassland and wetland and methane emissions from restored wetlands. Only a portion of the lands being conserved in a given year is expected to be lost to development in that year under BAU conditions. The following fractions for conservation areas expected to be lost under BAU were set based on Minnesota Agency input:

- Forest – 5%
- Native Prairie – 40%
- Other Grassland – 40%
- Other Wetland – 25%

Net Societal Costs:

The following costs associated with land conservation and restoration were supplied by Minnesota Agency staff.

Table F-5.19 Conservation and Restoration Costs Used in Modeling

Cost Variable	$/acre
Average Forest Easement Payment	$235
Average Wetland/Grassland Easement Payment	$5,500
Average Fee Title Cost	$6,000
Average CRP Rental Payment	$81
Average Prairie Planting Cost	$300
Average Wetland Restoration Cost	$2,000
Forest Program Costs	$0.50
Wetland/Grassland Program Costs	$1.30
Federal Cost Share	50%

[11] The Potential for Terrestrial Carbon Sequestration in Minnesota: Appendix II, 2008. http://www.wrc.umn.edu/prod/groups/cfans/@pub/@cfans/@wrc/documents/asset/cfans_asset_119302.pdf

Key Assumptions

Key assumptions are discussed above under GHG Benefits and Societal Costs.

Macroeconomic (Indirect) Impacts

Table below summarizes impacts of FOLU 5 option on GSP, employment and income earned in the state. Impacts of a sensitivity scenario are also evaluated.

Table F-5.20 Macroeconomic (Indirect) Economic Impacts

Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
FOLU-5 Low Income	-$114	-$87	-$1,301	-1,350	-1,060	-15,900	-$3	$67	$1,010
FOLU-5 Keep Income	-$75	-$59	-$883	-920	-720	-10,750	$117	$144	$2,157

Figure F-5.28 FOLU-5 Macroeconomic Impacts of Assuming Farms Lose Crop Revenue

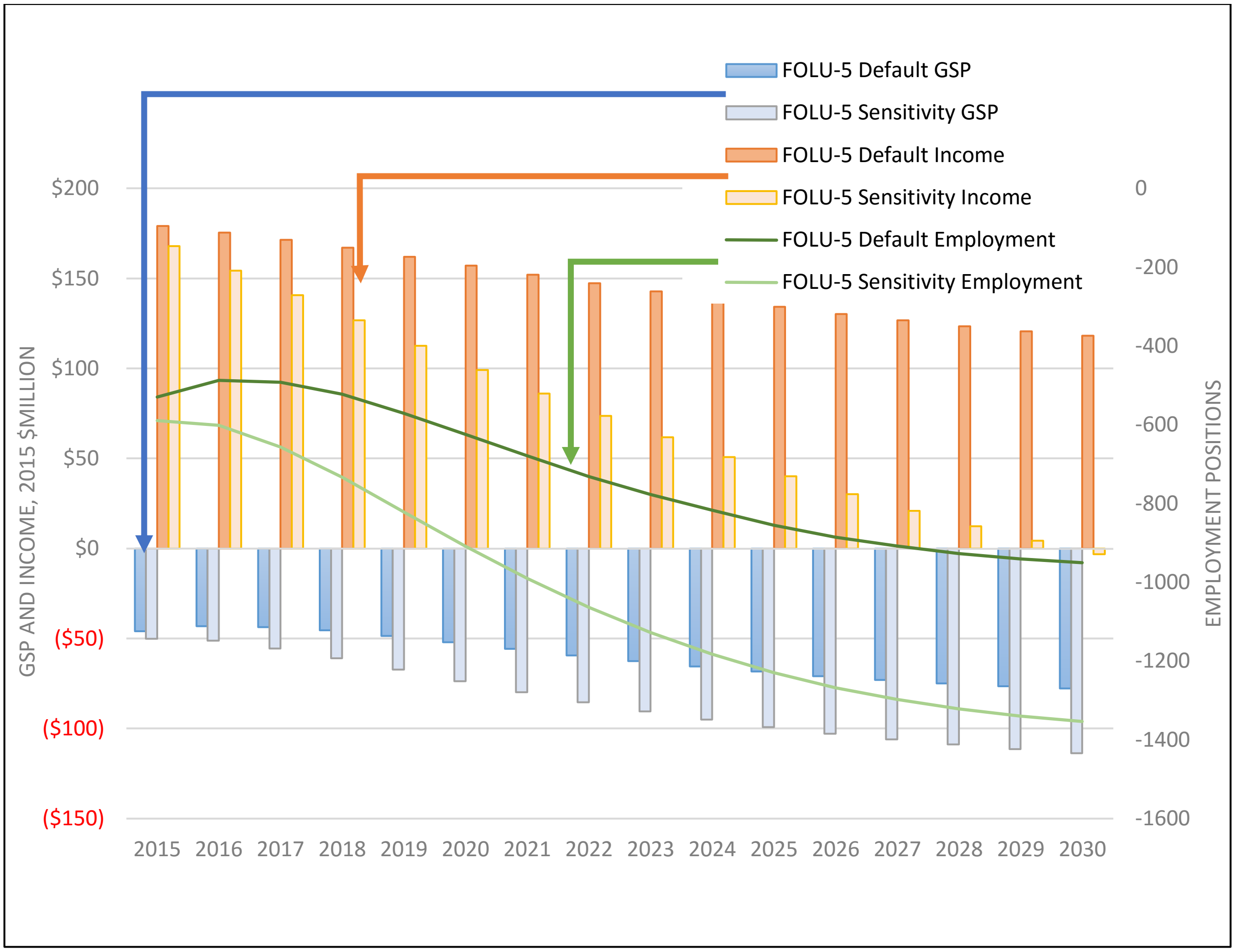


Figure F-5.29 FOLU-5 GSP Impacts ($2015 MM)

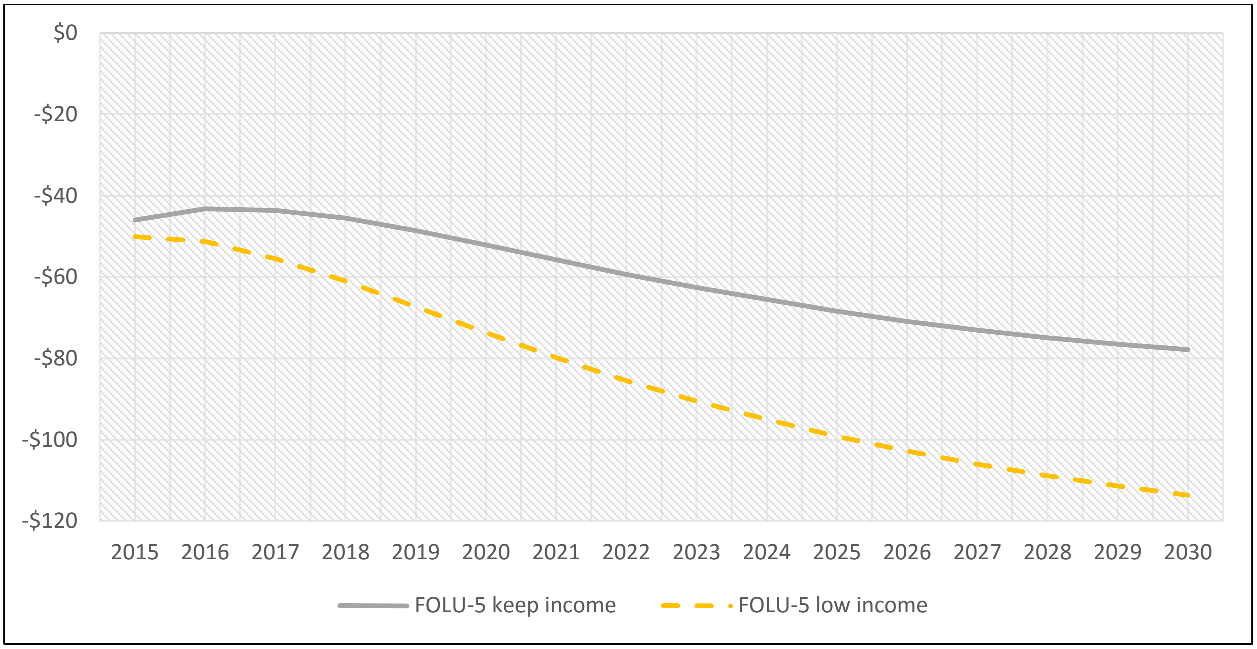


Figure F-5.30 FOLU-5 Income Impacts ($2015 MM)

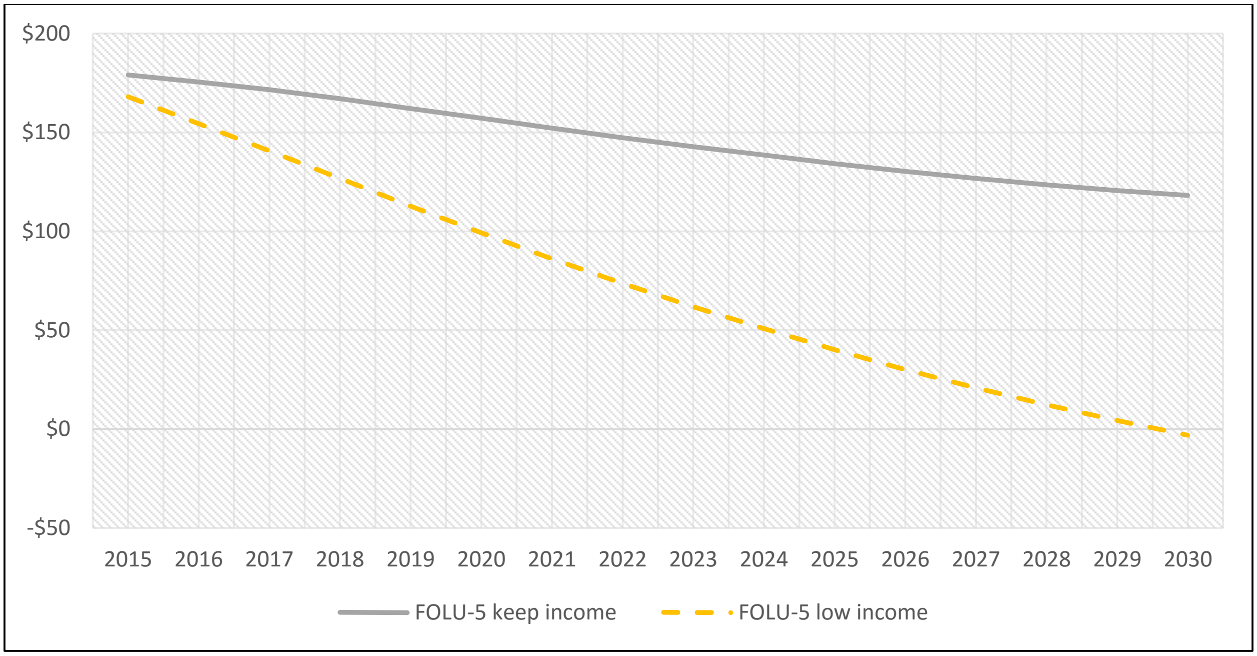
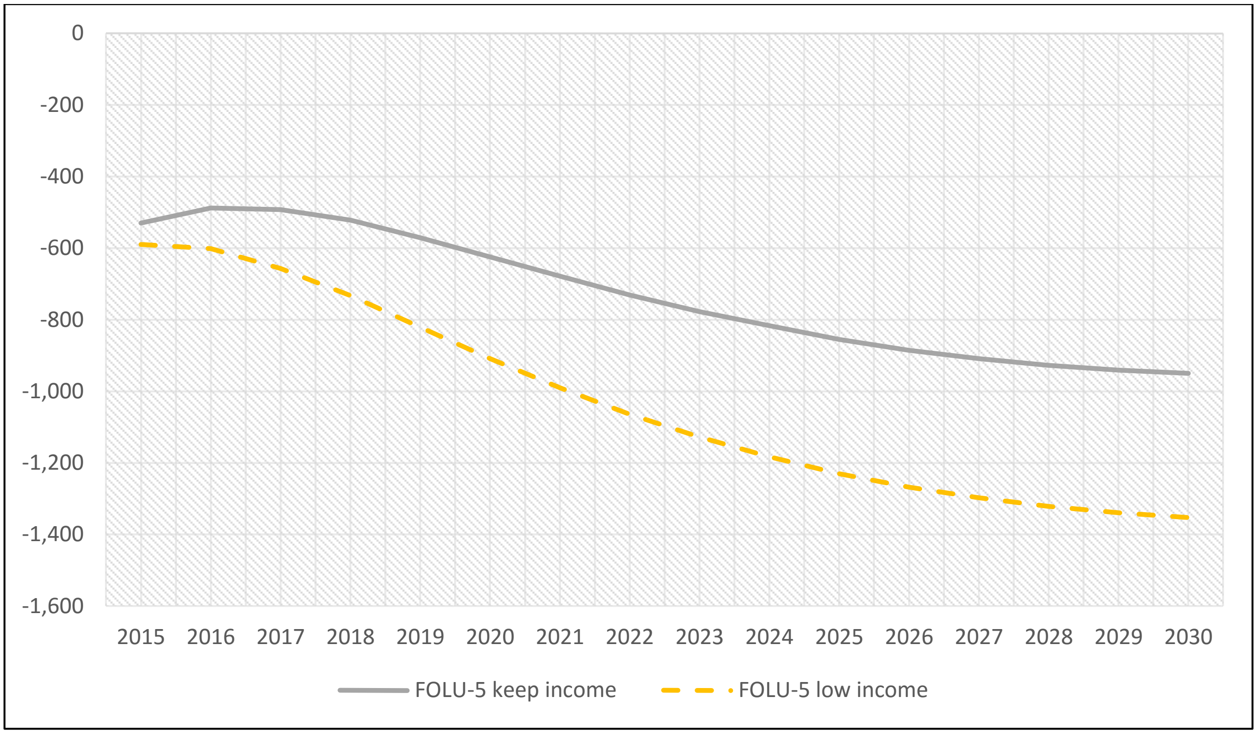


Figure F-5.31 FOLU-5 Employment Impacts (Individual Jobs)



<u>Principal Drivers of Macroeconomic Changes</u>

This policy is characterized by state and federal funds disbursed to landowners to purchase easement and other property access rights to advance preservation, reforestation and afforestation goals.

The influx of federal dollars into the state to support spending on easements and private land property rights, for the purposes of conservation, is the principal driver of the state economy expansion in this policy.

The fact that the state's tax base only bears half the cost of some of these easement programs means that significant new money enters the state in ways that either quickly turn into consumer spending (payments to individual land owners) or lower production costs (payments to corporate landowners). Both of these impacts are positive.

The total federal stimulus anticipated reaches approximately $175 million (in nominal dollars) by 2030.

Data Sources

- Easement costs paid by government, including 50% federal support to that expenditure.
- Easement earnings to private landowners, whether farms, private property owners, or corporate entities.
- CRP payments to landowners from federal programs.

Landscape restoration work costs.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and

intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Quantifications Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Uncertainties

The analysis is very sensitive to the degree to which existing forests, wetlands, and grasslands conserved through these policies are likely to be converted to row crop production or other development. There is limited in-state analysis and projection of these trends.

Wetland methane emissions are a significant variable in this analysis. There is some literature that suggests that northern prairie pothole type wetlands with mineral soils, and which are subject to seasonal freezing, are likely to contribute less methane than assumed here.

Additional Benefits and Costs

The strategy builds upon and extends the range of conservation values associated with land protection including:

- Sustaining landscape level ecological functions and habitats for native wildlife species and plant communities.
- Outdoor recreation opportunities associated with open lands and wildlife populations.

- Water retention and filtration to reduce peak flows and filter and purify storm water flows.
- Water retention to sustain ground water recharge and base stream flows.

Feasibility Issues

Minnesotans have voted to support land conservation through the Environmental and Natural Resource Trust Fund and the Legacy Amendment. These resources plus other traditional funding sources provide Minnesota with a unique opportunity to protect and conserve quality habitats, forage production and open lands. However, the existing resources are not likely to be sufficient to meet these goals. The proposal will rely on leveraging significant levels of federal funding as well as continued state investments from the general fund.

Most importantly, conservation land protection is dependent upon voluntary participation by landowners. Market conditions and land prices have significant impact on the level of interest and willingness to participate in programs. Some initiatives have seen very successful large-scale implementation (Minnesota River Conservation Reserve Enhancement Program [CREP] and WRP/RIM) and others have not (CREP II).

Permanent conservation easement programs in the past, such as the Conservation Reserve Enhancement Program, have faced strong opposition from agricultural groups.

Farm groups and others have noted the potential interest in perennial production systems if there were markets that could sustain profitable production. Traditional forage markets exist, but new markets are needed to expand the market potential for perennial crops.

Updating, Monitoring, and Reporting

The Minnesota Prairie Plan co-signatories have developed a Prairie Plan implementation team that is charged with tracking and monitoring progress towards achieving the plan goals. This effort builds upon a variety of individual program tracking efforts. Also the MN DNR and PCA are coordinating the Wetlands Status and Trends Program, which assess and quantified changes in wetland quantity and quality every five years.

Chapter XVII. Appendix F-6. Waste Management Policy Recommendations

Overview

The tables above provide a summary of the microeconomic analysis of Climate Solutions & Economic Opportunities (CSEO) policy options in the Waste Management (WM) sector. The first table provides a summary of results on a stand-alone basis, meaning that each policy option was analyzed separately against baseline (business as usual or BAU) conditions. Details on the analysis of each policy option are provided in each of the Policy Option Documents (PODs) that follow within this appendix.

Direct, Stand Alone Economic Impacts

The stand-alone results provide the annual greenhouse gas (GHG) reductions for 2020 and 2030 in teragrams (Tg) of carbon dioxide equivalent reductions (CO_2e), as well as the cumulative reductions through 2030 (1 Tg is equal to 1 million metric tons). The reductions shown are only those that have been estimated to occur within the state. Additional GHG reductions, typically those associated with upstream emissions in the supply of fuels or materials, have also been estimated and are reported within each of the analyses in each POD.

Also reported in the stand-alone results is the net present value (NPV) of societal costs/savings for each policy option. These are the net costs of implementing each policy option reported in 2014 dollars. The cost effectiveness (CE) estimated for each policy option is also provided. Cost effectiveness is a common metric that denotes the cost/savings for reducing each metric ton (t) of emissions. Note that the CE estimates use the total emission reductions for the policy option (i.e. those occurring both within and outside of the state).

As indicated in the first summary table, WM-2 builds upon and assumes full implementation of WM-3. For both WM-2 and WM-3, the policy options result in net in-state emissions in 2020. However, the total impact of each of these policy options, including out-of-state impacts, is a net reduction in emissions in 2020.

Integrative Adjustments & Overlaps

The second summary table above provides the same values described above after an assessment was made of any policy option interactions or overlaps. In the Waste Management sector there are no overlaps, as removal of any potential overlap between WM-2 and WM-3 was already removed in the analysis. Therefore, the values in the second table are the same as those in the stand-alone table.

Macroeconomic (Indirect) Economic Impacts

Table below provides a summary of the expected impacts of WM policies on jobs and economic growth during the CSEO planning period. This table focuses on the impact of policies on Gross State Product (the total amount spent on goods and services produced within the state), Employment (the total number of full-time and part-time positions), and Incomes (the total amount earned by households from all possible sources). These metrics represent three valuable indicators of both the overall size of the economy and that economy's structural orientation toward supporting livelihoods and utilizing productive work.

For the purposes of macro-economic analysis of CSEO policies, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software. This particular REMI model is developed specifically for Minnesota, and is developed consistently with the design of models in use by state agency staff within Minnesota for a range of economic analyses. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

The main inputs for macro-economic analysis are microeconomic estimates of direct costs and savings expected from the implementation of individual policy options. These inputs are supplemented with additional data and assumptions necessary to complete the picture of how these costs and savings (as well as price changes, demand and supply changes, and other factors) influence Minnesota's economy. These additional data and assumptions typically regard how various actors around the state (households, businesses and governments) respond to change by changing their own economic activity. A full articulation of the general and policy-specific assumptions made by the macroeconomic analysis team is provided in the Policy Option Documents, contained as appendices to this report.

Table AP F-6.1 Waste Management Policy Options, Direct Stand-Alone Impacts

Stand-Alone Analysis							
Policy Option ID	Policy Option Title	GHG Reductions				Costs	
		Annual CO_2e Reductions[a]		2030 Cumulative	2030 Cumulative[b]	Net Costs[c] 2015-2030	Cost Effectiveness[d]
		2020 Tg	2030 Tg	$TgCO_2e$	$TgCO_2e$	$Million	$/$tCO_2e$
WM-1	Waste Water Treatment - Energy Efficiency	0.051	0.068	0.89	0.99	($56)	($56)
WM-2	Front-End Waste Management - Source Reduction	(0.0020)	0.057	0.073	9.4	($277)	($30)

WM-3[e]	Front-End Waste Management - Re-Use, Composting & Recycling	(0.11)	0.15	(0.45)	27	($817)	($30)
Totals		**(0.058)**	**0.28**	**0.52**	**37**	**($1,150)**	**($31)**

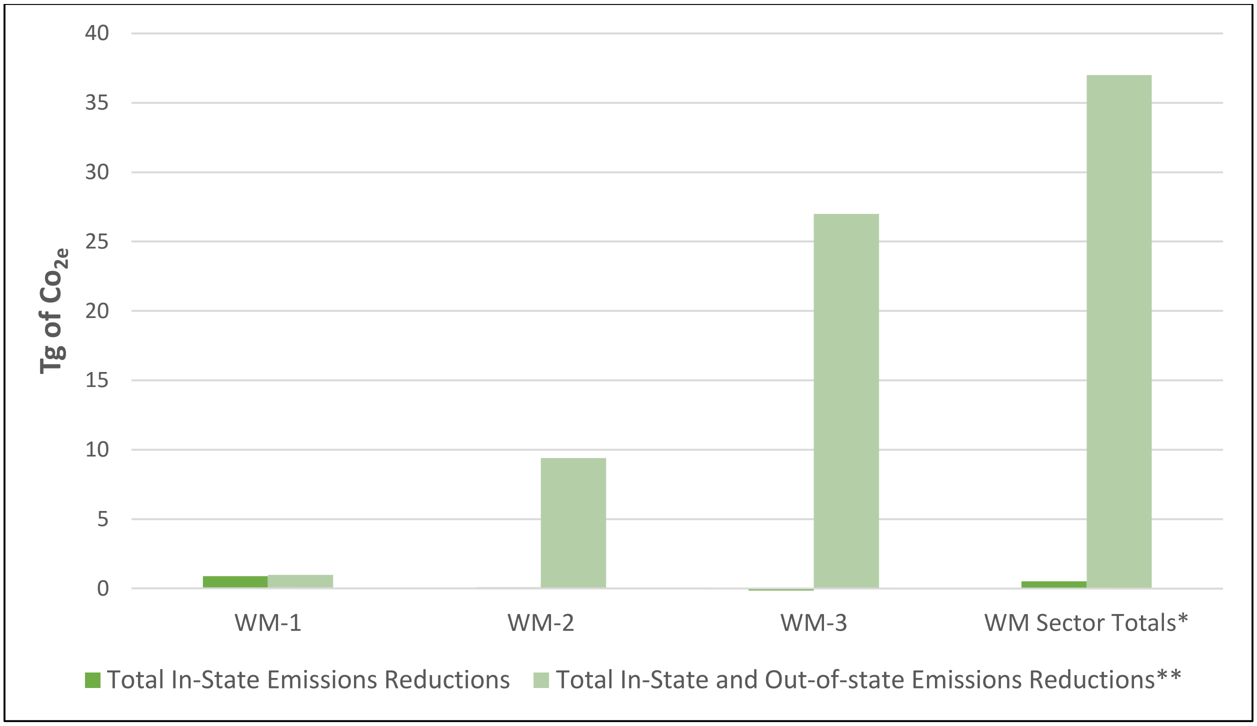
Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] Assumes full implementation of WM-2.

Table AP F-6.2 Waste Management Policy Options, Intra-Sector Interactions & Overlaps

Intra-Sector Interactions & Overlaps Adjusted Results							
Policy Option ID	**Policy Option Title**	**GHG Reductions**				**Costs**	
		Annual[a]		**2030 Cumulative[a]**	**2030 Cumulative[b]**	**Net Cost[c] 2015-2030**	**Cost Effectiveness[d]**
		2020 Tg	**2030 Tg**	**$TgCO_2e$**	**$TgCO_2e$**	**$Million**	**$/tCO$_2$e**
WM-1	Waste Water Treatment - Energy Efficiency	0.051	0.068	0.89	0.99	($56)	($56)
WM-2	Front-End Waste Management - Source Reduction	(0.0020)	0.057	0.073	9.4	($277)	($30)
WM-3	Front-End Waste Management - Re-Use, Composting & Recycling	(0.11)	0.15	(0.45)	27	($817)	($30)
Totals After Intra-Sector Interactions /Overlap		**(0.058)**	**0.28**	**0.52**	**37**	**($1,150)**	**($31)**

Notes:
[a] In-state (Direct) GHG Reductions.
[b] Total (Direct and Indirect) GHG Reductions.
[c] Net Present Value of fully implemented policy option using 2014 dollars ($2014).
[d] Cost effectiveness values include full energy-cycle GHG reductions, including those occurring out of state. Dollars expressed in $2014.
[e] WM-3 builds off of WM-2 and assumes full implementation; so no overlaps.

Figure AP F-6.1 WM Policies GHG Emissions Abatement, 2016-2030



Notes:
* All Policies Total's comprise emissions reductions achieved by WM policies combined.
** Total in and out-of-state emissions reduction are the reductions associated with the full energy cycle (fuel extraction, processing, distribution and consumption). Therefore, the emissions reductions that occur both inside and outside of the state borders as a result of a policy implementation are captured under this value.

Table AP F-6.3 Macroeconomic (Indirect) Impacts of WM Policy Options

Macroeconomic (Indirect) Impacts Results									
Scenario	Gross State Product GSP ($2015 Millions)			Employment (Full and Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)	Year 2030	Average (2015-2030)	Cumulative (2015-2030)
WM-1	$2	$2	$31	90	80	1,130	$8	$6	$86
WM-2	$6	$2	$31	150	60	930	$13	$5	$72
WM-3	$240	$203	$3,039	3,290	2,750	41,210	$319	$223	$3,338

WM Sector Total	**$248**	**$207**	**$3,101**	**3,530**	**2,890**	**43,280**	**$340**	**$233**	**$3,496**

Notes:
[a] Gross State Production changes in Minnesota. Dollars expressed in $2015.
[b] Total employment changes in Minnesota.
[c] Personal Income changes in Minnesota. Dollars expressed in $2015.
[d] Single final year value. Year 2030 is the final year of analyses in this project.
[e] Average value from the year 2016 to the year 2030. The average value is calculated from the first year of the policy implementation through the year 2030 if implementation of the policy starts after year 2016.
[f] Cumulative value from 2016-2030 time period.

Figure Ap F-6.2 – Average Annual Jobs Impact of WM Policies, Individually and in Concert

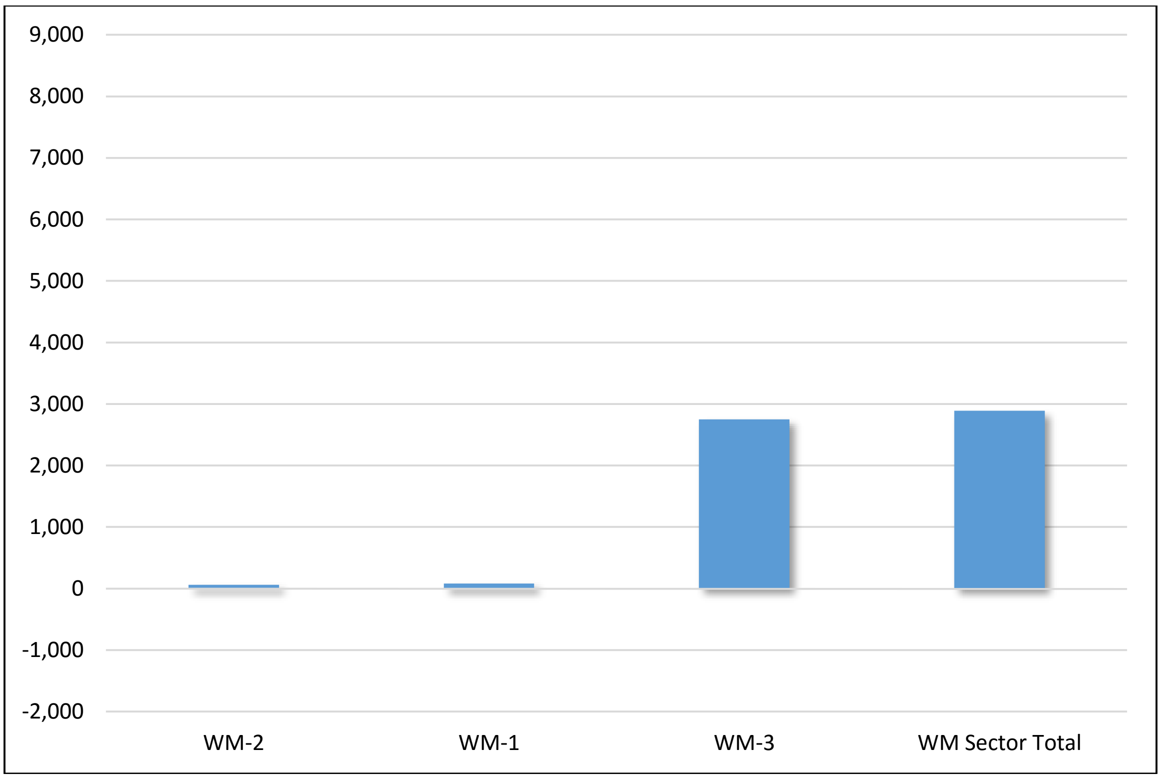
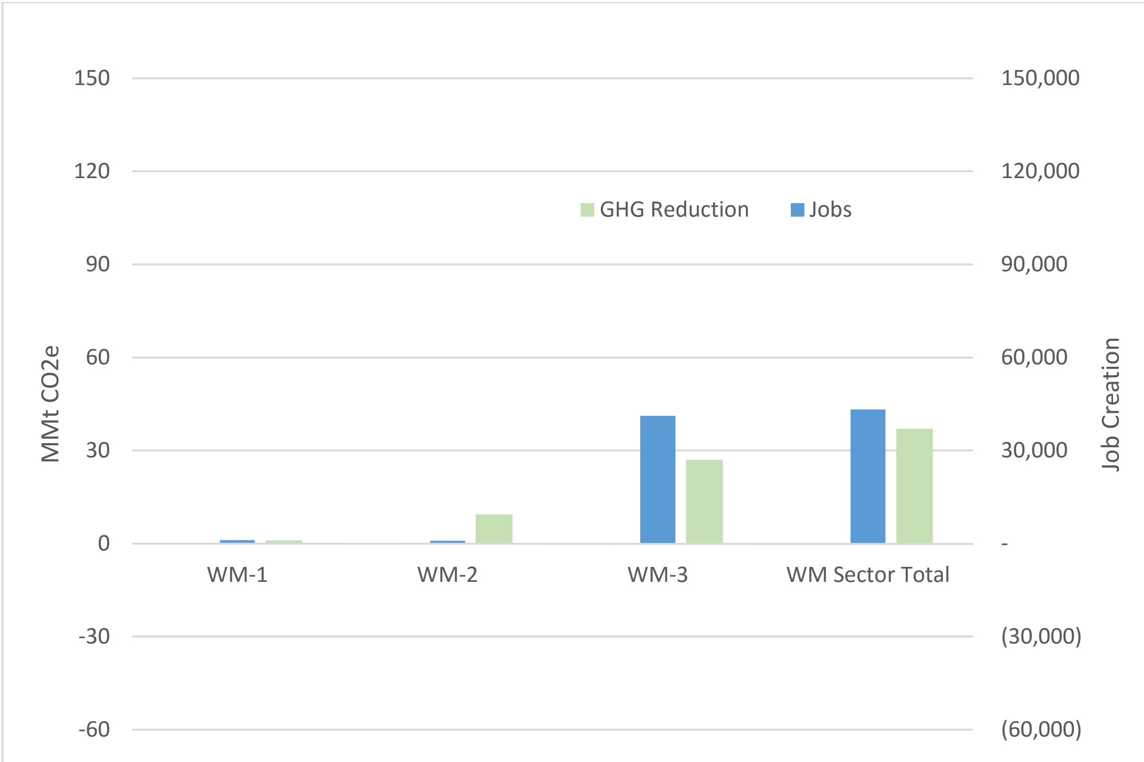


Figure F-3.3 below summarizes a potential for job creation and GHG emissions abatement of TLU sector policies on the same graph. This allows for a simultaneous assessment of performance of individual CSEO options against two crucial environmental and economic indicators.

Figure AP F-6.3 – Cumulative Jobs and Emissions Impacts of WM Policies



Sector level index

The graphs below express the overall economic impact from each scenario in a single score, and compares those scores. CCS created this single score (a Macroeconomic Impact Index) in order to encapsulate in one measurement the relative macroeconomic impacts (including jobs, GSP and incomes) of each policy. We have found in our own work and in the literature that indexed scores can be helpful to many readers when comparing options with multiple characteristics.

To produce this score, CCS set the results from the absolute best-case scenario (i.e. the implementation of all CSEO policies with all their optimal sensitivities in place) equal to 100, with that scenario's jobs, GSP and incomes impacts weighted equally at one third of the total score. Each policy's jobs, GSP and income impacts are scaled against that measure, and given a total score. The overall score indicates how significant a policy's impact is projected to be. Negative impacts are scaled the same way, except that those impacts are given negative scores and pull down the total score of the policy.

These scores are calculated separately for the final year of the study (2030), the *average* impact over the 2016-2030 period, and the *cumulative* impact of the policies over that period. While each scenario has one line, the relative importance of jobs, income and GSP remain visible as differently-shaded segments of that line.

Figure AP F-6.4 WM Macroeconomic Impacts, 2030

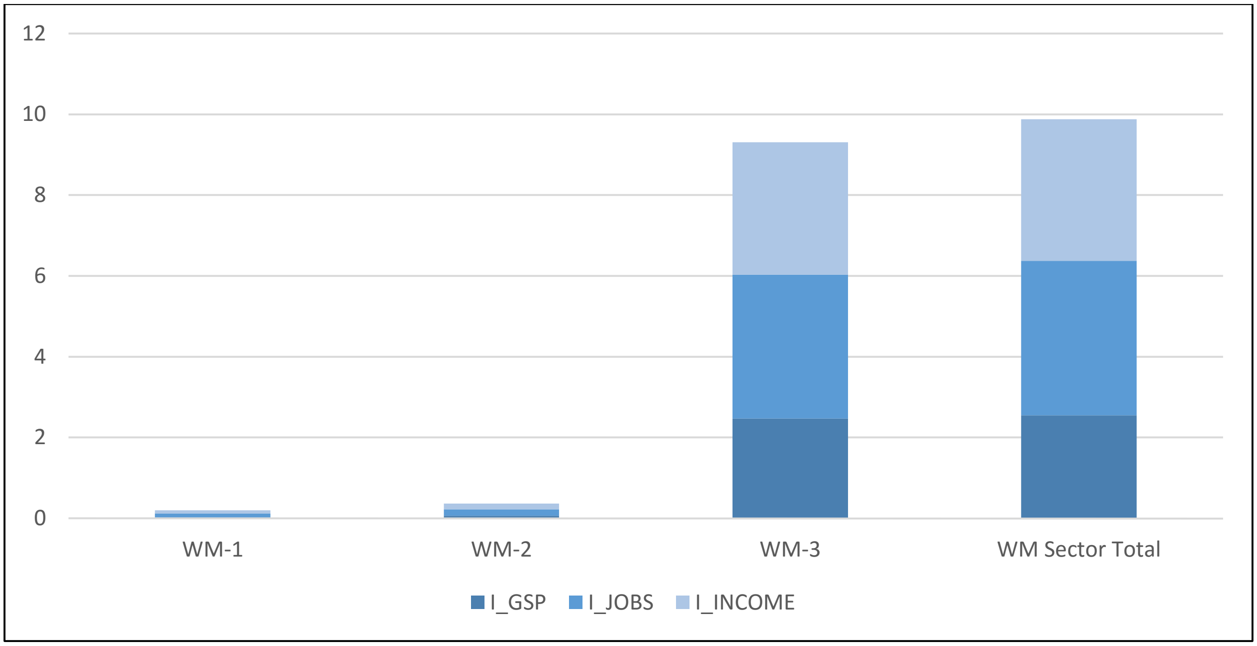


Figure AP F-6.5 WM Macroeconomic Impacts, 2016-2030, Yearly Average

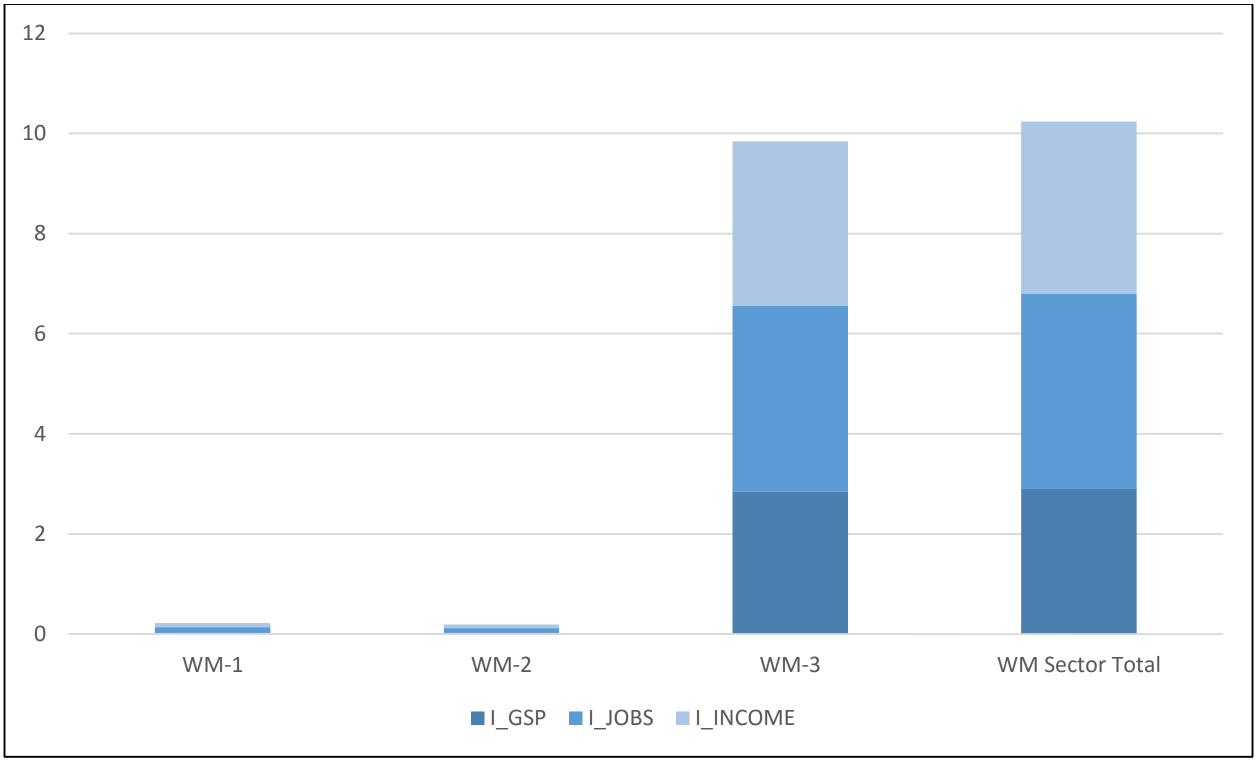
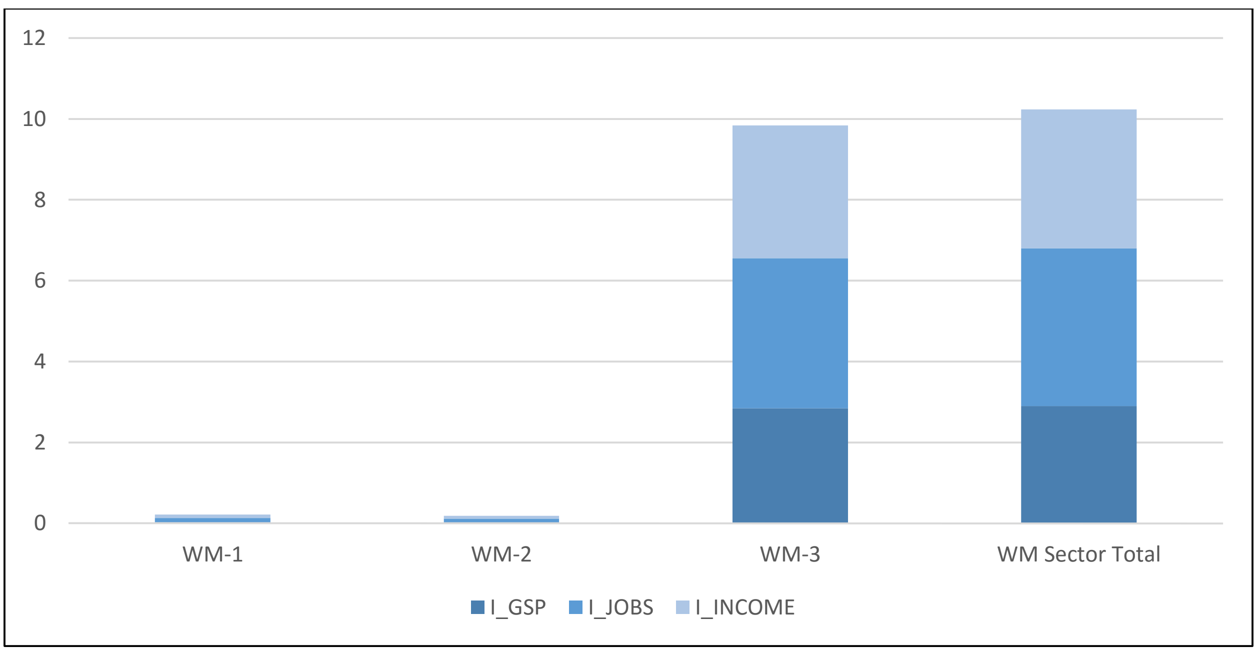


Figure AP F-6.6 WM Macroeconomic Impacts, 2016-2030, Cumulative



Graphs below show the trend of WM policy macroeconomic impacts during the year 2015 to the year 2030.

The Waste sector generates significant positive impacts – around $250 million in GSP and nearly $350 million in income, with 3,500 jobs more than would exist in the state by 2030 than if these policies were not implemented.

The sector impact on Minnesota's economy, according to this analysis, is really the story of the waste reduction policy focused on recycling, re-use and composting waste (WM-3). While the other policies are tiny in their overall impacts, driving very small positive or negative shifts over time, the WM-3 policy is responsible for effectively all of the sector's gains.

Figure AP F-6.7 WM GSP Impacts ($2015 MM)

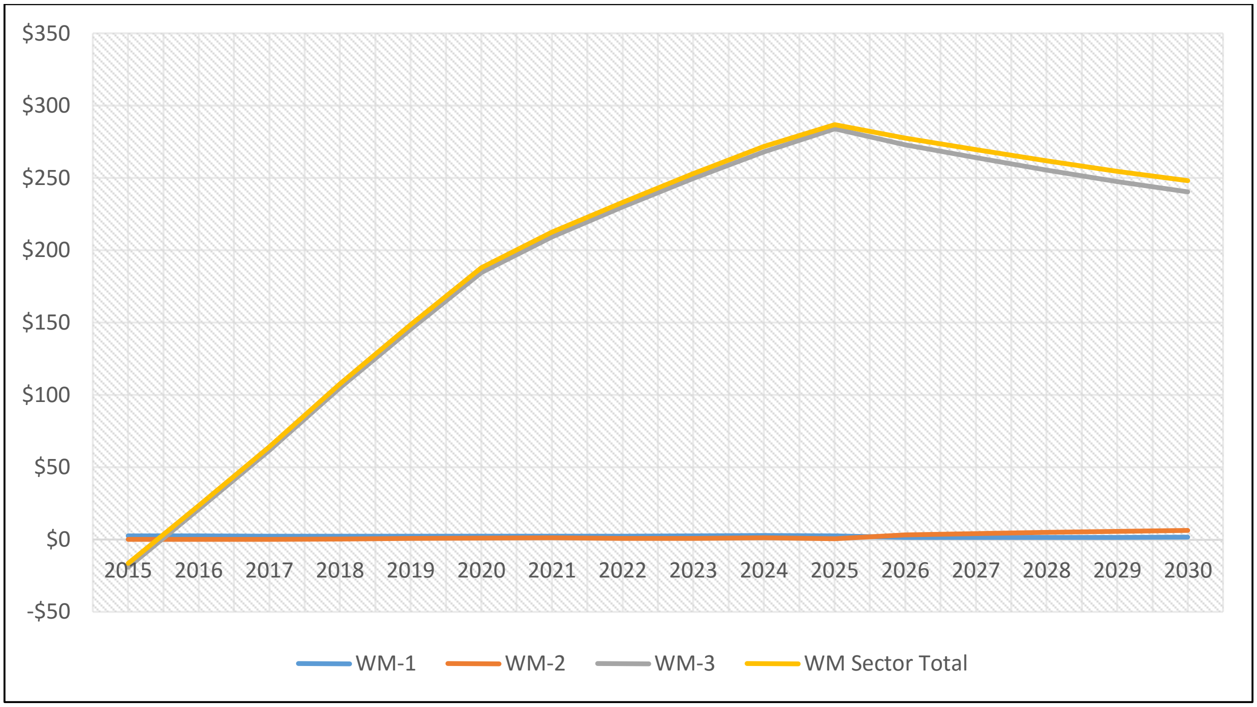


Figure AP F-6.8 WM Employment Impacts (Individual Jobs)

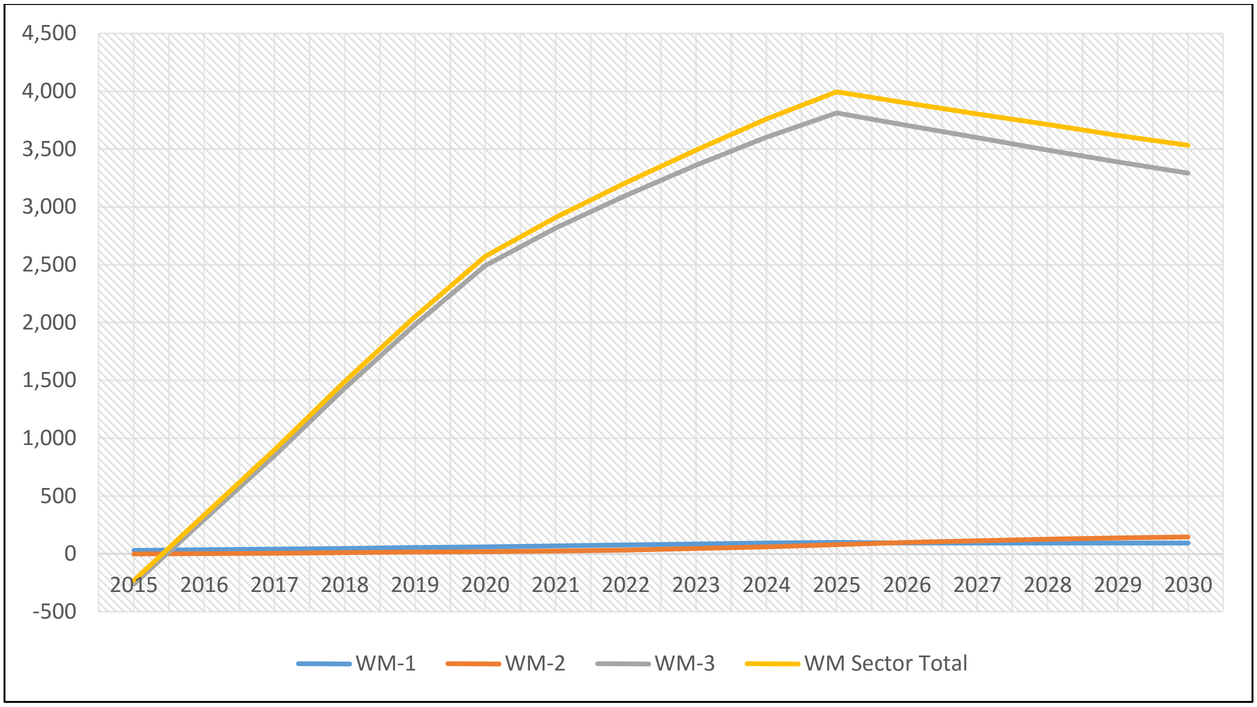
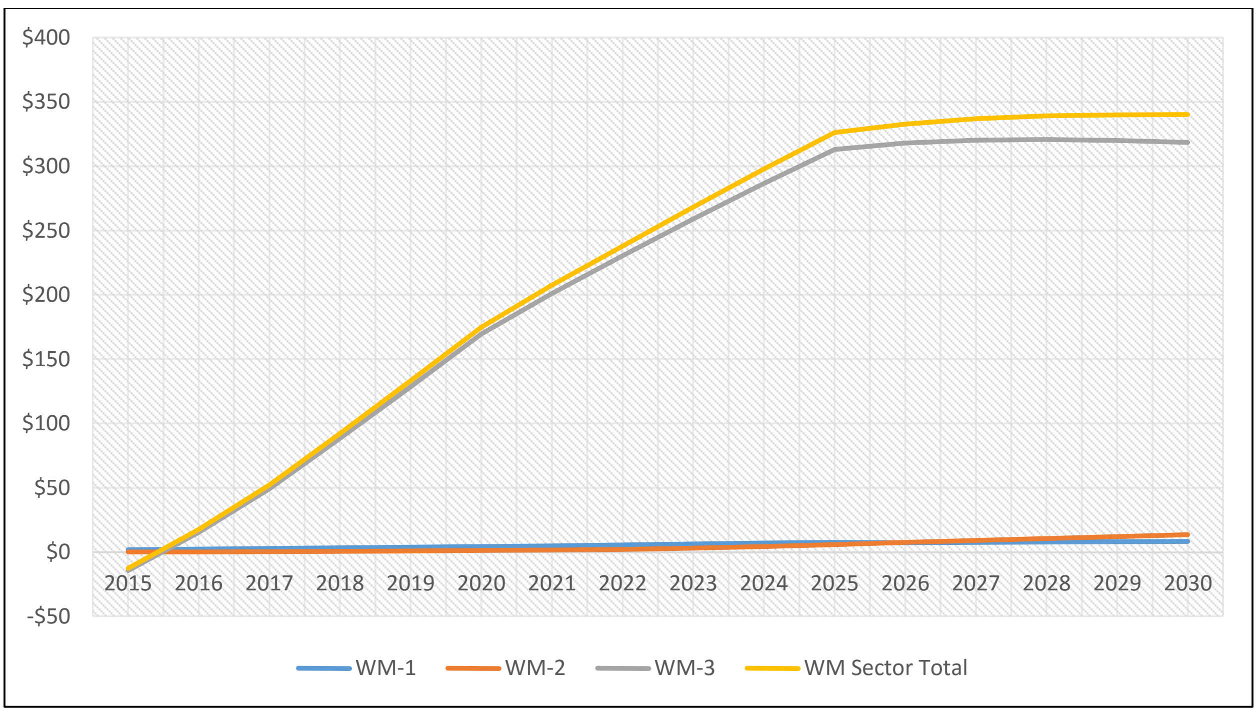


Figure AP F-6.9 WM Income Impacts ($2015 MM)



Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030).

Figure AP F-6.10 WM GSP Impacts, 2016-2030 Average ($2015 MM)

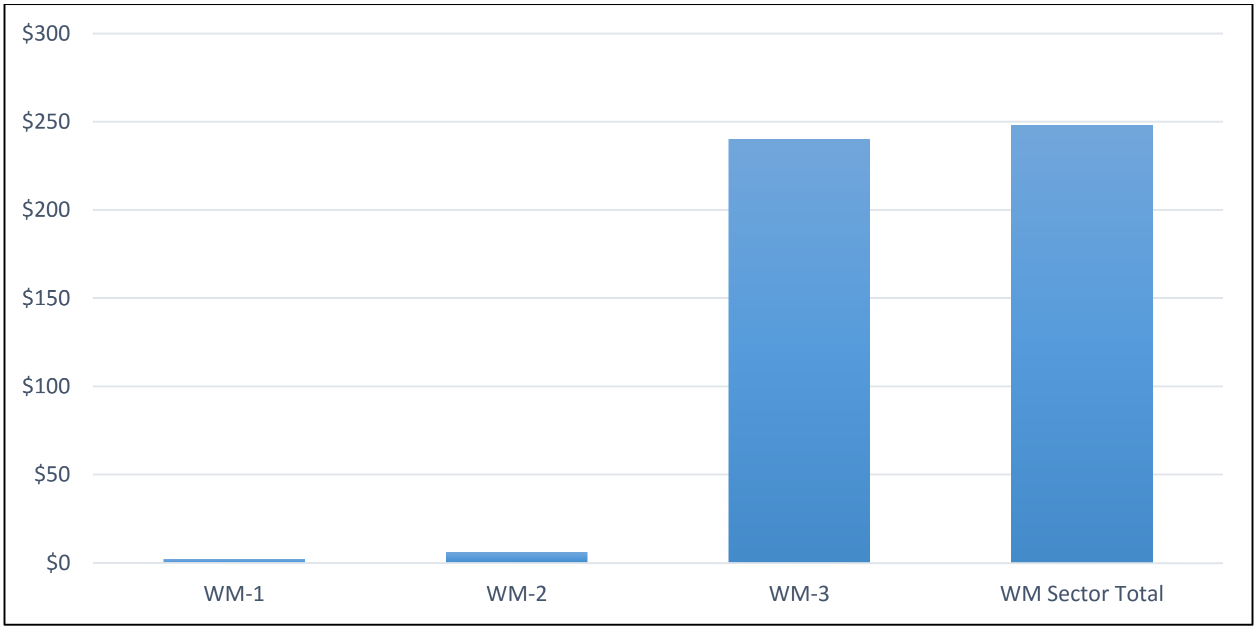


Figure AP F-6.11 WM GSP Impacts, 2016-2030 Cumulative ($2015 MM)

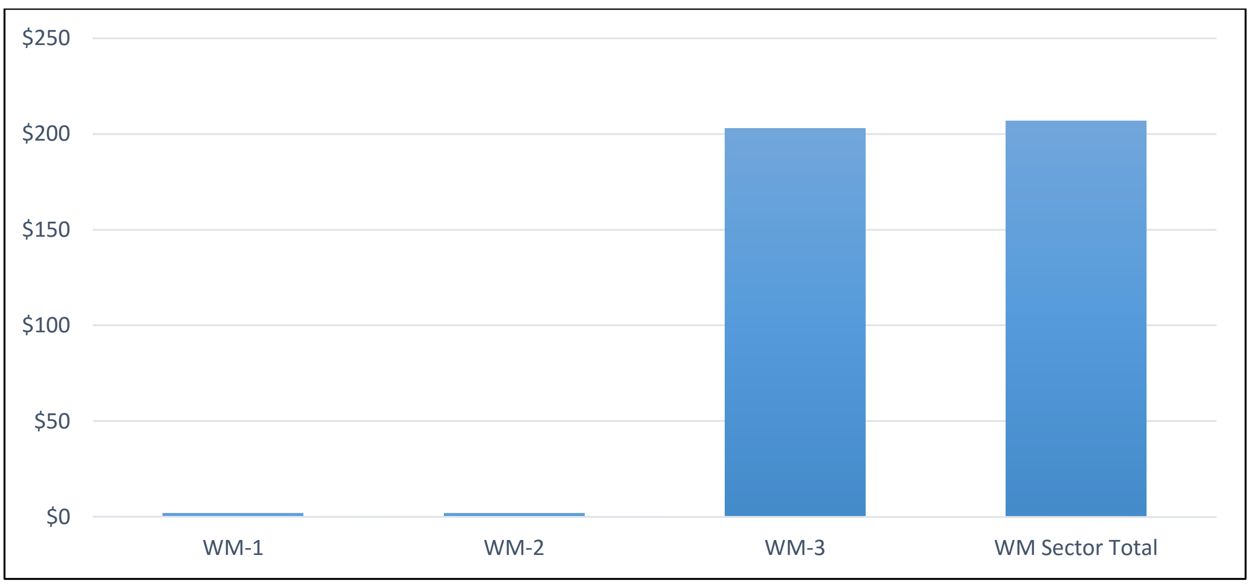


Figure AP F-6.12 WM GSP Impacts, Year 2030 ($2015 MM)

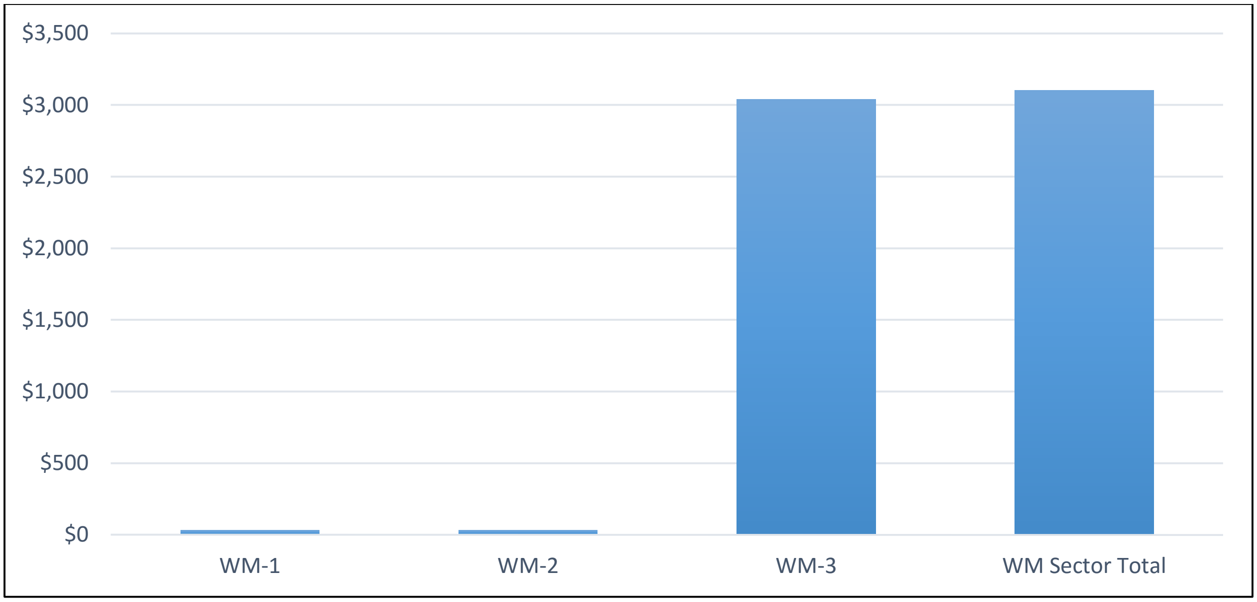


Figure AP F-6.13 WM Employment Impacts, 2016-2030 Average (Jobs)

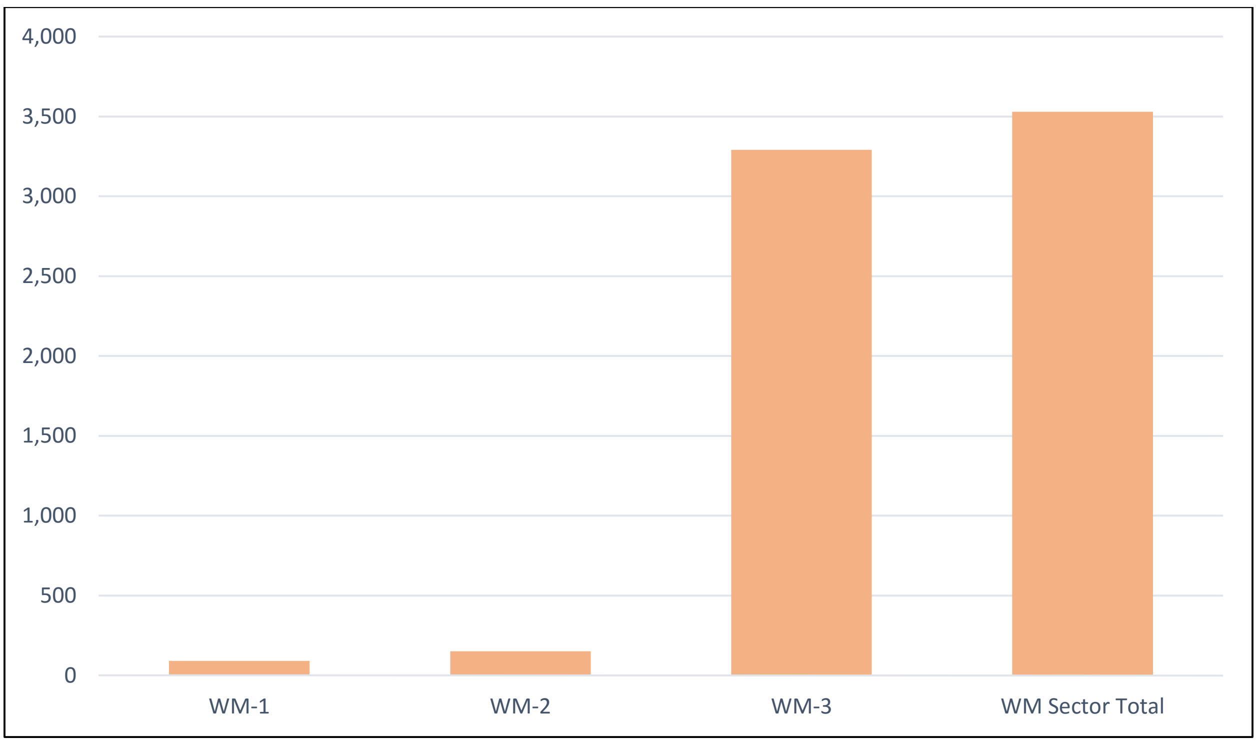


Figure AP F-6.14 WM Employment Impacts, 2016-2030 Cumulative (Jobs)

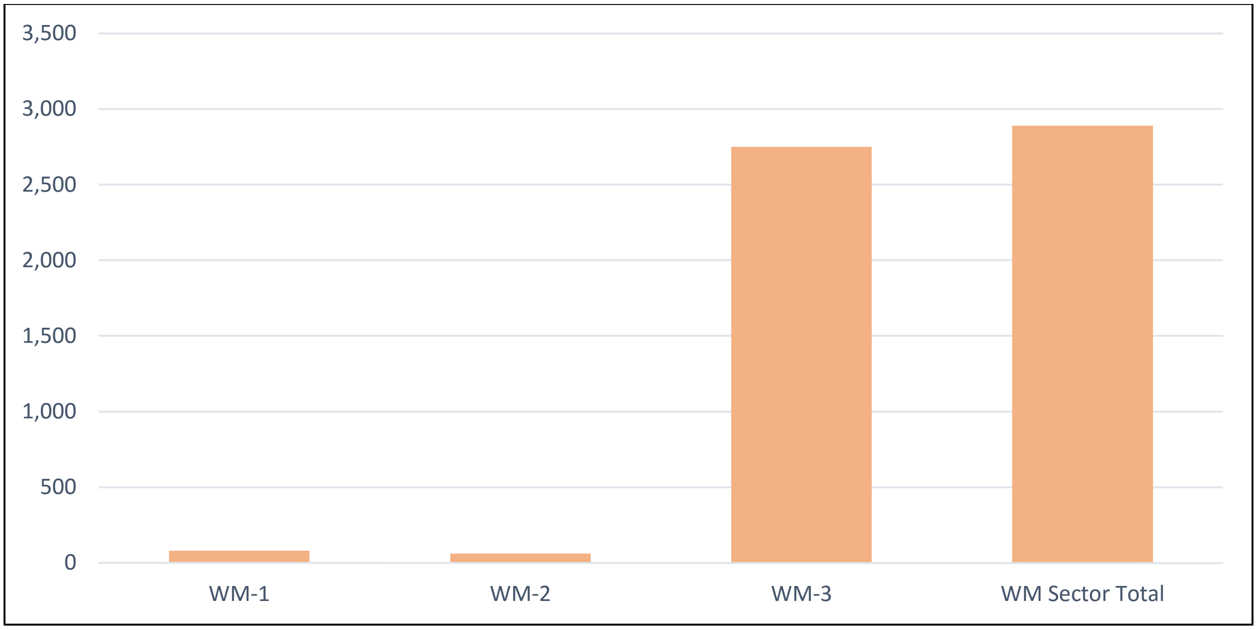


Figure AP F-6.15 WM Employment Impacts, Year 2030 (Jobs)

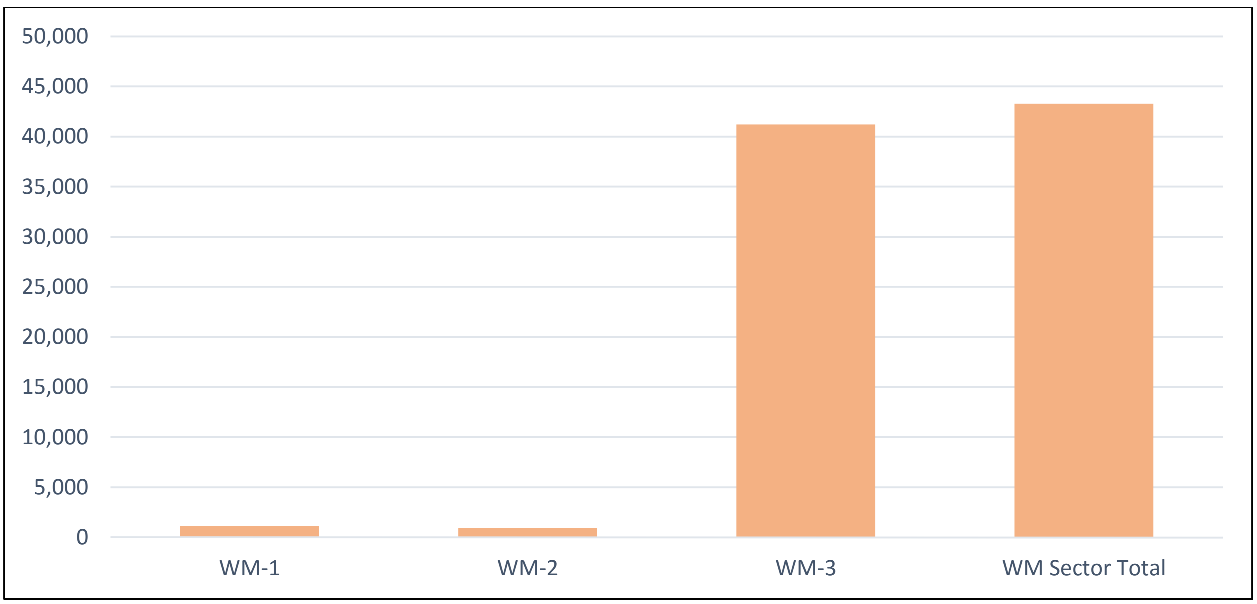


Figure AP F-6.16 WM Income Impacts, 2016-2030 Average ($2015 MM)

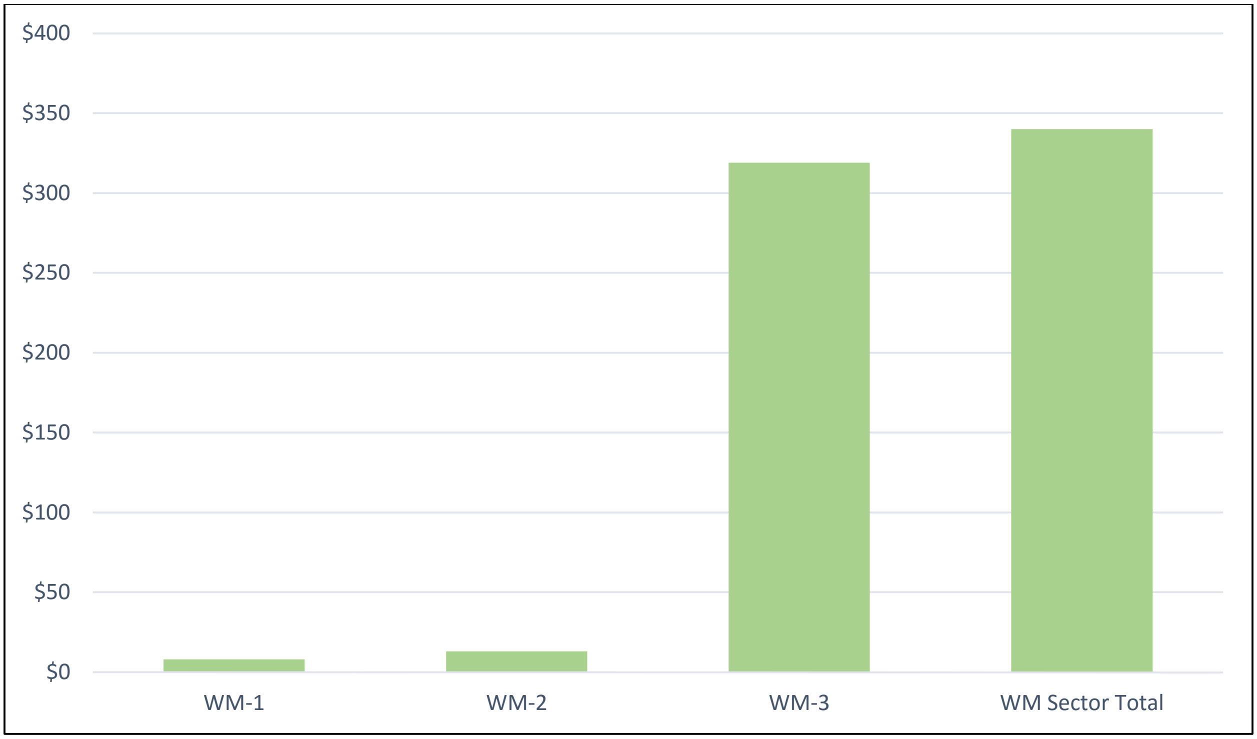


Figure AP F-6.17 WM Income Impacts, 2016-2030 Cumulative ($2015 MM)

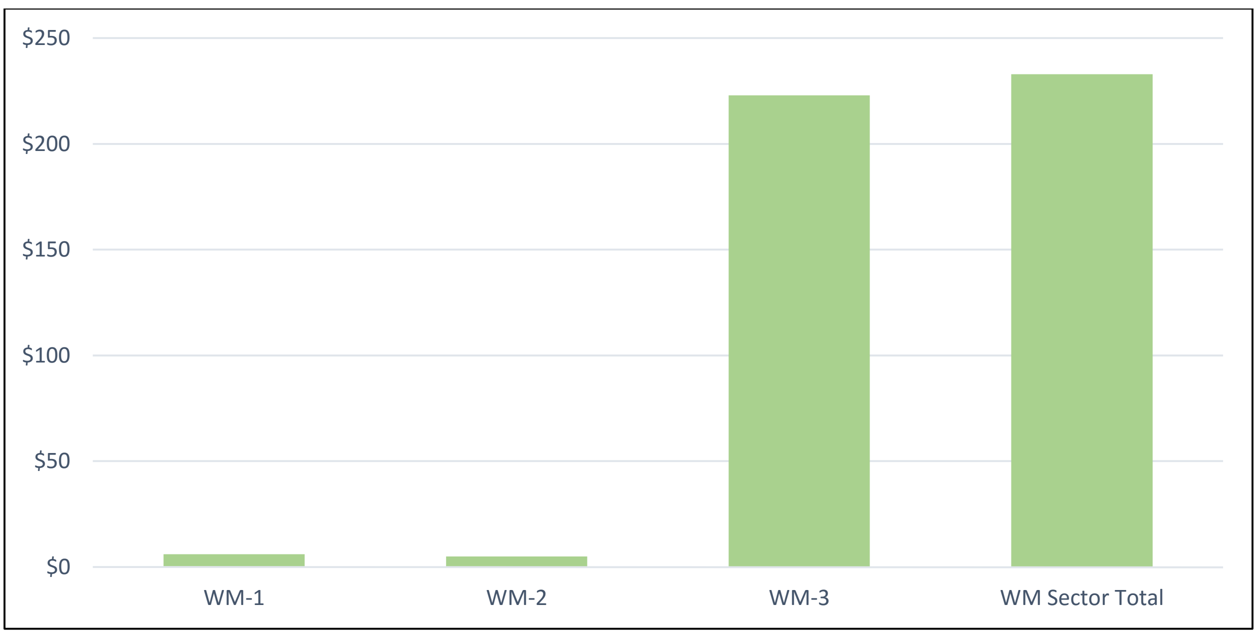
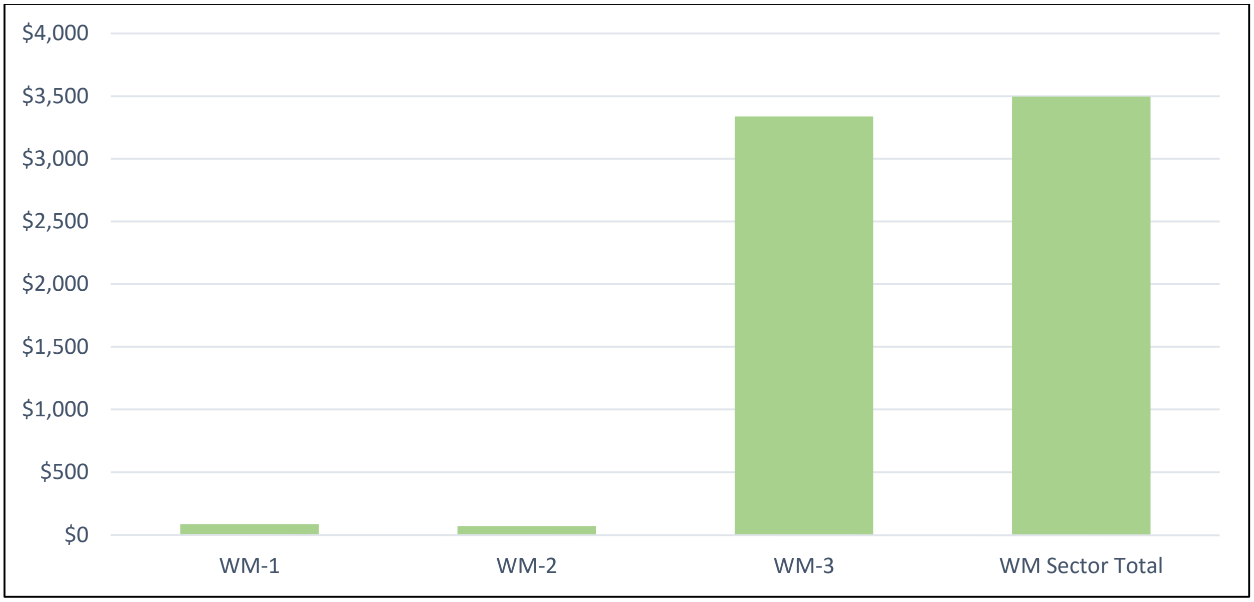


Figure AP F-6.18 WM Income Impacts, Year 2030 ($2015 MM)



WM-1. Wastewater Treatment – Energy Efficiency

Policy Option Description

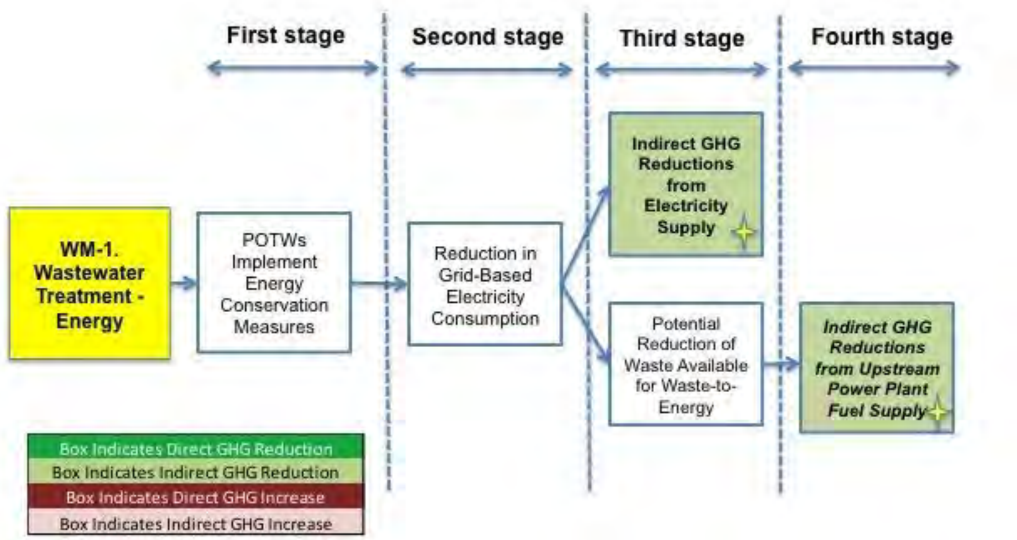
Publicly Owned Treatment Works (POTWs) are large energy consumers nationally, and in Minnesota. For instance, the Metropolitan Council's Environmental Services (MCES) is among the top 10 of Xcel Energy's customers in Minnesota and has successfully achieved great savings through energy conservation. However, the potential for conservation is still large and offers savings in utility bills for the Metro.

This policy option addresses opportunities for energy conservation within POTWs. The conservation mandate is technology agnostic to allow for flexibility. Biogas or other in-plant generation of energy can also be used to reduce the grid power purchase required. This could include, but is not limited to: wind, solar, anaerobic digestion (with or without co-digestion of non-wastewater feedstock), micro-hydro, recovery of heat (from wastewater or POTW processes, etc.).

GHG reductions are primarily achieved by reducing or off-setting the use of grid-based power and the associated fossil fuels combusted to generate power.

Causal Chain for GHG Reductions

Figure AP F-6.19 Causal Chain for WM-1



The causal chain above identifies the main policy option effects and the subsequent GHG impacts. The star symbol identifies GHG effects that will be quantified.

Policy Option Design

Goals: Mandate for Publicly-Owned Treatment Works (POTW) owners:

Energy Conservation: Reduce electrical energy purchase by 25% from continuing operations by 2025.

Timing: See above; assume a linear progression toward the goal with implementation beginning in 2015.

Parties Involved:

- Division of Energy Resources (DER) in the Department of Commerce, Pollution Control Agency, and Public Facilities Authority are state agencies that should coordinate implementation of the program.
- Energy utilities are impacted by the conservation and demand for Conservation Improvement Program (CIP) funding.

- MCES, other sanitary districts, and cities with their own POTWs will be affected. Their ratepayers may be affected by changed costs. Most conservation measures will save costs, over the lifecycle.

Implementation Mechanisms

The state should adopt the mandate listed above; state laws and rules will also need to be changed. It is proposed that the mandate have exemptions for economic hardship, to be defined later, and that state Wastewater Infrastructure Fund (WIF) program be targeted at energy efficiency improvements to make it economical for those exempted to get the needed energy work done. WIF is state capital bonding dollars and is available for those with economic hardships now; administered by Public Facilities Authority (PFA).

State agencies should budget as needed for their roles:

- PCA and DER are expected to generate and maintain a toolkit for POTW energy projects, and pursue program funding via alternative Conservation Improvement Program (CIP) dollars from energy utilities. PCA staff may be able to facilitate further energy savings by bringing together groups of similar facilities to work together on design changes and group buying of equipment.
- PCA should determine credit for early action (e.g. MCES work since 2007 which was verified by utilities and DER through CIP).
- Public Facilities Authority should (PFA), as allowable by federal rules, make:
- State Revolving Fund (SRF) green reserve funding available primarily for energy projects, and available independently of other POTW work rankings, and
- Wastewater Infrastructure Fund (WIF) grants available only for good energy designs.
- The POTWs should be entirely responsible to pick technologies and implement the projects.

In addition to the mandate incentives should be provided:

- The PFA should, within the state revolving funds, be required to de-link the green reserves from the usual water and wastewater facility project rankings, or preserve the green funds for emissions reducing improvements to the maximum extent allowed by federal law and EPA rules. PCA should create a separate ranking that provides funds based primarily on emissions reduction expectations at POTWs.
- Within the state WIF program, the PFA should be required to adopt the Energy Star methodology for measuring the energy efficiency in a POTW, and limit regular funding to those that meet an energy star ranking of 75 or more, in their designs (that is, POTWs

whose design is expected to perform better than 75% of peers for size and level of treatment technology).

- DER has, and should, continue to pursue federal grant money to assist a POTW energy program; and
- The PCA should pursue an alternative CIP to make funding available to POTWs from energy utilities' CIP programs for studies and enhanced conservation rebates.

Related Policies/Programs in Place and Recent Actions

The MCES wastewater division has a goal of 25% energy purchase reductions by 2015 and 50% reduction by 2020 based on a 2006 baseline. Through 2014, 19% reduction has been accomplished, saving approximately $4 million/year for MCES ratepayers.

Estimated policy Impacts

Direct Policy Impacts

Table AP F-6.4 WM-1 Estimated Net GHG Reductions and Net Costs or Savings

2030 GHG Reductions ($TgCO_2e$)	2015 – 2030 Cumulative Reductions ($TgCO_2e$)	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ tCO_2e)
0.07	**0.88**	**-$56**	**-$57**

Notes:

Each policy option analysis was done over a fifteen year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Data Sources

Facility-level flow rates for mechanical wastewater facilities were obtained from the Environmental Protection Agency (EPA) Clean Water Needs Survey (CWNS) 2008 Database. This database contained data for 144 Minnesota facilities. According to the MnTAP EPA R5 Study, there are 600 facilities in Minnesota; 300 of these are mechanical, and the other half is pond systems. An additional 138 mechanical facilities and 33 aerated pond systems were identified in the Minnesota Pollution Control Agency (MPCA) facility database, which contains design flow data. A comparison of design flow and existing flow between the two data sets indicated that most facilities are operating at around 50% of design flow. Therefore, existing flow for the additional facilities was estimated as 50% of design flow.

Baseline electricity consumption for typical mechanical wastewater facilities was estimated from data from the EPA report, “Energy Efficiency Demonstration Projects and Audits for Minnesota’s Wastewater Treatment Plants.” Electricity consumption values were estimated for four different wastewater capacities: less than 1 million gallons per day (mgd), 1-5 mgd, 5-10 mgd, and more than 10 mgd.

Quantification Methods

GHG Reductions:

According to the MnTAP EPA R5 Study, there are 600 wastewater facilities in Minnesota. Roughly half of these facilities are mechanical systems, the other half are pond systems. The two main types of ponds systems are stabilized lagoons and aerated lagoons. Stabilized lagoons are primarily gravity fed systems with no aeration. These systems have very low energy usage. Therefore, energy reductions and the associated GHG reductions were calculated for mechanical facilities and aerated lagoon systems only.

For mechanical facilities, the BAU energy consumption for different flow rate classes was based on estimated values for electricity consumption per unit of flow and the plant-level flow rates from the facility databases listed under Data Sources. BAU efficiency measures were assumed to reduce the baseline energy consumption over the forecast period. The BAU forecast assumes that 15% of facilities have initiated energy efficiency measures by 2015, with additional one percent initiating measures each year thereafter. BAU energy efficiency measures were assumed to reduce plant-wide electricity consumption by eight percent.

For aerated lagoon systems, most of the electricity consumption is from the aeration system. Baseline electricity consumption was estimated based on the assumption that the aeration blowers have a rated power of ten hp per million gallons of lagoon capacity.[1] Lagoon capacities were estimated from plant-level flow rates and estimated detention times (three days for aerated polishing ponds, and 25 days for aerated lagoons). [2]

Reductions in electricity consumption and associated emissions were estimated by applying the target reductions to the baseline consumption values.

Net Societal Costs:

Case studies of high-efficiency blower equipment installations were identified for six wastewater treatment facilities. These studies showed a cost and electricity reduction; installed, high-efficiency blowers are estimated to save $0.55 per annual kWh. This value was

[1] EPA, 2002. “Wastewater Technology Fact Sheet: Aerate, Partial Mix Lagoons.”
[2] MPCA, 2013. “Stabilization Pond Systems: Operations, Maintenance, Management.”

applied to the estimated reductions in electricity consumption to calculate capital costs. Capital costs were annualized assuming financing at five percent interest over 20 years.

The other component of the net costs is electricity savings, which was estimated based on the reductions in electricity consumption and the avoided costs for electricity.

Key Assumptions

While the policy option is technology agnostic, for the purposes of analysis, facilities were assumed to achieve energy efficiency goals by replacing aeration equipment. Aeration equipment accounts for slightly more than half the energy usage of mechanical facilities and most of the energy consumption for aerated lagoon facilities. Replacement of older aeration blowers with new high-efficiency blowers can reduce energy consumption for aeration by 50% or more. Therefore, it was assumed that replacing these systems would be sufficient to achieve the 25% energy consumption reduction goal of this policy option.

Other key assumptions are listed above under GHG Reductions and Net Societal Costs.

Macroeconomic (Indirect) Impacts

Table AP F-6.5 WM-1 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
WM-1	$2	$2	$31	90	80	1,130	$8	$6	$86

Graphs below show detail in GSP, employment and personal income impact of the WM-1 policy.

Figure AP F-6.20 WM-1 GSP Impacts ($2015 MM)

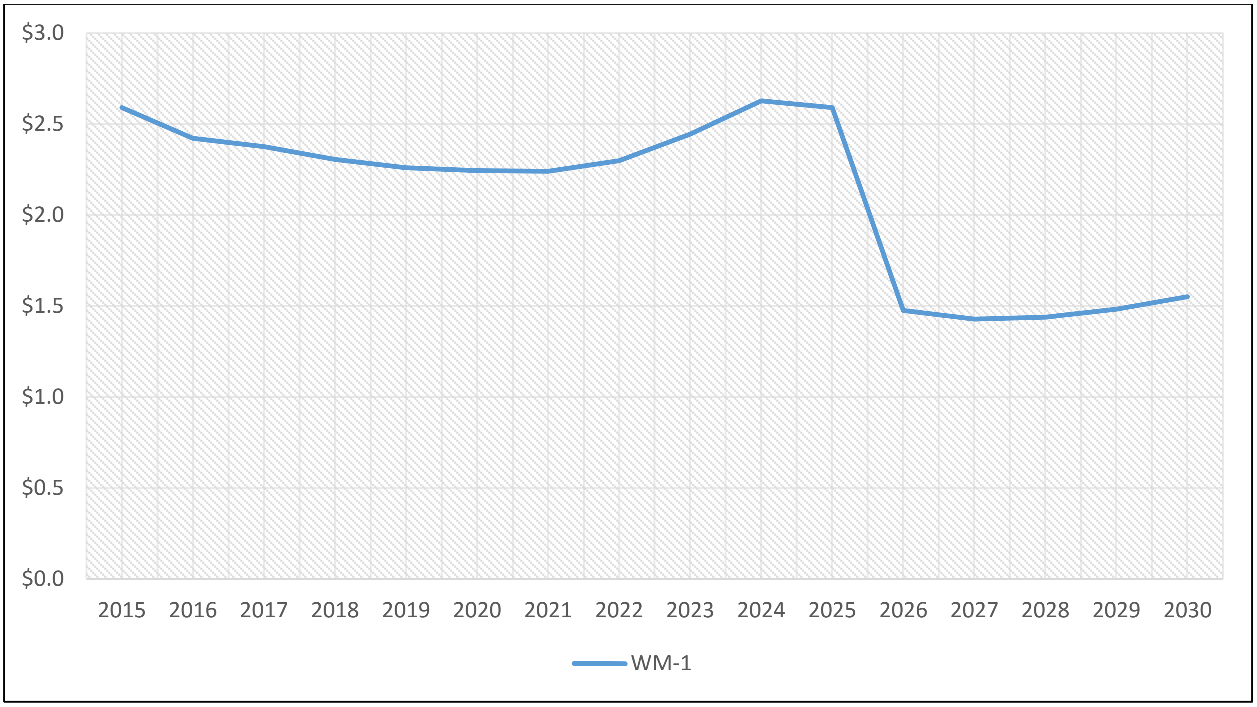


Figure AP F-6.21 WM-1 Employment Impacts (Individual Jobs)

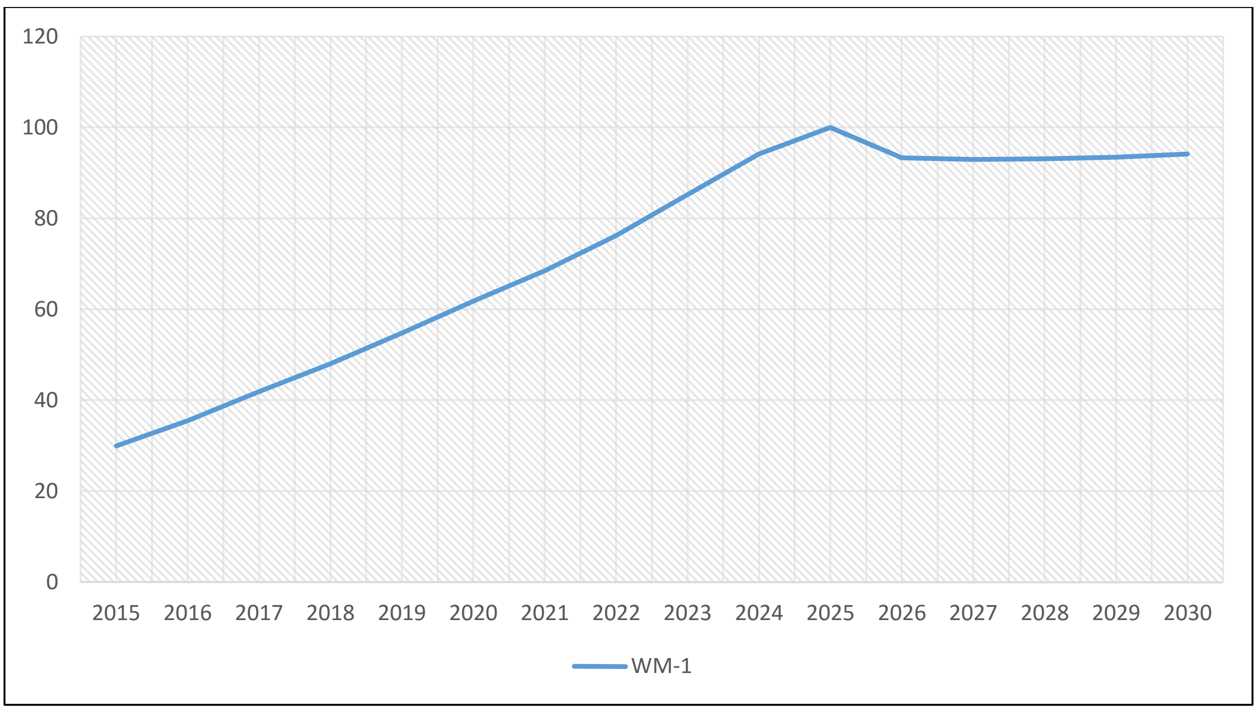
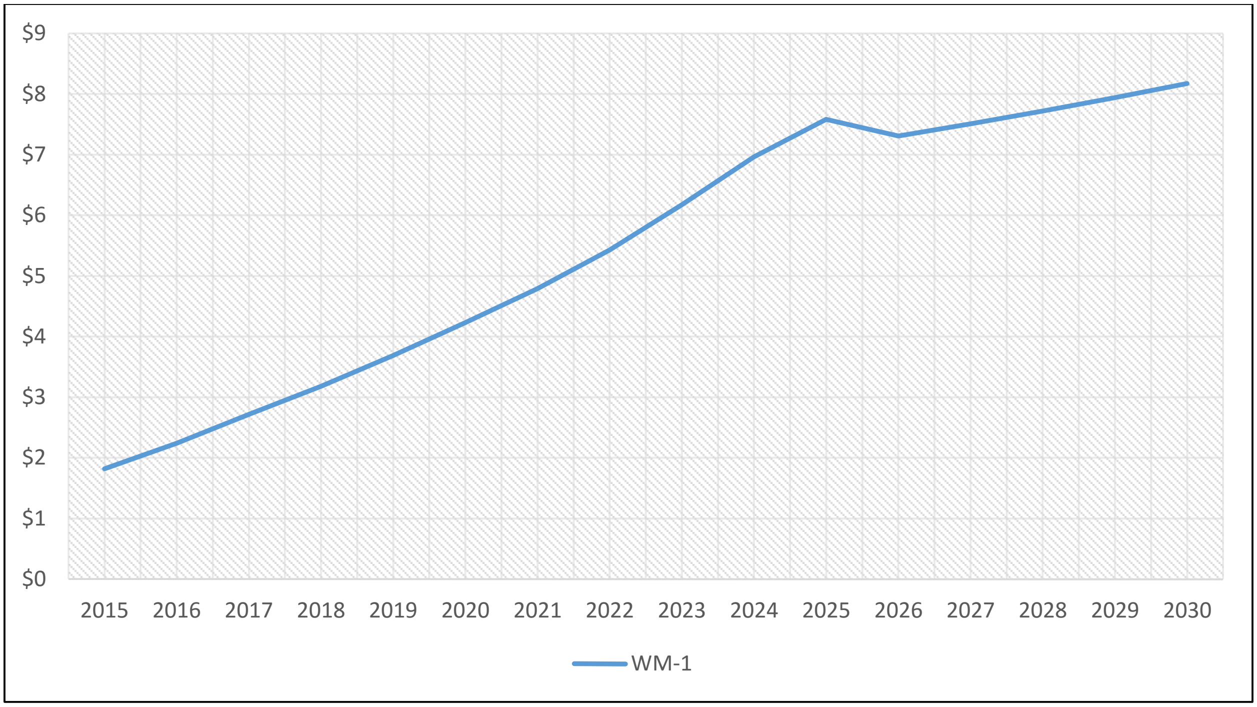
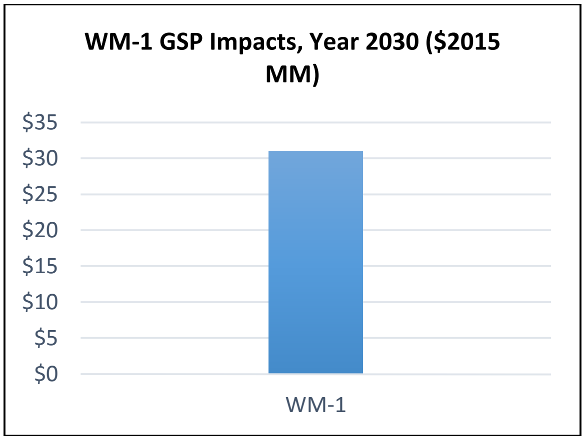
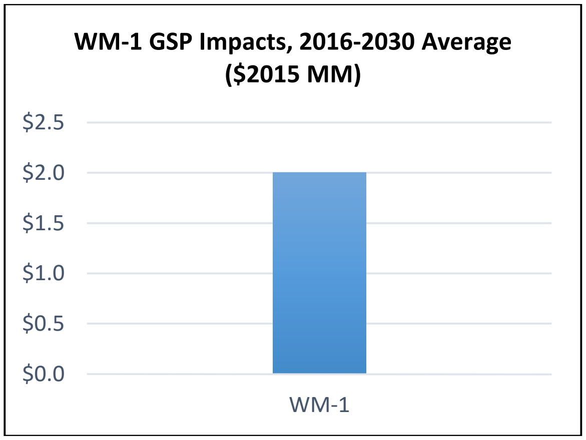


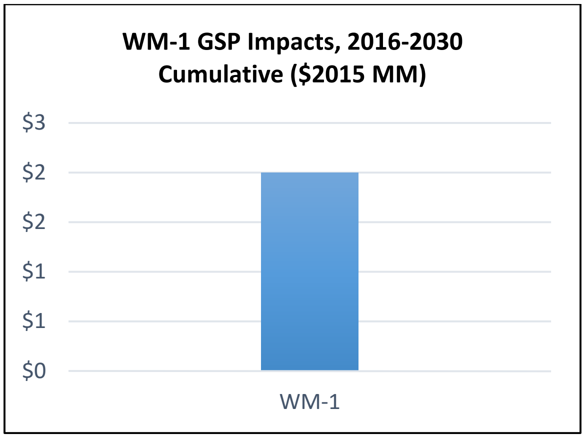
Figure AP F-6.22 WM-1 Income Impacts ($2015 MM)

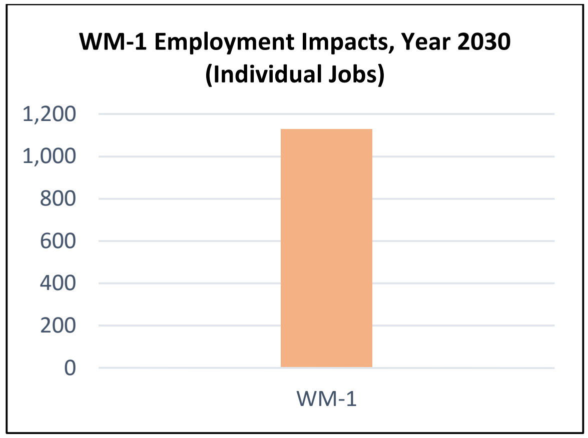


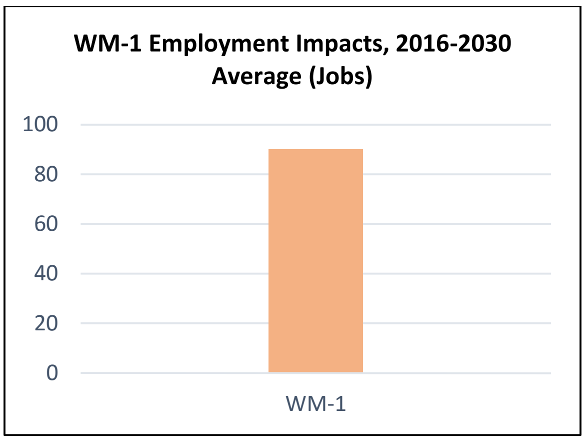
Graphs below show macroeconomic impacts on GSP, personal income, and employment in the final year (2030), in average (2016-2030) and in cumulative (2016-2030).

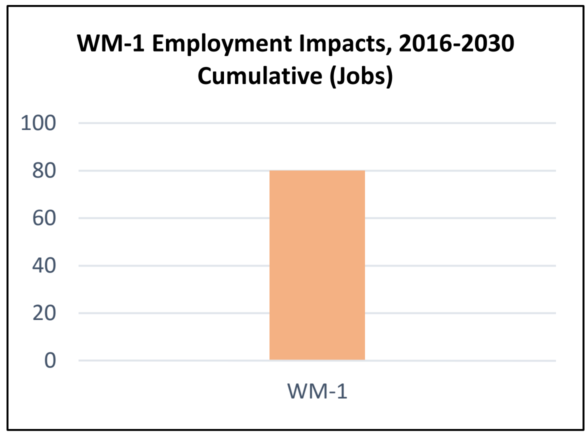


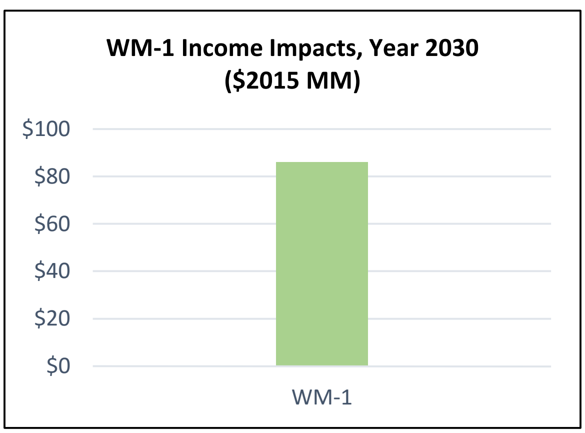


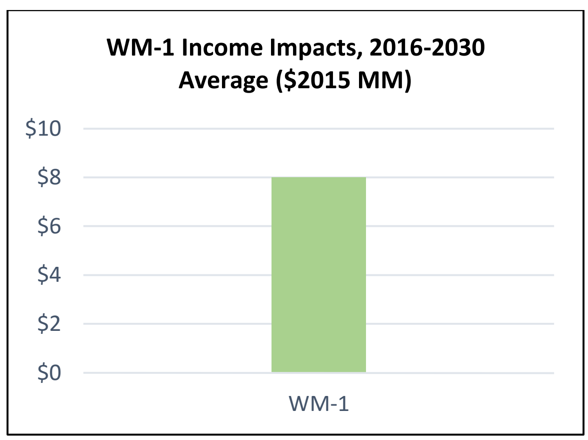

WM-1 GSP Impacts, 2016-2030
Cumulative ($2015 MM)
$3
$2
$2
$1
$1
$0
WM-1

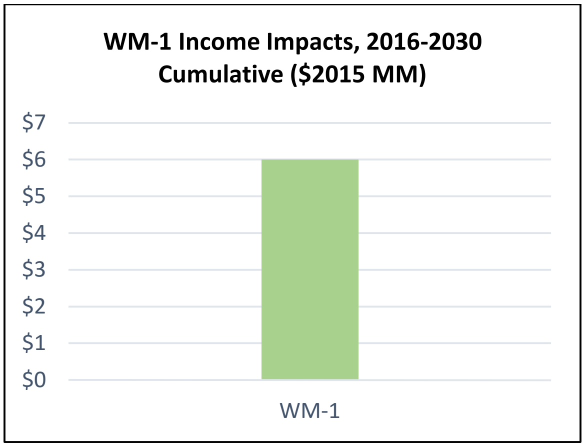

WM-1 Employment Impacts, Year 2030
(Individual Jobs)
1,200
1,000
800
600
400
200
0
WM-1


WM-1 Employment Impacts, 2016-2030
Average (Jobs)
100
80
60
40
20
0
WM-1


WM-1 Employment Impacts, 2016-2030
Cumulative (Jobs)
100
80
60
40
20
0
WM-1


WM-1 Income Impacts, Year 2030
($2015 MM)
$100
$80
$60
$40
$20
$0
WM-1


WM-1 Income Impacts, 2016-2030
Average ($2015 MM)
$10
$8
$6
$4
$2
$0
WM-1



Principal Drivers of Policy Impact on the Broader Economy

This policy shows slight positive impacts. The net savings to the government to carry out water treatment expands its ability to spend in other programs, though the volumes of spending changes are very small. GSP and incomes are never forecast by this analysis to vary more than a few million dollars statewide, and total employment never more than 100 total positions. This is best understood.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy.

These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the WM-1 policy, important data included:

- The cost of installing high-efficiency pumps in water treatment facilities.
- The electricity savings achieved as a result of using those pumps.
- The responsive ability of the government to spend more on other programs, as the savings from electricity overwhelm the financed capital cost of the new infrastructure.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.

- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.
- State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

Changes in rates of electricity or innovations that make efficiency technologies cheaper are uncertainties on the cost of implementation. In particular, the cost of generating biogas and using that energy may rapidly change with advances in technology.

Additional Benefits and Costs

Reducing unnecessary energy use saves municipalities money and reduces air and water impacts of electricity generation.

Feasibility Issues

It is acknowledged that without strong financial support, the mandate will be politically very difficult and that outreach to find an acceptable level needs to be done before this policy option should be publicly proposed or supported.

WM-2 & WM-3. Front-End Solid Waste Management

Policy Option Description

Front-end solid waste management (SWM) technologies promote the reduction of the sheer volume of waste needing disposal, as well as reduction in consumption through incentives, awareness, and increased efficiency. Four major areas of focus in Minnesota are source reduction, reuse, advanced recycling, and organics diversion. Source reduction, reuse, and recycling provide GHG benefits not only from avoided disposal emissions, but also from reducing product energy-cycle emissions that would otherwise come from the manufacture and transport of new products and packaging. Redirecting organic materials into food-to-people, food-to-livestock, and composting programs cuts GHG emissions compared to disposal in landfills (food-to-people and food-to-livestock programs also reduce upstream energy-cycle emissions).

This policy option reflects a continuation of the AFW-7 policy option from the Minnesota Climate Change Advisory Group (MCCAG) report. Following that report in 2008, the 2014 Legislature codified a 75% total recycling goal (that is, a total that combines conventional dry recycling and composting, food-rescue, and food-to-animals) for the seven Metro counties.[3] Following the MCCAG report, Minnesota has taken several important steps at the state and local levels to make those goals attainable. As of 2012, the statewide dry recycling rate was 42%, and the organics diversion rate was seven percent including yard waste, for a combined recycling rate of 49%.

This policy option would be implemented using two distinct policy option components:

- WM-2. Source Reduction
- WM-3. Re-Use, Recycling, and Composting

Details on goals for each component are provided in the Policy Option Design section below. The GHG reduction causal chains below provide a schematic for each component that indicates the policy option effects and the associated energy and GHG impacts.

[3] NOTE: commonly, within the SWM industry, this would be referred to as a "diversion" goal (diversion from landfills or combustion), rather than a "recycling" goal, since more management methods are being used than just recycling.

Causal Chains for GHG Reductions

Figure AP F-6.23 Causal Chain for W-2 GHG Reductions

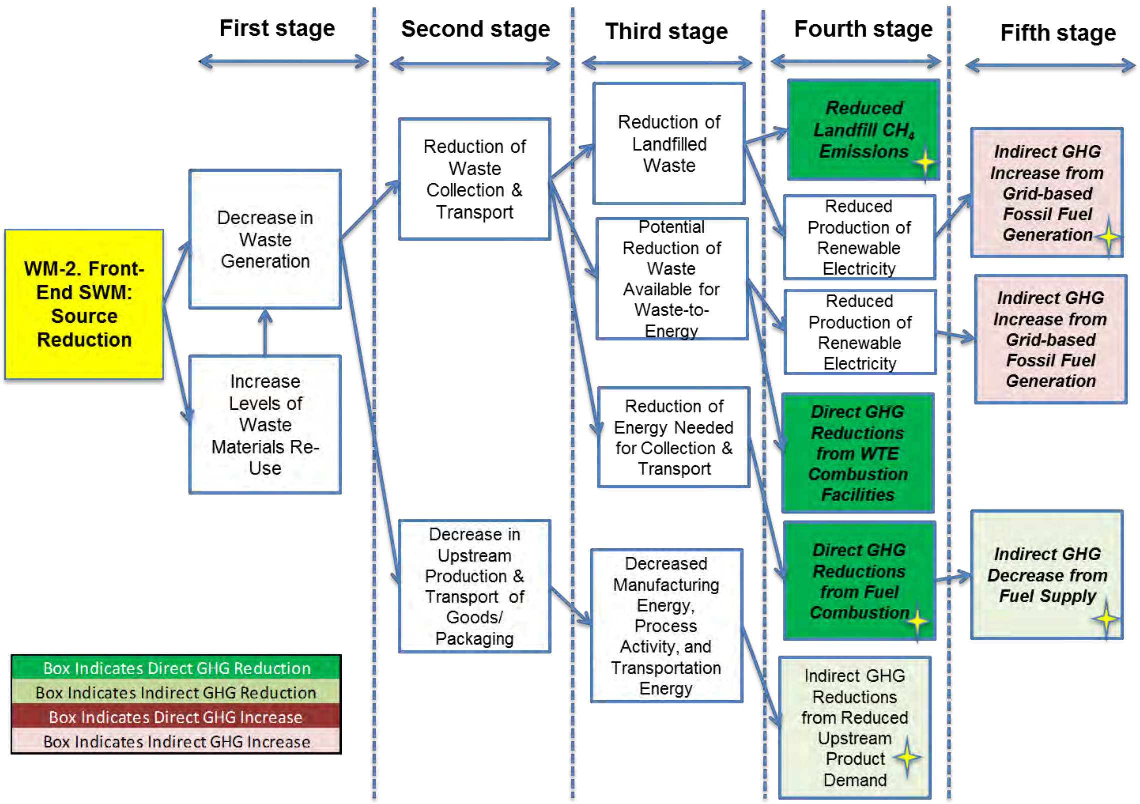
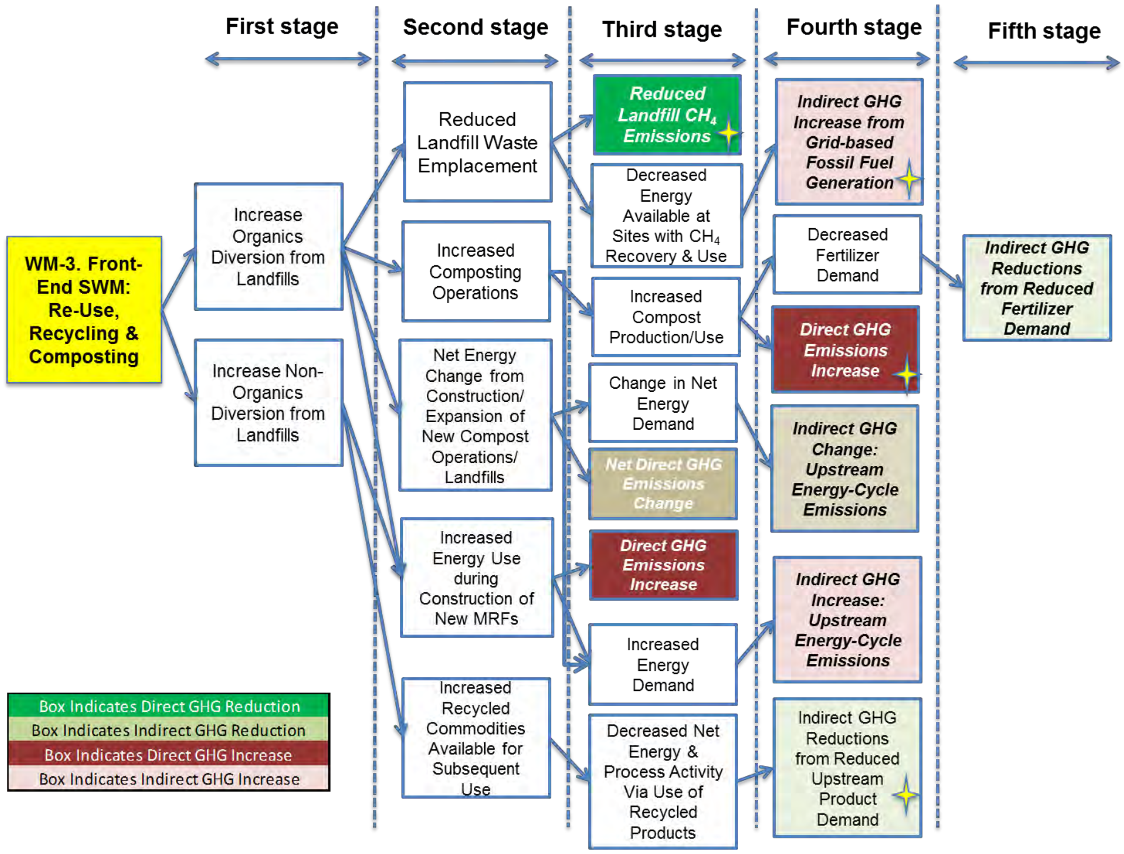


Figure AP F-6.24 Causal Chain for W-3 GHG Reductions



The star symbol identifies GHG effects that were quantified. GHG effects that were not quantified were not readily quantifiable (e.g. due to data or methodological limitations), but are also not considered to be significant. This policy option analysis assumes that the current mass of waste managed via waste-to-energy (WTE) combustion facilities stays constant through the CSEO planning period. Therefore, WTE impacts are not quantified.

Note that both landfilling and composting are often considered to store biogenic carbon (e.g. food/yard waste, paper, wood, cardboard). This GHG effect is not shown in the causal chain above; however, the net difference between these two management methods will also be quantified. Shifts away from downstream waste management (e.g. between landfilling and composting) as a result of source reduction and reuse also result in changes in energy consumption and GHG emissions associated with waste collection and transport which will be quantified.

Implementation of the policy option would involve some construction of new composting facilities and associated equipment manufacturing. The associated GHG emissions would be temporary, and, for the purposes of this analysis, are not considered to be significant. MPCA believes that the current capacity of material recovery facilities (MRFs) in the metro-region is sufficient for the additional recycling activity envisioned by this policy option.

Policy Option Design

Goals:

- *WM-2. Source Reduction Goal:* Achieve a zero percent per-capita increase by 2020 and a reduction of waste generation per capita of three percent by 2025.
- *WM-3. Reuse, Recycling and Composting*: Achieve a total recycling[4] rate (including composting) of 75% by 2025.

Timing:

- *Source Reduction & Reuse:* Achieve a zero percent per-capita increase by 2020 and a reduction of waste generation per capita of three percent by2025 statewide.
- *Recycling, Food to People, Food to Livestock and Composting:* The 75% goal is gradually introduced at a linear rate from 2016 to 2025. MSW is not diverted from WTE.[5]

Parties Involved: MPCA, Governor's Office, legislators, organic diversion and permitting staff, counties and other local units of government, private waste management industry, and general private industry (end markets for recycled materials). Significant societal changes will be needed to achieve the goals, which in turn will require significant support from policy option makers, decision makers, manufacturers, retailers, regulatory agencies, environmental and non-profit organizations, and the general public.

Other: As the recession hit, not surprisingly, Minnesota saw a decrease in the amount of MSW generated. Importantly, even after the economic recovery, as of 2012, the per-capita rate of MSW generation remained more than seven percent below 2005 levels. MPCA has also analyzed personal consumption expenditures of Minnesotans and has seen a weakening relationship between consumption expenditures and solid waste generated. While the source reduction numbers may not be caused by any one factor, one change that could be responsible for some of the reduction is that more people are choosing to live with less. We have seen trends that younger people are looking to live in the city, use public transportation/walk/bike to work and live in less square footage. All of these, plus light-weighting and material changes, lead to buying (and eventually disposing) of fewer goods and associated packaging.

[4] The Recycling sub-policy goal includes composting, recycling, and re-use. CCS understands the State of Minnesota's definition of recycling includes all three of these waste management methods, which is different in other jurisdictions (e.g. re-use and composting are considered by many to be organics management methods, but these aren't included within a definition of recycling).

[5] Assumption is based upon WTE's running at capacity to achieve maximum electricity generation.

Since the 1989 enactment of legislation based on recommendations of the Governor's Select Committee on Recycling and the Environment (SCORE), annual reports have estimated recycling in the state. According to the SCORE reports covering waste management in Minnesota, the rates of recycling have leveled off since 1989. In 2012, Minnesota had a statewide recycling rate of 49.2%, including an organics recycling (food to livestock, food to people, and source-separated composting). Minnesota had an estimated source reduction rate of three percent.

Though there are two separate sub-components included with this overall policy option, the two sub-components are quantified in a way that captures the results of both being implemented together. The over-arching assumption behind quantifying the sub-components together is: if there is a per-capita source reduction, this will affect the amount of resources available for the recycling sub-policy option.

Implementation Mechanisms

The following priority list of implementation mechanisms would benefit all aspects of front-end SWM:

- More attention to better recycling and composting practices at businesses, including non-MSW materials, such as industrial-process waste. Address outdated provisions in state rules and laws that have been encouraging businesses to switch garbage (mixed municipal solid waste, or MMSW) into non-MMSW waste categories that allow cheap dumping into non-MMSW landfills.
- Expand organized collection opportunities for traditional recyclables and organics at curbside, with particular attention to commercial generators.
- Changes to waste disposal fees (e.g. pay-as-you-throw plans and the SWM Tax at the generator level). The goal is to more accurately internalize costs and unfunded risks to the public. Among those currently externalized costs are gas emissions now being vented from some landfills (rather than flared or captured for energy), and long-term post-closure risks.
- Education of the public and those who produce goods and packaging: including product stewardship, reduction, and sustainable design. Barring some significant advance in source reduction or reusability as shown by a peer-reviewed life-cycle study, in general, packaging materials should be designed for recyclability or compostability. These save energy and offer a much higher job-creation potential than direct disposal.
- Better product design is not sufficient; valuable goods and materials must also be captured before discard. Residents need more feedback about good practices, particularly in single-sort systems now prone to high residue fractions. This feedback can and should be benchmarked on real data, such as the statewide waste-composition sort

published in 2013, and on periodic waste-composition sorts already being done under permit requirements at WTE plants. If landfills were also to conduct periodic composition sorts of incoming waste like WTE plants now do, decision makers would know whether curbside separation should be supplemented by mechanical sorting of MMSW before burial. Policy option responses to the “uncaptured and valuable materials” problem could include disposal bans on certain materials, and/or recovery targets.

Also, specific to organics:

- Provide a financially viable infrastructure for organics processing, including improved markets and public education. Better economics for expanded organics recovery is important because it won’t be possible to reach a combined rate of 75% recycling/organics rate by 2025 without major gains in affordable organics-processing and collection capacity.

Following is a secondary list of implementation mechanisms, depending on progress achieved with the primary methods listed above:

WM-2. Source Reduction:

- Better product design: in general, products with extended usefulness and reparability offer much better greenhouse gas avoidance than recycling after a short useful life. It’s important to have more reusability and reparability as well as recycled content into products in the design phase.
- Prevent food waste: Work on preventing food waste using the tools that have been developed by the EPA and the Minnesota resources. Multi-partner effort aimed at both residents and businesses.
- Expand Environmentally-Preferable Purchasing (EPP): Expand local, state and national EPP guidelines to include environmental life-cycle analysis on government purchasing (or at least energy-cycle analysis). Choose products and services that would have large greenhouse gas emission reductions and use the state purchasing contract to request vendors to offer lower-impact goods and services or use best practices. Encourage eligible users to purchase off the state contract.
- Acquire and track information about GHG and waste:
    - Identify consumer products and packaging that have high GHG footprints or that are neither recyclable nor compostable. Share this information with other government, institutions, business entities, and public.
    - MPCA tracks and reports **all** solid waste – including construction, demolition and industrial (CD&I) waste along with MSW. Not counting CD&I excludes

approximately 50% of Minnesota's waste (including high-GHG concrete and wood) from consideration and policy option attention.

- Employ Minnesota Consumption Based Emissions Inventory as a supplement to the conventional "territorial boundary" inventory. By looking beyond the state borders, this will allow for more accurate assessment and understanding of Minnesota-driven GHGs. It will estimate reductions of upstream GHG emissions when goods produced outside of but consumed in Minnesota are source reduced, and upstream benefits of recycling that accrue outside of Minnesota but due to Minnesota's increased recycling.

- Create voluntary initiatives, including increasing consumer education about consumption and waste and working with manufacturers and retailers to change product or packaging. These initiatives would be developed, prioritized, and targeted at products and packaging based on quantities in the waste stream, energy intensiveness of production, and disposal-related emissions.
- Participate in development of international or national product or packaging regulations (based on high footprint priorities) light-weighting of packaging, etc.
- Expand "Green Building" programs.

WM-3 Re-use, Recycling & Composting:

Increase reuse and recycling to limit GHG emissions associated with landfill methane generation, waste combustion, WTE combustion processes, and the extraction of raw materials and energy consumption during the manufacturing process. Mechanisms to achieve the recycling goals include:

- Significantly expand the types of materials collected, to include significant new materials (more types of plastics, mattresses, demolition and construction materials, industrial wastes, etc.) with associated funding for changes in collection infrastructure.
- Expand traditional and nontraditional recycling end markets.
- Assist local governments with organized recycling systems so that there is a clear and standardized list of recyclable materials within a particular community.
- Establish state and national recycled-content requirements.
- Establish state and national "design for recycling" requirements.
- Require up-front processing before disposal.
- Strengthen existing mandatory recycling requirements for all schools and public entities.

Organic Materials Recovery: Increase recycling of organic materials (e.g., lawn and garden, food waste, wood, and non-recyclable paper) to reduce methane emissions associated with landfilling. Mechanisms to achieve the organics goals include:

- For food waste, where possible, prioritize recovery options at the top of the EPA Food Recovery Hierarchy including source reduction, food to people (food recovery) and food-to-livestock.
- Improve measurement of yard waste recycling collections and on-site composting (small site and backyard) composting efforts.

Related Policies/Programs in Place and Recent Actions

Reuse as an Emerging Focus

Reuse, Rental and Repair Economic Analysis: Reuse of secondhand items of all kinds, rental of certain equipment and supplies, and repair services are all part of source reduction. They had never been studied here prior to the MPCA analysis in 2011 that showed that Minnesota's reuse, rental, and repair sector contributes about 46,000 direct jobs and $4 billion to the economy each year. Much of this is through used auto sales and repair, but also important are small reuse, repair, and rental businesses that typically employ one to three people. There were over 15,000 total businesses of this type. This study ignited more promotion of reuse in Minnesota and in many other parts of the country.

In recent years, MPCA has provided grant funding for reuse projects. Funded reuse projects included: determining average weights for common re-used materials, developing a network community for reuse, comparing reusable utensils and bowls in a school cafeteria to disposables, and trying to establish a sustainable system so that universities can capture and re-use off-campus goods (such as couches that would otherwise be disposed between school years).

Following the establishment of ReUseMN, there has been an increased amount of re-used goods exchanged between re-use. ReUseMN is a trade association that allows reuse organizations to network with one another. Through networking many of the organizations have reported an increase in material that they get for reuse. We only have anecdotal information until our data base is established in ReTRAC, which is underway.

Environmental Preferable Purchasing: Better government purchasing practices can reduce environmental impacts: raw materials acquisition, manufacturing, product transportation, and product disposal. MPCA recently completed an EPA-funded project to take the first steps to expand the environmental scope and improve the analysis of our EPP program. As a result of that work, the EPP focus has expanded from office supplies and office paper to include the top impact purchasing categories – fuel, information/communication technologies, food, and construction. These have high climate, ecosystem quality, resource depletion, and water consumption impacts. Now we look not just at a single attribute – like recycled content – but also environmental specifications based on much more sophisticated understanding of what parts of product or service carry the biggest environmental impacts.

A state pilot test of packaging reduction at two state agencies (MPCA and Department of Human Services [DHS]), tested replacement corrugated shipping boxes that are used just once compared to reusable plastic boxes that can be used a hundred times or more. The pilot showed that if fully implemented to state agencies, 52 metric tons of corrugated waste otherwise needing management could be avoided. This single action would reduce over 156 metric tons of GHG, primarily from reduced emissions from replacing the need for 208,000 boxes with only 2,100 plastic totes over a 16-year useful life.

Requirement of source reduction activities in Metro Solid Waste Policy Plans: Metro counties have made commitments to source reduction actions in their plans. Hennepin County has been especially strong in taking action in this area as a result, having documented over 7,000 pounds of household goods repaired at their Fixit Clinics in only about 18 events and partnering with City of Minneapolis and UM on reusing goods left behind by students moving out.

Source Reduction of paper containing priority chemicals: MPCA has undertaken a voluntary campaign to encourage businesses to source reduce receipt papers that contain endocrine active chemicals (BPA and BPS) by switching to electronic/digital receipts.

Recycle More Minnesota Campaign: This is an MPCA campaign to “reinvigorate recycling” and should be funded on a regular basis. Studies have proven that continual education will increase recycling; MPCA intends to increase that rate. Of MSW not recycled, one million tons is potentially recyclable. In fact, this material would have been worth more than $210 million in 2014, had it been separated for recycling. Even a slight increase in the rate would have a significant impact on reducing GHG emissions.

State Agency Recycling: The Minnesota State Resource Recovery Program was eliminated by the Legislature in 2009, and since 2012 recycling data has been collected from state agencies by the MPCA. Reporting for CY2012 data was minimal with 71% of metro area agencies not submitting any data. Data received indicates that only a handful of metro area agencies are meeting the 60% recycling goal. In the 2014 session, the legislature expanded reporting requirements to all agencies statewide. While this will give a better picture of state agency recycling as a whole, it will require additional staffing to meet for data collection needs and to adequately provide support agencies in implementing or improving recycling programs.

Increase Organics Recovery and Utilization: MPCA promotes increased composting of yard waste and other source-separated organics. And the need for better organics capture continues: while a 1991 statute prohibits the disposal of yard waste through landfilling or waste-to-energy, the 2013 waste characterization study found that approximately three percent of trash in Minnesota is yard waste, despite that law.

MPCA has completed updates to rules for source-separated composting facilities in Minnesota, as well as small site composting. Through SCORE, the 2014 Legislature has designated additional funding for organics recycling programs in the metro area.

MPCA is also promoting the collection of restaurant and grocery store waste to be used as food for livestock and other recovery options.

Estimated Policy Impacts

Direct Policy Impacts

Table AP F-6.6 WM – 2/3 Estimated Net GHG Reductions and Net Costs or Savings

Policy Option	2030 GHG Reductions ($TgCO_2e$)a	2015 – 2030 Cumulative Reductions (TgCO2e)[a]	Net Present Value of Societal Costs, 2015 – 2030 ($2014)	Cost Effectiveness ($2014/ tCO_2e)	2015 – 2030 In-state GHG Reductions[b]
WM-2	1.6	9.4	- $228	- $24	- 0.057
WM-3	2.7	27	- $817	- $30	0.15

[a] Reductions represent full energy-cycle reductions.

[b] Net emissions change that can be attributed to in-state policy option effects (meaning a slight net increase in emissions that can be attributed in-state). These in-State effects include lower levels of landfill carbon storage and reduced landfill gas to electricity generation potential.

The analysis of both policy option components found that significant reductions could be achieved by 2030 and on a cumulative basis. The values shown above include full energy-cycle GHG impacts (including upstream GHG emissions within the waste materials). Net societal costs were found to result in net savings, as shown above.

Due to data and modeling limitations, the upstream GHG reductions cannot be attributed to occur within the State. When the upstream GHG reductions are removed from the results, the net GHG impacts are reduced substantially. As shown in the final column above, the overall impacts within the state show slight increases above baseline. This is due to two main influences (as described in more detail below): 1: A lower amount of biogenic carbon storage in landfills; and 2: Lower levels of landfill methane production and subsequent renewable power generation, which offsets grid-based power. It should be noted that this potential increase is only about two percent of the total net GHG benefit for the entire policy option (0.79 Tg/36.2 Tg).

The following definitions should be useful when referring to GHG emissions results for this policy option:

- **Upstream emissions**: Emissions that occur at life-cycle stages prior to use: e.g., raw materials acquisition, manufacturing, and transportation[6].
- **Downstream emissions**: Emissions that occur at life-cycle state after use: e.g., waste management.
- **Total Emissions:** Are the sum of both up and downstream emissions.
- **In-State Emissions:** Are downstream emissions minus the waste management of MSW exported out-of-state.

Data Sources

MPCA's BAU GHG I&F with associated data on historic waste management practices; additional Minnesota data on historic recycling and organics management provided by MPCA. Data on presumed waste compositions of waste managed by each method (source reduced composition, composting composition, recycled composition, etc.), EPA's Landfill Gas Emissions Model (LandGEM) for estimating avoided landfill methane emissions (need data or assumptions on BAU levels of landfill gas management for active Minnesota landfills); EPA's Waste Reduction Model (WARM) for estimating upstream emissions for waste materials, fuel consumption for waste collection and waste management at the landfill site; International Panel on Climate Change (IPCC) Waste Modeling tool to calculate landfill carbon storage; and other literature data for costs associated with composting operations and source reduction programs.

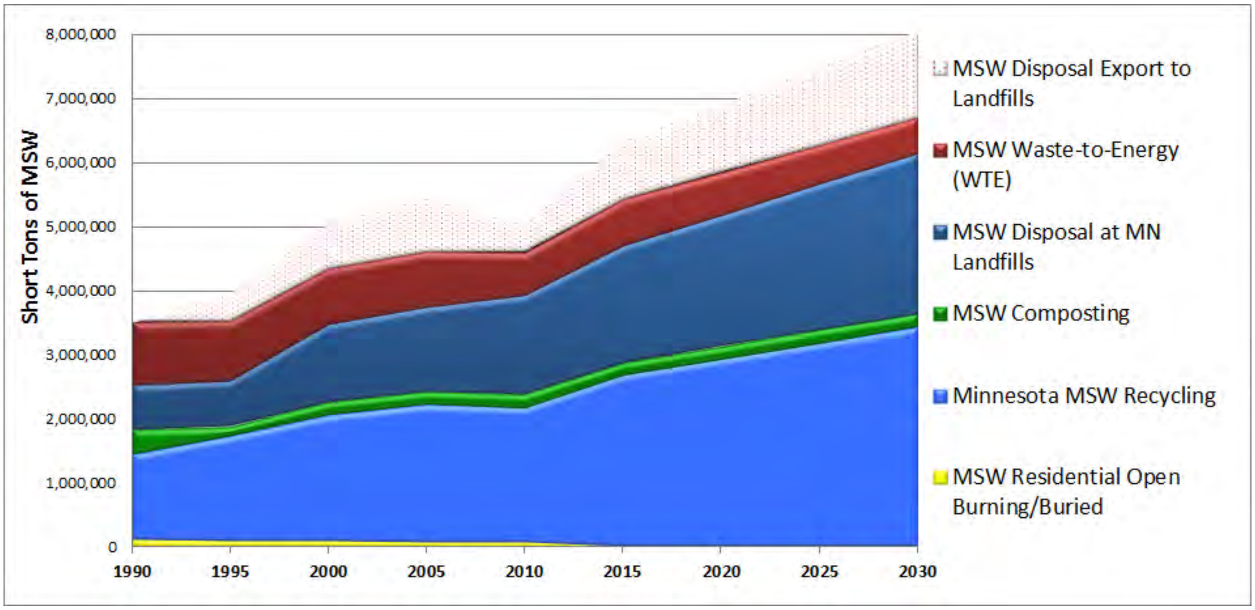
Quantification Methods

Net GHG & Energy Impacts:

Center for Climate Strategies (CCS) first developed a Solid Waste Management Profile (SWMP) to serve as a baseline of the state's management methods and to serve as a primary input to estimating emission reductions for each management method, including a reduction in waste generation. The SWMP is shown in the figure below. It covers residential open burning, recycling, composting, landfill emplacement, waste-to-energy combustion, and MSW that is managed and exported out of the state.

[6] http://epa.gov/epawaste/conserve/tools/warm/pdfs/warm-definitions-and-acronyms.pdf.

Figure AP F-6.25 Minnesota State-Wide Solid Waste Management Profile (1990-2030)



WM-2: Source Reduction

Using the SWMP, CCS developed a baseline of per capita waste generation. The baseline per capita waste generation is expected to increase 1.2% annually over the planning period. To achieve the policy option scenario (PS) goal, per capita waste generation will stabilize at 1.46%, which is the BAU per capita waste generation rate in 2019. Between years 2015-2019, a small linear decrease in the per capita waste generation rate will occur via policy option implementation. Beginning in 2020, a linear decrease in per capita waste generation will occur until 2025 is reached, when the three percent reduction in per capita waste generation goal is achieved. The table below outlines the BAU and Policy Option Scenario per capita waste generation rates and the total amount of MSW generated, reduced due to source reduction, and the total policy option scenario landfilled material amount.

Table AP F-6.7 BAU and Policy Option Scenario MSW Generation

Item	2015	2017	2020	2025	2030
Per Capita Generation (BAU): short tons/capita	1.37	1.41	1.48	1.58	1.65
Per Capita Generation (PS): short tons/capita	1.37	1.41	1.46	1.43	1.43
Total MSW Generation (BAU): short tons	7,541,463	7,880,509	8,389,077	9,252,691	9,886,565
Total MSW Generation (PS): short tons	7,541,463	7,840,586	8,289,270	8,337,392	8,538,607
Total MSW Reduction (PS minus BAU): short tons	0	-39,923	-99,808	-915,299	-1,347,957
Landfilled Material (Goal): short tons	3,411,495	3,592,106	3,863,024	3,598,869	3,717,546

To determine the GHG impact of the policy option, CCS used several resources and input assumptions to calculate the total GHG reductions. For both WM-2A and 2B, CCS used EPA's WARM model.[7] WARM allows the user to input a BAU scenario and a Policy Option Scenario waste stream. WARM then provides a combination of upstream and downstream emissions. To break-out the upstream from the downstream emissions, CCS calculated an amount of emissions that are associated with upstream emissions from the WARM Landfilling Chapter methodology.[8] CCS calculated a total of 2.6 metric tons (t) of upstream CO_2e is reduced from each ton of source reduced MSW. This value is based upon an assumption that all waste materials will be source reduced at the levels they are found in the waste composition profile used for this study (i.e. no materials are reduced at a higher rate than others). That composition is shown in the table below.

Table AP F-6.8 WARM Inputs for 2017 and 2025

WARM Entry (t MSW)	2017			2025			
	Total BAU	Total Goal	Source Red.	WARM Entry	Total BAU	Total Goal	Source Red.
Aluminum Cans	115,365	114,097	1,268	143,249	114,295	28,954	143,249
Steel Cans	73,414	72,607	807	91,158	72,733	18,425	91,158
Copper Wire	6,960	6,883	76	8,425	6,867	1,558	8,425
Glass	95,694	94,642	1,052	118,938	94,822	24,116	118,938
HDPE	80,043	79,163	880	99,486	79,314	20,172	99,486
LDPE	487,536	482,177	5,359	605,958	483,093	122,865	605,958
PET	94,597	93,557	1,040	117,574	93,734	23,839	117,574
PP	43,660	43,180	480	54,265	43,262	11,003	54,265
PS	72,767	71,967	800	90,441	72,103	18,338	90,441
Corrugated Containers	581,554	575,161	6,392	722,812	576,254	146,558	722,812
Magazines/ Third-class Mail	101,772	100,653	1,119	126,492	100,844	25,648	126,492
Newspaper	203,544	201,306	2,237	252,984	201,689	51,295	252,984
Office Paper	159,927	158,169	1,758	198,773	158,470	40,304	198,773
Phonebooks	14,539	14,379	160	18,070	14,406	3,664	18,070
Dimensional Lumber	292,243	289,030	3,212	363,228	289,579	73,649	363,228
Food Waste (non-meat)	912,618	902,586	10,031	1,134,290	904,300	229,990	1,134,290
Yard Trimmings	143,558	141,980	1,578	178,428	142,249	36,178	178,428
Carpet	100,044	98,944	1,100	124,344	99,132	25,212	124,344
Personal Computers	52,197	51,623	574	64,875	51,721	13,154	64,875
Totals	**3,632,029**	**3,592,106**	**39,923**	**4,513,792**	**3,598,869**	**914,923**	**4,513,792**

Once the upstream emissions were calculated, CCS then calculated the downstream emissions. The downstream emissions include landfill methane (CH_4) that is not captured, flared,

[7] http://epa.gov/epawaste/conserve/tools/warm/Warm_Form.html (CCS used the downloaded version)

[8] http://epa.gov/epawaste/conserve/tools/warm/pdfs/Landfilling.pdf

combusted in landfill gas to energy (LFGTE) equipment, or oxidized in the soil; diesel fuel emissions, including vehicles used for curb side pick-up and vehicles used to move MSW once it reaches the landfill; landfill biogenic carbon storage; and grid offset emissions from the reduced landfill gas (LFG) generation and subsequent reduced renewable energy generation.

To calculate the total amount of landfill gas that is emitted from landfilled waste, CCS input the total amount of MSW emplaced into landfills for both the BAU and Policy Option Scenario into EPA's LandGEM.[9] LandGEM provides the user with the total amount of CH_4 generated from a landfill without controls or applying the standard ten percent oxidation factor.[10]

In Minnesota's waste management forecast excel file provided to CCS,[11] Minnesota provides the waste baseline assumptions for waste sent to landfills with no controls, landfills with flaring technology, and LFGTE. Below are the percentages used for each type of landfill:

Table AP F-6.9 Percent of Future Waste Emplacement into Landfills

Landfill Emplacement into uncontrolled landfills	21%
Landfill Emplacement into flared landfills	31%
Landfill Emplacement into LFGTE controlled landfills	48%

Using the above percentages, CCS applied these and the ten percent oxidation factor to determine the total amount of landfill CH_4 that is not captured, flared, or oxidized. Below are the total metric tons of CO_2e emitted from the BAU and policy option scenario landfill MSW emplacement. Landfill GHG reductions account for the majority of CO_2e reductions under the policy option scenario.

Table AP F-6.10Percent of Future Waste Emplacement into Landfills

Year	BAU	Policy Option Scenario
	CH_4 Emissions (tCO_2e)	CH_4 Emissions (tCO_2e)
2016	45,584	45,584
2020	222,338	190,861
2025	421,749	296,351
2030	575,355	332,656
2016 - 2030	**4,979,144**	**3,509,149**

The second source of CO_2e emission reductions under this policy option scenario are those associated with transportation. EPA's WARM model assigns an emission factor to both emissions from vehicles that perform curbside pick-up and vehicles that move the MSW once it arrives at the landfill.

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[9] http://www.epa.gov/nrmrl/appcd/combustion/cec_models_dbases.html

[10] http://epa.gov/epawaste/conserve/tools/warm/pdfs/Landfilling.pdf. The 10% factor addresses methane that is typically oxidized to CO_2 as it migrates through the surface layers of the landfill.

[11] Uploaded to CCS' online workspace by Peter Ciborowski, MPCA, on March 11, 2015.

Table AP F-6.11 Refuse Collection Emission Factors

Fuel Combustion Source	Diesel Fuel gallons/ 10^3 lbs Landfilled	TJ Diesel/ t waste
Collection Vehicles	0.90	0.00027
Landfill Site Fuel Use	0.04	0.000012

Removing MSW from the landfill also results in CO_2e emissions to increase on an indirect basis. Sources of CO_2e include biogenic landfill carbon storage and offset grid emissions from the reduced LFG available to convert into electricity. The lost renewable generation capacity will need to be made up from the local grid. Per the CSEO project determinations of the make-up of the marginal resource mix, this lost capacity will need to be made up from a combination of natural gas and coal-fired resources.[12]

Landfill biogenic carbon storage was included in the downstream emissions to account for the biogenic carbon that is stored long-term in landfills. According to the IPCC waste modeling methodology, an estimated amount of 50% of all biogenic carbon that is emplaced in a landfill is stored over many decades.[13] To determine the total amount of actual biogenic carbon stored in the landfill, CCS used an average value for fraction of degradable organic carbon (DOC) from IPCC's waste model.[14] CCS split food/yard/other MSW apart from paper and wood because of their vastly different DOC fractions. After determining the amount of DOC for each year, that value was multiplied by 0.5 to determine the amount of biogenic carbon stored.

Table AP F-6.12 . DOC Values for IPCC's Waste Model

Food/Yard/Other	0.175
Paper and Wood	0.415

A certain percentage of the landfilled material will be emplaced into landfills that have LFGTE technologies. These landfills capture the CH_4 emissions from the landfill and convert the CH_4 into electricity that offsets power from the grid. When the LFGTE landfill emplacement rates are reduced, these landfills will produce less CH_4. The lost renewable energy that results will require an increase in generation from plants that supply the grid. CCS refers to the associated emissions from grid resources as "lost grid offsets". These are summarized in the table below.

Table AP F-6.13 Lost Grid Offsets

Year	BAU		Policy Option Scenario		
	Power Produced by LFGTE	Offset Grid Emissions from LFGTE	Power Produced by LFGTE	Offset Grid Emissions from LFGTE	Lost Grid Offsets

[12] The carbon intensity of the CSEO marginal resource mix ranges from 0.936 tCO_2e/MWh in 2015 to 0.758 tCO_2e/MWh in 2030 (lower future intensity driven by higher amounts of natural gas generation in the future marginal resource mix relative to coal).

[13] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

[14] http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html

	MWh	$TgCO_2e$	MWh	$TgCO_2e$	$TgCO_2e$
2016	12,354	(0.011)	3,014	(0.0028)	0.0090
2020	60,258	(0.054)	12,621	(0.011)	0.043
2025	114,303	(0.094)	19,597	(0.016)	0.078
2030	155,933	(0.12)	21,998	(0.017)	0.10
2016 - 2030	**1,349,449**	**(1.11)**	**232,056**	**(0.19)**	**0.92**

Table AP F-6.14 Total GHG Emissions Change

Year	In-State Reductions	Upstream (Out of State) Reductions	Total
	$TgCO_2e$		
2015	(0.0071)	0.0000	(0.0071)
2016	0.028	(0.27)	(0.25)
2017	0.055	(0.53)	(0.48)
2018	0.079	(0.83)	(0.75)
2019	0.10	(1.2)	(1.1)
2020	0.11	(1.4)	(1.3)
2021	0.10	(1.6)	(1.5)
2022	0.097	(1.8)	(1.7)
2023	0.087	(2.0)	(2.0)
2024	0.073	(2.3)	(2.2)
2025	0.054	(2.5)	(2.4)
2026	0.025	(2.7)	(2.6)
2027	(0.022)	(2.6)	(2.7)
2028	(0.067)	(2.6)	(2.7)
2029	(0.11)	(2.6)	(2.7)
2030	(0.15)	(2.6)	(2.7)
Total	**0.45**	**(27)**	**(27)**

Notes:

Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

The sum of the in-state and out-of-state (upstream) emission reductions is 9.2 $TgCO_2e$. The total out-of-state CO_2e emission reductions are 9.3 $TgCO_2e$, and the total amount of emissions associated with in-state activity slightly increases CO_2e emissions by 0.13 $TgCO_2e$. The increase of emissions is a result of two factors: the lower amount of biogenic carbon storage in landfills; and the grid offset CO_2e emissions. The sum of these two factors is slightly greater than the amount of methane reduction at landfill sites. However, the net result of the policy option shows significant GHG reduction potential when the complete energy-cycle results are included (i.e. both upstream and downstream GHGs associated with production of waste materials and their subsequent management via the waste stream).

Net Cost Results:

The costs associated with WM-3A are driven by landfill tipping fees (used as a proxy for estimating total waste management system costs via landfilling), diesel fuel costs, and the program implementation costs. To calculate BAU landfilling costs, CCS used an average landfill tipping fee provided by MPCA.[15] Total annual landfilled MSW under both BAU and PS were multiplied by the average landfill tipping fee to estimate the total landfilling costs. Since the total amount of landfilled material under the BAU scenario is greater than under the policy option scenario, the net cost is a cost savings.

Table AP F-6.15 Cost of Landfill

Year	Landfilling Costs	Landfilling Costs	Net Source Reduction Landfilling Costs Savings
	MM$	MM$	MM$
2016	$ 107	$ 106	$ (0.52)
2020	$ 120	$ 118	$ (2.5)
2025	$ 139	$ 112	$ (27)
2030	$ 158	$ 117	$ (41)
2016 - 2030	**$ 2,078**	**$ 1,839**	**$ (239)**

CCS also separately calculated the costs associated with diesel fuel use. The total amount of diesel fuel consumed is described above. The cost in each year was calculated using the CSEO project fuel price forecast used across all sectors and policy options. Since the total amount of landfilled MSW is reduced in the policy option scenario, then that directly translates into lower PS fuel costs for collecting and managing the MSW at the landfill site. The diesel fuel costs were subtracted out of the total landfilling costs (with the assumption that these would already be accounted for in the tipping fees).

[15] Provided by J. Chiles, MPCA to L. Bauer, CCS, August, 2014

Table AP F-6.16 Diesel Fuel Costs

Year	Diesel Fuel Costs	Diesel Fuel Costs	Net Diesel Fuel Cost Savings
	MM$	MM$	MM$
2016	$ 12.9	$ 12.7	$ (0.16)
2020	$ 15.0	$ 14.1	$ (0.88)
2025	$ 18.0	$ 13.4	$ (4.6)
2030	$ 21.0	$ 14.0	$ (6.9)
2016 - 2030	**$ 265**	**$ 220**	**$ (45)**

The final cost piece was the source reduction program costs. These are the costs associated with implementing the program each year (by state and local agencies). CCS used a study developed by the Bio Intelligence Service under the European Union (EU).[16] The EU study targets food waste source reduction. The program costs are associated with a waste reporting program to encourage legislation and behavioral changes. The annual cost to implement the source reduction program was estimated to be $3.9 million. CCS applied a 2% annual escalation to the $3.9 million annual costs each year to account for program cost increases. Total net societal costs are shown below. These total a net savings of $283 million (in $2014) with a cost effectiveness of $-17/t$CO_2$e.

Table AP F-6.17 Source Reduction Program Costs

Year	Net Source Reduction Landfilling Costs	Net Diesel Fuel Costs	Program Costs	Total Policy Option Cost	Total Discounted Policy Option Cost	Cost Effectiveness
	MM$	MM$	MM$	MM$	MM$2014	$2014/t$CO_2$e
2016	$ (0.52)	$ (0.16)	4.0	$ 3.4	$ (0.7)	
2020	$ (2.5)	$ (0.88)	4.4	$ 0.97	$ (3.4)	
2025	$ (27)	$ (4.6)	4.8	$ (27)	$ (32)	
2030	$ (41)	$ (6.9)	5.3	$ (42)	$ (48)	
2016 - 2030	**$ (239)**	**$ (45)**	**74**	**$ (209)**	**$ (283)**	**$ (17)**

WM-3: 75% Recycling Goal:

CCS used the policy option scenario results from WM-2 to create a revised set of WM-3 BAU values for landfill waste emplacement. The BAU upstream emissions (mainly out-of-state emissions) were calculated using the same WARM output based emission factors as in WM-2. The downstream GHG emissions include: landfill methane not captured, flared, or oxidized; nitrous oxide (N_2O) and CH_4 emissions from composting; biogenic carbon stored long term in landfills; and grid offset emissions associated with the reduction in landfill CH_4 generation.

[16] http://www.biois.com/en/menu-en/expertise-en/assess/highlights-a/ec-preparatory-study-on-food-waste-eu27.html.

The BAU landfill CH_4 emissions for WM-3 were taken from the WM-2 policy option scenario results. The policy option scenario LFG results were derived from using EPA's LandGEM model. Below are the input data to LandGEM.

Table AP F-6.18 Data Used in LandGEM Model

Year	BAU Landfilled MSW	PS Landfilled MSW	BAU Landfill CH_4 Emissions	PS Landfill CH_4 Emissions
	Tg	Tg	$TgCO_2e$	$TgCO_2e$
2016	1.9	1.8	0.025	0.025
2020	2.1	1.4	0.12	0.10
2025	2.0	0.80	0.23	0.16
2030	2.1	0.84	0.33	0.19
2016 - 2030	**33**	**20**	**2.8**	**1.9**

Below are the total landfill Gas Emissions outputs from LandGEM accounting for capture, flaring, and oxidation.

Table AP F-6.19 Landfill Gas Emissions Calculated from LandGEM Model

Year	BAU Landfill CH_4 Emissions	Policy Option Scenario Landfill CH_4 Emissions
	$TgCO_2e$	$TgCO_2e$
2016	0.025	0.025
2020	0.12	0.10
2025	0.23	0.16
2030	0.33	0.19
2016 - 2030	**2.8**	**1.9**

CCS also quantified the total amount of CO_2e emissions from composted material. To quantify the amount of CO_2e emission from composting, CCS used the emission factors below:[17]

Table AP F-6.20 Compost Emission Factors

CH_4 Emission Composting Factor (tCH_4/t compost)	7.89×10^{-4}
N_2O Emission Composting Factor (tN_2O/t compost)	4.74×10^{-5}

The table below provides the estimated GHG emissions for increased composting activity under the policy option scenario.

[17] UNFCCC. 2005. "Approved Baseline Methodology AM0025; Avoided emissions from organic waste composting at landfill sites." Available at: http://cdm.unfccc.int/EB/021/eb21repan15.pdf.

Table AP F-6.21 Estimated GHG Emissions from WM-3

Year	BAU Composted Material	PS Composted Material	BAU Composting CH_4 & N_2O Emissions	PS Composting CH_4 & N_2O Emissions
	Tg	Tg	$TgCO_2e$	$TgCO_2e$
2016	0.11	0.11	0.004	0.004
2020	0.11	0.37	0.004	0.010
2025	0.12	0.57	0.004	0.014
2030	0.12	0.60	0.004	0.020
2016 - 2030	**1.8**	**6.8**	**.047**	**0.23**

Landfilled biogenic carbon storage was quantified using the same methodology as in WM-2.

Table AP F-6.22 Landfilled Biogenic Carbon Storage

Year	BAU Scenario		Policy Option Scenario	
	Landfill Carbon Storage (Food/Yard Waste/Other Organics)	Landfill Carbon Storage (Wood and Paper Products)	Landfill Carbon Storage (Food/Yard Waste/Other Organics)	Landfill Carbon Storage (Wood and Paper Products)
	$TgCO_2e$	$TgCO_2e$	$TgCO_2e$	$TgCO_2e$
2015	(0.042)	(0.12)	(0.042)	(0.12)
2020	(0.048)	(0.13)	(0.033)	(0.09)
2025	(0.045)	(0.12)	(0.018)	(0.05)
2030	(0.048)	(0.13)	(0.019)	(0.05)
2016 - 2030	**(0.75)**	**(2.1)**	**(0.45)**	**(1.3)**

The final piece of the in-state net GHG emissions impact analysis is the lost grid offset from the reduction in landfill gas generation. Again, the reduction in waste emplaced into the landfills, specifically those that capture CH_4 for electricity generation, creates less CH_4 for collection and LFGTE. The power not produced due to lower levels of CH_4 generation will need to be offset by grid-based power. These impacts are summarized below:

Table AP F-6.23 Lost Grid Offset for Landfill Gas Generation

Year	BAU		Policy Option Scenario	
	Power Produced from LFGTE (MWh)	Offset Grid Emissions from LFGTE Power ($TgCO_2e$)	Power Produced from LFGTE (MWh)	Offset Grid Emissions from LFGTE Power ($TgCO_2e$)
2016	4,321	(0.0040)	4,321	(0.0040)
2020	21,223	(0.019)	18,219	(0.016)
2025	40,884	(0.034)	28,728	(0.024)
2030	56,799	(0.043)	32,840	(0.025)
2016 - 2030	**483,375**	**(0.40)**	**340,064**	**(0.28)**

Total net CO_2e emission results for downstream sources (in-state) and upstream sources (out-of-state) are shown below. The in-state totals assume that all landfill diversion is occurring from landfills within the state. As shown in the SWMP figure above, Minnesota exports a fair amount of waste for landfilling. Therefore, there is potential for some of the downstream reductions to actually occur out of state. Similar to the results for WM-2, the net results show that due to lower renewable energy output and lower biogenic carbon storage, the in-state portion of the results is a net increase over BAU. However, overall, just as with WM-2, the policy option is shown to result in substantial GHG reductions due to the large upstream emissions reduction potential which far outweighs any downstream impacts.

Table AP F-6.24 Summary of GHG Emissions Reductions

Year	Total Out-of-State Emissions	Total In-State	Total
	$TgCO_2e$	$TgCO_2e$	$TgCO_2e$
2015	-	0.000	0.00
2016	(0.27)	0.022	(0.24)
2017	(0.52)	0.042	(0.48)
2018	(0.81)	0.064	(0.75)
2019	(1.1)	0.088	(1.06)
2020	(1.4)	0.10	(1.3)
2021	(1.6)	0.11	(1.5)
2022	(1.8)	0.12	(1.7)
2023	(2.0)	0.13	(1.9)
2024	(2.2)	0.14	(2.1)
2025	(2.5)	0.15	(2.3)
2026	(2.7)	0.15	(2.5)
2027	(2.6)	0.14	(2.5)
2028	(2.6)	0.13	(2.5)
2029	(2.6)	0.11	(2.5)
2030	(2.6)	0.10	(2.5)
2015 - 2030	(27)	1.6	(26)

Notes:

Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Net Societal Cost Analysis:

Like in WM-2, CCS used tipping fees to calculate the BAU and policy option scenario costs for landfilled, composted, and recycled material (as proxies for the total levelized costs for constructing and operating these differing waste management systems). The tipping fees were average values derived from data provided by MPCA.

Table AP F-6.25 Landfill Tipping Fees

Landfilling Tip Fee Average ($/t MSW):	$ 62.53
Composting Tip Fee Average ($/t MSW):	$ 46.81
Recycling Tip Fee Average ($/t MSW):	$ 61.30

The cost results for BAU and policy option scenario are outlined below:

Table AP F-6.26 WM-3 Cost Results

Year	BAU Landfilling Costs	BAU Composting & Recycling Tipping Fees	PS Landfilling Costs	PS Composting & Recycling Tipping Fees
	MM$	**MM$**	**MM$**	**MM$**
2015	$ 116	$ 110	$ 116	$ 110
2020	$ 132	$123	$ 90	$ 161
2025	$ 125	$ 138	$ 50	$ 204
2030	$ 131	$143	$ 52	$ 213
2015 - 2030	**$ 2,062**	**$ 86**	**$ 1,227**	**$ 2,794**

Under the policy option scenario, additional composting facilities will be constructed. MPCA recommended that CCS model an Aerated Static Pile composting facility.[18] According to guidance from MPCA, no additional materials recover facilities (MRF) will be needed under the policy option scenario.[19] Below are the capital and O&M costs associated with the construction of composting facilities. Total capital costs were spread evenly across the planning period. Capital costs for these facilities were estimated assuming 100% financing at 5% over 10 years.

[18] http://www.compost.org/pdf/compost_proc_tech_eng.pdf, provided my Jim Chiles, MPCA

[19] J. Chiles MPCA (Personal Communication) to L. Bauer, CCS, August 2014

Table AP F-6.27 Capital Costs of Composting

Year	Composting Operating Costs	Composting Capital Costs	Annualized Capital Costs
	MM$	MM$	MM$
2015	$ 124	$ 1.7	0.22
2020	$ 176	$ 1.7	1.3
2025	$ 221	$ 1.7	2.4
2030	$ 230	$ 1.7	2.4
2015 - 2030	**$ 3,042**	**$ 22**	**26**

To calculate the capital and O&M costs above for composting facilities, CCS used the below factors:

Table AP F-6.28 Cost Factors for Capital Cost Calculation

Capital Cost to Construct Composting Facility ($/t Compost)[20]	$ 52.10
Composting Operation Costs ($/t Compost)[21]	$ 30.62

CCS also calculated the average commodity value for recycling and composted material. The values for the recycling commodity values were provided by MPCA.

Table AP F-6.29 Commodity Values of Compost

Average Recycling Commodity Value $/t Compost[22]	$ 317
Average Composting Commodity Value $/t Compost[23]	$ 33

Below are the calculated commodity values for the BAU and Policy Option Scenario.

[20] http://www.compost.org/pdf/compost_proc_tech_eng.pdf

[21] http://www.compost.org/pdf/compost_proc_tech_eng.pdf

[22] Values provided by J. Chiles: 2007newfinal value rcy materials.xls on July 21, 2014

[23] http://www.co.olmsted.mn.us/environmentalresources/garbagerecycling/compostsite/Pages/default.aspx

Table AP F-6.30 Calculated Commodity Values for Compost

Year	BAU Recycling & Composting Commodity Value	PS Recycling & Composting Commodity Value
	MM$	MM$
2015	($ 497)	($ 497)
2020	($ 558)	($ 686)
2025	($ 624)	($ 852)
2030	($ 647)	($ 888)
2015 - 2030	**($ 9,341)**	**($ 11,833)**

Below are the net costs of the policy option. Net societal results indicate a net savings. The net present value of policy option costs is -$860 million (in $2014). Cost effectiveness is -$32/t$CO_2$e reduced:

Table AP F-6.31 Net Costs of Policy Option

Year	Total Policy Option Cost	Total Discounted Policy Option Cost	Cost Effectiveness
	MM$	MM$2014	tCO_2e
2015	$4	$0.0	
2016	$3	($1.2)	
2017	$2	($2.5)	
2018	$0	($3.7)	
2019	($1)	($5.0)	
2020	($2)	($6.2)	
2021	($3)	($7.9)	
2022	($13)	($17)	
2023	($22)	($27)	
2024	($31)	($36)	
2025	($52)	($57)	
2026	($48)	($53)	
2027	($56)	($61)	
2028	($63)	($69)	
2029	($71)	($76)	
2030	($79)	($84)	
Totals	**($434)**	**($508)**	**($54)**

Notes:

Each policy option analysis was done over a fifteen-year planning horizon. While implementation of each policy option is not expected to occur beginning this year, the analytical results are consistent with those expected over fifteen years with implementation in the next one to two years.

Macroeconomic (Indirect) Impacts for WM-2 and WM-3

WM-2 Policy

Table AP F-6.32 WM-2 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
WM-2	$6	$2	$31	150	60	930	$13	$5	$72

What follows are graphs that show expected changes in GSP, employment and personal income as a results of WM-2 policy implementation.

Figure AP F-6.26 WM-2 GSP Impacts ($2015 MM)

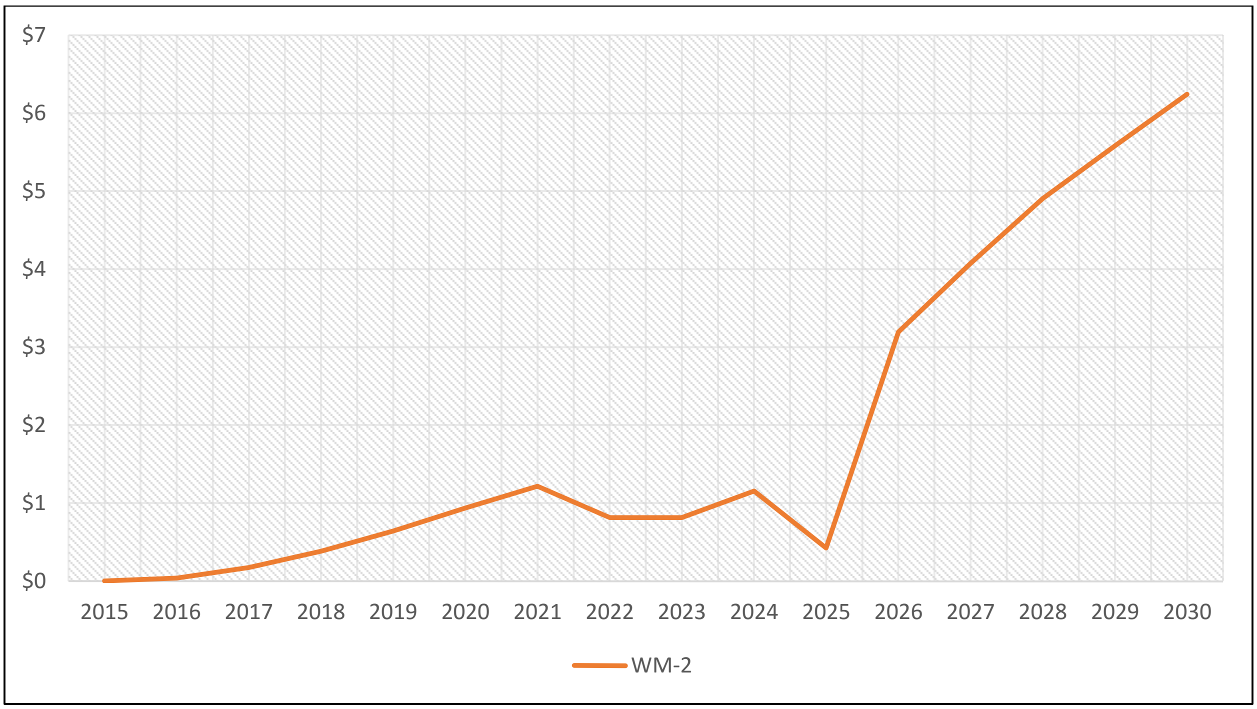


Figure AP F-6.27 WM-2 Employment Impacts (Individual Jobs)

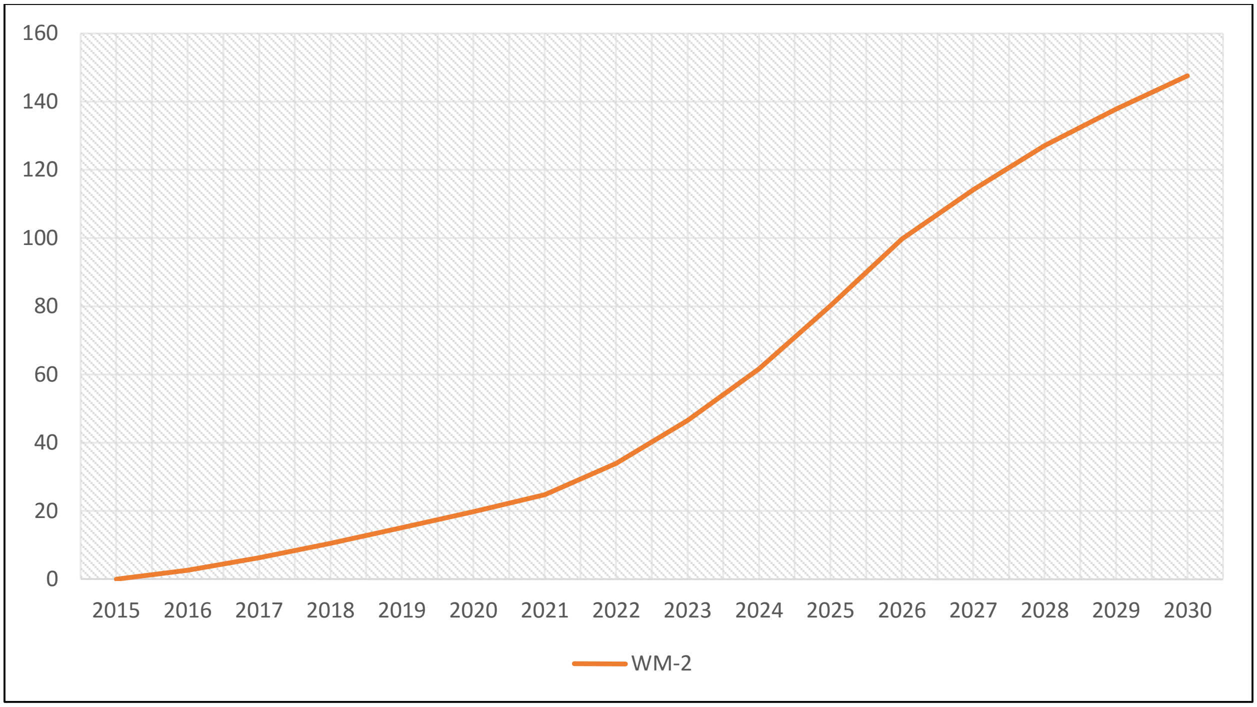
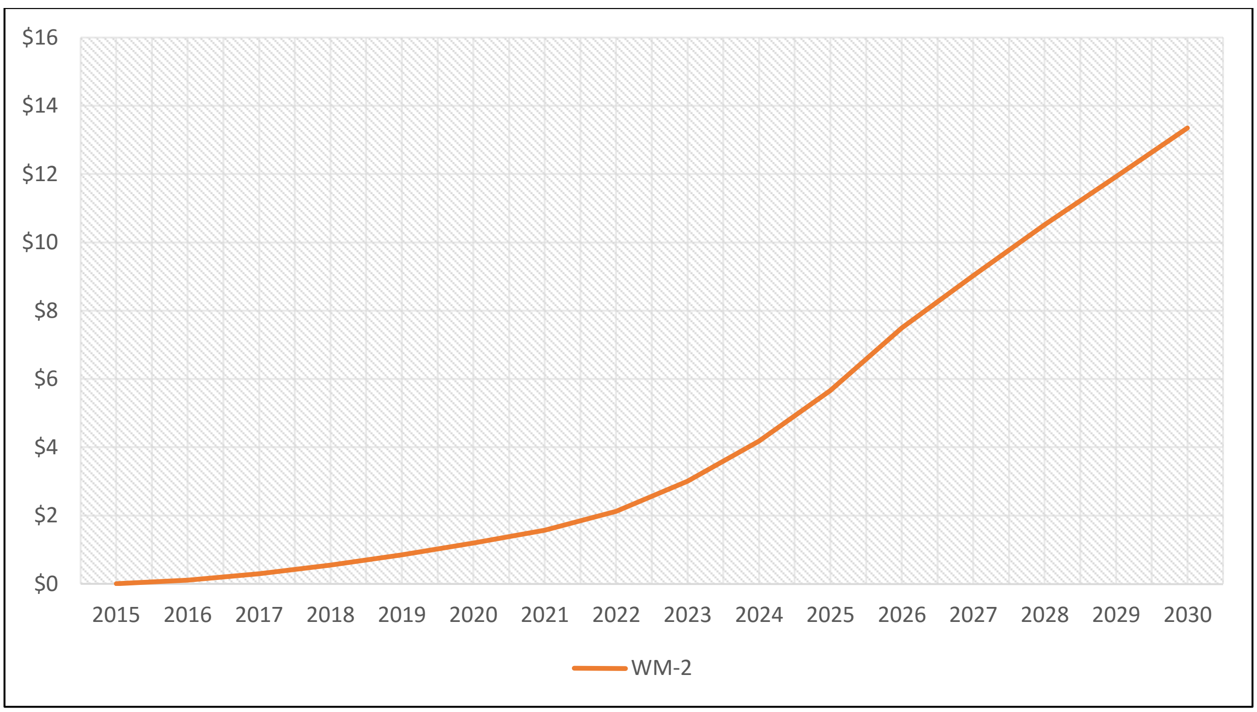
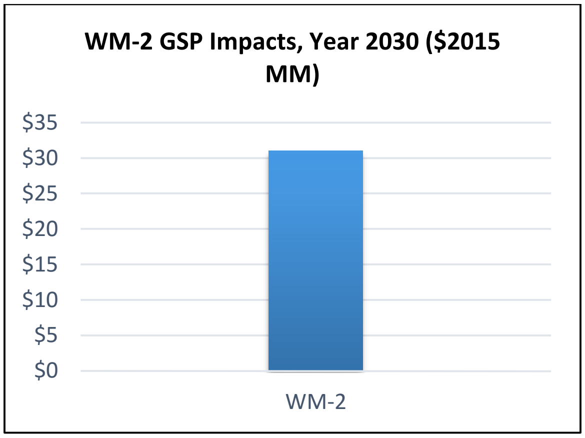
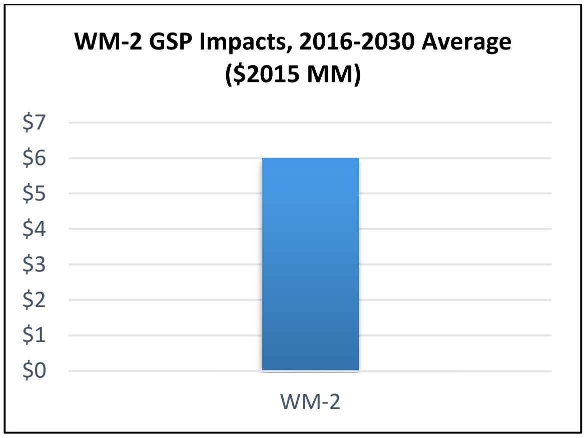


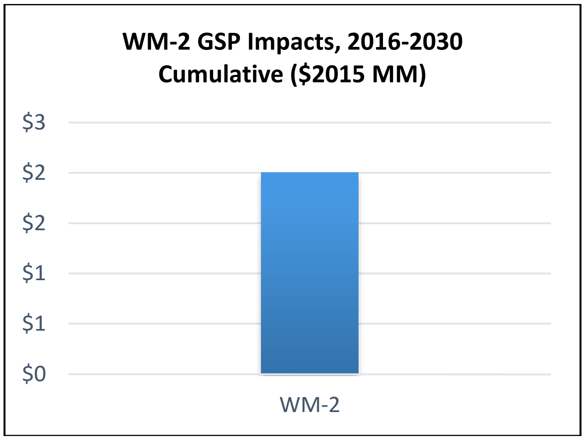
Figure AP F-6.28 WM-2 Income Impacts ($2015 MM)

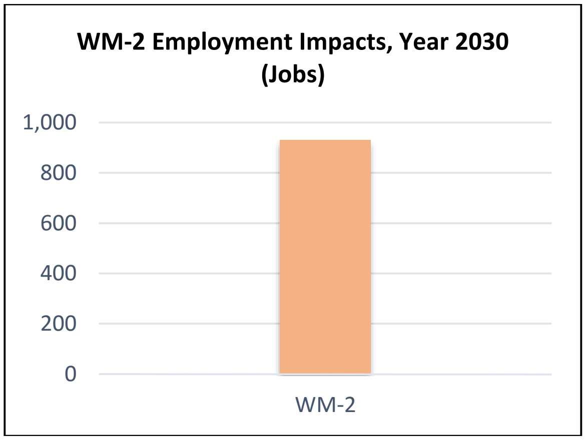


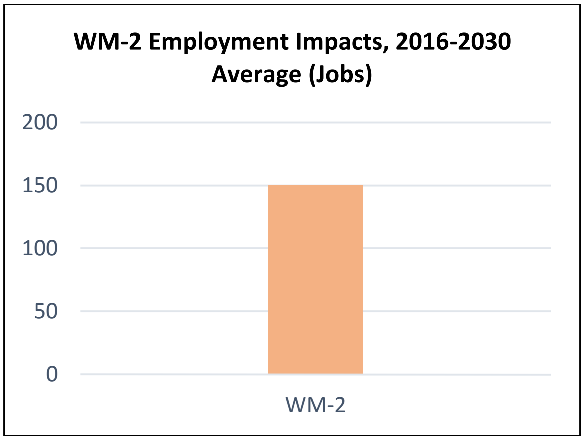
Graphs below show WM-2 macroeconomic impacts on GSP, personal income, and employment in the final year (2030), average (2016-2030) and cumulative (2016-2030).

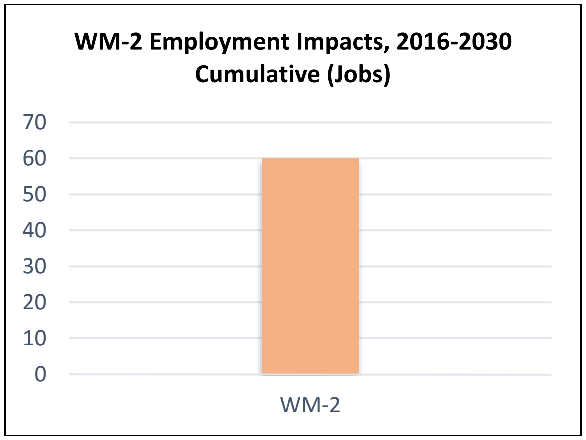


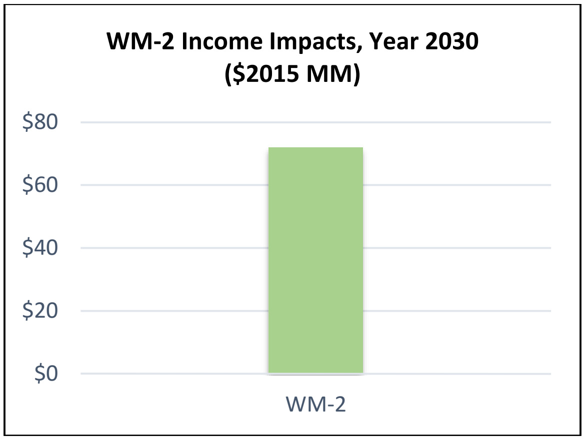


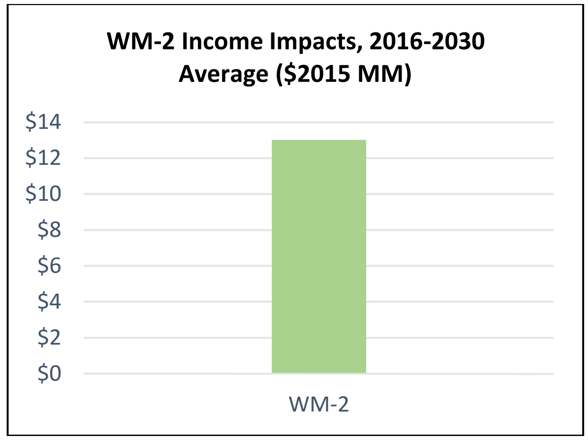


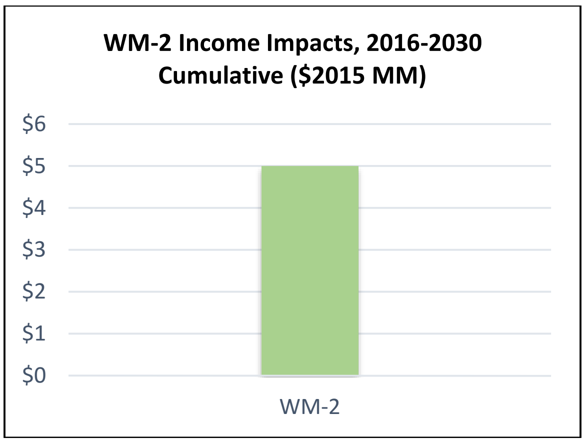












Principal Drivers of Macroeconomic Changes

Similar to WM-1, WM-2 policy shows slight positive impacts. The net savings to the government to carry out water treatment expands its ability to spend in other programs, though the volumes of spending changes are very small. GSP and incomes are never forecast by this analysis to vary more than a few million dollars statewide, and total employment never more than 100 total positions.

This is the result of a balancing upward pressure from the additional spending power of homes and businesses as they reduce their spending on waste management and the reduction in scale of the waste management sector itself. Other sectors see slight gains while waste management and the sectors that support it see slight losses.

WM-3 Policy

Table AP F-6.33 WM-3 Macroeconomic Impacts on GSP, Employment and Income

Scenario	GSP ($2015 MM)			Employment (Individual)			Personal Income ($2015 MM)		
	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
WM-3	$240	$203	$3,039	3,290	2,750	41,210	$319	$223	$3,338

Graphs below show expected temporal changes in GSP, employment and personal income as a result of the WM-3 policy implementation.

Figure AP F-6.29 WM-3 GSP Impacts ($2015 MM)

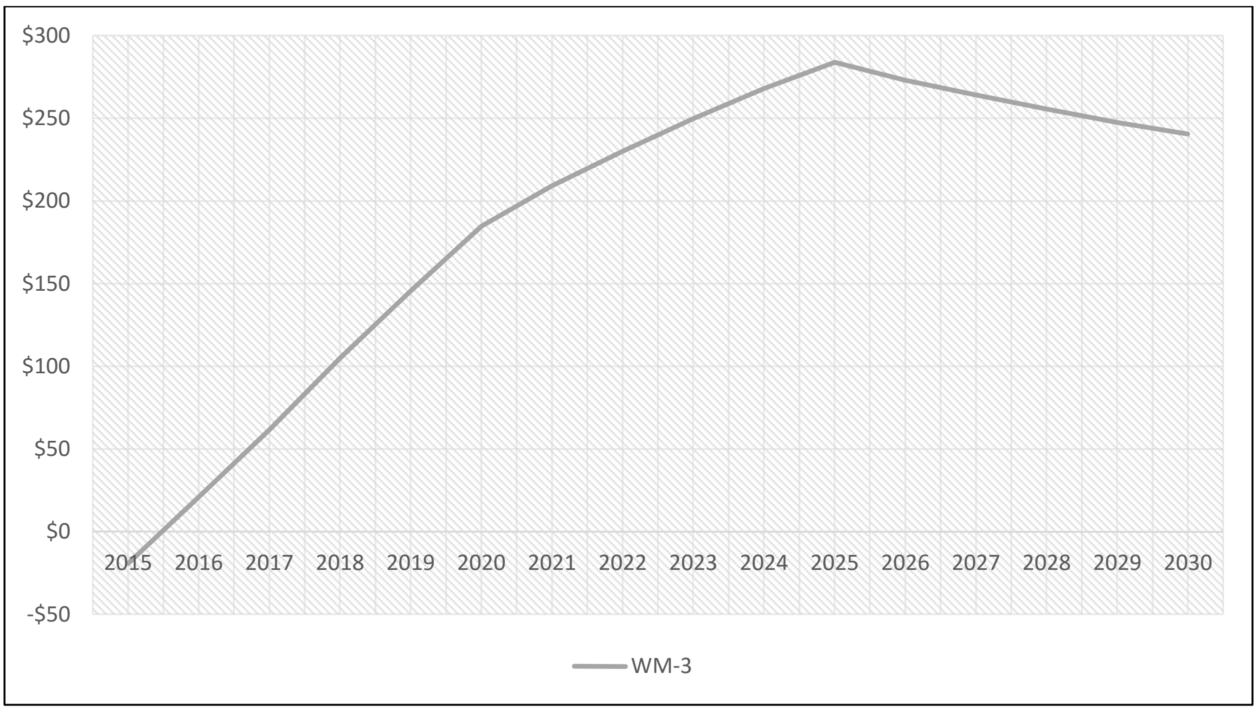


Figure AP F-6.30 WM-3 Employment Impacts (Individual Jobs)

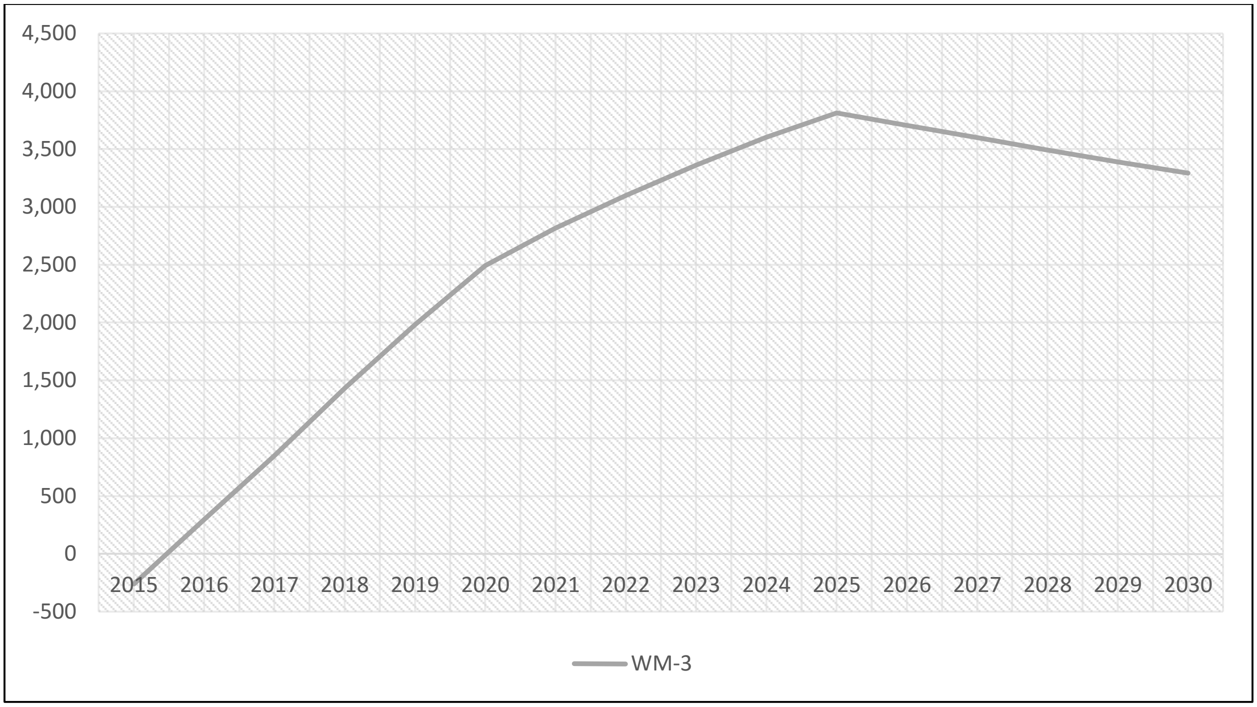
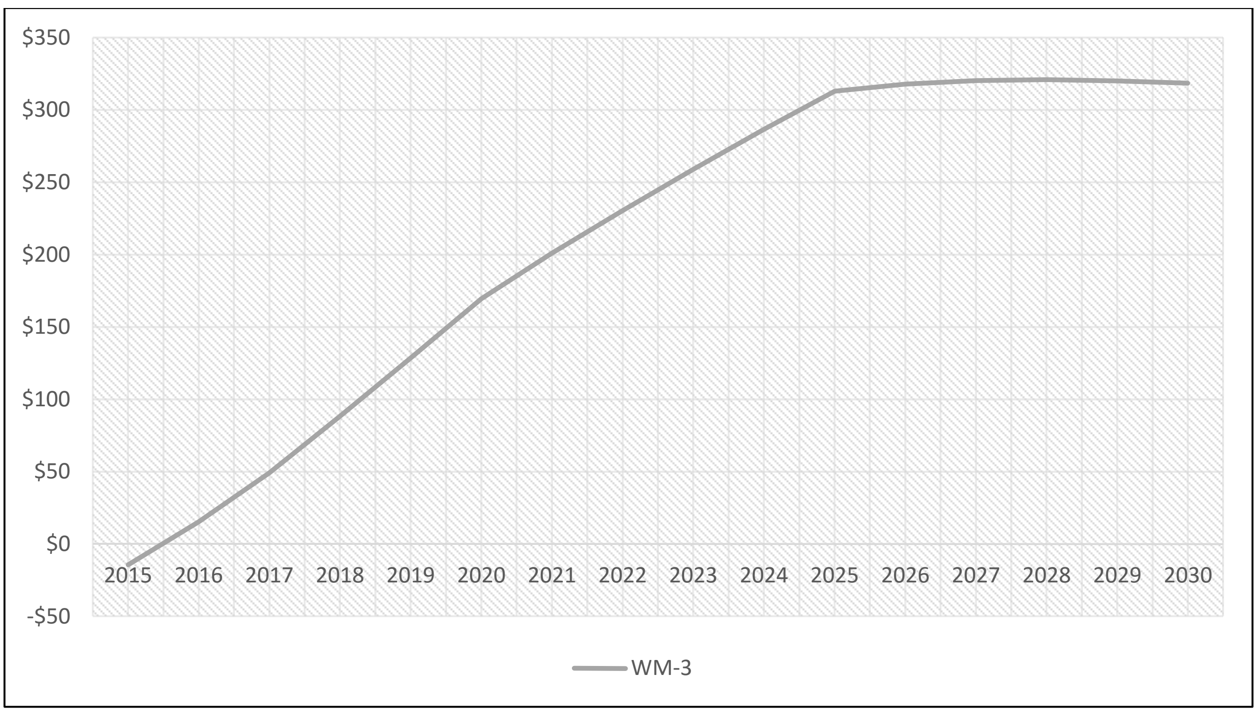
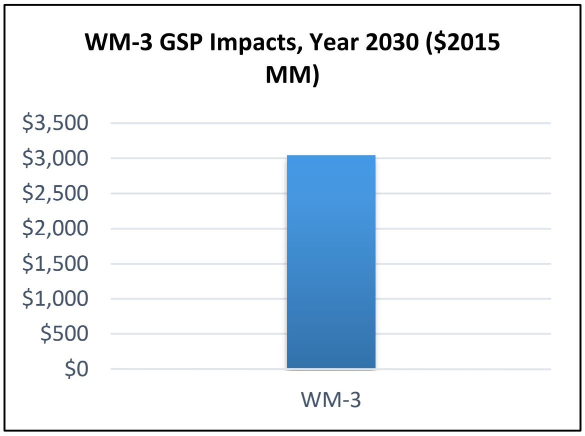
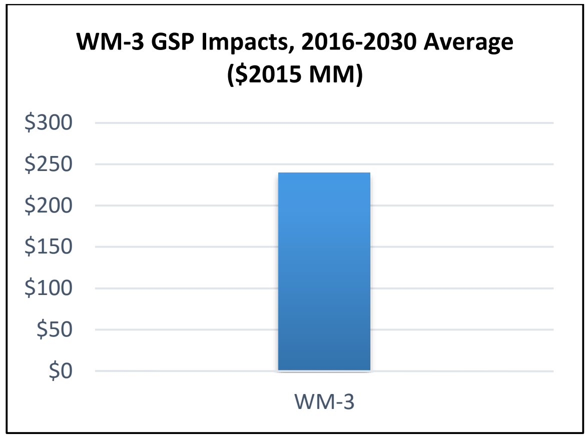
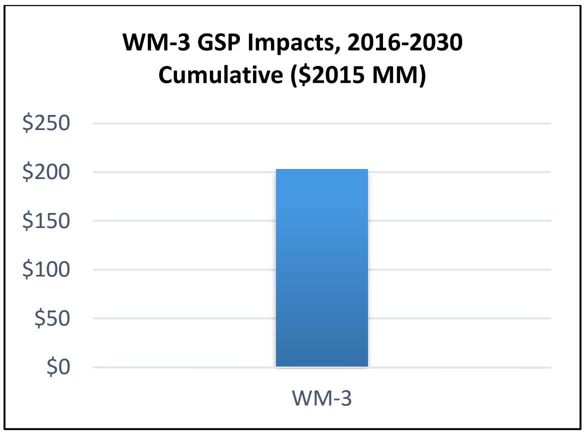


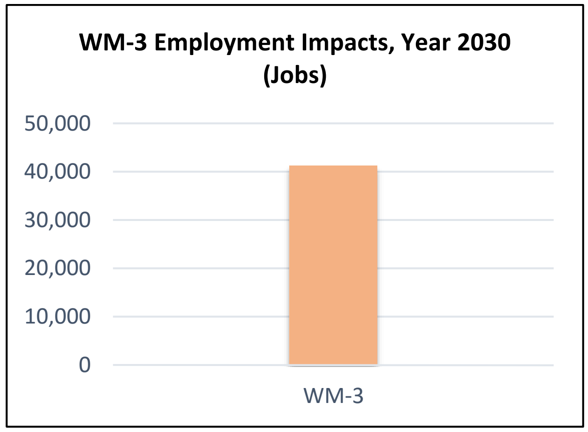
Figure AP F-6.31 WM-3 Income Impacts ($2015 MM)

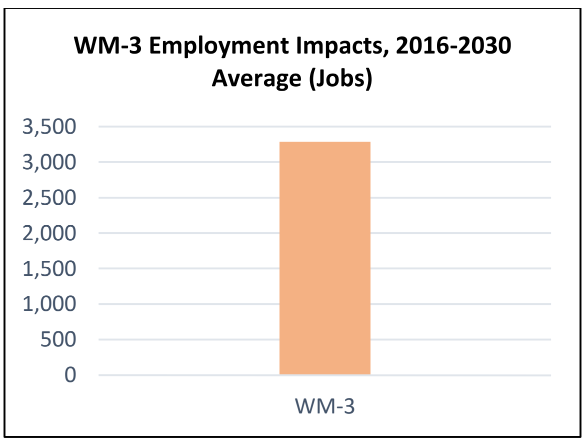


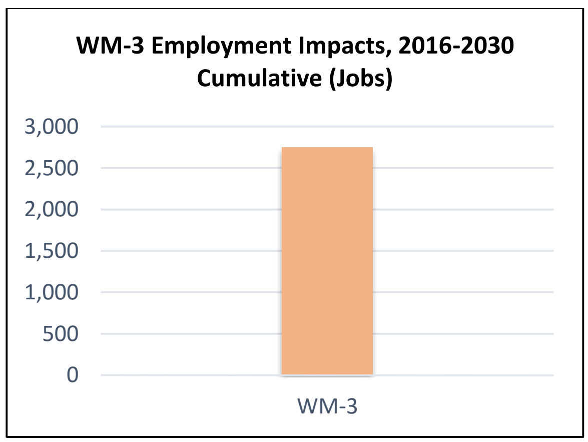

WM-3 GSP Impacts, Year 2030 ($2015 MM)
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
WM-3

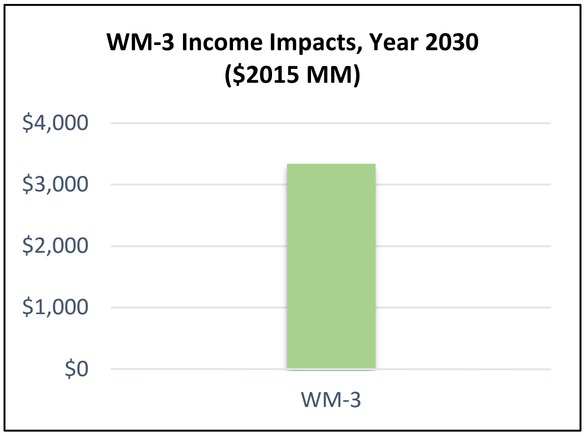

WM-3 GSP Impacts, 2016-2030 Average ($2015 MM)
$300
$250
$200
$150
$100
$50
$0
WM-3

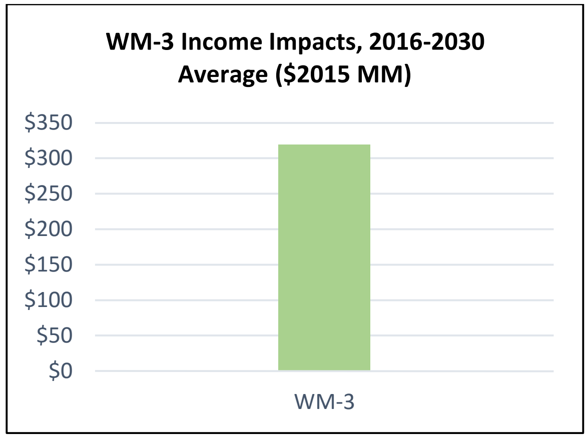

WM-3 GSP Impacts, 2016-2030 Cumulative ($2015 MM)
$250
$200
$150
$100
$50
$0
WM-3

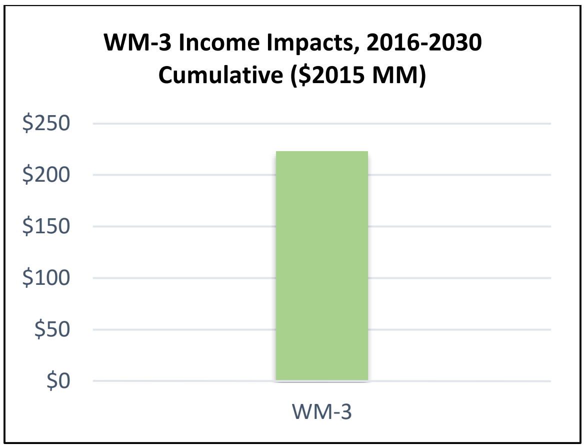

WM-3 Employment Impacts, Year 2030 (Jobs)
50,000
40,000
30,000
20,000
10,000
0
WM-3


WM-3 Employment Impacts, 2016-2030 Average (Jobs)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
WM-3


WM-3 Employment Impacts, 2016-2030 Cumulative (Jobs)
3,000
2,500
2,000
1,500
1,000
500
0
WM-3







Principal Drivers of Macroeconomic Changes

WM-3 is a larger policy in scale, but the real gains it provides to the statewide Minnesota economy are due to the anticipated revenue from recyclable materials collected by governments under this program. While the recycling effort itself is roughly self-funding through fees to homes and businesses, the revenue from sales of recycled materials rises steadily from about $15 million in the first year to nearly $250 million in the final year. This expands the state's budget and serves as a pure export, as these commoditized materials either displace imports or are sold externally.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

In the case of the WM-3 policy, important data included:

- The savings in reduction of costs to pay for waste management services, as the total amount of waste is reduced.
- Lost sales to the government and private waste managers from tipping fees at landfills
- New government spending on composting infrastructure
- The collection by government of recycling fees and the reallocation of those fees back into other government spending (by local governments, in this case).
- Expanded cost to government of operating recycling facilities, which is a productive activity but displaces other government spending.
- Significant revenue to governments from the sale of recyclable material.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction

- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.
- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a

party will react to changes in cost, price, supply or demand, these standard assumptions were applied.

State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Key Uncertainties

Key uncertainties are the assumptions underlying the BAU waste management forecast, which affects the estimated GHG reductions. Other uncertainties: an incomplete data record of individual components of the Minnesota solid waste stream, limitations of modeling within WARM (inability to model source reduction within mixed waste categories), and data rounding. Statewide waste composition studies have been done infrequently. Some additional information will be forthcoming in future years as the ReTRAC reporting system matures.

Assuming that source reduction continues on an accelerated schedule, a key uncertainty in the projection is the composition of that avoided waste in future years, as consumer habits and the marketplace continue to evolve.

Additional Benefits and Costs

Implementation of this policy option is expected to lead to job growth in the state based on previous macro-economic analysis of waste management policies.

Feasibility Issues

Transforming Minnesota’s waste management practices to achieve these higher levels of source reduction, recycling, and composting will present significant challenges: hitting the 75% combined diversion goal will require more than doubling the best rolling-average “recycling improvement rate” per year (from about a half of one percent gain per year, to more than one percent gain per year). On a positive note, some encouragement came from legislative actions after MCCAG’s final report, which institutionalized the 75% diversion goal for the Metro counties, and provided additional funding for all counties.

Chapter XVIII. Appendix F-7. EPA's 111 (d) Rule Policy Option Recommendations

Policy Option Description

Since the official release date of EPA's Clean Power Plan (CPP), based on the Section 111(d) of the Clean Air Act (August 3rd 2015) that imposed first national limits on carbon dioxide (CO_2) pollution from power plants, substantial planning in many states has been conducted. States have been carefully assessing potential pathways for compliance and working on their electricity sector carbon mitigation plans. EPA's calculated target for the state of Minnesota (MN) is one of the highest in the nation (the targeted emissions rate for Minnesota overall electricity generation fleet is 1213 lbs CO2e/MWh[1], or 42% reduction in carbon dioxide emissions from power plants by 2030, using 2012 values as the baseline).

The Climate Solutions & Economic Opportunities (CSEO) project has analyzed the ability of Minnesota to comply with the Clean Power Plan's minimum emission limitations by implementing a package of CSEO policies with electricity system impacts. Minnesota must impose those emission limitations on the affected electricity generation units (EGUs) through standards of performance[2]. CSEO policies that affect electric utility system behavior in Minnesota and neighboring states, either through changing electricity supply composition or changing the demand for electricity, are: Energy supply (ES 1 and 2) sector, Residential, Commercial, Industrial and Institutional sector policies (RCII 1,2 and 4) , Forestry and Land Use (FOLU) policy 3 and Waste Management policy 1. Additionally, there are polices that cause marginal increase in electricity demand: Agriculture policy 4, WM 2 and WM 3. All the policies other than ES 1 and ES 2 are coded as "energy efficiency" (EE) in this analysis. Summary descriptions of the listed policies are provided at the end of this section, whereas more detailed descriptions can be found in respective policy option documentation (POD) chapters of this report. An evaluation of how the policies contribute to meeting the Clean Power Plan's target provides an additional perspective on the total value of the proposed policies, and place them more completely in the current national regulatory context.

Policies of greatest interest to Minnesota are Energy Supply (ES) sector and Residential, Commercial, Industrial, and Institutional (RCII) sector policies. ES and RCII policies together account for about 73% of the total GHG reductions achieved by the entire package of proposed policies against business as usual scenario (BAU), thus are considered crucial for the state of Minnesota. As Appendices V-7. 1 and 2 of this report show, these policies are not only cost effective, in terms of greenhouse gas (GHG) emissions abatement, but also a majority of them

[1] The description of EPA's targets for Minnesota is available at http://www3.epa.gov/airquality/cpptoolbox/minnesota.pdf

[2] Environmental Protection Agency. (2015, October 23). Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Final Rule. *80*. 14, Retrieved from https://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22842.pdf

produce negative net present values (NPVs), which indicates that they save money over the projected implementation period (2015-2030).

Policies evaluated under the 111(d) compliance analysis are ES 1 and 2, and EE policies, which comprise RCII 1, RCII-2, RCII-4, FOLU-3, A-4, WM-1, WM-2 and WM-3.

The Energy Supply (ES) sector covers sources of electricity, heat, and fuel supply for buildings, facilities, manufacturing, and other stationary uses. Most important of these in Minnesota (MN) is the electricity supply subsector, which includes emissions from all sources of generation used to supply the state's consumption of power. Legislation passed in 2013 supports the investigation of higher levels of renewable energy use in Minnesota, starting with increasing the Renewable Electricity Standard (RES) to 40% by 2030, and to higher proportions thereafter. State legislation also sets the goal that by 2030, 10% of the retail electric sales in Minnesota be generated by solar energy. ES 1 policy option aims to expand RES to 40% by 2030.

Minnesota's three largest coal-fired boilers at Xcel Energy's Sherburne County (Sherco) generating plant are Unit 1, 2 and 3. Units 1 and 2 are susceptible to both mercury and Regional Haze requirements, and may therefore be useful to analyze for some combination of repowering or retirement strategies. ES 2 policy evaluates a scenario in which Sherco Unit 1 is repowered in 2025 with natural gas and Sherco Unit 2 is retired in 2023 and replaced with a natural gas combined-cycle (NGCC) power plant. These policies modify the composition of Minnesota's electricity generation fleet.

The Residential, Commercial, Institutional, & Industrial (RCII) sector covers energy consumption (fuels and electricity) in buildings, facilities, municipal infrastructure, and industrial process. It also covers non-energy (process) emissions in the Industrial subsector. RCII-1 includes targets for implementing combined heat and power systems (CHP) systems fueled with natural gas, and systems fueled with biomass (typically wood) to displace central grid electricity and natural gas and fossil fuels use for commercial and industrial space, water, and process heating and cooling. The overall goals of this option are to implement 800 MW of gas-fired CHP and 300 MW of biomass-fired CHP by 2030. RCII 2 policy analyzes implementation of Minnesota's Sustainable Building 2030 (SB2030) initiative, which implies a transition to "Zero Energy" buildings: constructing highly energy efficient buildings and phasing in the use of renewable energy sources--such as solar thermal, solar photovoltaic, and biomass-fired heat use--to provide for the remaining energy needs of the buildings, and in some cases to export energy for use outside the building. This policy option will provide incentives for or mandates construction of buildings so that net zero energy use in new and renovated buildings is achieved incrementally by 2030. RCII 4 policy option increases the requirements of the existing utility energy efficiency resource standard (EERS) by increasing the EERS for electric utilities to 2.5% annually, while allowing utilities to count electric energy savings from energy utility infrastructure (EUI) improvements and electricity displaced by combined heat and power projects (CHP) on top of a minimum savings goal of 1.5% from end-use efficiency. All of the RCII policies reduce the demand for electricity and heating fuels.

The Forestry and Other Land Use (FOLU) sector primarily addresses carbon sequestration in forested and urban areas (i.e. "sinks" of carbon dioxide [CO_2]). Additionally, there are sources of greenhouse gases (GHG) in this sector, including wildfires and prescribed burns, and importantly methane emissions from wetlands (an uncertain, but potentially significant source). FOLU 3 policy option strengthens community forests across the state by increasing and maintaining the overall tree canopy cover of community forests to 40% by 2050. This policy reduces the demand for electricity and heating.

The Agriculture (A) sector addresses emissions sources in two primary subsectors: crop production and livestock management. This sector is important to the state's economy and is also a significant greenhouse gas (GHG) contributor (15% of Minnesota's emissions in 2010 and about 16% of Minnesota's emissions expected in 2030). A-4 policy option (advanced biofuels production) includes production based incentives to support commercial development of advanced biofuels in Minnesota. Advanced biofuel would be sourced primarily from Minnesota biomass feedstocks from agricultural or forestry sources, or the organic content of municipal solid waste. This policy crates marginal demand increase for electricity.

The Waste Management (WM) sector includes two subsectors: solid waste management and wastewater treatment. Key sources include landfills and municipal wastewater treatment. The sector contributed less than two percent of Minnesota's emissions in 2010 and is expected to contribute about 1.5% in 2030. WM-1 policy option addresses opportunities for energy conservation within wastewater treatment plants (WWTPs). The conservation mandate is technology agnostic to allow for flexibility. The policy option design calls for a state-wide reduction in energy usage from WWTPs of 25% by 2025. WM-2 policy (Front-End Waste Management: Source Reduction) aims at achieving a zero percent per capita increase in waste generation per capita by 2020 and a three percent decrease by 2025. WM-3 policy option has a goal of achieving a total recycling rate, including composting of 75% by 2025. WM-1 policy reduces demand for electricity in MN, whereas WM-2 and WM-3 policies create marginal increase in electricity demand.

Policy Options Design

In this section the design elements of the policies with the most significant impact on electricity demand are briefly described. As mentioned above, these policies are: all ES and RCII policies, FOLU-3 and WM-1 polices.

In ES policy package, ES-1 policy modeled in this section is structured as a Renewable Electricity Standard with the following design:

- Forty percent by 2030 – (modeling assumptions: 31% wind + 3% hydro + 3% biomass combined heat and power (CHP) + 3% solar)
- Goals are stated as a percent of annual Minnesota retail electricity sales (representing total contribution and not 'new' or 'incremental').

Note: Large industrial ratepayers are exempted from the current Solar Electricity Standard (216B.1691, Subd 2f. (d)) but as the specifics of the exemption are still in progress, for the purpose of modeling the proposed goals these ratepayers will be included in calculations of retail sales.

ES-2 policy was initially considered in a form of three distinct scenarios:

- Scenario 1: Repower Sherburne County unit 1 by 2025; retire unit 2 and replace it with NGCC by 2023
- Scenario 2: Retire both units and replace them with NGCCs by 2020
- Scenario 3: Repower unit 1 by 2020 and retire unit 2 and replace it with NGCC by 2020

After final consideration, Scenario 1 was chosen for purposes of analyzing integrative effects with other sectoral policies.

In RCII policy package, a brief design illustration of RCII-1, 2 and 4 policies is in the following table:

Table F-7.1 RCII Policy Options Design Goals

CSEO	Policy Option	Goal	Timeline	Details
RCII-1	Combined Heat and Power	CIP (RCII-4): Natural Gas 34TBtu by 2030 Electric 800 MW by 2030 RES (ES-1): 300 MW	2016 - 2030	Includes: All CHP (SEE BELOW)

RCII-2	SB2030/ Zero Energy Transition/Codes	All new and renovated commercial buildings in the state, and all multi-family residential buildings four or more stories in height, will be required to use SB2030 through a stepped process, by 2020. All new one and two family dwellings and multi-family residential buildings three stories or less in height in the state will be required to use SB2030, through a stepped process, by 2025. Sufficient technical assistance and training is available to assist local units of government, architects, engineers, builders, developers in moving toward SB2030.	Two separate schedules for new and renovated commercial buildings (2015-2030), and residential buildings (2016-2030).	Parties Involved**:** All parties involved in owning, operating, renovating, occupying, or other activities associated with Minnesota's new or major renovations of residential, commercial, institutional, municipal, and industrial building stock.
RCII-4	Increase EE Requirement (CIP)	Natural Gas Utility: 1.5% CIP Goal (Include 1% from Demand-side Management only) (Include 34 TBtu output of displaced fossil fuels goal by 2030) Electric Utility: 2.5% Demand-Side Management (1.5% must be DSM as defined in 216B.241) (Include an embedded 800 MW of generated electricity from CHP systems goal to be achieved by 2030)	2016 - 2030 3 Year ramp up period between 2016-2019 Minimum goal for End-Use Efficiency with an embedded CHP goal for electric and natural gas utilities.	Includes: Projects as defined in 216B.241, Subdivision 1 (e) (n) and (o); and Subdivision 10 Natural Gas CHP and distributed generation tech/fuel sources eligible under 216B.2411

FOLU-3 policy was designed to accomplish three following goals:

By 2050, all Minnesota cities/towns will have at least 40% overall tree canopy cover, with discrete goals for residential, commercial/industrial, and other land use types.

By 2035, all Minnesota cities/towns will achieve no net loss of overall tree canopy cover, using DNR's 2010 Rapid Assessment as a baseline. This will be achieved primarily through preservation of canopy cover and secondarily through tree planting. *Goal is strategic in nature, and represents a key milestone toward achievement of the 2050 goal. It is a non-GHG quantified goal*.

- By 2035, 350 Minnesota communities will have implemented inventory base management plans. Similarly, this goal is strategic in nature and represents a key milestone toward achievement of the 2050 goal. This is a non-GHG quantified goal.

WM-1 policy option addresses opportunities for energy conservation within wastewater treatment plants (WWTPs). Its design implies the following goals and timing:

Goals: Mandate for Publicly-Owned Treatment Works (POTW) owners:

Energy Conservation: Reduce electrical energy purchase by 25% from continuing operations by 2025.

Timing: See above; assume a linear progression toward the goal with implementation beginning in 2015.

Implementation Mechanisms

Our 111(d) analysis assesses the selected policies under both rate-based and mass-based (with the new source complement) approaches.

Under the state average rate-based approach, the average CO_2 emissions rate of the entire fleet of the existing fossil steam and natural gas combined cycle units (the "affected units: as defined in the final 111(d) rule) that constitute the baseline in each year is estimated. Then, the average annual emissions rate for the existing affected units achieved by implementing the combination of supply and demand side energy policies is estimated, based on two scenarios addressing different displaced electricity assumptions explained further under "quantification methods" chapter in this section. These resulting emission rates for the two scenarios are then compared to the appropriate annual rates prescribed by EPA under the CPP emissions trajectory to determine if CSEO policies allow the state of Minnesota to be compliant under the final 111(d) enforcement framework.

Under the mass- based approach, an equivalent process is undertaken except that the total CO_2 emissions for both existing units and new NGCC units are estimated. The total emissions from 111(d) affected EGUs (fossil steam and natural gas combined cycle plants) are estimated and an estimate of the emissions of new units that will come online in the baseline is added, to obtain the total annual baseline emissions for the state. Then, the annual CO_2 emissions for these units after the implementation of CSEO policies under two displaced electricity scenarios are estimated. The results of these scenarios are then compared to the CPP mass-based goal (with new source complement) to determine which CSEO policy scenarios allow MN to be compliant under the CPP, and what relative shift in emissions from the baseline can be expected.

It should be noted that EPA's estimated new source complement emissions are much lower than emissions projections prepared by the MN staff under the baseline inventory (the new NGCC units under MN projection emit 1,967,958 short tones of CO_2e in 2030, whereas the new source complement NGCC units projected by EPA for MN emit 252,805 short tones of CO_2e in 2030). This discrepancy creates a situation where it becomes more difficult for MN to comply with the rule than EPA expects, if it chooses a mass-based + the new source complement approach.

Related Policies/Programs in Place and Recent Actions

Mercury and Air Toxic Standards (MATS) are designed by EPA (under 112 amendment of the Clean Air Act) to limit the emissions of mercury, arsenic and other toxic air pollutants, and they cover coal and oil fired power plants that have 25 MW power capacity or higher[3]. The standards were released on November 19, 2014. Minnesota's affected electricity generation units are fully compliant with MATS.

Clean Energy Incentive Program (CEIP) is a special voluntary program established under the Clean Power Plan. Its purpose is to incentivize states to implement early eligible renewable energy and energy efficiency projects during 2020 and 2021 (before the beginning of the interim compliance period in 2022), earn credits for MWhs of renewable electricity generated or MWh of electricity demand reduced and use those credits for compliance purposes during the interim or the final compliance period. EPA determined that the size of CEIP set-aside pool of credits to be 300 million of CO_2 allowance available for all the states[4]. Market dynamics resulting from trading of CEIP credits under both rate and mass based approaches is not reflected in this analysis. These dynamics would influence generation behavior of particular affected EGUs (thereby influencing their emissions) in ways that are not captured in this analysis.

Quantification Methods

Estimation of 111(d) Baseline

Unit-level emission and generation forecasts were not available for the MN Electricity Supply Sector, therefore, the 111(d) baseline was estimated based on applying the fuel/technology-level MPCA forecast trends to 2012 EPA data for 111(d) applicable units (i.e., the trend for total coal generation was applied to the 2012 EPA data for coal-fired 111(d) units). The estimated baseline assumes that 111(d) units generation in these fuel/technology categories will grow at the same rate as the MPCA forecast for total generation in those categories. Generation and emissions forecast values for new and existing NGCC units were estimated using the capacity

[3] Environmental Protection Agency (2015, November 19). Mercury and Air Toxics Standards (MATS) Basic Information. Retrieved from http://www3.epa.gov/mats/basic.html

[4] Environmental Protection Agency. (2015, October 23). Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Final Rule. *80*. 15, Retrieved from https://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22842.pdf

(MW) and capacity factors for those units used in the MPCA baseline forecasts. For the rate-based baseline, only the existing NGCC units were included for projecting the 2012 EPA data. For the mass-based baseline, emissions from new NGCC units were also included.

Estimation of Emission and Emission Rate Reductions

Reductions in electricity generation and the associated reductions in emissions estimated as a part of the CSEO policy analyses were subtracted from the estimated 111(d) baselines to approximate the resulting emissions mass and emission rates. These were compared to EPA's rate-based and mass-based goals for MN. For the rate-based goal, only existing fossil steam and NGCC units were included in the estimated baseline. This was done to reflect the stipulation in the final rule, which precludes the shift in generation between the existing and new fossil fueled units (coal and natural gas), but allows only that shift to occur among the existing units (building block 2) under the rate-based approaches. For the mass-based (with the new source complement) goal, new and existing fossil steam and NGCC units were included in the estimated baseline. This is consistent with a simplified requirement EPA offered to the states that opt for this approach[5]. Two scenarios for how the CSEO policies will offset MN ES sources were analyzed; these include:

- All source offset proportionally – assumes that 111(d) units will be offset in the same proportion as the proportion of 111(d) unit generation to the total ES baseline (including imports). For example, in 2015 111(d) sources generate 60% of the total electricity consumed in MN, so 60% of emission reductions from RE/EE measures are allocated to 111(d) sources.
- ES-1 (RE) offsets in-state sources; EE policies offset imports - assumes that ES-1 will offset in-state sources (111(d) sources offset proportionally to total in-state generation), and EE will offset imports before offset in-state sources. In other words, no reductions from EE measures will be allocated to 111(d) sources until reductions from those policies exceed electricity imports.

Results of the Analysis

For the purposes of this analysis, Center for Climate Strategies' (CCS) 3E Planning Synthesis Module tool was used, while utilizing input data both from EPA's Emissions & Generation Resource Integrated Database (eGRID) from 2012[6] and Minnesota Pollution Control Agency (MPCA)[7].

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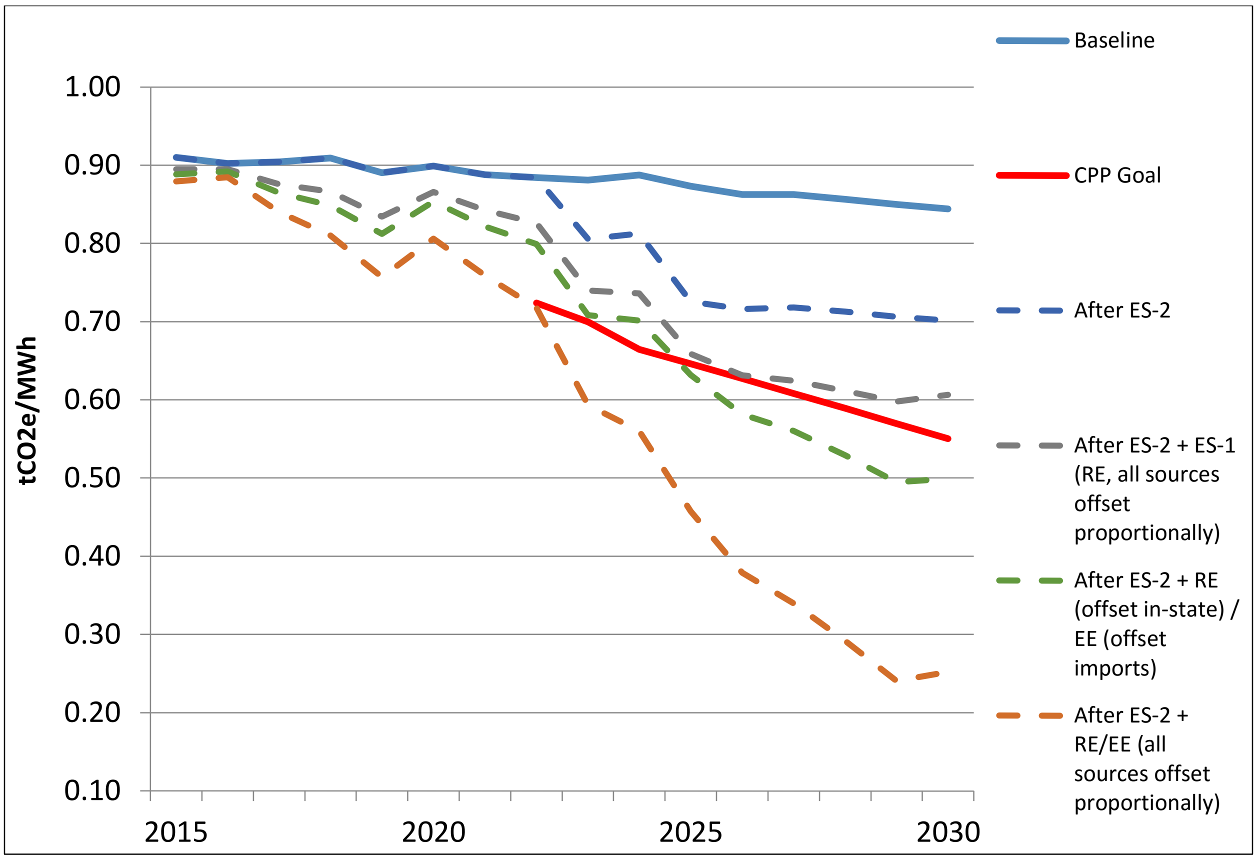
[5] The description of EPA's targets for Minnesota and the streamlined requirement are available at http://www3.epa.gov/airquality/cpptoolbox/minnesota.pdf

[6] Environmental Protection Agency. (2015, October 29). eGRID. Retrieved from http://www.epa.gov/energy/egrid

[7] More details on this analytical approach are provided in **Quantification Methods** section of this chapter.

Figure F-7.1 Emission Rate for 111(d) Applicable Units



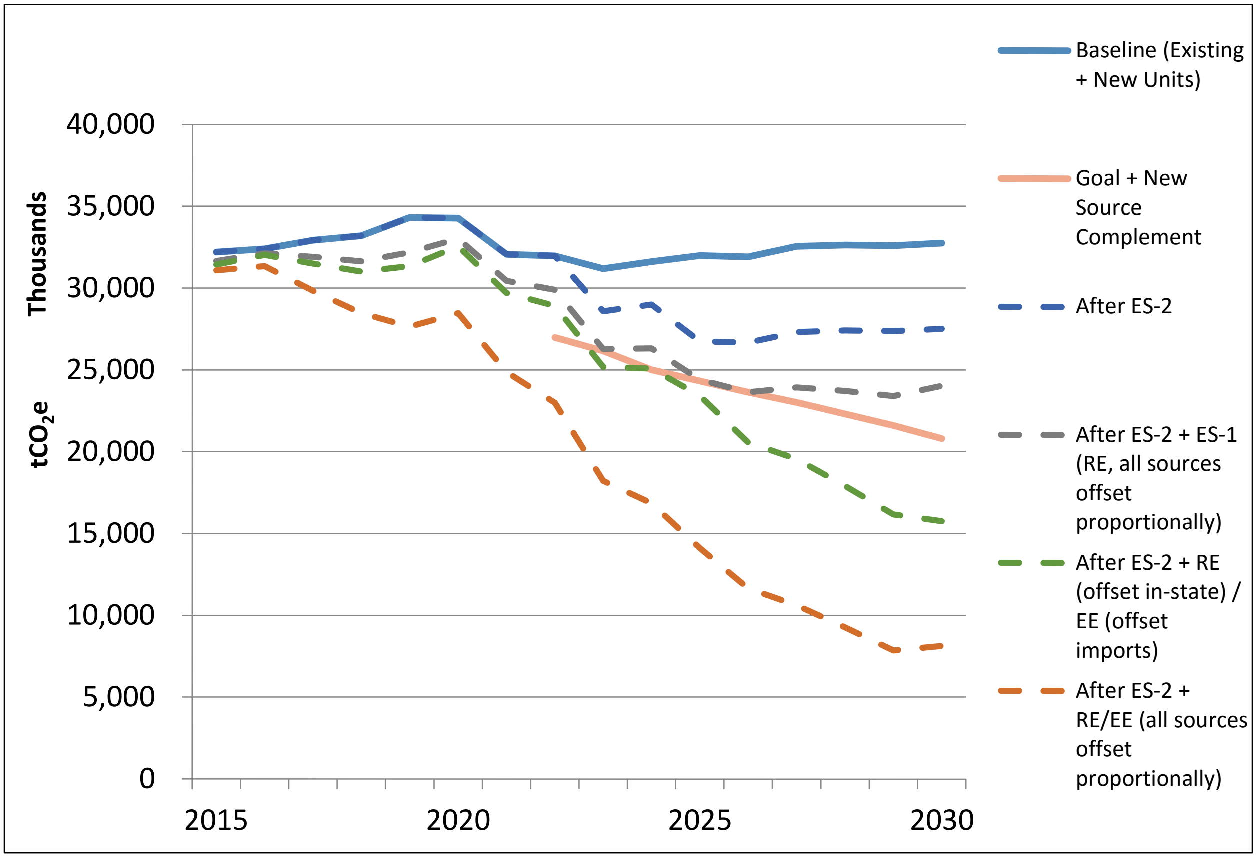
Notes:

The dashed lines present various CSEO policy scenarios' pathways in terms of the emission rate of the overall MN electricity sector that they induce.

Blue solid line presents an estimated MN greenhouse gas and energy baseline, using marginal resource mix assumptions provided by MPCA.

Red solid line presents Clean Power Plan goal calculated for Minnesota, expressed as CO_2 emissions rate pathway.

Figure F-7.2 Mass Emissions for 111(d) Applicable Units



Notes:
The dashed lines present various CSEO policy scenarios' pathways in terms of the mass-based rate of the overall MN electricity sector CO_2 emissions that they induce.
Blue solid line presents an estimated MN CO_2 and energy baseline, using marginal resource mix assumptions provided by MPCA.
Red solid line presents Clean Power Plan goal calculated for Minnesota, expressed as mass-based CO_2 emissions pathway.

The two graphs above show both compliance and non-compliance pathways modeled under different assumptions pertaining to what electricity will be displaced by implementing CSEO policies: in-state generated electricity, out-of-state electricity imports, or both with different ratios (detailed explanation of these crucial assumptions is provided under "quantification methods" section of this chapter). The first graph shows the changes in the average state emissions rate of the existing 111(d) applicable electricity generation fleet in Minnesota as a result of introduction of zero emission, renewable sources, and the demand side energy efficiency measures. This is consistent with the EPA's approach to calculating state specific emission rate goals based on averaging of subcategory specific emissions performs rates[8].

The second graph shows changes in the total amount of annual CO_2 emissions from 111(d) applicable MN generation (mass-based approach with the source complement) as a result of implementing CSEO policies that affect electricity supply and demand. EPA establishes equivalency between this mass-based and rate-based targets, and both are derived from the application of best system for emissions reductions (BSER)[9]. As a result of BSER application, the expected emissions limits in each year are quantified for the interim period (2022-2029) and the final period (2030 and beyond). These limits are shown in both graphs as solid red line (for the rate-based approach) and the solid orange line (for the mass-based approach). Solid blue lines represent Minnesota's electricity sector baseline, estimated using marginal electricity resource mix and other relevant assumptions provided by MPCA.

It is evident from both graphs that two policy scenarios (light green and brown colors) that combine all the mentioned CSEO policies realized under different displaced electricity assumptions described above, enable the Minnesota to comply with the goals set by the Clean Power Plan in the final compliance period, while one of them (ES + EE policies-all sources offset proportionally) establishes compliance even during the interim period. This is also true under the mass-based (with new source complement) approach. At the same time, if the state decides not to implement these policies, the compliance gap between CCP goal and the baseline remains large (estimated baseline emissions in 2030 are 32,766,605 tCO2e, whereas the estimate CCP target for that year is 20,573,680 tCO2e), assuming the state continues with business as usual only.

Tables F-7.2 and F-7.3 below are quantitative translation of the above graphs. Table F-7.2 represents the rate-based case (this time we express the emission rates in lbs CO2e/MWh the same way EPA does in its final rule) and Table F-7.3 contains the outcomes for the mass-based case. The years chosen are: the assumed beginning of the policy implementation period (2015), the middle of the CPP interim period (2025), and the beginning of the CPP final period (2030). Scenarios ES-2 + RE/EE (all sources offset proportionally) and ES-2 + RE (offset in-state) / EE (offset imports) both individually allow Minnesota to achieve compliance with the EPA's 111(d) rule targets for the state in the final period. This is true whether the state opts for the state rate-based or the mass-based approach.

[8] Environmental Protection Agency. (2015, October 23). Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Final Rule. *80*. 161. Retrieved from https://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22842.pdf

[9] Environmental Protection Agency. (2015, October 23). Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Final Rule. *80*. 6. Retrieved from https://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22842.pdf

Table F-7.2 Forecasted Emission Rates for Baseline, CPP Goal Scenario and Different CSEO Policy Scenarios

Scenarios	Units	Year		
		2015	2025	2030
Baseline (Existing Units)	lbs CO2e/MWh	2007	1925	1861
CPP Goal	lbs CO2e/MWh		1424	1213
After ES-2	lbs CO2e/MWh	2007	1599	1547
After ES-2 + ES-1 (RE, all sources offset proportionally)	lbs CO2e/MWh	1973	1453	1337
After ES-2 + RE/EE (all sources offset proportionally)	lbs CO2e/MWh	1939	1009	555
After ES-2 + RE (offset in-state) / EE (offset imports)	lbs CO2e/MWh	1959	1392	1100

Notes:
Acronym "EE" means "energy efficiency" and comprises all the policies that reduce demand for electricity on the grid to various degrees, among other actions and economic impacts they cause. As noted in the first page of this chapter, these are all RCII policies, TLU-2, FOLU-3, A-4, WM-1, WM-2 and WM-3.
The cell reserved for CPP scenario emission rate for 2015 is intentionally left empty, since the CCP compliance period starts in 2022.

Table F-7.3 Forecasted Mass-based Emissions for Baseline, CPP Goal Scenario and Different CSEO Policy Scenarios

Scenarios	Units	Year		
		2015	2025	2030
Baseline (Existing + New Units)	tCO2e	32,208,028	31,981,444	32,746,153
Mass Goal + New Source Complement	tCO2e		24,320,241	20,803,024
After ES-2	tCO2e	32,208,532	26,750,241	27,514,962
After ES-2 + ES-1 (RE, all sources offset proportionally)	tCO2e	31,662,881	24,391,627	24,026,089
After ES-2 + RE/EE (all sources offset proportionally)	tCO2e	31,092,564	14,103,026	8,126,943

After ES-2 + RE (offset in-state) / EE (offset imports)	tCO2e	31,441,561	23,424,943	15,746,795

Notes:
tCO2e are metric tons of CO_2 equivalent.
Acronym “EE” means “energy efficiency” and comprises all the policies that reduce demand for electricity on the grid to various degrees, among other actions and economic impacts they cause. As noted in the first page of this chapter, these are all RCII policies, TLU-2, FOLU-3, A-4, WM-1, WM-2 and WM-3.
The cell reserved for CPP scenario emission-based value for 2015 is intentionally left empty, since the CCP compliance period starts in 2022.

The aggregate cost effectiveness (CE) value for the scenario “ES-2 + RE/EE (all sources offset proportionally)” was calculated to be -$2.0/ton CO_2 e. This scenario comprises all the CSEO policies that affect electricity generation and emissions (ES-1 and 2, RCII -1,2 and 4, TLU-2, WM-1 ,2 and 3, FOLU-3, and A-4/A-5 policies) within the confines of the Section 111(d) rule, Clean Power Plan (CPP). The negative sign indicates that the package of CSEO policies that allow Minnesota to comply with the CPP, when implemented, achieve net cost savings of $2 per ton of CO_2 e they reduce over the modeling period.

As explained in Appendix E, Policy Quantifications Principles Guidelines, the CE metric for each policy is calculated by dividing its NVP values with its cumulative GHG reductions achieved by that policy, which produces values expressed in $/ ton of CO_2 e. For the purposes of CPP compliance, only the electricity system related GHG reductions for each policy achieves are derived, and then those values are used to calculate CPP related cost effectiveness. Individual policy CE values used in this section for the calculation of the aggregate CE related to compliance with CPP are different then the total CEs of each policy, which consider all GHG reductions each policy achieves (not just those related to the electricity system and 111(d) rule limitations).

The contribution of each policy to complying with the CPP (expressed as a percentage of the total contribution) are shown in the table below.

Table F-7.4 Contribution of Individual Policies to Complying with 111(d) (in %)

ES-2	17.41
ES-1	22.94
RCII-1	23.36
RCII-2	21.13
RCII-4	12.15
TLU-2	2.10

FOLU-3	0.96
WM-1	0.38
A-4/A-5	N/A
WM-2	N/A
WM-3	N/A

Table F-7.4 shows that ES and RCII polices achieve the greatest reduction in GHG emissions related to affected EGUs and have the greatest contribution to Minnesota CPP compliance. Since A-4/A-5, WM-2 and WM-3 policies increase the demand for electricity and increase the electricity system emissions (to a small extent), for those policies the contribution calculation is not applicable as a GHG reduction but is included in net effects within the sectors.

Aggregate CE is used here as a “cost of compliance” metric, but is not the same as “carbon price” (or CO2 allowance price) that might result from implementation of a market based program. Allowance price estimation requires additional consideration of regional supply and demand dynamics affecting transaction prices. To the extent that CE is lower in Minnesota than surrounding states, its cost of allowance prices is lower and its ability to sell allowances into higher cost markets is higher.

It is important to understand that a variety of metrics for carbon costs and prices can be used, depending on the situation. These include six different metrics described in more detail below. The relative adequacy of using each metric depends on the type of question asked and the associated analysis. All are defined in terms of \$/CO_2 ton, which can sometimes lead to confusion. These include: carbon allowance price, carbon tax, average policy cost, marginal abatement cost, social cost of carbon and an effective price on carbon.

1. **Carbon allowance price** approach is used in assessing the costs to GHG emitters operating under a “cap-and-trade” system. One allowance presents a right to a covered entity to emit one tone of $CO_{2.}$ The fact that they have a monetary value gives an incentive to polluters to either reduce their emissions in order to reduce the need to buy additional allowances to cover the remaining emissions, or to sell the allowances they possess and make profits. Justification for this approach, as defined in economic theory, lies in an effort to internalize the externality caused by emitting $CO_{2.}$ It fundamentally presents the price to *reduce* the emissions of CO2.
2. **Carbon tax** imposed on each tone of CO_2 emitted, similar to carbon allowance price, has a purpose to internalize the externality caused by carbon pollution (that externality constitutes the socio-ecological impacts of climate change). The main difference is that tax is defined by legislation and provides certainty of cost/price to polluters, but it does not guarantee the level of emissions reductions achieved (which depends on the abatement costs that generally change overtime). On the other hand, the number of carbon allowances available in a cap-and trade system secures that the mitigation target (expressed as a number of emissions reductions required) will be met, but does not provide the certainty of price/cost (since the market dynamics can lead to allowance

price fluctuation, as with a market of any other commodity). As with a carbon allowance, to a polluting entity subject to the carbon tax this is a cost to *reduce* its CO2 emissions.

3. **Marginal abatement cost of carbon** presents the cost of abating the last tone of CO2e in order to achieve certain carbon mitigation goal, assuming the abatement measures are undertaken in a specific order, from the least expensive to the most expensive one. Marginal abatement cost curves in general have been present in analytical field since the seventies, and they are used in conventional economics to determine an optimal levels of production, and in environmental economics to determine an optimal levels of pollution, among other applications. They also used to assess an economic potential and the total cost of achieving certain target. In the context of climate mitigation, it involves constructing a supply curve of abatement options, starting with the least expensive (in terms of its average cost per tone of CO2e reduced) option at the beginning of the curve, than stacking options with the increasing costs of abatement up the curve. The place where the supply curve intersects the quantitative carbon abatement target is the cost margin, and the price of the last mitigation option (in $/tone CO2e) required to reduce that marginal tone is the marginal abatement cost. Consequently, the integral of the area under the curve presents the total cost of achieving that specific target. Economic theory suggests that, in an efficient cap-and-trade market, if the price of carbon allowances closely follows the desired marginal cost of abatement, then that cap-and-trade system will cause the abatement of CO2 emissions that corresponds to that marginal abatement cost (and can be read from the marginal abatement curve). In this regard, marginal abatement curves play import role in setting the initial price of carbon allowances, or a carbon tax.
4. **Average cost of carbon** policy (on $/tone CO2 basis) is obtained by deriving first a net present value (NPV) of a policy, which is the difference between the total societal costs and the total benefits achieved by the policy over the implementation period, both first aggregated and then discounted to the initial year, and then dividing that NPV by the estimated total cumulative CO_2 emissions reductions achieved over the same period. If the policy implementation produces net benefits, which are expressed as a negative NPV, that the average cost of carbon policy will have a negative sign, as oppose to the rest of the carbon price metric described here which always have a positive sign. All cost effectiveness values estimated in this report, including the one in this section that relates to 111(d) compliance, present average costs of the CSEO policies. This is an average price of CO2e tone *reduced* by the policy.
5. **Social cost of carbon** (SCC) is a product of a damage function modeling associated with socio-economic and environmental impacts of climate change. It presents monetized present and future damages caused by one additional tone of CO_2 emitted, aggregated and discounted to the year that tone entered the atmosphere. It attempts to answer the question how much it costs the entire society to continue emitting, so it is a cost of a tone of CO2 *emitted*.
6. **Effective price on carbon** is a non-market based approach associated with command and control mechanisms, where a regulatory entity sets a pollution standard that must be met with a prescribed technology (or a set of technologies). The prescriptive

guidelines create a predetermined cost of reducing pollution by certain amount of CO2e tones, which yields a price of a tone of carbon *reduced* faced by the covered entity, but it is obtained through a non-market based approach.

U.S. federal agencies generally use SCC in their regulatory rule making and regulatory impact analyses (RIAs). Carbon allowance price is a most widely used approach to modeling a cost of a future carbon policy with a national or a global scope, when that policy is expected to take on the design of a cap-and-trade system.

Many modeling studies that assess impacts of a potential future carbon regulation on electricity sector use estimates of carbon allowance prices to project future cost of compliance for electric utilities. The principle is that the cost is imposed on every tone emitted by the polluting sources, and that affects their production costs and the dispatch order of affected generation units, which modeling captures.

Some utilities use effective price on carbon when modeling their Integrated Resource Plans (IRPs) to simulate a financial risk of future carbon regulation anticipated to come in a form of a standard. They do that either voluntary or under a mandate set by the states in which they operate. In other cases, carbon pricing value in utilities' IRPs is set by a Public Utility Commission (PUC). PUCs tend to use the latest studies and publications available, produced by government and non-government institutions, to decide what cost best represents the risk of future carbon regulation, to be included as a cost of compliance in utilities IRPs modeling efforts.

Minnesota Public Utility Commission's most recent estimate of the cost of future carbon dioxide regulation are in the range between $9 to $34 per tone of CO2. Their use in regional utilities' IRPs as a projection of future cost for each tone of CO2 emitted is mandated. That value is derived from a set of studies that most likely focused on analyzes of carbon allowance price forecasts in different cap-and-trade markets, and related marginal carbon abatement cost curves.

Xcel Energy, the utility operating in Minnesota and six other states, is the only entity directly affected by ES-2 policy potential implementation. ES-2 policy was one of the scenarios considered in Xcel Energy's IRP from 2013. In its most recent IRP update, Xcel Energy used $ 21.5/tone of CO2 cost of compliance, as mandated by Minnesota PUC, in order to evaluate different energy resource acquisition scenarios' costs and impacts on rate-payers. It is important to note that CCS's estimation of 111(d) related compliance cost of a portfolio of CSEO policies is based on an aggregate cost effectiveness (CE) value, which is an average cost of policy implementation per tone of CO2e reduced. Also, CCS's analysis of ES-2 policy uses the same principle for calculating ES-2 CE. Therefore, the cost of compliance values in Xcel Energy's IRP and CCS's 111(d) analysis are derived from different methodological approaches, as explained above, even though the unit is the same ($/toneCO2). Due to this methodological disparity, any comparison between these two approaches to policy evaluation would be misleading.

Key Uncertainties

- Generation from units subject to 111(d) standards may follow trends different than those for other in-state units under BAU conditions.
- Differences in carbon intensity between 111(d) units, other in-state units, and electricity imports are not captured in this analysis.
- Market dynamics resulting from trading of energy rate credits (ERCs) under the rate-based approach, carbon allowances under the mass- based approach assumed here, or CEIP credits under both approaches is not reflected in this analysis. These dynamics would influence generation behavior of particular affected EGUs (thereby influencing their emissions) in ways that are not captured in this analysis.

Macroeconomic Impacts of CPP Set of Policies

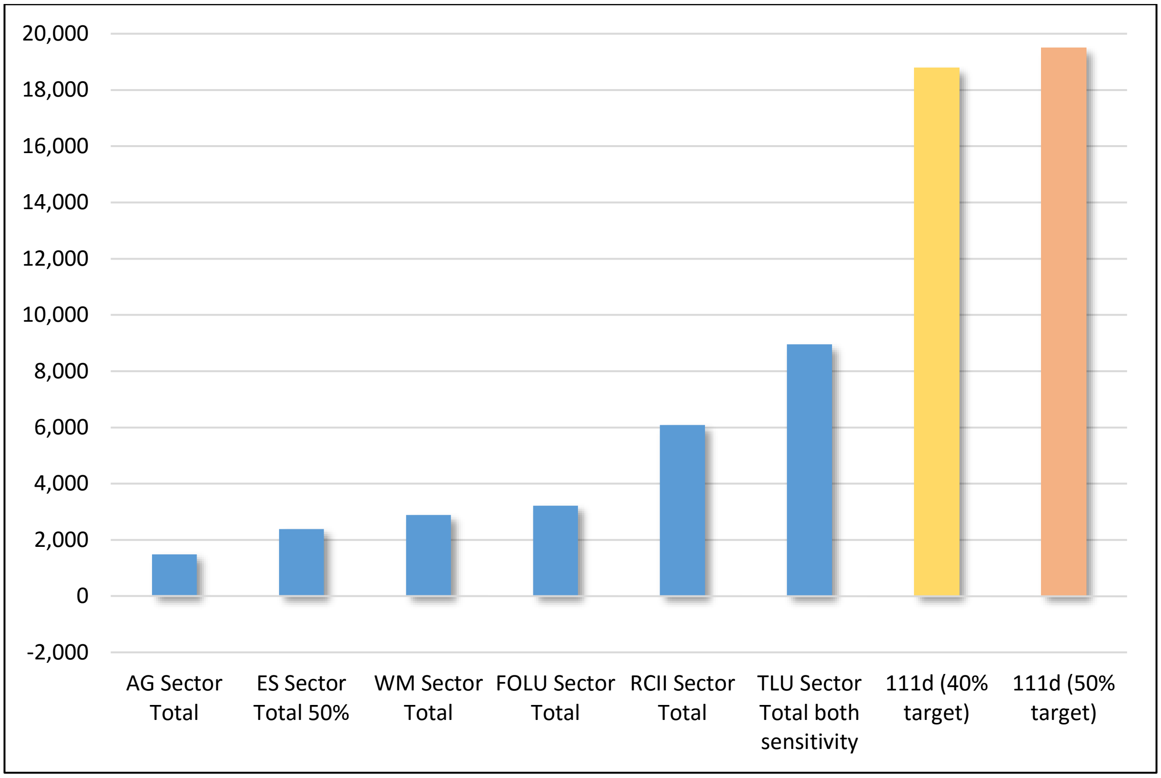
In addition to macroeconomic analyses of individual options, CCS utilized the Regional Economic Models, Inc. (REMI) PI+ software to also assess potential macroeconomic impacts of the package of CSEO options relevant to compliance with the CPP. Table below summarizes the results of that analysis. It shows estimated CPP policy package's impact on GSP, employment and total earned income in the state.

Table F-7.5 Macroeconomic (Indirect) Impacts of Clean Power Plan

Macroeconomic (Indirect) Impacts Results									
Scenario	Gross State Product (GSP, $2015 Millions)			Employment (Full & Part-Time Jobs)			Income Earned ($2015 Millions)		
	Year 2030[d]	Average (2016-2030)[e]	Cumulative (2016-2030)[f]	Year 2030	Average (2016-2030)	Cumulative (2016-2030)	Year 2030	Average (2016-2030)	Cumulative (2016-2030)
CPP (ES-1 40%)	$2,669	$ 1,831	$ 27,463	26,480	18,796	281,940	$2,605	$ 1,604	$ 24,063
CPP (ES-1 50%)	$2,894	$ 1,914	$ 28,716	28,140	19,507	292,610	$2,798	$ 1,672	$ 25,078

Notes:
[a] Gross State Production changes in Minnesota. Dollars expressed in $2015.
[b] Total employment changes in Minnesota.
[c] Personal Income changes in Minnesota. Dollars expressed in $2015.
[d] Single final year value. Year 2030 is the final year of analyses in this project.
[e] Average value from the year 2016 to the year 2030. The average value is calculated from the first year of the policy implementation through the year 2030 if implementation of the policy starts after year 2016.
[f] Cumulative value from 2016-2030 time period.

Figure AP F-7.3 – Average Annual Jobs Impact of 111(d) Scenarios vs. Sector Impacts



Macroeconomic index

Graphs below present the overall macroeconomic impacts of the set of CSEO policies relevant to the compliance with the CPP.

The overall economic impact from each scenario is expressed by a single score, and compares those scores. CCS created this single score (a Macroeconomic Impact Index) in order to encapsulate in one measurement the relative macroeconomic impacts (including jobs, GSP and incomes) of each policy. We have found in our own work and in the literature that indexed scores can be helpful to many readers when comparing options with multiple characteristics.

To produce this score, CCS set the results from the absolute best-case scenario (i.e. the implementation of all CSEO policies with all their optimal sensitivities in place) equal to 100, with that scenario's jobs, GSP and incomes impacts weighted equally at one third of the total score. Each policy's jobs, GSP and income impacts are scaled against that measure, and given a total score. The overall score indicates how significant a policy's impact is projected to be. Negative impacts are scaled the same way, except that those impacts are given negative scores and pull down the total score of the policy.

These scores are calculated separately for the final year of the study (2030), the *average* impact over the 2016-2030 period, and the *cumulative* impact of the policies over that period. While each scenario has one line, the relative importance of jobs, income and GSP remains visible as differently-shaded segments of that line.

Figure F-7.4 Macroeconomic Impact Index, 2030

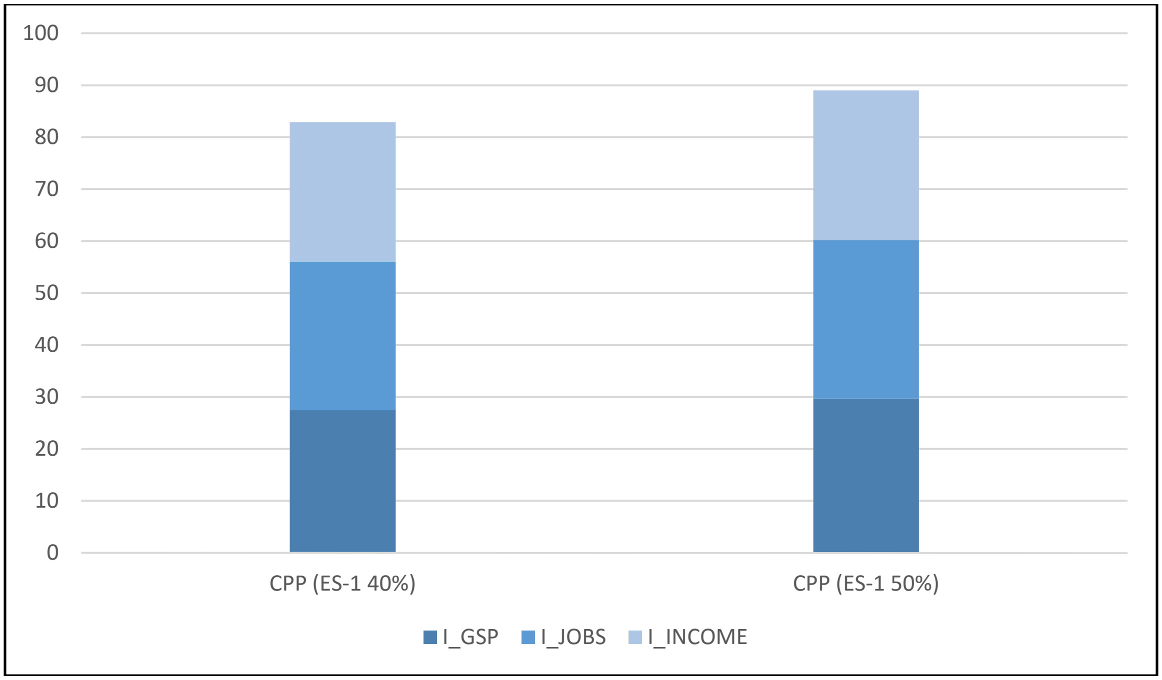


Figure F-7.5 Macroeconomic Impact Index, 2016-2030, Cumulative Value

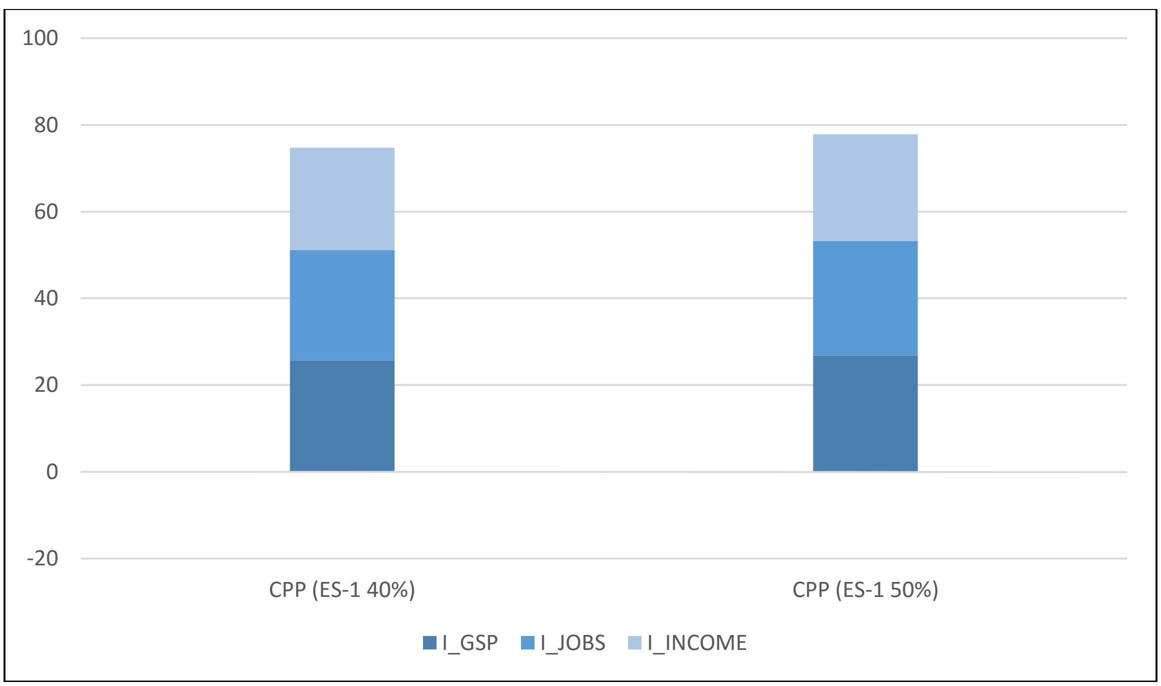
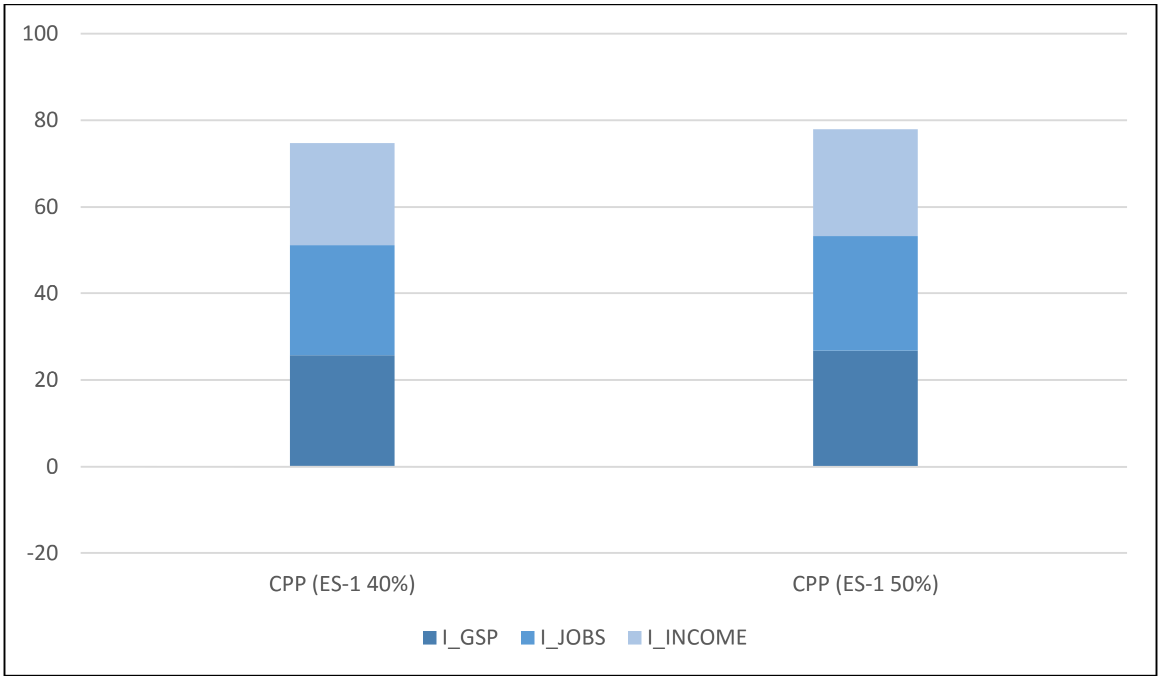


Figure F-7.6 Macroeconomic Impact Index, 2016-2030, Average Value



Graphs below show the trend of CPP policies impacts during the year 2015 to the year 2030.

Figure F-7.7 CPP Impacts on GSP

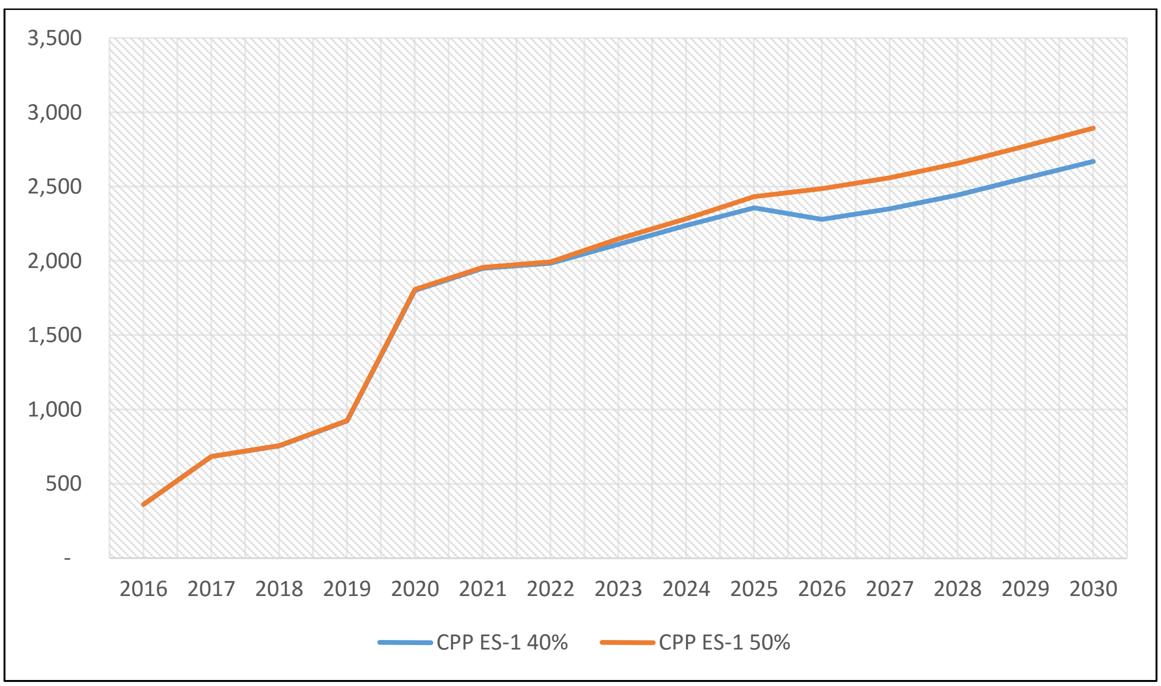


Figure F-7.8 CPP Impacts on Employment

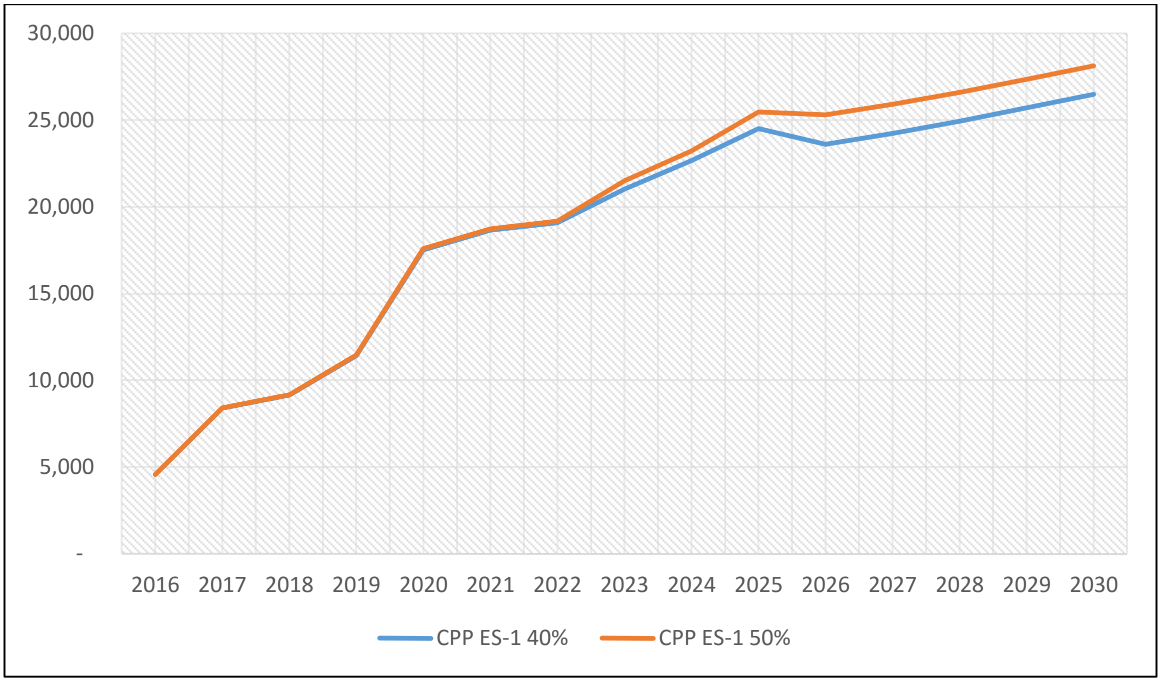
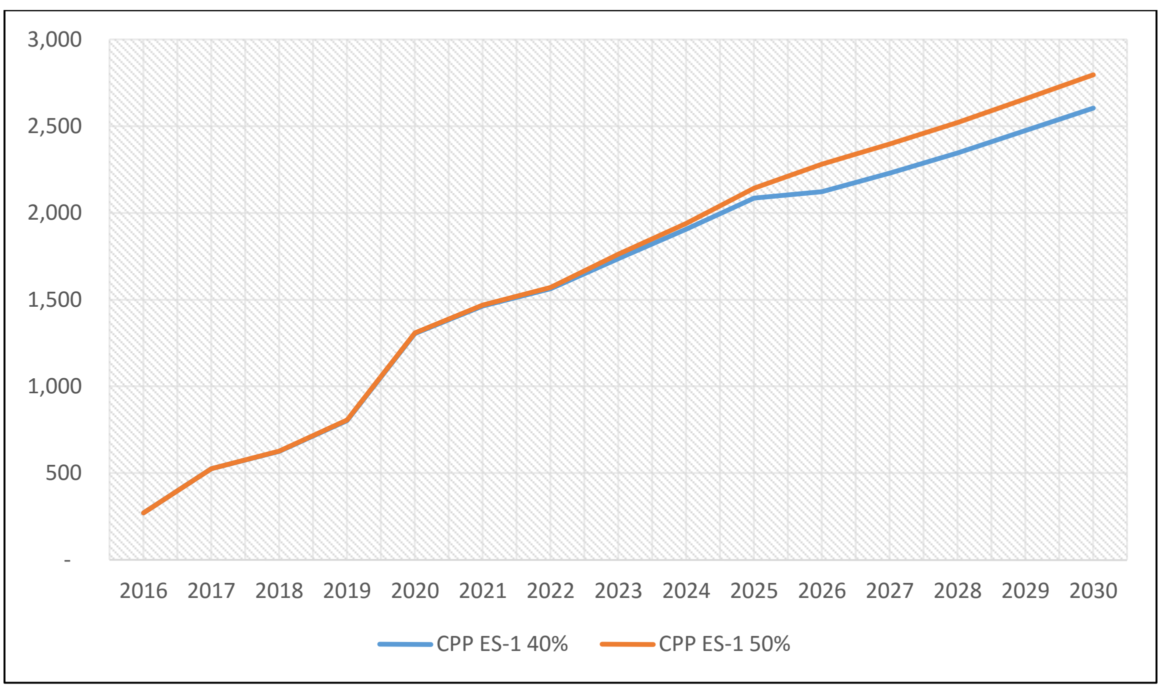


Figure F-7.9 CPP Impacts on Income



Bar charts that follow show macroeconomic impacts of CPP policies on GSP, personal income, and employment in the final year (2030), average (2016-2030) and cumulative (2016-2030). Light color indicates sensitivity scenarios.

Figure F-7.10 CPP Impact on GSP, year 2030

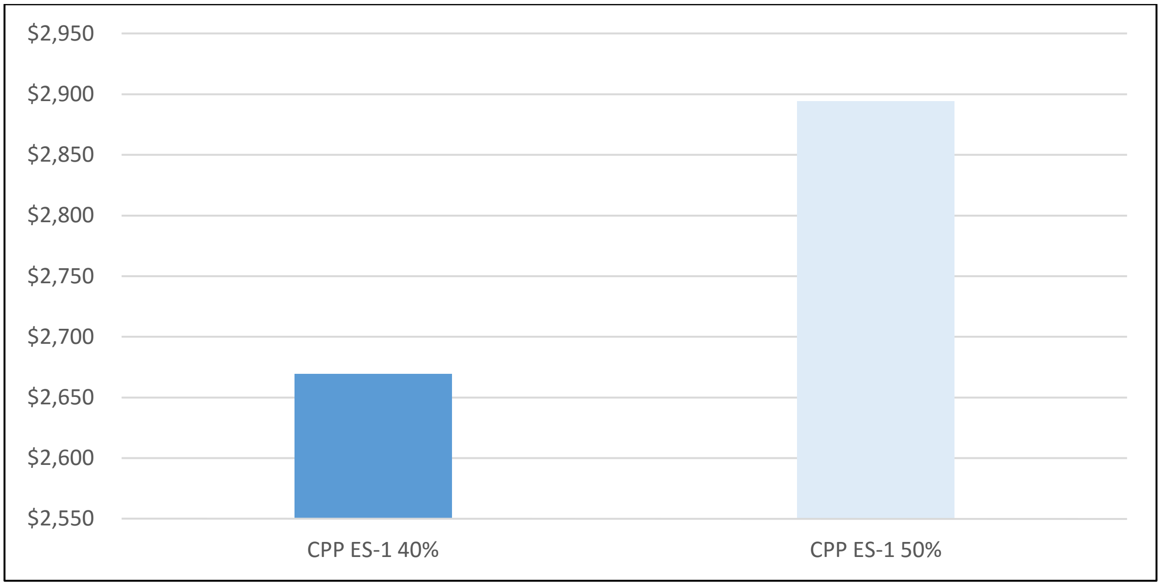


Figure F-7.11 CPP Impacts on GSP, 2016-2030 Average

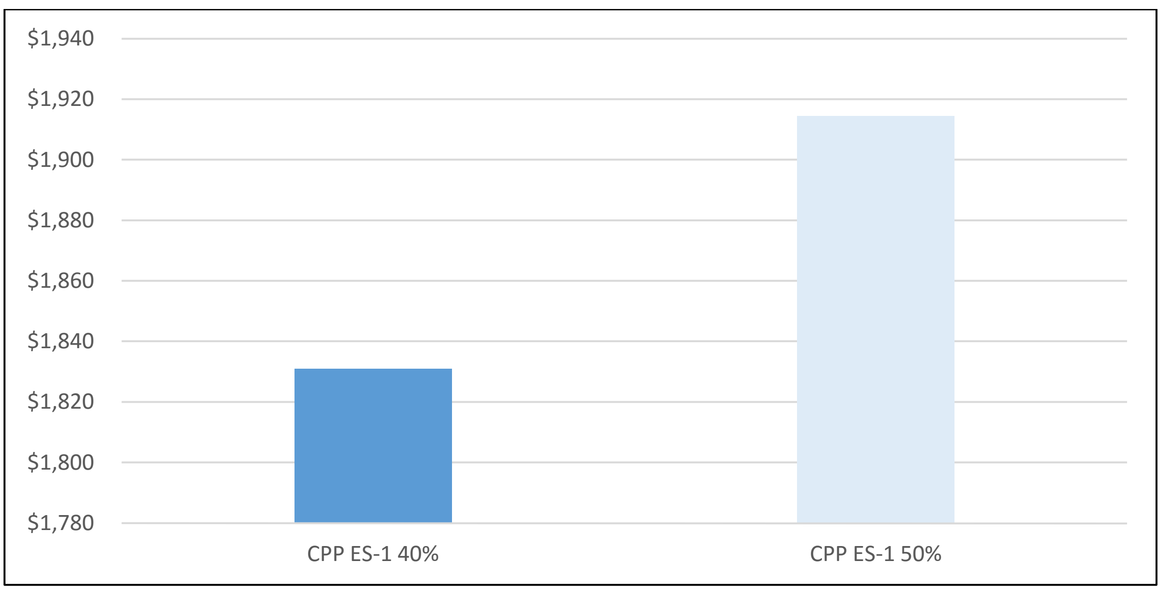


Figure F-7.12 CPP Impacts on GSP, 2016-2030 Cumulative

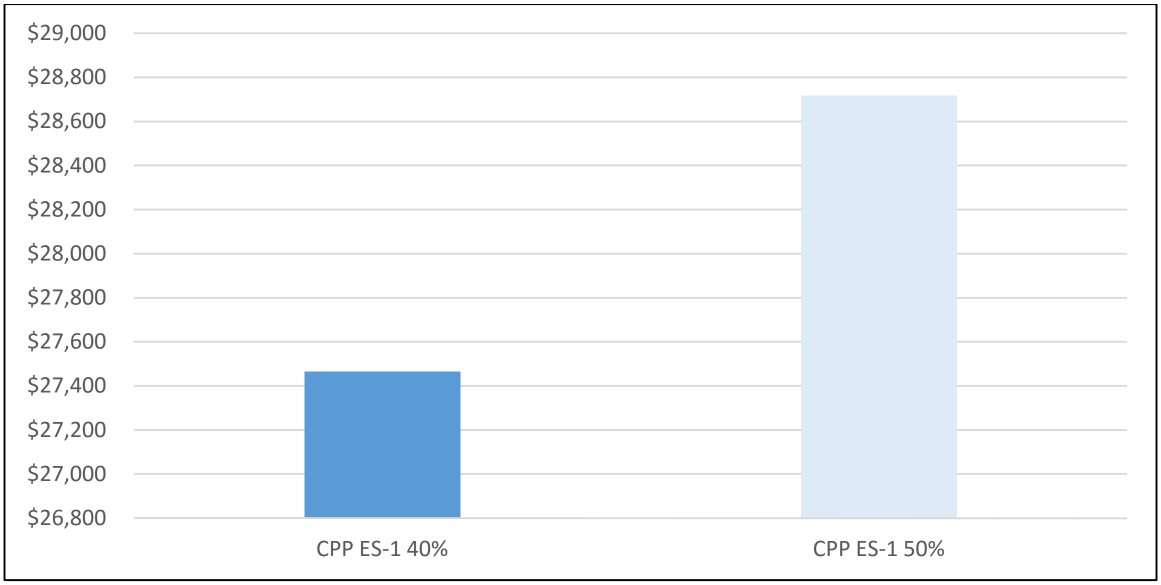


Figure F-7.13 CPP Employment Impacts, Year 2030

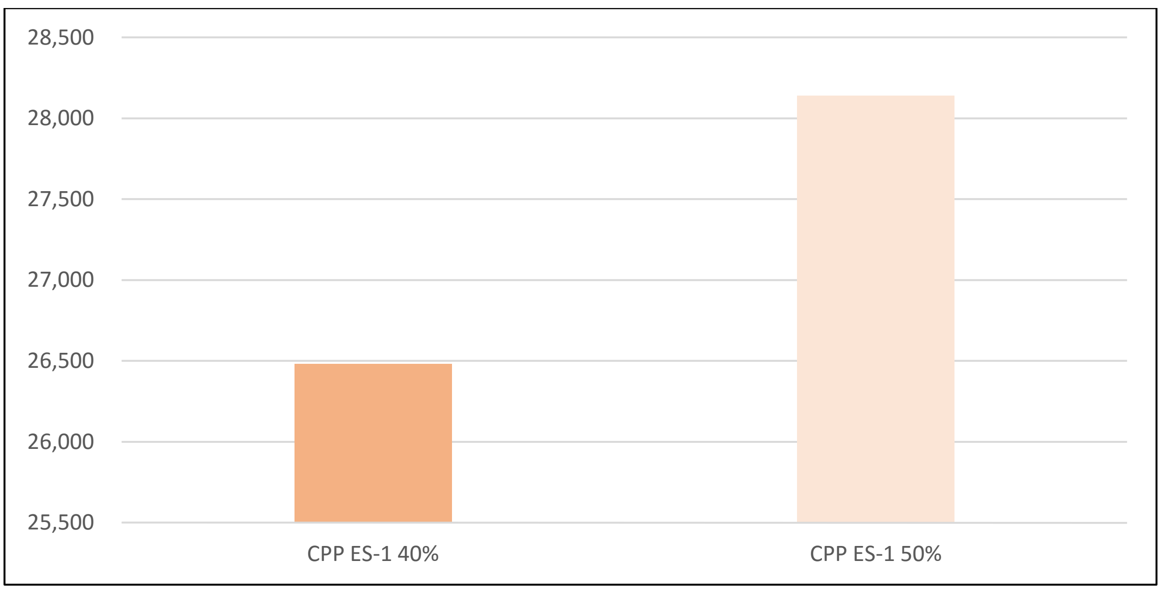


Figure F-7.14 CPP Employment Impacts, 2016-2030 Average

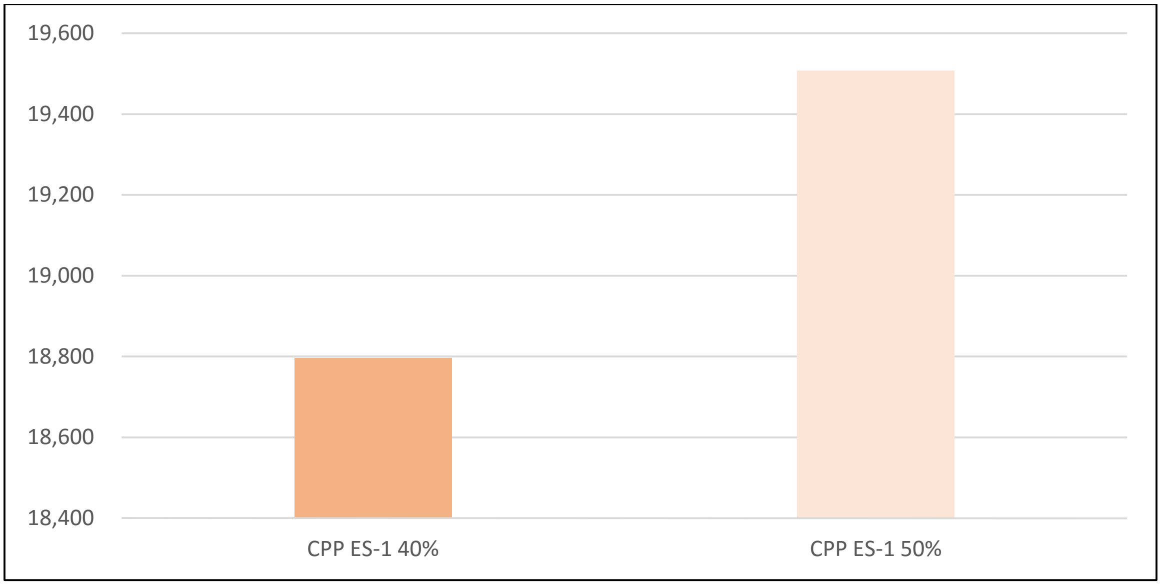


Figure F-7.15 CPP Employment Impacts, 2016-2030 Cumulative

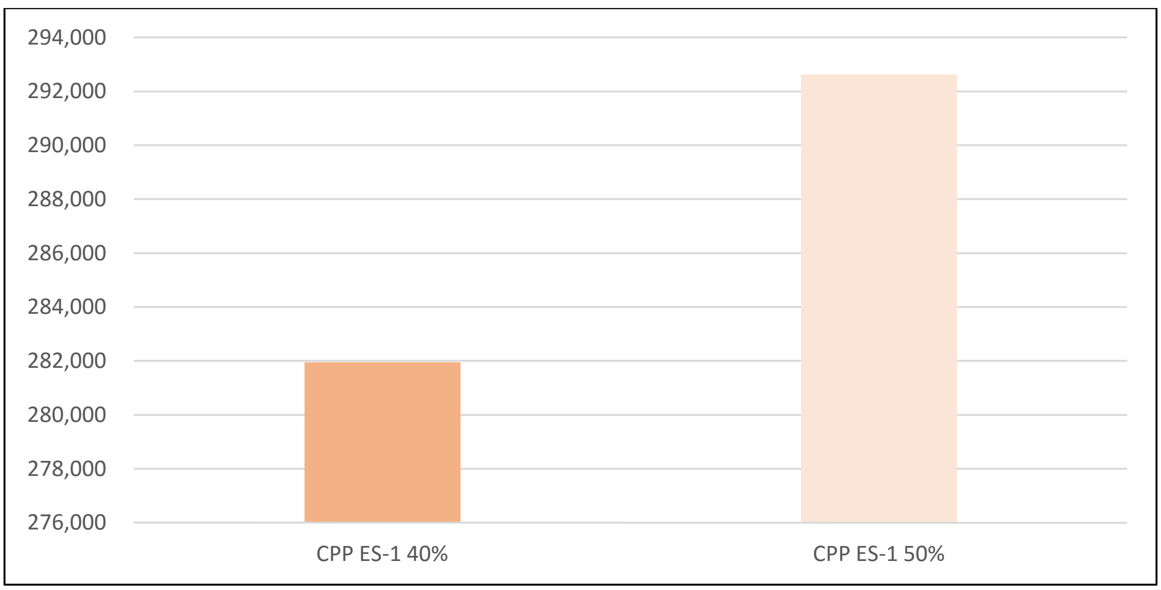


Figure F-7.16 CPP Income Impacts, Year 2030

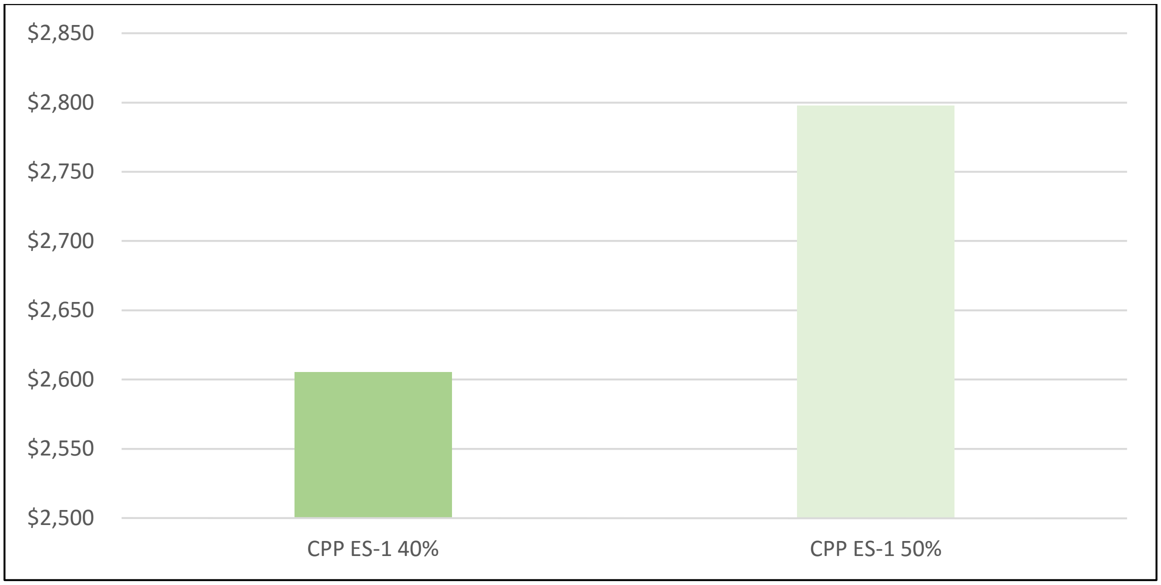


Figure F-7.17 CPP Income Impacts, 2016-2030 Average

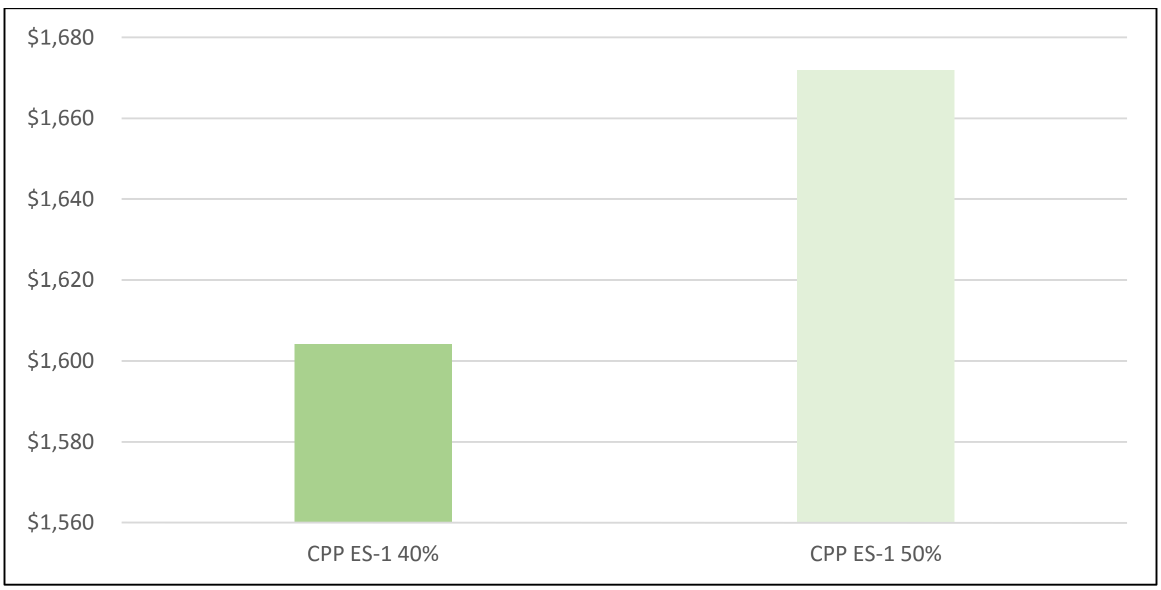
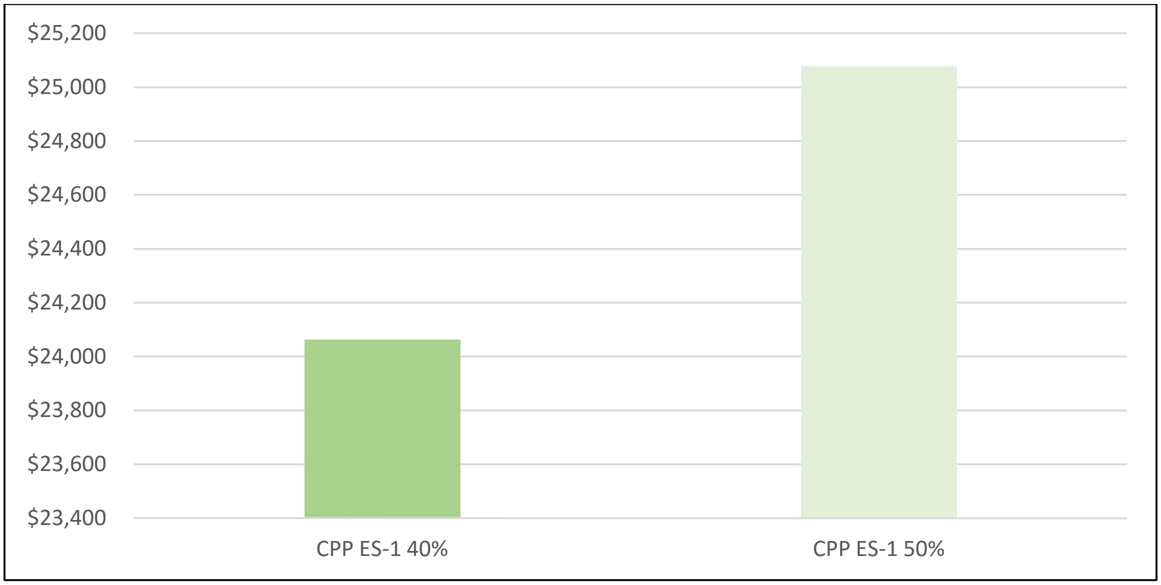


Figure F-7.18 CPP Income Impacts, 2016-2030 Cumulative



Principal Drivers of Macroeconomic Changes

These Clean Power Plan Scenarios represent combinations of policies described in other chapters and their respective appendices. Policies evaluated under the 111(d) compliance analysis are ES 1 and 2, and EE policies, which comprise RCII 1, RCII-2, RCII-4, FOLU-3, TLU-2, A-4, WM-1, WM-2 and WM-3. The principal drivers, consequently, are those described within those discussions of macroeconomic impact. Those influences (such as the cost-saving shift involved in ES-1 or the energy-efficiency impacts of the RCII policies) remain in place in the CPP analysis, which simply aggregates into a single scenario (with some integrations to represent the integrative effects identified in the microeconomic analysis) these policies and their major influences on the larger Minnesota economy.

Data Sources

The principal data sources for the macroeconomic impacts analysis of this and all other policies in the CSEO process are the direct spending, saving, cost and price impacts developed as part of the microeconomic (direct impacts) analysis. For each policy, the cost-effectiveness analysis described above develops year-by-year estimates of the costs, savings prices, and changes demand or supply that households, businesses and government agencies are expected to encounter in a scenario where the policy is implemented as designed.

A secondary data source is the policy design. Balancing financial flows for each direct impact identified are established based on understanding the implementation mechanism, and quantitative values for these flows are developed for each direct impact identified. This balancing identifies and quantifies the responsive change that occurs as a result of the direct impact in question. For example, if a household is anticipated to save $100 per year on electricity bills as a result of a policy, the direct impact is a $100 savings to the household (which expands its spending capacity for other things) but the balancing impact is a $100 loss in revenue and demand to the utility provider (which reduces its ability and need to spend on labor, capital, profit, and other inputs). The quantitative measure of both sides of a change is of importance to a complete macroeconomic analysis. This balancing ensures that both the supply and the demand side of each economic change is fully represented in the analysis.

A third data source is direct communication with Minnesota agency staff and others involved in policy design or in a position to understand in detail the financial flows involved in the policy. These people assisted in clarifying the nature of economic changes involved so that the modeling and analysis would be accurate.

The final crucial data source is the baseline and forecast of economic activity within the REMI software. This data is compiled into a scenario that is characterized not only by the total size of the economy and its many consuming and producing sectors, but also the mechanisms by which impacts in one sector can change the broader economy – such as intermediate demands, regional purchase coefficients, and equilibria around price and quantity, labor and capital, and savings and spending, to name a few of many. REMI, Inc. maintains a full discussion of all the sources of the baseline data on its own website, www.remi.com.

Quantification Methods

Utilizing the data developed from the microeconomic analysis, CCS analysts established for each individual change the following characteristics:

- The category of change involved (change in spending, savings, costs, prices, supply or demand)
- The party involved on both sides of each transaction
- The volume of money involved in this change in each year of the period of analysis

These values, so characterized, were then processed into inputs to the REMI PI+ software model built specifically for use by CCS and consistent with that in use by state agencies within Minnesota. These inputs were applied to the model and run. Key results were then drawn from the model and processed for consistency of units and presentation before inclusion in this report.

Key Assumptions

The macroeconomic impact analyses of this policy, as well as of the others in the CSEO process, rely on a consistent set of key assumptions:

- State and local spending is always budget-constrained. If a policy calls for the state or local government to spend money in any fashion, that spending must be either funded by a new revenue stream or offset by reductions in spending on other programs. Savings or revenues collected by the government are also expected to be returned to the economy as spending in the same year as they are collected.

- Federal spending is not budget-constrained. The capacity of the federal government to carry out deficit spending means that no CSEO policy is held responsible for driving either an increase or decrease in federal tax spending by businesses or households in the state of Minnesota.
- Consumer spending increases are sometimes financed. Small-scale purchases or purchases of consumer goods are treated as direct spending from existing household cash flows (or short-term credit). Durable goods, home improvements or vehicle purchases, however, are treated as financed. Consumers were assumed to spread out costs based on common borrowing time frames, such as five years for financing a new vehicle or 10-20 years for home improvements that might be funded by home-equity or other lending. The assumption of financing and the term of years applied was considered anew in each case.
- Business spending increases are often financed. Where spending strikes a sector which routinely utilizes financing or lines of credit to ensure steady payment of recurring costs, significant spending of nearly any type was considered a candidate for financing, thus allowing costs to spread out over time. This methodology is preferable for the modeling work, as sudden spikes or dips in business operating costs can show up as volatility when the scenario may depict a managed adoption of new equipment in an orderly fashion. The assumption of financing and the term of years applied was considered anew in each case.
- Unless otherwise stated, all changes to consumer spending or to the producers' cost of producing goods and services were treated in a standard fashion. Consumers are assumed to spend on a pre-set mix of goods, services, and basic needs, and businesses spend (based on their particular sector of the economy) on a mix of labor, capital, and intermediate demands from other sectors. Unless a policy specifically defines how a party will react to changes in cost, price, supply or demand, these standard assumptions were applied.
- State and local spending gains and reductions driven by policy are assumed to apply to standard mixes of spending. Again, unless a policy specifically states that a government entity will draw from a specific source or direct savings or revenues to a specific form of spending, all gains and losses were assumed to apply to a standard profile of government spending within the economy.

Sectors Most Impacted by This Policy

The direct impacts from the individual policies that we saw before remain present, in general. The construction sector continues to grow rapidly, seeing large gains in size and in the number of people it employees. Chemical manufacturing, which captures the growth in biofuels production, remains a growing sector in the Clean Power Plan scenarios, as that biofuels production is just as present in the combined analysis as it was in the individual analysis.

By contrast, utilities still see smaller scale in demand, and thus require less inputs and labor to carry out their business. The Waste Management policies also bring direct reductions in the scale of the waste disposal sectors, as their goal of reducing and diverting the waste stream reduces the amount to be hauled, tipped and disposed in landfills.

The Clean Power Plan scenarios end up capturing most of the policies that produce significant savings to households and businesses, and a familiar profile of gains – reflecting the availability of more money in pocket and more capacity to spend on the part of households – appears. The greatest indirect gains in employment are in retail sales, health care, clothing and food service, as well as direct hiring by homes; gains in these are all solid indicators that money saved elsewhere has made itself useful in popular consumer-spending destinations. Educational, financial and other services focusing on longer-term returns to consumers also see significant gains, but are less labor-intensive per dollar, and so the job growth there is not as steep.

Businesses, likewise, show signs that their overall costs to operate fall under this scenario rather than rise. Gains in white collar fields, such as management and administrative support, indicate expansion that comes with lower overall costs. The combination of ES-1's reduction in costs to produce electricity along with the lower costs associated with efficiencies from the RCII sector and less demand for waste and other services drives a structural shift toward lower costs that even some less successful policies (such as ES-2, which raises utility costs to produce a bit) do not fully offset.

Key Uncertainties

All of the key uncertainties discussed and reflected in the discussion of the individual policies associated with this scenario remain relevant to this discussion.

Feasibility Issues

All of the feasibility issues discussed and reflected in the discussion of the individual policies associated with this scenario remain relevant to this discussion.

Chapter XIX. Appendix G. Macroeconomic Analysis Methodology, REMI Model Selection, and Specifications

Introduction

Comprehensive policy option impact analysis begins its analytical process with the development of bottom-up baseline, or "business as usual", inventories of current greenhouse gas emissions and forecasts of the levels of those emissions as they are expected to rise or fall over upcoming years. These baseline emissions forecasts are typically built from data about activities (such as the volume of energy produced and used or the volume of crops produced or the amount of vehicle travel). These activity levels are converted to emissions through understandings of the energy use and emissions intensity involved in those activities, and finally aggregated to totals for each sector as well as a single economy-wide emissions baseline.

It is in the context of this customized baseline that individual policies and scenarios are analyzed for their potential to reduce emissions, as well as their potential to cost or save money to various actors. This phase is often referred to as the "micro-economic analysis" phase, or the "direct-impacts analysis" phase. The name refers to the fact that the costs and savings captured are those encountered directly by those implementing or affected by a policy.

These direct costs and savings serve as the basis for the macroeconomic analysis. This phase seeks to use the direct spending, saving, cost and price changes identified in the microeconomic phase and understand how those will affect the larger economy.

The principal data sources for macro-economic modeling are microeconomic quantifications results of direct costs and savings of individual policy options. However, these inputs are also supplemented with additional data and assumptions that were made internally, based on research and expert judgement, when certain cost/savings or other conditions pertaining to policy option implementation where not specified in micro economic analysis.

For the purposes of macro-economic analysis of CSEO policies, Regional Economic Models, Inc. (REMI) software was used. Its analytical power and accuracy made REMI a leading modeling tool in the industry used by numerous research institutions, consulting firms, non-government organizations and government agencies to analyze impacts of proposed policies on key macro-economic parameters, such as GDP, income levels and employment.

Role of Macroeconomic Analysis

There are important distinctions between a macroeconomic analysis and other types of common impacts analysis approaches, such as micro-economic analysis, cost-effectiveness analysis or cost-benefits analysis. Micro economic analysis, as briefly indicated above, seeks to identify monetized costs and benefits incurred by the targeted actors that are directly affected by the policy (for instance, costs to electric utilities due to implementation of a Renewable Portfolio Standard or savings to electricity consumers due to energy efficiency mandates).

Cost–effectiveness analysis sets a desired public or corporate policy goal, and then attempts to quantify total individual costs of different policy measures designed to achieve that goal, thereby determining what is the least cost way to accomplish the desired condition.

Cost-benefit analysis is a more comprehensive process, normally conducted by government agencies in their regulatory rulemaking, which goal is to identify and quantify all possible market and non-market costs and benefits expected to occur due to policy implementation, and assign a monetary value to these costs and benefits. This is especially challenging for non-market benefits: such as improvements in air or soil quality, expansion in the population of particular animal species, expected saving of certain numbers of human lives etc. and non-market costs: lake water quality degradation, increased instance of asthma attacks etc.

All the above policy analysis approaches have different purpose and value to policy makers and other stakeholders. Macro-economic analysis, on the other hand, seeks specifically to understand how the direct financial and economic impacts of a policy drive responsive changes throughout the rest of the economy. It effectively puts an individual policy into a broader economic context, allowing for consideration of complex intra and inter sector economic linkages induces by the policy to be estimated, and resulting macro-economic outcomes to be displayed in an approachable form (changes in GSP, jobs, incomes etc.)

Impact Analysis Modeling and Baseline Development

It is important to understand that both micro and macro-economic analyzes undertaken in this project belong to the category of ex ante impact analyzes. The fundamental goal of an impact analysis is to evaluate the difference between an anticipated economic conditions that would develop *with* and *without* the implementation of the policy in question and compare those. *Ex ante* means that a present day study is carried out to estimate future economic conditions that a policy may incite, and compare them with expected default, or business as usual BAU conditions that would take place without that policy in place. In this way, the policy impacts of interest can be quantified and understood. Therefore, an ex ante impact analysis requires modeling both a BAU and an alternative, or policy scenario, in order to estimate policy impacts. On the other hand, an ex post study attempts to evaluate "an alternative present" that would have taken place without a policy change, and compare it to directly observable real present conditions in order to estimate the nature and magnitude of potential policy impacts. This type of analysis does not require the development of a BAU scenario.

For the purposes of CSEO macroeconomic impact analysis, REMI built a BAU scenario forecast for Minnesota's economy and demography. In this process they utilized both national data regarding the major trends present in appropriate economic sectors, but also unique state level data. This baseline forecast simulates future economic and demographic conditions in the state in each year that are based only on the set of current policies in Minnesota. These conditions describe the state of major parameters such as capital stock of individual industries, imports and exports per commodity category, labor structure and migration, prices of different products etc.

CCS macro modelers then construct alternative policy scenarios in the model, changing the appropriate policy levels in each year, which will impose modifications on the baseline conditions, effectively creating alternative conditions. REMI model is capable of capturing and quantifying those changes to the baseline and display them as positive or negative shifts in area's total employment, consumption, production and earnings levels. These are most commonly expressed as the number of jobs supported by a region's economy, the estimate of a region's gross domestic product (GDP) shifts, changes to income levels and other macroeconomic parameters.

Micro and Macro Economic Modeling Consistency

Consistency between the assumptions of the microeconomic and macroeconomic analysis is crucial. Varying or disregarding the original analysis's precepts produces a macroeconomic analysis that is not accurate, and which is in fact modeling some other scenario – not the policy that has been so carefully designed and analyzed up to this point.

In order to remain consistent, the macroeconomic analysis seeks to retain exact accuracy of the volume of money moving in each transaction, and to make the most appropriate characterization of a) who is spending and receiving that money, as well as b) how those actors will perceive and respond to that change.

Macroeconomic analysis concepts

Intermediate demands

A valuable concept in understanding how macroeconomic analysis varies from direct-impacts analysis, cost-benefit analysis, or cost-effectiveness analysis is that of intermediate demands. When a party purchases a good or service they would not have purchased in the absence of the policy, the impact does not stop with that party. Indeed, the vendor of that good or service must buy more of the inputs necessary to produce what was bought, and the producers of those inputs must buy more of their own inputs as well.

Take the example of a shirt, bought from a store at a shopping mall. The buyer of the shirt might pay (to take a random figure) $50. The retailer will take some of that as profit, but the majority actually goes to other sellers. The store buys the shirt from a wholesaler or manufacturer, it pays rent to the mall, it pays utility bills to the utilities, it pays labor to run the store, it pays advertisers to communicate with customers, it pays printers for signs, and it pays accountants and lawyers to keep books, manage contracts and legal compliance – all just to name a few. These expenditures are intermediate demands.

However, each intermediate demand is a producer in its own right, and has intermediate demands of its own. In the case of the shirt retailer, its landlord pays a mortgage to a bank, its advertisers, lawyers and accountants pay their own staff and for materials, rentals and other services (as well as rent on their own offices), and finally all the employees –both those at the store selling the shirt and those working for all its supporting services – will spend their wages on the full range of consumer demands, ranging from basics such as food, clothing, housing and transportation through entertainment, travel and luxury items.

From there, one can envision the money moving through many more steps, though in smaller and smaller amounts as only a fraction of each expenditure goes to any one intermediate demand. These follow-on transactions, and the impacts they have on total economic activity and total employment around the economy (along with the impacts to those directly affected by a policy) are what macroeconomic analyses seek to capture. And we often find that impacts fall far from home: a policy driving money to energy efficiency might well (and often does, in CCS's experience) result in doctors' offices seeing more patients, or software engineers seeing more demand for their products.

Equilibria

Another concept that can aid in understanding how macroeconomic modeling works is that of equilibria. Markets for each good or service have, to at least some extent, established total quantities of that good or service that are to be bought and sold and a range of prices within which transactions will fall. If a policy imposes a change to the economy in ways that reduces demand for a given good or service (as many environmental policies seek to do with demand for sources of energy), the economy will not simply produce less of that good or service, but rather it will adjust both the quantity and the price to arrive at a new balance between supply and demand.

This effect works both ways – a change in price or in the ability to produce will also influence demand. Prices can be felt both by purchasers as the cost to buy something and also by sellers as the cost to bring something to market and sell it without losing money. Each market finds consumers and producers with distinct “elasticities” - consumers have varying preferences to respond to a price change by paying a different amount vs. consuming a different quantity, and producers have varying preferences to lower/raise price in response to change vs. lowering/raising the quantity they produce.

Intermediate Demands and Equilibria – A Computational Challenge

Keeping track of how a wide range of actors respond to changes in demand and price in dozens of different sectors of the economy involves voluminous calculation to establish a single balance of all the supplies and demands after a series of changes occur as a result of a single policy. Considering a scenario with a complex set of policy impacts, or a scenario of multiple policies acting in concert, only multiplies the volume of calculation to be done. As a result, this form of analysis relies on software capable of receiving direct changes from policy, processing the many intermediate-demand changes and equilibrium adjustments, and measuring and displaying the changes to the economy that result.

For the Minnesota CSEO effort, the CCS team utilized the Policy Insight+ software from Regional Economic Models, Inc. (usually referred to as the REMI PI+ model, or simply as “REMI”). The model has the same specifications in terms of economic and geographic detail as the model utilized by Minnesota’s economic analysts within DEED.

Macroeconomic Analysis – Key Tasks

Characterizing actors’ response to change

While models do the hard work of calculating the results, there is still a significant task in turning direct policy impacts into the inputs necessary to model broader economic changes. One key task that macroeconomic modelers must carry out is determining the reaction to each spending flow. If a household saves money, the direct analysis may register that as a savings and be satisfied, but the macroeconomic analysis depends on some assumption about how that extra money is spent. If companies are required to buy newer equipment, this is registered as a cost, but we must also understand how they’ll respond to this additional cost.

Balancing Spending Flows

Another task in the hands of the macroeconomic analyst is that of balancing spending. The best introductory way to think of this is by keeping both sides of every transaction in mind. If we say that businesses face large costs from a policy, then we must model both the consumer side (the business spending more money to cover that cost) and the producer side (the different businesses now facing higher demand for their goods and services as a result). If a policy reduces the need for certain things, thus creating a savings, the macroeconomic analysis must also account for the fact that sellers of those things suddenly face less demand for their product, and must adjust either price or quantity of their product to respond to the change in the market. This task of capturing the impacts of both sides of change in economic activity (the supply side and the demand side) is an important step in the process.

Further, characterizing *how* parties will react to change is an analytical task that is done by the analyst rather than the model. If a policy only determines that homeowners will save a certain amount of money, the analyst must decide how that money will be allocated by those households. If, on the other hand, a policy analysis includes a requirement for how that money is spent, then the households' reaction to savings must be modeled differently.

Balancing such as this brings up some common, but important, assumptions that CCS analysts make routinely in the CSEO process and in other analyses:

- Where a government is forecast to spend more money to implement an effort or pay for something, CCS assumes this spending to be revenue-neutral – that is, that other spending must be reduced to remain within the same total budget. By the same token, additional savings or earnings by governments is matched immediately with additional spending on its existing mix of programs.
- If a government is not explicitly developing a new revenue stream to fund an expenditure, it is assumed other spending must fall in a dollar-for-dollar exchange for any expansion of spending related to a policy.
- Consumers are also assumed to increase or reduce their spending on general blend of consumer goods and services whenever a policy assumes they will encounter a requirement to spend or a freedom not to spend.
- Significant capital investments by businesses, and the purchase of real property and even some durable goods (like cars) by households, are assumed to be financed over reasonable terms. This allows buyers to spread costs over time and moderate their spending changes, avoiding huge and dislocating shocks in response to a policy. This is both consistent with real-world behavior and better at producing appropriate results out of software models which have no contextual ability to differentiate between periodic purchases and unstable economic dislocations.
- Sales or purchases to global commodity markets are usually treated as exports or imports, respectively, and not in need of strict balancing.

A key exception to this balancing requirement is a change in price. Because models typically have elasticity and equilibrium assumptions built in, the analyst allows the model to exert its own responsive change on those facing changes in price. This extends to changes in the cost of producing a unit of a good or service – which is a common way to model the way businesses respond to regulatory requirements.

A second key exception to the balancing requirement has to do with imports and exports. A policy driving sales of a product to buyers outside the study area can record the sales as greater demand for a product, but does not require an offsetting reduction in consumers' other spending – because the only buyers are outside the area of study. On the other hand, imports will show up as a shift in spending, but the producer's gain in new demand will not register in the local economy – sacrificing those benefits.

Modeling Individual and Joint Policy Impacts

In this study, we first run the REMI PI+ model for each of the CSEO policy options individually in a comparative static manner, i.e., one at a time, holding everything else constant. This represents a scenario for each policy that imagines that policy occurring alone – without any of the other CSEO policies in implementation at the same time. This individual analysis allows CCS and Minnesota to understand the direction and scale of the influences on the statewide economy of each policy as that policy proceeds through the 2016-2030 time period.

Once these individual inputs are developed, CCS carried out simultaneous simulations in which we assume that options under same categories (such as Energy Supply, or Agriculture) are bundled together. The macroeconomic analysis inputs for all the policies within a given category were aggregated into the REMI PI+ software and modeled as a single event, representing the changes to the economy if all these policies were implemented at the same time. This allows the software to estimate the combined indirect changes to sectors that are affected only by virtue of being connected to the affected actors via intermediate demands, as well as to understand the combined impact on equilibria produced my multiple policies.

CCS then progressed to further, larger simultaneous simulations. These simulations combined policies from multiple categories to represent the progress potential of approximately half of all the CSEO policy options toward meeting Minnesota's expected target under the draft US EPA Clean Power Plan rule. The prior analyses (the direct-impacts analysis and the integration analysis) identified key ways in which the energy-supply and building-energy-use policies would influence each other if implemented jointly. CCS analysts adjusted the macroeconomic analysis inputs to reflect those changes and retain consistency with prior analyses. As with the category-level combined analyses, the inputs to all these policies (with the necessary integrative modifications) were aggregated into the software and modeled as a single policy initiative.

Finally, CCS carried out a simulation that includes all the policies together. This analysis produced a forecast of impact to the economy of the implementation of the entire suite of CSEO policy options.

The simple summation of the effects of individual options is rarely equal to the simultaneous simulation results. The "whole" is different from the "sum" of the parts. Differences arise from non-linearities and/or synergies, which arise from complex functional relationships of the differing consumptive and productive actors in the economy – and within the REMI PI+ Model. For this reason, our report does not simply total up the impacts of the different categories of policies to represent the whole. Readers closely comparing results will note that such sums will differ from the combined results by significant margins. This represents not a mathematical error but rather the ways in which multiple influences on the economy can interfere with or synergize with each other.

Common Assumptions

Every policy and sector analyzed is considered individually, and no assumption is applied automatically. But certain mechanisms were frequently identified as appropriate ways to represent the way actors encountered policy impacts. These are briefly described below:

- Production cost changes. When businesses face costs that do not directly relate to the production of more of their product or service, they encounter a higher production cost change. This tends to drive a mix of price increases and reduced total production (meaning less demand for inputs, including labor). On the other hand, when a businesses face lower costs, and production cost per unit falls, the opposite tendencies occur. Most often, however, businesses face a mix of spending requirements and savings opportunities. The *net effect* of these combined influences drives production cost up or down (again, so long as these influences are not associated with scaling up or down the total production).
- Demand changes. When businesses or households demand more of a good or service, that demand enters the existing market, which is made up of a mix of exports and domestic production. If (and only if) a policy drives new demand just to in-state suppliers, this variable is replaced with a change in sales by in-state industries – which strictly assumes that 100% of the demand is met locally.
- Consumption reallocation by households. Whenever households must buy more (or get to buy less) of something, they have a different amount of money left over than in the absence of the policy. This money is put back into a function that spreads spending over a blend of consumed goods and services by households, rather than individually allocated to all the sectors by the analyst. If a household has less to spare than before, the amount here is negative – indicating a reduction in demand. If the household has more, the amount is positive and demand rises.
- Demand changes vs. price changes. Policies that require replacement or a shift in consumption (i.e. you must buy ethanol and not gasoline, or you must buy solar panels and not whatever else you wanted) shift economic activity from one set of sectors to another set of sectors. By contrast, policies that make consumers spend more (or let

them spend less) for the same outcome are price changes. Examples of this are shifting to more expensive automobiles, or shifting to less expensive equipment. Price changes in one area expand or contract buying power over the entire economy, and have a bigger positive or negative effect by far on the total economy.

While these models (and REMI specifically) contain a wide range of policy levers, some mix of the above mechanisms makes up part of almost every scenario run.

Decisions Made at Microeconomic and Macroeconomic Analysis Stages

Often, macroeconomic analyses are examined for their methodology. To assist that examination in the CSEO process, it may be useful to identify which questions are answered prior to the macroeconomic analysis and which are answered within that analysis.

Microeconomic Phase:

- Questions about policy effectiveness or feasibility – will this policy truly change so much behavior, will it really occur on the forecast schedule, etc.
- Questions about how much a policy will change demand for a product (a form of policy effectiveness) or the price for a specific product (if that price is set by policy).
- Questions about the allocation of costs or savings to particular parties – this is set possibly as early as the policy-design stage, if not in the microeconomic impacts analysis stage

Macroeconomic Phase:

- Questions about responsive changes – are parties treating changes as price impacts or simply shifting demand?
- Questions about what drives larger impacts to the overall economy
- Questions about how or whether a given assumption makes a big difference in the economic impact of a policy

The Selection of the REMI Policy Insight+ (PI+) Model

Several modeling approaches can be used to estimate the total regional economic impacts of environmental policy, including both direct (on-site) effects and various types of indirect (off-site) effects. These include: input-output (I-O), computable generated equilibrium (CGE), mathematical programming (MP), and macroeconometric (ME) models. Each has its own strengths and weaknesses (see, e.g., Rose and Miernyk, 1989; Partridge and Rickman, 1998).

The choice of which model to use depends on the purpose of the analysis and various considerations that can be considered as performance criteria, such as accuracy, transparency, manageability, and costs. After careful consideration of these criteria, we chose to use the REMI PI+ Model. The REMI PI+ Model is superior to the others reviewed in terms of its forecasting ability and is comparable to CGE models in terms of analytical power and accuracy. With careful explanation of the model, its application, and its results, it can be made as transparent as any of the others. Moreover, the CCS team has used the model successfully in similar analyses in the states/regions of Washington, Oregon, Southern California Florida, Pennsylvania, Michigan and Wisconsin.

The macroeconomic character of the model is able to analyze the interactions between sectors (ordinary multiplier effects) but with some refinement for price changes not found in I-O models. The REMI Model also brings into play features of labor and capital markets, as well as trade with other states or countries, including changes in competitiveness.

The econometric feature of the model refers to two considerations. The first is that the model is based on inferential statistical estimation of key parameters based on pooled time series and regional (panel) data across all states of the U.S. (the other candidate models use "calibration," based on a single year's data).[1] This gives the REMI PI+ models an additional capability of being better able to extrapolate[2] the future course of the economy, a capability the other models lack.

The REMI PI+ was also the right choice because it is in use already by both the Metropolitan Council and Minnesota's Department of Employment and Economic Development. In utilizing the same model with the same specifications as these agencies, the CCS analyst team was able to work closely with both of these entities to vet, verify and improve the analyses of several policies. Their meaningful collaboration made the analysis and the understanding thereof better, and at the same time allowed for greater confidence by Minnesota state agency counterparts in the final results in each case. During the course of the macroeconomic analysis effort, DEED economists have received and reviewed all assumptions and inputs to every policy, every group of policies and every attempt to model the joint impact of multiple policies (such as the progress toward 111D and the impact of all CSEO policies together) throughout this effort, and having REMI access on both sides of the conversation has also facilitated complete transparency of the policy analysis process.

[1] REMI is the only one of the models reviewed that really addresses the fact that many impacts take time to materialize and that the size of impacts changes over time as prices and wages adjust. In short, it better incorporates the actual dynamics of the economy.

[2] The model can be used alone for forecasting with some caveats, or used in conjunction with other forecast "drivers".

Full Description of the REMI PI+ Model and Comparative Capabilities Vs. Alternative Tools

This section provides a more detailed explanation of the model for readers seeking greater specificity as to the functionality and attributes of the software. More information is available at www.remi.com, both via their website and from REMI staff.

REMI PI+ is a structural economic forecasting and policy analysis model. It integrates input-output, computable general equilibrium, econometric and economic geography methodologies. The model is dynamic, with forecasts and simulations generated on an annual basis and behavioral responses to wage, price, and other economic factors.

The REMI model consists of thousands of simultaneous equations with a structure that is relatively straightforward. The exact number of equations used varies depending on the extent of industry, demographic, demand, and other detail in the model. The overall structure of the model can be summarized in five major blocks: (1) Output and Demand, (2) Labor and Capital Demand, (3) Population and Labor Supply, (4) Compensation, Prices, and Costs, and (5) Market Shares. The blocks and their key interactions are shown in Figures G-1 and G-2.

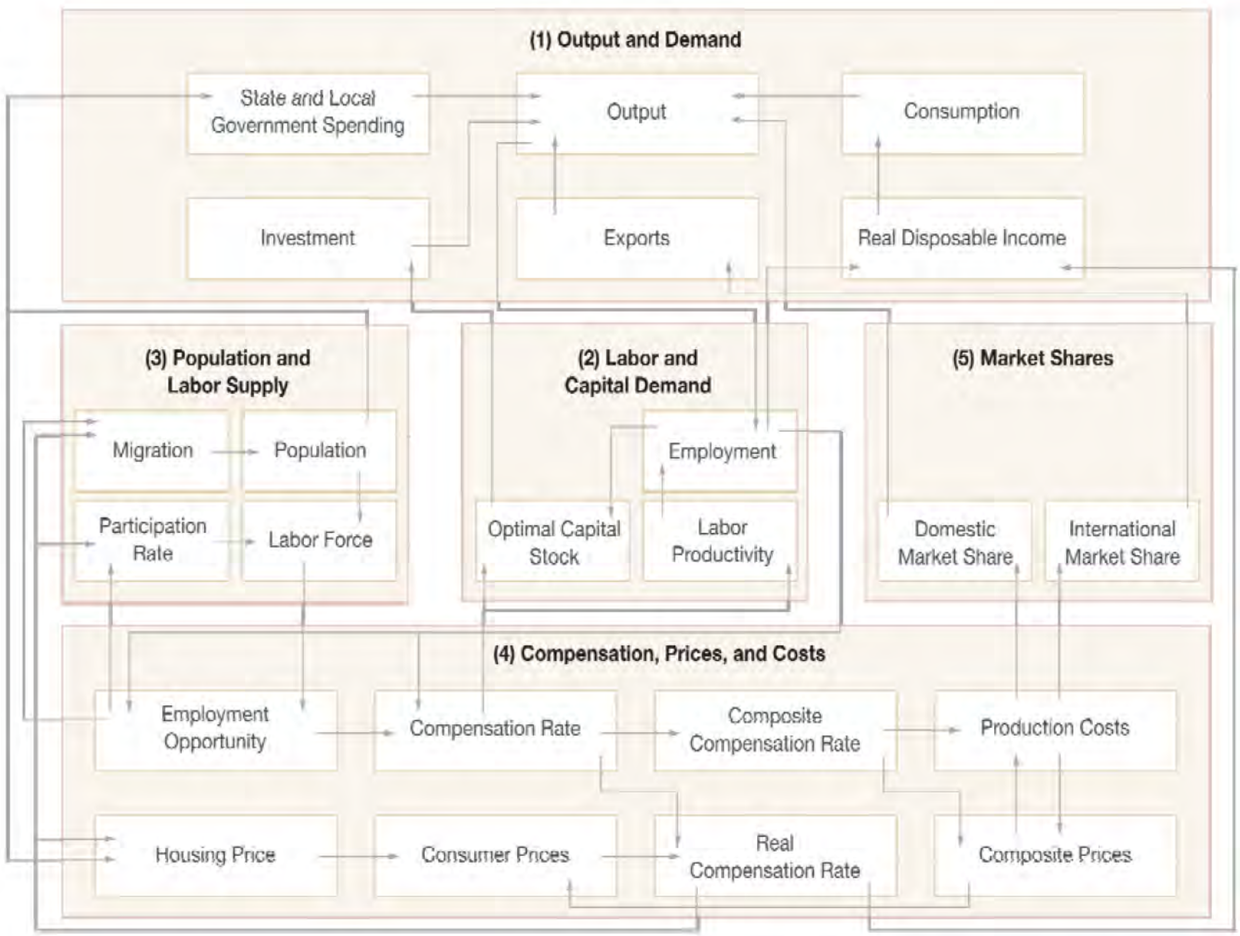
The Output and Demand block includes output, demand, consumption, investment, government spending, import, product access, and export concepts. Output for each industry is determined by industry demand in a given region and its trade with the US market, and international imports and exports. For each industry, demand is determined by the amount of output, consumption, investment, and capital demand on that industry. Consumption depends on real disposable income per capita, relative prices, differential income elasticities and population. Input productivity depends on access to inputs because the larger the choice set of inputs, the more likely that the input with the specific characteristics required for the job will be formed. In the capital stock adjustment process, investment occurs to fill the difference between optimal and actual capital stock for residential, non-residential, and equipment investment. Government spending changes are determined by changes in the population.

The Labor and Capital Demand block includes the determination of labor productivity, labor intensity and the optimal capital stocks. Industry-specific labor productivity depends on the availability of workers with differentiated skills for the occupations used in each industry. The occupational labor supply and commuting costs determine firms' access to a specialized labor force.

Labor intensity is determined by the cost of labor relative to the other factor inputs, capital and fuel. Demand for capital is driven by the optimal capital stock equation for both non-residential capital and equipment. Optimal capital stock for each industry depends on the relative cost of labor and capital, and the employment weighted by capital use for each industry. Employment in private industries is determined by the value added and employment per unit of value added in each industry.

The Population and Labor Supply block includes detailed demographic information about the region. Population data is given for age and gender, with birth and survival rates for each group. The size and labor force participation rate of each group determines the labor supply. These participation rates respond to changes in employment relative to the potential labor force and to changes in the real after tax compensation rate. Migration includes retirement, military, international and economic migration. Economic migration is determined by the relative real after tax compensation rate, relative employment opportunity and consumer access to variety.

Figure Ap G-1. REMI Model Linkages (Excluding Economic Geography Linkages)

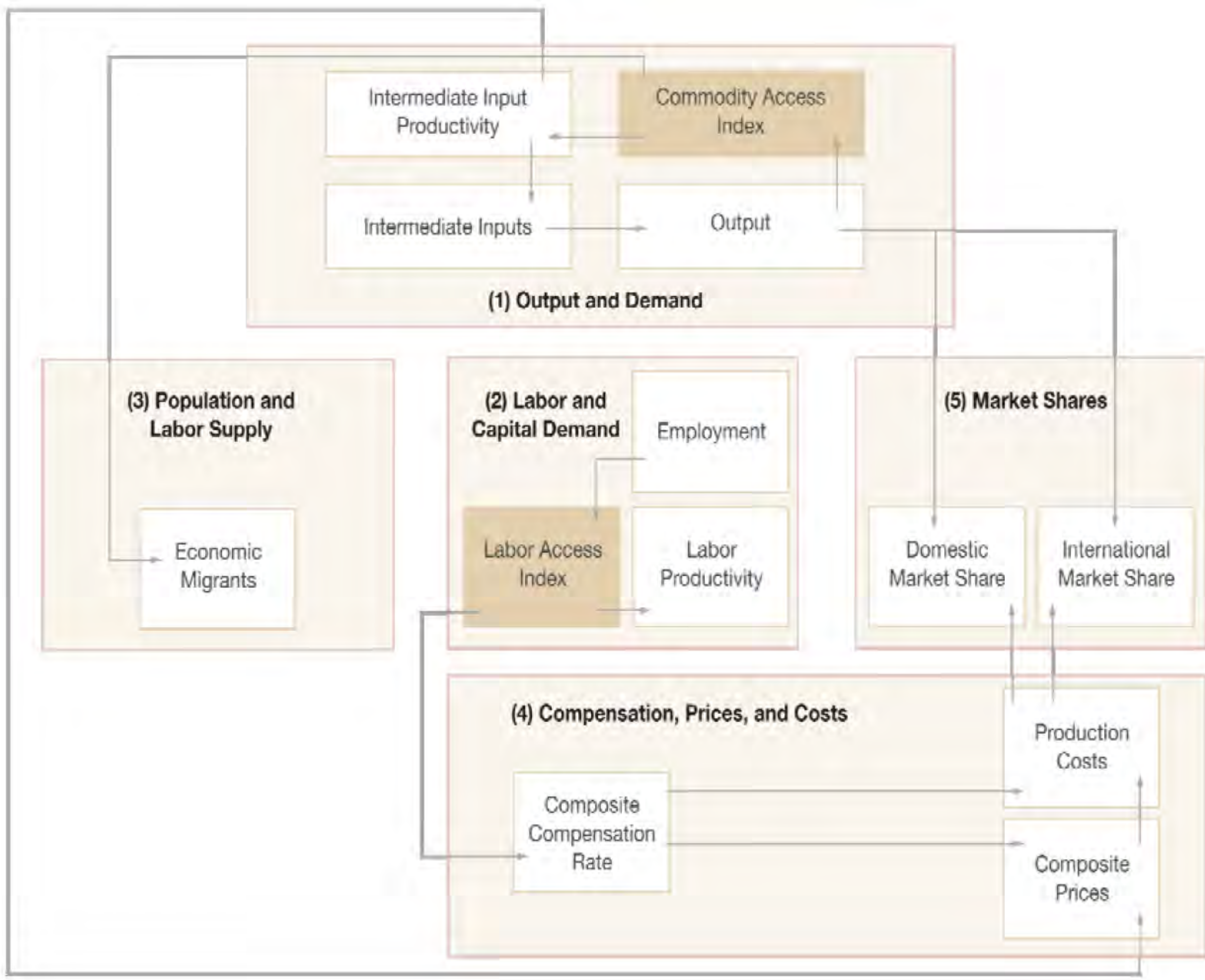


The Compensation, Prices, and Costs block includes delivered prices, production costs, equipment cost, the consumption deflator, consumer prices, the price of housing, and the wage equation. Economic geography concepts account for the productivity and price effects of access to specialized labor, goods and services.

These prices measure the value of the industry output, taking into account the access to production locations. This access is important due to the specialization of production that takes place within each industry, and because transportation and transaction costs associated with distance are significant. Composite prices for each industry are then calculated based on the production costs of supplying regions, the effective distance to these regions, and the index of access to the variety of output in the industry relative to the access by other uses of the product.

The cost of production for each industry is determined by cost of labor, capital, fuel and intermediate inputs. Labor costs reflect a productivity adjustment to account for access to specialized labor, as well as underlying compensation rates. Capital costs include costs of non-residential structures and equipment, while fuel costs incorporate electricity, natural gas and residual fuels.

Figure Ap G-2. Economic Geography Linkages



The consumption deflator converts industry prices to prices for consumption commodities. For potential migrants, the consumer price is additionally calculated to include housing prices. Housing price changes from their initial level depend on changes in income and population density. Regional employee compensation changes are due to changes in labor demand and supply conditions, and changes in the national compensation rate. Changes in employment opportunities relative to the labor force and occupational demand change determine compensation rates by industry.

The Market Shares equations measure the proportion of local and export markets that are captured by each industry. These depend on relative production costs, the estimated price elasticity of demand, and effective distance between the home region and each of the other regions. The change in share of a specific area in any region depends on changes in its delivered price and the quantity it produces compared with the same factors for competitors in that market. The share of local and external markets then drives the exports from and imports to the home economy.

As shown in Figure G-2, the Labor and Capital Demand block includes labor intensity and productivity, as well as demand for labor and capital. Labor force participation rate and migration equations are in the Population and Labor Supply block. The Compensation, Prices, and Costs block includes composite prices, determinants of production costs, the consumption price deflator, housing prices, and the wage equations. The proportion of local, interregional and international markets captured by each region is included in the Market Shares block.

I. OVERALL CRITERIA AND MODEL SPECIFICATIONS

In evaluating economic models, it is first prudent to identify a set of criteria on which to base the decision.

A. Model Performance Criteria:

1. Accuracy. This pertains to the extent the model will yield predictions of macroeconomic impacts that are likely to be close to actual occurrences. Of course, it cannot be absolutely ascertained in advance. Therefore, we depend on standard model features that are likely to enhance accuracy. These include the level of sophistication of the model and its consistency with economic theory, the data that it utilizes, and “goodness of fit” measures where applicable.
2. Scope. This relates to the breadth of coverage of the model. It would include such features as whether it consists only of selected sectors or the entire economy. It also pertains to the number of mitigation and sequestration options that can be included.
3. Detail. This pertains to the degree of resolution of the model. This is indicated by the extent to which the model is divided into a number of sectors and to the number of macroeconomic indicators that can be analyzed with it.
4. Transparency. This pertains to whether the workings of the model can be made clear to those who would utilize its results, as well as whether the model can offer a clear picture of how the results were obtained.
5. Manageability. This relates to the ability of the modeler to develop simulations with the model in a reasonable amount of time. It also pertains to the potential for the eventual transfer of the inputs to DEED staff.
6. Cost. This pertains primarily to the expense of building and operating the model itself. It also pertains to the expense of updating and refining the model at a later date.

7. Other. No other criteria were specified during the conference call. However, forecasting ability should be considered.

B. Model Specifications

1. Geographic area of coverage. This pertains to whether the analysis is to be performed only for the State of Minnesota, or whether there is a need to include any sub-regions. Models can include both sub-regions (parts of states) and outside regions (the rest of the US or collections of neighboring states) to gauge economic and emissions leakage
2. Time of analysis. This refers to the time horizon for the policy simulation.
3. Macroeconomic Indicators. There is a large list, but the conclusion of the conference call was an emphasis on gross state product (GSP) and employment.
4. Sectoral Resolution. It would be preferable to have as much resolution as possible, especially with respect to manufacturing sector detail.
5. Income distribution. The model chosen needs to be able to analyze the income distribution impacts of CSEO policies.

C. Parameter Values

1. Flexibility. This refers to the extent that models can address considerations such as substitution of one fuel or energy technology for another.
2. Productivity and Competitiveness. This refers to the extent that the model can incorporate cost changes and improvements stemming from technological change and the extent to which these considerations affect the region's cost of production relative to that of other regions.
3. Economic Growth. This refers to the extent to which the model can factor economic growth into the baseline forecast.
4. Population Growth. Same as above but with respect to population.
5. Trend Factors. This refers to other secular changes that affect the baseline or the analysis, such as a steady increase in energy efficiency or a steady change in electricity prices.

Selection of the REMI PI+ Model over Computable General Equilibrium Models

Below, we share an evaluation of the REMI Model and a generic CGE Model (adapted from, e.g., Rose and Oladosu, 2002) in terms of the criteria and other considerations listed in the previous section. This discussion was originally produced by Professors Adam Rose and Dan Wei at the

Price School of economics at the University of Southern California, but remains relevant for the CSEO process. The language has been adapted to make it relevant to the CSEO process.

A. Model Performance Criteria

1. Accuracy. Both models are capable of a high level of accuracy. This relates in part to their inherent capabilities, but also depends somewhat on how the models are structured and applied. Both modeling approaches are widely used, indirectly testifying to their abilities on this score. Unfortunately, there are no formal comparisons in the literature between the two (including any type of CGE model). Moreover, analysts rarely go back and assess past projections or impact study results. While there are goodness of fit measures for macroeconometric models, they are not available for individual equations or the entirety of REMI. CGE models are "calibrated", i.e., based on a single year's data. This approach is considered less sound than the inferential statistical approach to parameter estimation using time series data inherent in macroeconometric modeling. Increasing the sectoral resolution (from REMI's 70-sector model to its more-detailed 160+-sector model) would improve the accuracy, as it would in any model. Of course, there is a tradeoff between cost and accuracy (see below).
2. Scope. Both models are equally capable of analyzing the entire state economy and the major macroeconomic indicators of interest to this study.
3. Detail. Both models can be disaggregated to as fine a level of detail as desired in terms of economic sectors. However, the 160+-sector REMI Model contains more sectors than the standard CGE model.
4. Transparency. Neither approach is a black box. The workings can be readily explained by using simple economic principles. Individual functional relationships (e.g., production functions or consumption functions) can be extracted for further examination, though it is more of an effort to do this in REMI (it would require help from REMI staff).
5. Manageability. Both models are relatively straightforward to use. However, REMI has a major advantage in that it comes with a user's guide.
6. Cost. REMI has a clear advantage here, for many reasons. First, DEED and the Metropolitan Council already have the model in hand. CCS's cost to procure an additional license for its own use is clear, and it would cost an uncertain amount (almost certainly much higher than the REMI license cost) to build a CGE model. The costs of preparing the model for application (linking mitigation options to relevant variables) and the actual application are about equivalent to the REMI Model.
7. Forecasting ability. REMI is able to generate forecasts for future baselines. The CGE model cannot do so, and must depend on external forecasts. If only differences in GSP and employment are crucial, rather than their absolute levels, this is not so important.

But when seeking to understand the scale of impacts on an economy (e.g. does a renewable-energy standard make a 0.2% change to the economy or a 20% change?), this access to the relative scale of the baseline economy in comparison to the policy-induced changes is very valuable.

B. Model Specifications

1. Geographic area of coverage. The REMI Model in the possession of DEED, and the model procured by CCS as well, are 2-region models. This means that they accept inputs for, and produce results for, both the Minneapolis-St. Paul 7-country metropolitan area and the rest of the state of Minnesota. The impacts to the two regions are additive – their sum represents the impact to the entire state (including both the metro area and the rest of the state. A two-region CGE model could be built as well, though this would increase the cost of model building and the cost of application.
2. Time period of analysis. Both models are capable of analyzing the entire time period of 2016-2030.
3. Macroeconomic Indicators. Both models are adept at evaluating impacts on both GSP and employment, though REMI specifically generates results regarding a wide range of other variables. For this study, the reporting of income impacts (including buying-power impacts, referred to as real, disposable income after taxes and inflation) was deemed important and REMI produced these results clearly with no additional modeling effort.
4. Sectoral Resolution. The REMI model of 169 sectors is adequate to the task. A comparable sectoring scheme can be developed for the CGE Model. It has the advantage here, if a tailored sectoring scheme is deemed important.

C. Parameter Values

1. Flexibility. The production functions of the CGE model are more sophisticated, and thus it is able to perform better in terms of modeling substitution between fossil fuels and between thee fuels and renewables. This has implications for accuracy as well.
2. Productivity and Competitiveness. Both models can address this somewhat. However, REMI has a more formal and comprehensive approach.
3. Economic Growth. REMI can do this in its forecasts. The CGE model cannot.
4. Population Growth. REMI can do this in its forecasts. The CGE model cannot.
5. Trend Factors. Both models can do this through the inclusion of exogenous variables.
6. Discount Rate. Both models can do this equally well.

Based on the analysis of above, the REMI Model has a strong overall edge over a CGE Model to analyze the macroeconomic impacts of the CSEO process. It is not the superior alternative according to all indicators, but it is for most.

A good deal of the edge stems from the fact that DEED and Met Council have the model in house and have experience using it. Other major advantages stem from its econometric foundation, including its forecasting ability.