Reducing Greenhouse Gas Emissions from Transportation

Opportunities in the Northeast and Mid-Atlantic

Technical Appendix

Emission Reduction Strategy Analysis

November 2015

Appendix Prepared for Georgetown Climate Center by Cambridge Systematics

CAMBRIDGE SYSTEMATICS

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1.0 Introduction

This analysis considers the potential greenhouse gas (GHG) emission reduction benefits achievable in the Transportation Climate Initiative (TCI) region. TCI is comprised of 11 states in the Northeast and Mid-Atlantic, plus the District of Columbia.

The analysis models the GHG emissions reductions from a suite of transportation investments, as well as from a hypothetical comprehensive policy bundle GHG pricing and reinvestment. Benefits are evaluated over the period 2015 to 2030.

The remainder of Section 1.0 describes the clean transportation investment and comprehensive policy bundle approaches. Section 2.0 provides a summary of findings on expected GHG reductions. Section 3.0 describes key methods and assumptions for each of the approaches. Section 4.0 discusses additional issues, including economies vs. diseconomies of scale (investment and comprehensive approaches) and feedback of revenue effects in strategy effectiveness (comprehensive policy bundle approach only). Section 5.0 describes key methods, assumptions, and results from the analysis of macroeconomic impacts of the comprehensive policy bundle approach. Section 6.0 describes the analysis of other benefits.

Clean Transportation Investment Approach (no pricing policy)

The clean transportation investment approach analysis examined a range of policy scenarios at different levels of implementation. The analysis looked at the potential GHG reductions that could be achieved by clean transportation investments at three different levels of funding — $1.5 billion, $3 billion, and $6 billion on annual average over the region. The funding levels are referred to as modest, moderate, and aggressive, respectively, in the main report.

The GHG reductions would be achieved by a suite of clean transportation policies in the region. The allocation of funding for each strategy was based on input from state officials. The allocation is shown in Table 1.1a, below.

Table 1.1a Investment Allocation by Strategy

GHG Mitigation Strategy	Allocation[a]
EV/alt. fuel infra. and incentives	20.0%
Urban and intercity transit	25.0%
Land use/smart growth	7.5%
Active transportation	7.5%
TDM and ecodriving	10.0%
System operations/efficiency	15.0%
Freight/intermodal infra./operations	15.0%
Total	**100.0%**

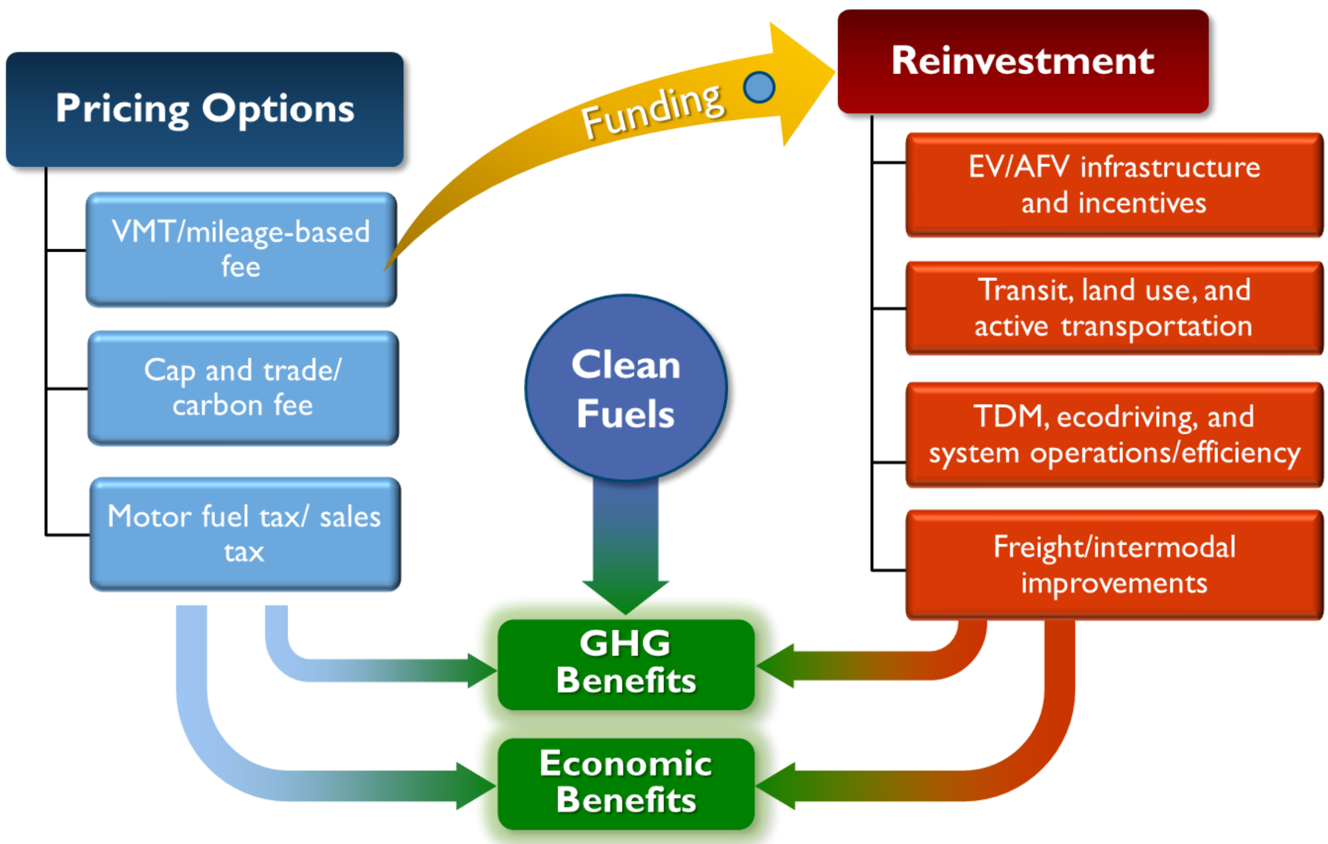
[a]Allocation shown for the 100% reinvestment strategy as described below

Comprehensive Policy Bundle Approach: Pricing and Reinvestment

The comprehensive approach built on the investment approach and included a hypothetical pricing policy raising either $3 billion or $6 billion on annual average in the bundle of policies. The comprehensive approach analysis looked at the potential effects of the pricing policies on both GHG emissions and funding. The net economic benefits to the TCI region are also evaluated. The comprehensive policy bundle approach, which is illustrated in Figure 1.1, includes:

- **Price-based policies** that reduce emissions from transportation by providing incentives to travel in less carbon-intensive ways and also generate proceeds that can be reinvested into GHG reduction or other transportation strategies;
- **Reinvestment strategies** to reduce transportation GHG emissions through clean vehicles, alternative modes and sustainable communities, and more efficient operation of the transportation system;
- Complementary **clean fuels strategies** to reduce carbon emissions per unit of fuel consumed.

Figure 1.1 Comprehensive Policy Bundle Approach



Section 3 and Section 5 of this paper describes in more detail how the GHG and economic benefits of such a comprehensive approach were estimated.

A variety of methods were used to estimate the potential greenhouse gas benefits of each strategy at different levels of funding and reinvestment. Data from studies conducted within the TCI region were used to the extent possible to supplement national data on strategy impacts and effectiveness. A unique aspect of this study is that factors were developed to link GHG reductions to funding levels (e.g., tons of emissions reduced per dollar spent),[1] so that different levels of pricing could be tested for their overall impact on emissions.

Pricing policy scenarios: The primary scenario assumes a pricing policy that generates approximately $3 billion a year for the TCI region, or $50 billion cumulatively for the 2015-2030 period.[2] The analysis modeled impacts of three different types of pricing policies that could result in proceeds equal to this $3 billion annual average: a carbon fee, VMT fee, and an additional motor fuel tax. An alternate scenario with pricing at twice these levels was also tested.

Reinvestment scenarios included scenarios with 100 percent reinvestment of revenues raised by the pricing policy into GHG reduction strategies (100% Mitigation scenarios), as well as scenarios with 50 percent reinvestment of new funding into GHG reduction strategies and 50 percent directed towards other transportation investments supporting clean and resilient transportation but without additional GHG reduction benefits (50/50 Scenarios).[3] The allocation of reinvestment funds across strategies was based on input from TCI workgroup participants and surveys circulated to TCI agencies.

Table 1.1b shows cumulative new proceeds for the TCI region between 2015 and 2030 under these scenarios and the amount of proceeds available for each strategy at the assumed allocation. A total of nearly $50 billion is available under the primary pricing scenarios; nearly $100 billion is available under the double pricing scenario.[4]

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[1] Throughout this document, tons of CO_2 emissions refer to metric tons.

[2] All costs in this report are in current (or nominal) dollars, i.e., not indexed to inflation. The fees and taxes are assumed constant in nominal terms and not indexed to inflation. This means that $3 billion in revenue in 2030 is worth less than $3 billion in 2015.

[3] There is not necessarily a clear distinction between GHG reduction strategies and the other forms of transportation investment considered here. For example, one of the "other" strategies tested is providing funding for *maintaining* transit operations at current levels. It could be argued that this provides GHG benefits in comparison to some baseline of reduced transit investment (or disinvestment) which leads to a shift towards more personal vehicle use. For the purpose of this analysis, "other" strategies are assumed to maintain transportation system at current levels, while GHG reduction/mitigation strategies make new investments that are expected to further reduce emissions.

[4] Table 1.1 accounts for the fact that new TCI region revenues would be slightly lower than expected, due to reduced VMT and fuel consumption resulting from the GHG reduction strategies, compared to a baseline where VMT and fuel consumption remain the same. However, it does not account for losses in other (general) transportation revenue that may result from this reduced VMT and fuel consumption.

Table 1.2 illustrates the quantity of proceeds available to each state, hypothetically allocated by VMT (and funding collected) in each state. Both annual and cumulative funding levels are shown. Actual state motor fuel tax receipts for 2012 are also shown for comparison (as reported in FHWA's Highway Statistics). Current receipts per VMT vary by state based on the motor fuel tax level in that state.

Table 1.1b Pricing Policy Proceeds and Reinvestment Allocation Scenarios

	Reinvestment Percent		New Average Annual Funding 2015-2030 (millions of current dollars)			
Strategy	**100% GHG Mitigation**	**50% Mit./ 50% Other**	**Primary Pricing, 100% Mitigation**	**Primary Pricing, 50% Mit./ 50% Other**	**Double Pricing, 100% Mitigation**	**Double Pricing, 50% Mit./ 50% Other**
GHG mitigation						
EV/alt. fuel infra. and incentives	20.0%	10.0%	$613	$311	$1,227	$621
Urban and intercity transit	25.0%	12.5%	$767	$388	$1,533	$777
Land use/smart growth	7.5%	3.75%	$230	$116	$460	$233
Active transportation	7.5%	3.75%	$230	$116	$460	$233
TDM and ecodriving	10.0%	5.0%	$307	$155	$613	$311
System operations/efficiency	15.0%	7.5%	$460	$233	$920	$466
Freight/intermodal infra./operations	15.0%	7.5%	$460	$233	$920	$466
Other sustainable transportation						
Highway preservation		32.5%	$-	$544	$-	$1,087
Transit operations		16.5%	$-	$1,010	$-	$2,019
Total	**100.0%**	**100.0%**	**$3,067**	**$3,106**	**$6,133**	**$6,213**
Cumulative, 2015-2030			**$49,064**	**$49,702**	**$98,128**	**$99,404**

These losses could total up to 10 to 20 percent of the new revenue value, as discussed further in Section 4.2. The exact amount of this revenue loss will not be measurable in practice because it will not be possible to distinguish any effects of the TCI implemented policies from the variety of other factors that influence VMT and fuel consumption over time.

Table 1.2 Pricing Policy Proceeds by State (millions of current dollars)

State	State Motor Fuel Tax Receipts - 2012	Avg. Annual, Primary Pricing	Avg. Annual, Double Pricing	2015-2030 Total, Primary Pricing	2015-2030 Total, Double Pricing
Connecticut	$700	$196	$392	$3,134	$6,268
Delaware	$116	$56	$113	$901	$1,801
Dist. of Columbia	$23	$24	$47	$379	$758
Maine	$248	$88	$175	$1,402	$2,803
Maryland	$720	$343	$687	$5,495	$10,989
Massachusetts	$653	$339	$678	$5,420	$10,841
New Hampshire	$144	$80	$161	$1,284	$2,569
New Jersey	$529	$449	$898	$7,185	$14,371
New York	$1,594	$780	$1,559	$12,473	$24,946
Pennsylvania	$2,115	$620	$1,239	$9,912	$19,824
Rhode Island	$139	$49	$98	$783	$1,567
Vermont	$102	$43	$87	$696	$1,391
TCI Region Total	**$7,081**	**$3,067**	**$6,133**	**$49,064**	**$98,128**

2.0 Summary of Impacts

2.1 Greenhouse Gas Emission Reductions

The scenarios analyzed and resulting greenhouse gas emission reductions in 2030 compared to the 2011 baseline are described below. GHG emissions are reported in million metric tons (mmt) of carbon dioxide equivalents (CO_2e) for on-road sources only.

In the development of this analysis, a shorthand scenario naming convention was applied that was later changed to a less technical naming convention for use in the main "synthesis" report. The original shorthand naming convention used for the technical analysis is retained in the figures and appendix tables of this document. The crosswalk between the summary scenario names and the technical analysis scenario names is shown in Table 2.0.

Table 2.0 Scenario Names

Scenario Names in Summary Report	Technical Analysis Scenario Names (Figures and Appendix Tables of This Document)
Baseline	Baseline (pre-MY2017 standards)
(not included in summary scenarios)	Federal Policies
Existing Federal + State Policies	Fed Policies + MOU State ZEVs
With Pricing	
Modest Investment Scenario + $3 billion pricing	1x Funding + 50/50 Reinvestment
Modest Investment Scenario +$3 billion pricing + Clean Fuels (10%)	1x Funding + 50/50 Reinvestment + CFS 10%
Moderate Investment Scenario +$3 billion pricing	1x Funding + 100% Reinvestment
Moderate Investment Scenario + Clean Fuels (10%) + $3 billion pricing	1x Funding + 100% Reinvestment + CFS 10%
Moderate Investment Scenario + Clean Fuels (15%) + $3 billion pricing	1x Funding + 100% Reinvestment + CFS 15%
Moderate Investment Scenario + Clean Fuels (10%) + $6 billion pricing	2x Funding + 50/50 Reinvestment + CFS 10%
Aggressive Investment Scenario + Clean Fuels (15%) + $6 billion pricing	2x Funding + 100% Reinvestment + CFS 15%
Without Pricing	
Modest Investment Scenario	1x Funding + 50/50 Reinvestment
Modest Investment Scenario + Clean Fuels (10%)	1x Funding + 50/50 Reinvestment + CFS 10%
Moderate Investment Scenario	1x Funding + 100% Reinvestment
Moderate Investment Scenario + Clean Fuels (10%)	1x Funding + 100% Reinvestment + CFS 10%
Moderate Investment Scenario + Clean Fuels (15%)	1x Funding + 100% Reinvestment + CFS 15%
(not included in GCC Scenarios)	2x Funding + 50/50 Reinvestment + CFS 10%
Aggressive Investment Scenario + Clean Fuels (15%)	2x Funding + 100% Reinvestment + CFS 15%

2.1.1 Baseline and Existing Policies

- **Baseline Scenario** – What emissions would have been without the most recent Federal policy actions, including Model Year 2017-2025 light-duty fuel efficiency/GHG standards, Model Year 2014-2018 light-duty standards, and Renewable Fuels Standard 2 (RFS2). This provides a 5.5 percent reduction in 2030 GHG emissions compared to the 2011 on-road baseline of 256.3 mmt.

- **Federal policies + MOU state ZEVs** – Adopted Federal fuel efficiency/GHG and RFS2 standards, plus accounting for vehicles sold in the six TCI states participating in the Memorandum of Understanding (MOU) on Zero Emission Vehicles (ZEV) to meet a 2025 target (see further discussion below).[5] This provides a 29.0 percent reduction in 2030 GHG emissions compared to the 2011 baseline.

2.1.2 Clean Transportation Investment Scenarios (No Pricing Policy)

- **Modest Implementation** – Investments in GHG mitigation policies (see Table 1.1a above) of approximately $1.5 billion per year, with an additional $1.5 billion per year invested in strategies supporting clean and resilient transportation. This provides a 30.9 percent reduction in 2030 GHG emissions compared to the 2011 baseline.

- **Moderate Implementation** – Investments in GHG mitigation policies of approximately $3 billion per year. This provides a 32.5 percent reduction in 2030 GHG emissions compared to the 2011 baseline.

- **Moderate Implementation with clean fuels 15%** – Adding a clean fuels standard (15 percent reduction in carbon intensity by 2030) to the Moderate Implementation scenario. This provides a 37.2 percent reduction in 2030 GHG emissions compared to the 2011 baseline.

- **Aggressive Implementation with clean fuels 15%** – Doubling investments in GHG mitigation policies to approximately $6 billion per year. Adding a clean fuels standard to achieve a 15 percent reduction in carbon intensity by 2030. This provides a 39.0 percent reduction in 2030 GHG emissions compared to the 2011 baseline.

Table 2.1a compares summary results for various scenarios, considering the following variations:

- Level of Investment – $1.5 billion, $3 billion, or $6 billion

- Clean fuels – no requirement beyond current levels, 10% standard by 2025, or 15% standard by 2030.

[5] The Federal policies scenario includes only the benefits of ZEVs sold *beyond* the vehicles subsidized by TCI incentives, as needed to meet the MOU targets. The benefits of vehicles subsidized by TCI incentives (in MOU and other states) are included in the pricing/reinvestment scenario benefits.

Figures 2.1a and 2.1b show the resulting impacts of clean transportation investments on GHG emissions, with effects of pricing not considered.

Table 2.1a Summary Results by Scenario (GHG Emissions in mmt)

Scenario Name	Level of Investment	Clean Fuels	2030	2015-2030	2030 %∆ vs. 2011 Baseline
2011 Baseline			256.3		
Pre-MY2017-25 Standards			242.3	3,965	5.5%
Federal Policies[a]			183.4	3,380	28.4%
Federal Policies + MOU ZEV[b]			182.0	3,366	29.0%
Modest Implementation (No pricing policy)[c]	$1.5 billion	None	177.0	3,313	30.9%
		10%	172.2	3,249	32.8%
Moderate Implementation (No pricing policy)	$3 billion	None	172.9	3,275	32.5%
		10%	169.5	3,221	33.8%
Moderate Implementation + clean fuels (No pricing policy)		15%	160.9	3,194	37.2%
Aggressive Implementation + clean fuels (No pricing policy)	$6 billion	15%	156.5	3,143	39.0%

[a]Federal Policies include light-duty vehicle standards through Model Year 2025, heavy-duty standards through MY2018, and Renewable Fuels Standard 2 (RFS-2). The values shown here are slightly lower than in the Inventory & Forecast document because they include a post-processing procedure to account for the RFS-2 standards which are not considered in the MOVES model.

[b]Includes benefits of ZEVs sold in MOU states up to level required to meet 2025 target, but not including ZEVs receiving subsidies from modeled investment scenarios.

[c]All subsequent scenarios include Federal Policies and MOU ZEV.

Figure 2.1a GHG Emissions Benefits: Moderate and Aggressive ($3 Billion and $6 Billion Average Annual Investment Levels)

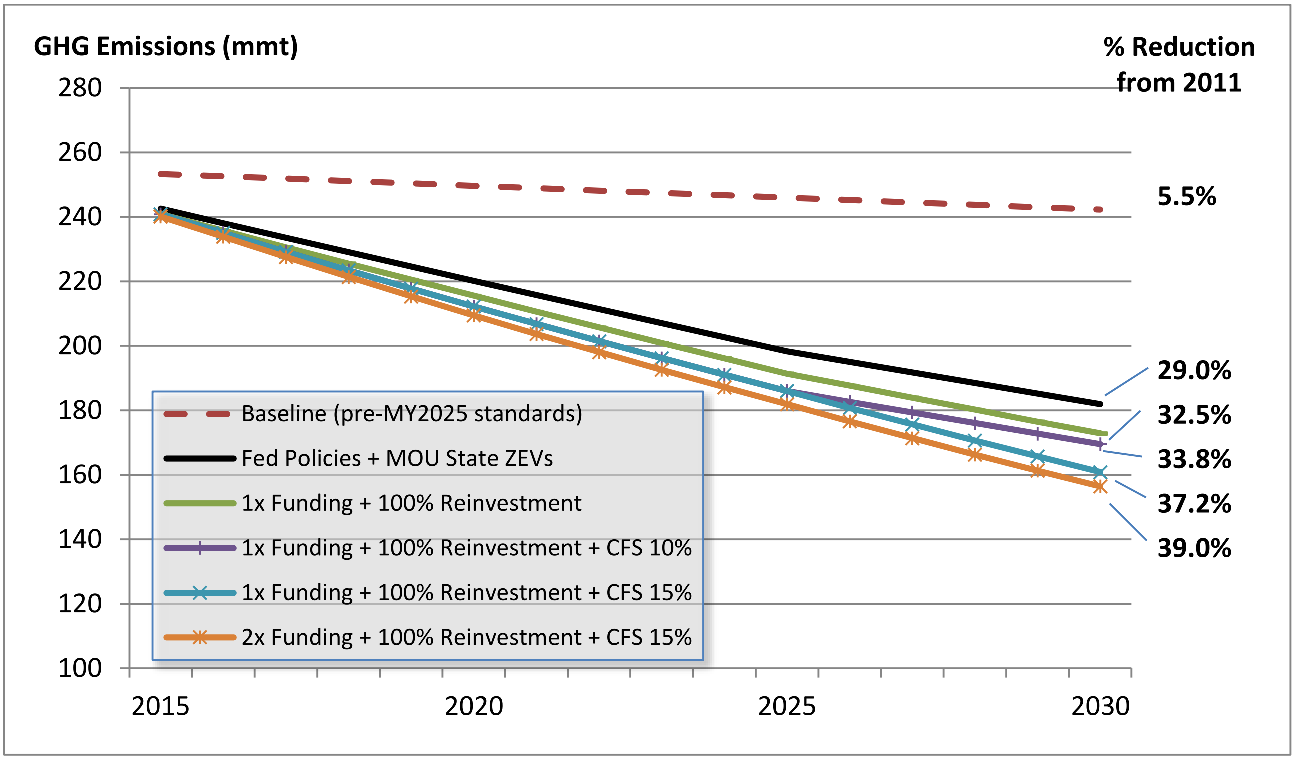
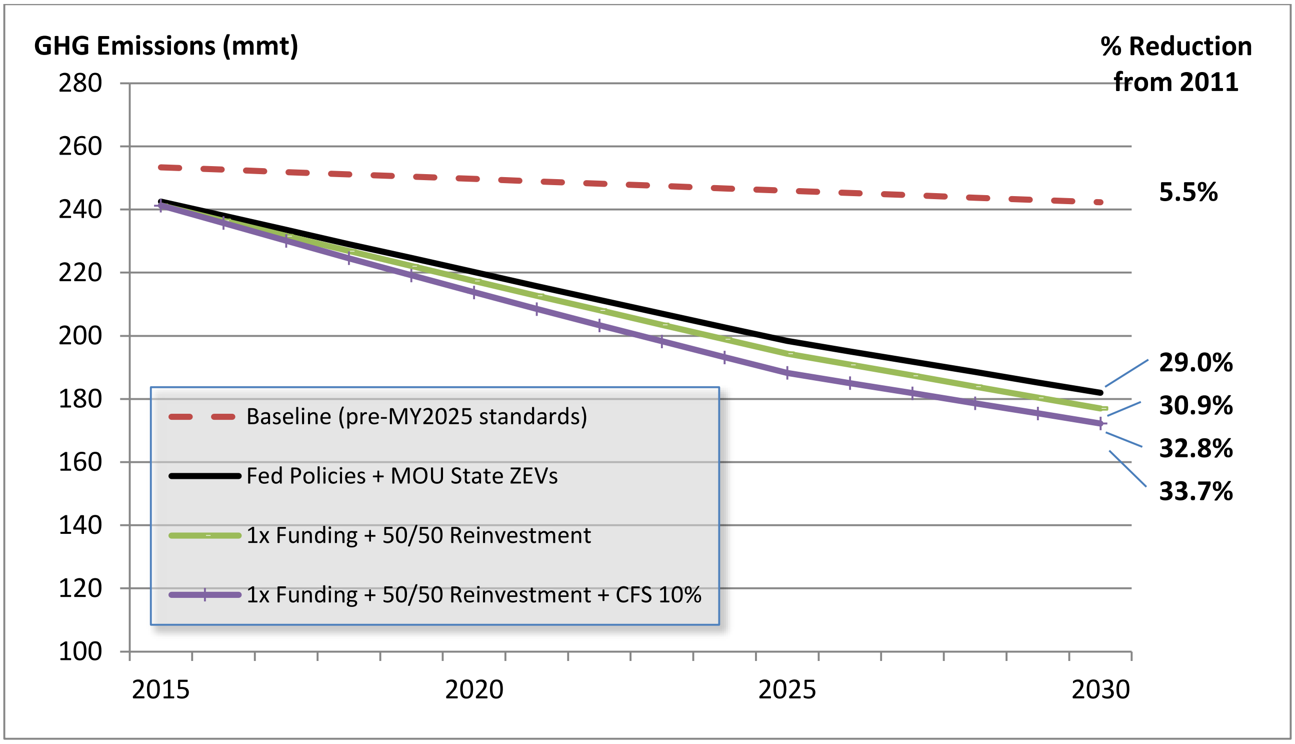


Figure 2.1b GHG Emissions Benefits: Modest ($1.5 Billion Average Annual Investment Level)



2.1.3 Pricing Policies + Reinvestment Scenarios

- **Modest Investment with $3 Billion Annual Average Pricing (50% mitigation)** – Adding the primary pricing scenario (approximately $3 billion per year) to the Federal and MOU state ZEV policies, reinvesting half the revenue in additional GHG reduction strategies and the other half in strategies supporting clean and resilient transportation. This provides a 31.5 percent reduction in 2030 GHG emissions compared to the 2011 baseline. Referred to as the "Second Policy Bundle" or "Scenario 2" for the economic analysis.

- **Moderate Investment with $3 Billion Annual Average Pricing (100% mitigation)** – Same as above, but reinvesting all the revenue in GHG reduction strategies. This provides a 33.1 percent reduction in 2030 GHG emissions compared to the 2011 baseline. Referred to as the "First Policy Bundle" or "Scenario 1" for the economic analysis.

- **Moderate Investment with $3 Billion Annual Average Pricing (100% mitigation) with Clean Fuels 10%** – Adding a clean fuels standard (10 percent reduction in carbon intensity by 2025) to the primary pricing + 100% reinvestment scenario. This provides a 34.4 percent reduction in 2030 GHG emissions compared to the 2011 baseline.

- **Moderate Investment with $3 Billion Annual Average Pricing (100% mitigation) with Clean Fuels 15%** – Extending the clean fuels standard to achieve a 15 percent reduction in carbon intensity by 2030. This provides a 37.8 percent reduction in 2030 GHG emissions compared to the 2011 baseline.

- **Aggressive Investment with $6 Billion Annual Average Pricing (Double funding, 50% mitigation) with Clean Fuels 10%** – Double the primary pricing scenario (approximately $6 billion per year), reinvesting half the revenue in GHG reduction strategies, and adding a 10 percent clean fuels standard. This provides a 34.9 percent reduction in 2030 GHG emissions compared to the 2011 baseline.

- **Aggressive Investment with $6 Billion Annual Average Pricing (Double Funding, 100% mitigation) with Clean Fuels 15%**– Double the primary pricing scenario (approximately $6 billion per year) with 100% reinvestment and 15 percent clean fuels standard. This provides a 40.0 percent reduction in 2030 GHG emissions compared to the 2011 baseline.

Table 2.1b compares summary results for various scenarios, considering the following variations:

- Pricing level – 1x (base), or 2x (double);
- Reinvestment scenario – 50/50 (half of new proceeds are directed to GHG mitigation strategies, with the other half directed towards other sustainable transportation investments with minimal GHG benefits), or 100% (all proceeds are directed to GHG mitigation strategies);
- Clean fuels – no requirement beyond current levels, 10% standard by 2025, or 15% standard by 2030;

- With pricing effects, vs. without pricing effects (i.e., only considering GHG reductions from reinvestment mitigation strategies and clean fuels).

Table 2.1b Summary Results by Scenario (GHG Emissions in mmt)

Scenario			With Pricing Effects			Without Pricing Effects		
Funding	Reinvest.	Clean Fuels	2030	2015-2030	2030 %Δ vs. 2011 Baseline	2030	2015-2030	2030 %Δ vs. 2011 Baseline
2011 Baseline						256.3		
Pre-MY2025 Standards						242.3	3,965	5.5%
Federal Policies[a]						183.4	3,380	28.4%
Federal Policies + MOU ZEV[b]						182.0	3,366	29.0%
1x[c]	50/50	None	175.5	3,290	31.5%	177.0	3,313	30.9%
		10%	170.8	3,227	33.4%	172.2	3,249	32.8%
1x	100%	None	171.4	3,252	33.1%	172.9	3,275	32.5%
		10%	168.1	3,199	34.4%	169.5	3,221	33.8%
		15%	159.5	3,172	37.8%	160.9	3,194	37.2%
2x	50/50	10%	166.9	3,179	34.9%	169.8	3,223	33.7%
	100%	15%	153.7	3,100	40.0%	156.5	3,143	39.0%

[a]Federal Policies include light-duty vehicle standards through Model Year 2025, heavy-duty standards through MY 2018, and Renewable Fuels Standard 2 (RFS-2).
[b]Includes benefits of ZEVs sold in MOU states up to level required to meet 2025 target, but not including ZEVs receiving TCI subsidies.
[c]All subsequent scenarios include Federal Policies and MOU ZEV.

Figures 2.2a and 2.2b show results including the direct effects of pricing on emissions.

Table 2.1c summarizes GHG impacts by strategy for combinations of strategies, including use of proceeds 100 percent for reinvestment. The analysis is based on the average annual funding level of $3 billion for the region as discussed above. The carbon price shows a slightly higher direct impact (0.5 percent higher emissions reductions) in 2030 than the other two pricing options, since it starts lower and increases over time. However, cumulative emission reductions are nearly the same under all three pricing options. If bonding were conducted to invest carbon price revenues at a level rate over the timeframe, the 2030 results would also be very similar for all three pricing options.[6]

[6] This analysis assumes that a VMT fee, motor fuels tax, or carbon price will have similar impacts on travel. There is recent evidence to suggest this may not be the case. An evaluation using the Maryland statewide travel demand model found evidence of a lower impact from a motor fuels tax than from an

Figure 2.2a GHG Emissions Benefits: 100% Reinvestment Scenarios

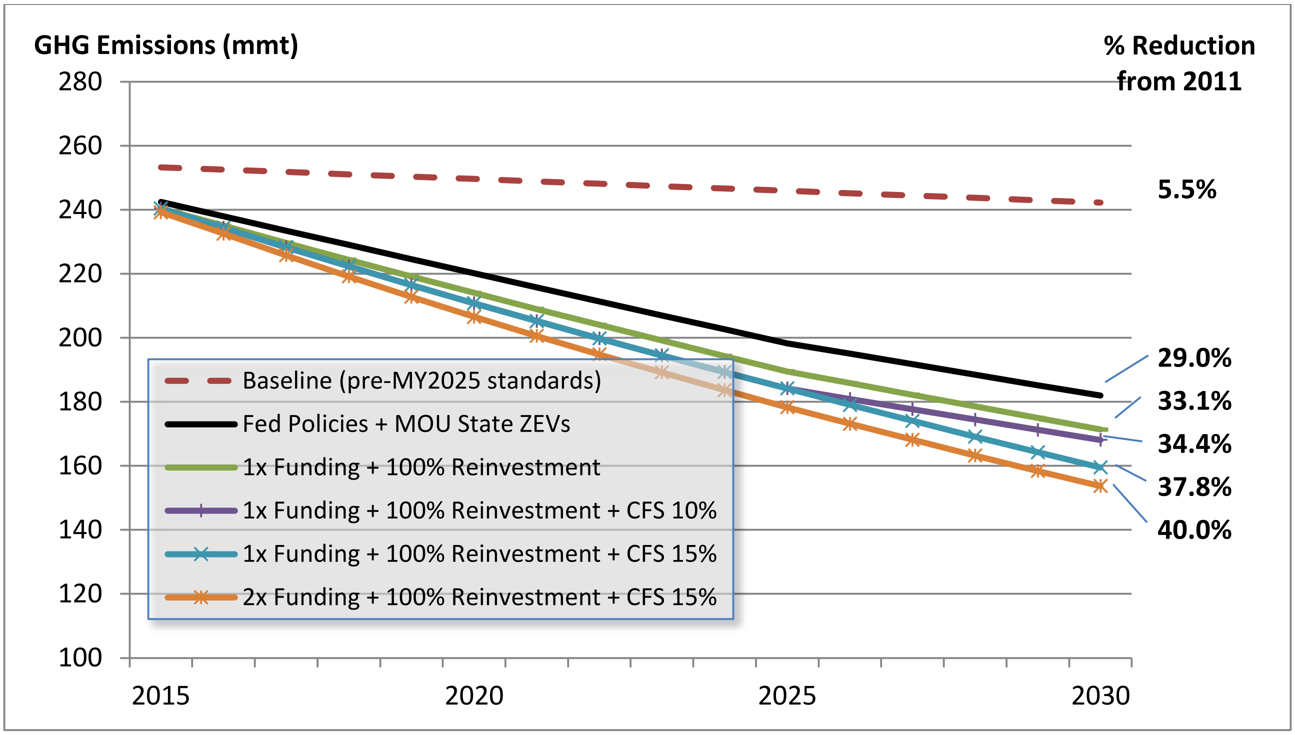
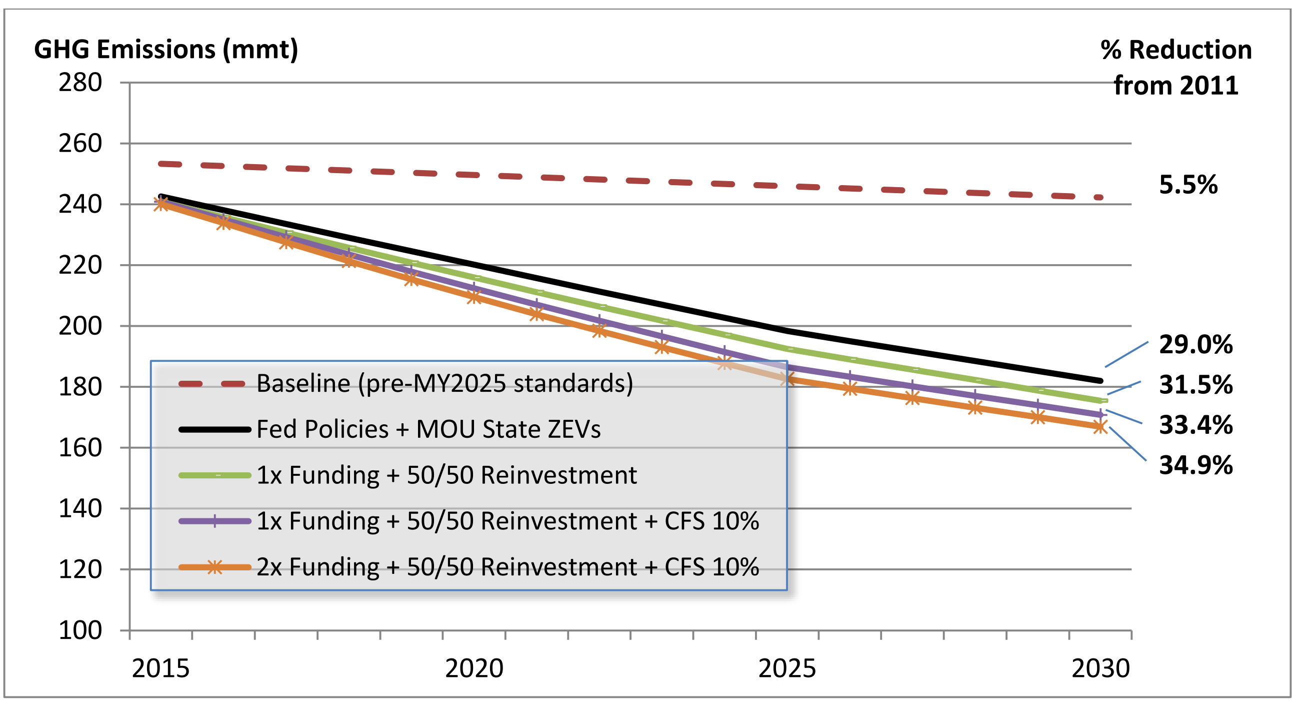


Figure 2.2b GHG Emissions Benefits: 50/50 Reinvestment Scenarios



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equivalent level of VMT fee. The explanation provided by the author (Dr. Timothy Welch at Georgia Tech) has to do with the fact that the model evaluates the impact of pricing on different income groups differently. His research also suggests that a VMT fee would have lower welfare impacts on low-income travelers than a gas tax.

Table 2.1c Summary Results by Strategy (1x Funding, 100% Reinvestment)

	GHG Reduction (mmt)		% Reduction vs. 2011 Baseline[d]	
Strategy	**2030**	**2015-2030**	**2030**	**2015-2030**
Pricing Options[a]				
VMT fee (0.6 c/mi)	1.60	22.11	0.6%	0.6%
Motor fuel tax ($0.137/gal)	1.50	22.80	0.6%	0.6%
Carbon price ($5-30/ton CO_2)	2. 75	25.77	1.1%	0.6%
EV/AFV infrastructure & incentives[b]	2.84	21.12	1.1%	0.5%
Urban and intercity transit	0.20	2.06	0.1%	0.0%
Land use/smart growth	1.69	19.12	0.7%	0.5%
Active transportation	1.32	12.66	0.5%	0.3%
TDM and ecodriving	0.69	13.73	0.3%	0.3%
System operations/efficiency	1.58	16.04	0.6%	0.4%
Freight/intermodal infra/ops	0.94	8.60	0.4%	0.2%
Total, Pricing + Reinvestment	**10.77**	**116.13**	**4.2%**	**2.9%**
Clean Fuels Standard 10%[c]	7.37	86.71	2.9%	2.2%

[a]The relative results for the pricing options in 2030 and 2015-2030 are different because of differences in the timing of the revenue stream from each source. VMT revenue remains roughly constant over time, motor fuel tax revenue declines because of increasing vehicle efficiency, and carbon price revenue increases because of the increasing carbon fee. The 2030 GHG reduction levels are affected by 2030 revenue levels as well as cumulative revenues.

[b]EV infrastructure/incentives includes only benefits of ZEVs sold in non-MOU states and alternative-fuel heavy-duty vehicles, as well as TCI-subsidized vehicles in MOU states. Benefits of ZEVs sold in MOU states to meet the MOU targets are included in the Federal Policies + MOU EV scenario.

[c]Clean fuels standard shows benefits as a stand-alone policy. Benefits are reduced when combined with other strategies because of overlap with EV/AFV benefits.

[d]% Reduction in 2030 = 2030 GHG reduction / 2011 GHG baseline. % Reduction in 2015-2030 = 2015-2030 GHG reduction / 2015-2030 cumulative GHG under pre-Federal Policies Baseline scenario.

Table 2.2 illustrates the approximate magnitude of emission reductions that would be achieved for each state in 2030 under various scenarios, compared with the "Federal Policies + MOU ZEV" scenario. The results shown here assume that reductions in each state are proportional to total VMT in each state. It does not consider state-specific differences in strategy effectiveness, which were beyond the scope of this analysis. Therefore, Table 2.2 should be considered as illustrative only of the magnitude of reductions that might be expected. Results are shown for the standard funding scenario including pricing effects, with 100% and 50/50 reinvestment, and with and without a 10 percent clean fuels requirement.

Table 2.2 Illustrative GHG Reductions by State (mmt in 2030)

	Without Clean Fuels		With 10% Clean Fuels Requirement	
State	**100% Reinvestment**	**50/50 Reinvestment**	**100% Reinvestment**	**50/50 Reinvestment**
Connecticut	-0.68	-0.41	-0.89	-0.71
Delaware	-0.19	-0.12	-0.25	-0.21
Dist. of Columbia	-0.08	-0.05	-0.11	-0.09
Maine	-0.30	-0.19	-0.40	-0.32
Maryland	-1.19	-0.73	-1.55	-1.25
Massachusetts	-1.17	-0.72	-1.53	-1.23
New Hampshire	-0.28	-0.17	-0.36	-0.29
New Jersey	-1.55	-0.95	-2.03	-1.64
New York	-2.69	-1.65	-3.53	-2.84
Pennsylvania	-2.14	-1.31	-2.80	-2.26
Rhode Island	-0.17	-0.10	-0.22	-0.18
Vermont	-0.15	-0.09	-0.20	-0.16
TCI Region Total	**-10.59**	**-6.49**	**-13.88**	**-11.18**

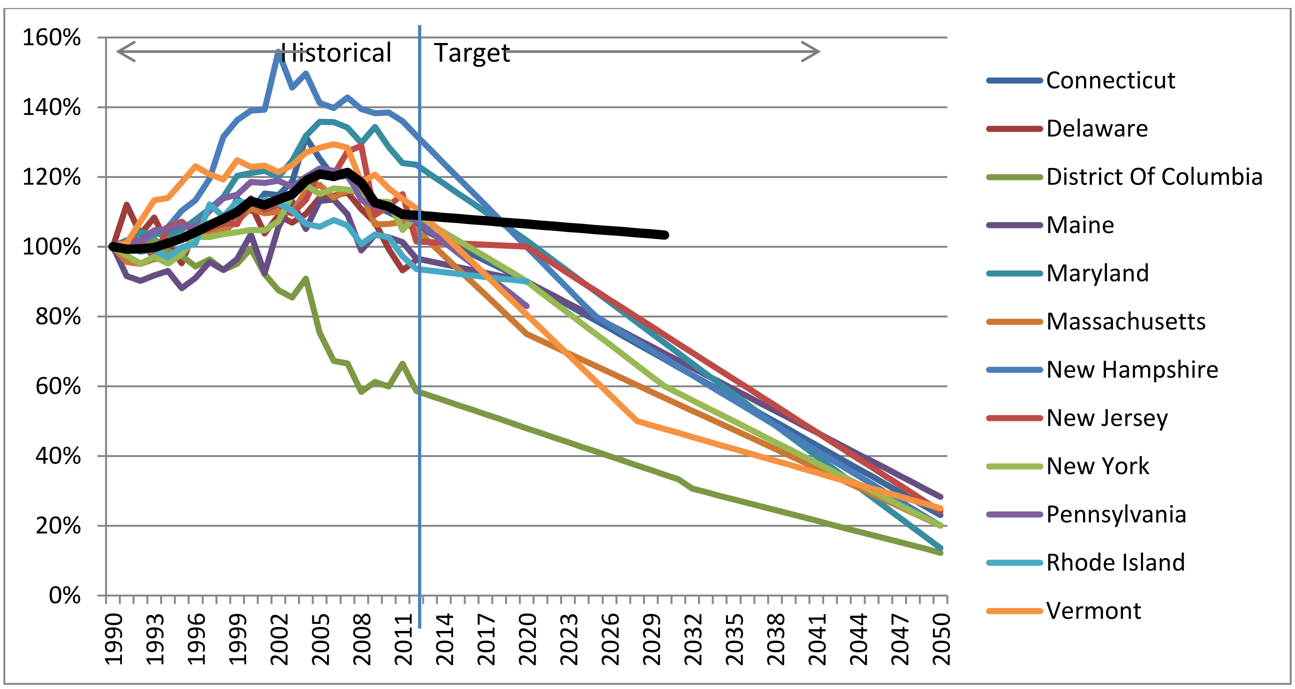
Note: Results are in comparison with Federal Policies + MOU State ZEV baseline in 2030.

The results shown here are illustrative of the nature and magnitude of impacts that could be expected. A range of pricing levels and reinvestment options could be selected. Furthermore, this is a broad-brush analysis that uses average effectiveness values for the TCI region. The Actual GHG benefits will depend upon the specific mix of projects or programs and their impacts on travel and fuel efficiency.

2.2 Comparison with State Targets

The anticipated GHG reductions with TCI-funded strategies were compared with the various states' target GHG reduction levels. States have expressed GHG reduction targets in a variety of ways, such as 2020, 2030, and 2050 targets relative to a baseline such as 1990, 2006, or another year. Historical transportation-sector CO_2 emissions by state for 1990 - 2012, from the U.S. Department of Energy, Energy Information Administration State Energy Data Systems, were used to normalize all states' emission levels relative to 1990.[7] These are for the entire transportation sector, which is broader than the surface transportation subset considered in the TCI analysis, but overall trends should be similar. Figure 2.3 shows historical and target emissions levels by state, along with baseline projections without current Federal policies. Figure 2.4 shows the Federal policies and various TCI scenario projections overlaid on the state goals. It can be seen that the Federal policies begin to pull regional GHG reductions into the range of targets set by the states, but the TCI strategies make further progress towards doing so. Table B.1 in Appendix B shows the percent reduction in 2030 GHG emissions in each scenario compared to varying year regional baselines (1990 through 2011).

Figure 2.3 Historical and Target GHG Emissions by State, Relative to 1990



[7] This was done by expressing each year's emissions (1990 through 2012, the latest in the dataset) as a percentage of 1990 emissions (Figure 2.3). For future years, the target levels (2020, 2030, 2050, or other year) were calculated as a percentage of the state's baseline year (1990, 2006, etc.). Linear interpolation was then performed between the 2012 level and the future target year level to obtain a stream of future year emissions.

Figure 2.4 TCI Scenario Emission Reductions vs. State Goals, Relative to 1990

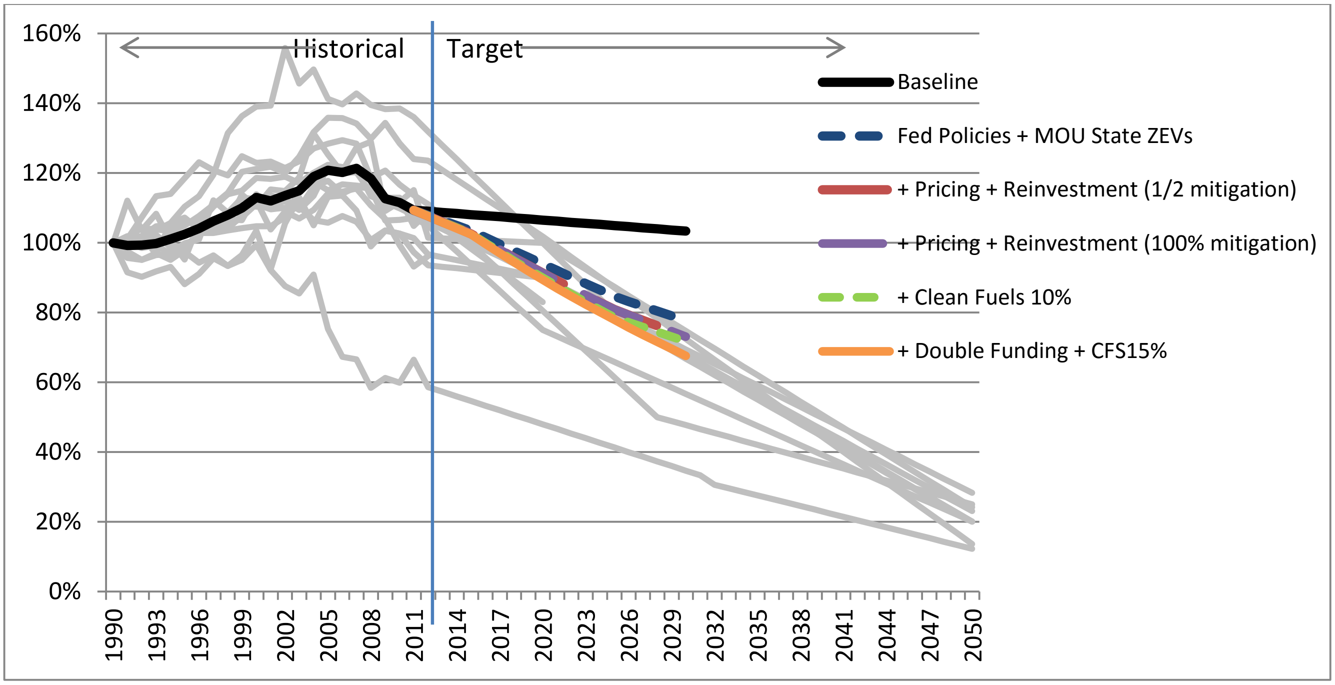


Table 2.3 shows how closely each scenario will come to achieving a regional emissions reduction of 80 percent in 2050, compared to the 2011 level. This assumes that GHG reductions continue to occur along the same trajectory beyond 2030 (i.e., a linear trend line). The Federal policies scenario will put the region on a trajectory to reducing GHG emissions by roughly 58 percent. The funding and reinvestment scenarios move the region closer to the target, achieving between 63 and 72 percent reductions for most of the scenarios. Including a more aggressive clean fuels standard (15 percent) along with a higher funding/reinvestment level could lead the region to reach an 80 percent reduction threshold. These scenarios are purely illustrative and will be affected by the rate of baseline growth (see next section) and the ability to continually achieve further GHG emission reductions over the entire analysis period.

Table 2.3 Projected Transportation GHG Reductions in 2030 and 2050 vs. 2011 Baseline

			With Pricing Effects		Without Pricing Effects	
Funding	**Reinvest.**	**Clean Fuels**	**2030 %Δ vs. 2011 Baseline**	**2050 %Δ vs. 2011 Baseline**	**2030 %Δ vs. 2011 Baseline**	**2050 %Δ vs. 2011 Baseline**
2011 Baseline						
Pre-MY2025 Standards					5.5%	**11.3%**
Federal Policies[a]					28.4%	**58.3%**
Federal Policies + MOU ZEV[b]					29.0%	**59.5%**
1x[c]	50/50	None	31.5%	**64.7%**	30.9%	**63.4%**
		10%	33.4%	**68.6%**	32.8%	**67.3%**
1x	100%	None	33.1%	**67.9%**	32.5%	**66.7%**
		10%	34.4%	**70.6%**	33.8%	**69.4%**
		15%	37.8%	**77.6%**	37.2%	**76.4%**
2x	50/50	10%	34.9%	**71.6%**	33.7%	**69.2%**
	100%	15%	40.0%	**82.1%**	39.0%	**80.1%**

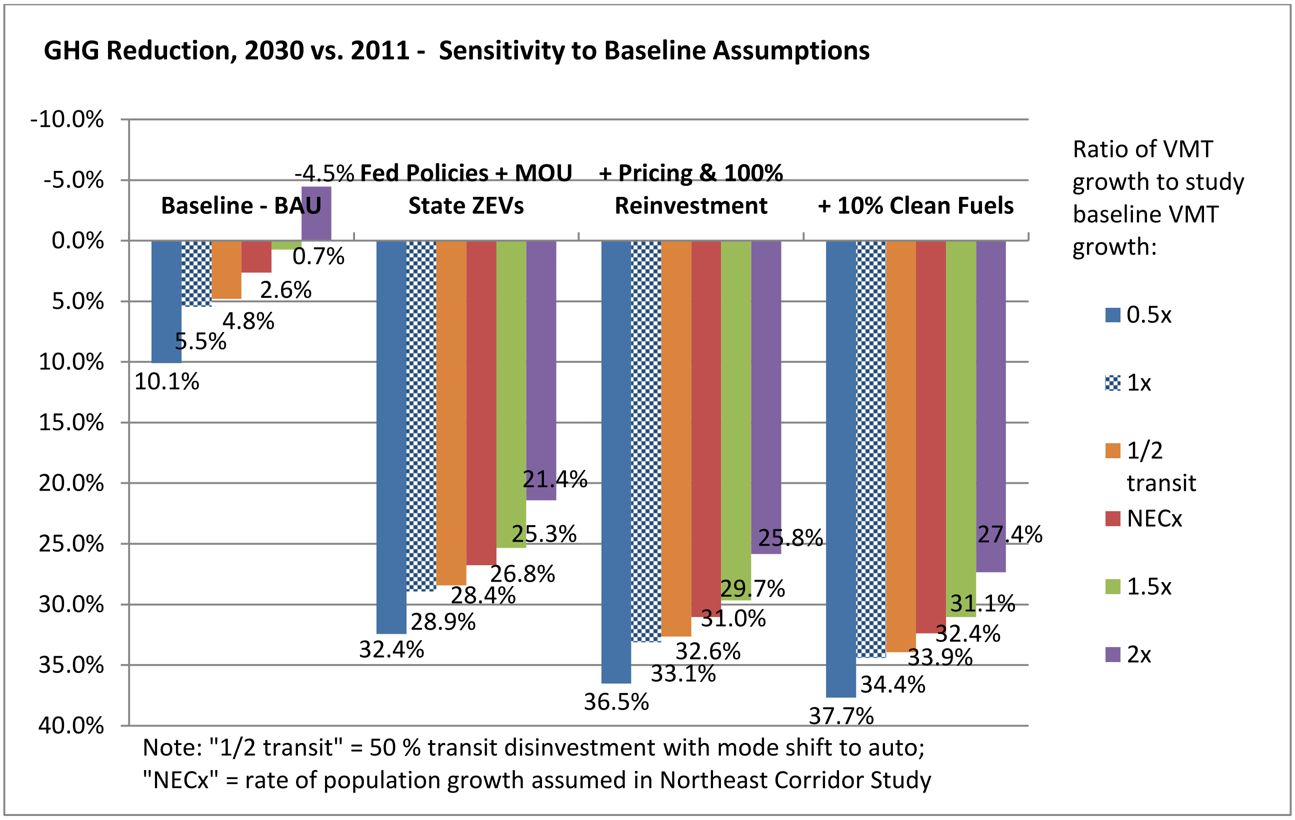
2.3 Effects of Varying Baseline

The ability to meet a GHG reduction target through mitigation strategies depends greatly upon the assumed baseline future projection of GHG emissions from the transportation sector. The projection used here is only one possible future condition. Any number of factors, including population and job growth, income growth, fuel prices, additional Federal policies (such as fuel economy or clean fuel requirements), urban growth patterns, and demographic and cultural trends could affect future VMT, fuel efficiency, and GHG emissions.

To test the effects of different baselines on the ability to achieve GHG targets, a number of alternative scenarios were tested with different rates of VMT growth. The baseline VMT growth rate of 0.53 percent annually between 2011 and 2030 is based on a weighted average of state-level projections, which themselves reflect a variety of different methods and assumptions. Alternatives tested include one-half the baseline rate (0.27 percent) as well as 1.5 and 2 times the baseline rate (up to 1.06 percent annually). In addition, a scenario was tested reflecting major reduction in transit usage and a corresponding shift to automobile travel (explained further below), as well as one in which a somewhat higher growth rate (0.69 percent) is assumed that is more consistent with population growth assumptions in the ongoing the Northeast Corridor study.

Figure 2.5 shows the effects of these different baselines on the projected 2030 vs. 2011 GHG emission reduction under four scenarios – the Baseline Scenario (what would have happened without the most recent Federal policies), Federal policies + MOU state ZEVs, pricing and 100% reinvestment, and the same scenario with 10% clean fuels requirement. Taking the pricing and 100% reinvestment scenario as an example, it can be seen that if VMT growth is half of what is projected, it is possible to hit a 36.5 percent reduction target rather than 33 percent. However, if VMT growth is greater, it may be possible to achieve a lower target in the range of 30 to 32 percent, or even less than that if VMT increases by over 1 percent a year.

Figure 2.5 Effect of Different Baseline on Achievable Target



The baseline fuel economy of the vehicle fleet in 2030 could also change, for example, if consumers choose to buy larger vehicles than anticipated in the rulemaking for the MY2017-2025 standards. (The standards are applied based on the footprint of the vehicle rather than fleet-wide, so if consumers buy larger vehicles than projected, manufacturers will need to meet a lower fuel economy average.) The 1.5x VMT scenario shown above is roughly equal to 5 percent lower average fuel economy for cars and trucks, while the 2x scenario is roughly equal to a 10 percent lower average fuel economy. Therefore this figure appears to illustrate well the potential range of impacts of different baseline fuel economies. Effects could be compounded, for example, if VMT grew faster than projected *and* fuel economy was lower than projected.

2.4 Summary of Economic Impacts

The Regional Economic Models, Inc. (REMI) Policy Insight model was used to estimate the macroeconomic benefits of investing in GHG emission reduction strategies. REMI is the premier economic simulation model in the U.S. and is a dynamic model, measuring interactions among all sectors of the economy over time. The REMI model analyzes *changes in monetary flows* through the economy, and the resulting impacts on jobs, gross regional product (GRP), income, and various other metrics. Thus, the analysis considers benefits and costs that can be directly monetized, such as time savings that improve business productivity, vehicle operating cost savings to businesses and consumers, and government spending. The economic analysis is a comprehensive analysis that considers the impacts of money *not spent* by consumers because they pay more in taxes or fees, as well as the benefits resulting from cost savings.

Table 2.4 shows the range of potential economic benefits to the TCI region that might be expected from the baseline level of revenue and reinvestment in transportation (i.e., corresponding to a pricing policy generating $3 billion in average annual proceeds). The range shows the results that might be expected from a 100 percent mitigation scenario or a 50/50 reinvestment scenario. The range also considers assumptions about whether some of the new TCI revenue is diverted to other transportation uses to help fill expected revenue shortfalls. In any case, the investment scenarios are expected to show significant economic benefits to the TCI region – on the order of 100,000 jobs annually by 2030, $12 to $18 billion in new GRP, and $10 to $14 billion in new personal disposable income. These impacts are on the order of one-quarter to one-third percent of the regional economy. Benefits of this magnitude are expected as long as the new revenue is used for *productive* transportation investments that reduce costs and save time for travelers.

Table 2.4 Economic Benefits to TCI Region of Pricing and Reinvestment Strategies

Industry	2030	2030 Percent of Region	Cumulative, 2015-2030
Change in Regional Employment	91,000 - 125,000	0.23% - 0.31%	794,000 - 1,167,000
Change in Gross Regional Product ($Billions, 2009)	11.7 - 17.7	0.25% - 0.38%	92 - 144
Change in Disposable Personal Income ($Billions, 2009)	9.9 - 14.4	0.19% - 0.28%	71 - 109

2.5 Summary of Other Benefits

Investing in transportation options that reduce GHG emissions has the potential to support a variety of other benefits that are not reflected in the economic analysis. The other benefits that were quantified but not reflected in the REMI economic analysis include:

- Energy independence – A reduction in petroleum fuel use;
- Time savings – For personal or "off-the-clock" travel (the economic benefits reflect savings in business or "on-the-clock" travel);
- Safety – A reduction in fatalities and injuries due to reduced motor vehicle crashes;
- Air pollution – A reduction in a variety of negative health outcomes associated with emissions from motor vehicles (changes in premature deaths and asthma cases are shown here);
- Physical activity – Reduced mortality as a result of greater participation in "active" transportation options including walking and bicycling; and
- Pavement damage – Reduced wear and tear on the region's highways.

While some of these benefits were quantified in monetary terms (e.g., based on value of statistical life saved or health outcomes), these cost savings were not included in the economic analysis since they may affect the economy in complex ways which were beyond the scope of this analysis to assess. Table 2.5 summarizes estimates of other benefits for selected scenarios, including only the benefits of reinvestment, not of VMT or energy use reduction from pricing. However, an illustrative benefit-cost analysis also was conducted to show how the magnitude of monetizable benefits compares to the magnitude of public investment costs.

Section 6.0 provides additional detail on how these benefits were estimated. Appendix C provides detail for all scenarios evaluated.

Table 2.5 Summary of Other Benefits (Not Including Direct Effects of Pricing)

	1x Funding + 50/50 Reinvestment			1x Funding + 100% Reinvestment			2x Funding + 100% Reinvest. + 15% Clean Fuels		
	2030	2015-2030	Average Annual	2030	2015-2030	Average Annual	2030	2015-2030	Average Annual
Energy Independence									
Reduction in petroleum consumption (millions of gal.)	695	6,395	400	1,279	11,168	698	4,838	43,760	2,735
% of regional	3.9%	1.9%	1.9%	7.1%	3.4%	3.4%	26.8%	13.3%	13.3%
Time Savings									
Personal time savings (millions of hours)	385	3,114	195	718	5,590	349	1,360	10,266	642
Safety/Crashes									
Fatalities prevented	166	1,543	96	296	2,601	163	532	4,475	280
Injuries prevented	2,495	23,141	1,446	4,442	39,008	2,438	7,975	67,126	4,195
Monetary val. ($millions)	$1,494	$14,666	$917	$2,600	$24,118	$1,507	$4,543	$40,359	$2,522
Air Pollution									
Premature deaths prevented	19	191	12	35	344	22	65	633	40
Asthma cases prevented	1,099	11,066	692	2,011	19,703	1,231	3,728	35,874	2,242
Monetary val. ($millions)	$152	$1,823	$114	$265	$2,966	$185	$463	$4,907	$307
Physical Activity									
Deaths prevented	420	3,567	223	826	7,021	439	1,455	12,367	773
Statistical value of lives saved ($millions)	$2,941	$25,001	$1,563	$5,789	$49,210	$3,076	$10,199	$86,692	$5,418
Pavement Damage									
Roadway maintenance cost savings ($millions)	$408	$2,748	$172	$801	$5,399	$337	$1,596	$10,742	$671

An illustrative benefit-cost analysis (BCA) was also conducted. The benefit-cost analysis compares the sum of monetized business, consumer, and government benefits to the investment costs of the scenario (i.e. new expenditures on transportation infrastructure and services), to develop a benefit-cost ratio. BCA differs from economic impact analysis in that the BCA simply compares the sum of all monetizable costs and benefits (some of which are not monetary exchanges, but rather reflect how people or firms value different benefits). In contrast, the economic impact analysis considers flows of money through the economy and the resulting impacts on jobs, income, and regional product.

The benefits included in this BCA are:

- Value of time savings (business and personal travel);
- Fuel, electricity, and vehicle maintenance cost savings;
- Additional vehicle purchase costs (a "negative" benefit);
- Air pollution cost savings;
- Safety cost savings (reduced crashes); and
- Reduced pavement damage.

The stream of benefits and costs for 2015-2030 was translated into net present value (NPV) using a discount rate of 5 percent. The illustrative results obtained are shown in Table 2.6 and show a benefit-cost ratio of 2.0 to 3.5, indicating that benefits exceed costs. These results are very conservative because they do not take into account benefits that will continue to accrue beyond 2030 as a result of the infrastructure investments made during the 2015-2030 period. They also do not include the benefits from direct pricing effects; benefits of physical activity (which are estimated to be quite substantial based on the value of statistical lives saved, but the methods and assumptions have not yet been widely accepted for use in transportation BCA); or any benefits and costs of a clean fuels standard (which were beyond the scope of this analysis to evaluate).

Table 2.6 Sample Benefit-Cost Results (Not Including Direct Pricing Effects)

Outcome	1x Funding + 50/50 Reinvestment	1x Funding + 100% Reinvestment	2x Funding + 100% Reinvest.
Net present value of 2015-2030 investment costs ($millions)	$49,181	$48,403	$96,805
Net present value of 2015-2030 business, consumer, and government benefits ($millions)	$99,741	$173,181	$308,991
Benefit-cost ratio	2.0	3.5	3.0

3.0 GHG Strategy Analysis

(Subsections 3.1 – 3.8 apply to both Transportation Investment Approach and Comprehensive Policy Bundle Approach. Subsection 3.9 applies only to Comprehensive Policy Bundle Approach.)

3.1 Electric/Alternative Fuel Vehicles

Three types of plug-in electric/alternative fuel vehicles are included in this analysis: full battery electric (EV) and plug-in hybrid electric (PHEV) light-duty vehicles, and heavy-duty vehicles running on compressed natural gas (CNG) or liquefied natural gas (LNG).

An important qualification for this analysis is that electric vehicles are assumed to provide a net GHG benefit even considering the Federal fuel economy/GHG standards. This will not necessarily be the case. Since automobile manufacturers only have to meet a nationwide average fuel economy/GHG standard, it is possible they will sell less fuel-efficient conventional vehicles which offset the benefits achieved from EV sales. However, initiatives by states (including TCI region members) to promote EVs are likely to help increase the marketability of this technology, making it easier for auto manufacturers to meet the existing standards through 2025 as well as any potential future, more advanced standards. Therefore, this analysis should be taken as illustrative of potential EV benefits, rather than a precise estimate.

The basic analysis approach is to assume that funding is provided to make up the cost differential between an alternative-fuel vehicle and a conventional vehicle. This is a simplifying assumption that does not consider differences in vehicle performance characteristics, market segments with different use characteristics and preferences, etc. The funding could be provided in various forms such as consumer purchase incentives, infrastructure investment, consumer education, etc. The cost differential includes three components:

- **The incremental capital (purchase) cost** of the vehicle compared to a conventional light duty vehicle. For EV and PHEV, this is taken from a California Air Resources Board (CARB) analysis for the ZEV rulemaking for costs in 2013 through 2025, declining to values cited in a U.S. DOT report by 2030.[8] It varies by year, decreasing over time (Table 3.3). The costs in this table represent the "true" cost of the vehicle before any Federal or state rebates or manufacturer discounts. For CNG/LNG trucks, an incremental price of $50,000 is assumed, based on a review conducted by CS for the Oregon Department of Energy.[9]

- **Incremental fuel/energy costs**. Consumers realize energy cost savings from both EV and CNG/LNG vehicles. Costs by fuel type are based on AEO projections, with electric

[8] California Air Resources Board. "Emissions Data" – Compliance Cost Sheet. http://www.arb.ca.gov/msprog/clean_cars/clean_cars_ab1085/clean_cars_ab1085.htm; U.S. DOT (2010). "Transportation's Role in Reducing U.S. Greenhouse Gas Emissions." Report to Congress.

[9] Memorandum to Bill Drumheller, Oregon Department of Energy, from Chris Porter, Cambridge Systematics, December 31, 2013.

compared to gasoline and CNG/LNG to diesel. Fuel (energy) savings are based on energy efficiency ratios (3.0 for EV and PHEV, 0.94 for CNG) from a NESCAUM report.[10] Fuel savings are considered over a 10-year period in this analysis.

- **Costs of recharging/refueling infrastructure.** A cost per vehicle of $1,500 is assumed for EV/PHEV recharging equipment. For heavy-duty CNG/LNG, a cost per vehicle is inferred from the estimated infrastructure cost to serve Oregon with CNG stations (built-out over 10 years), divided by projected CNG vehicle sales in each year, from the analysis by CS for Oregon DOE. The cost adds about $2,200 per vehicle in 2020.

Table 3.3 Incremental Vehicle Purchase Cost Assumptions

Vehicle Type	2015	2020	2025	2030
EV	$ 27,406	$ 21,304	$ 15,202	$ 9,100
PHEV	$ 19,162	$ 14,274	$ 9,387	$ 4,500

Funding under the baseline scenario was provided 30 percent to EVs, 60 percent to PHEVs, and 10 percent to CNG/LNG HDV. The EV/PHEV split is generally consistent with CARB and other analysis suggesting that PHEVs will make up the majority of plug-in vehicles in the near term. PHEVs are assumed to travel 45 percent of their distance on electricity and 55 percent on gasoline.[11]

In 2013, eight states, including six in the TCI region,[12] signed a memorandum of understanding (MOU) to collectively achieve 3.3 million EV sales by 2025. The target number of cumulative ZEV sales by 2025 in the six TCI states is 1,670,000.[13] The TCI funding directed towards EVs is split proportionately among MOU and non-MOU states (57 and 43 percent, respectively, proportioned by 2012 VMT). The funding directed to MOU states is allocated to vehicles until it is used up, with these benefits counted as part of the EV/alternative fuel vehicle strategy, and then manufacturers are assumed to sell additional vehicles until the MOU target is met, with these benefits included as part of the regional baseline with Federal Policies. It is further assumed that a manufacturer's discount of 25 percent of the incremental purchase

[10] Northeast States for Coordinated Air Use Management (2011), Economic Analysis of a Program to Promote Clean Transportation Fuels in the Northeast/Mid-Atlantic Region.

[11] Based on CS analysis for Oregon DOE, considering information presented in: National Academy of Sciences (2013), Transitions to Alternative Vehicles and Fuels.

[12] The six TCI region states include Connecticut, Maryland, Massachusetts, New York, Rhode Island, and Vermont. These states join California and Oregon in the MOU.

[13] Proportioned by 2012 new vehicle registrations in each state, per correspondence with Matt Solomon, NESCAUM.

cost difference for EVs[14] is provided to reduce the cost to the consumer in the MOU states, thus reducing the level of TCI funding needed per vehicle.

If all of the vehicles required by the MOU were included in the Federal Policies baseline, the 2030 Federal Policies emission reduction (compared to 2011) would be about 1.0 mmt greater than shown, or an additional 0.5 percent of the 2011 baseline.[15] Also, New Jersey and Maine have ZEV requirements (like the MOU states) but were not signatories to the MOU. An estimate of the ZEV requirement impacts in these states was not made because there are different combinations of vehicle technologies (PHEV, ZEV, and FCEV) that could be deployed to meet the requirement rather than a specific target as set forth in the MOU. However, assuming that these two states generated ZEV sales in proportion to the MOU states as set forth in their MOU (proportional to VMT in each state), there would be an additional 510,000 ZEVs in 2030, representing 0.7 mmt GHG or 0.4 percent of the 2011 baseline. Combining all MOU-required vehicles plus New Jersey and Maine ZEV-required vehicles could therefore result in a nearly 1 percent additional reduction in the Federal Policies scenario compared to the 2011 baseline, or 30 percent instead of 29 percent reduction.

Some of the assumptions for EVs and AFVs, especially cost differentials, are highly uncertain. The cost differentials assumed in this analysis are conservative and some sources have provided lower estimates. Table 3.4 provides a sensitivity analysis for the key EV/AFV assumptions, **assuming TCI funding only and no additional policy requirements or incentives to sell MOU vehicles**. The cumulative number of EVs in 2025 is compared to the MOU level of approximately 1,670,000 vehicles sold by this year.

[14] This discount starts at about $7,000 for EVs and $5,000 for PHEVs in 2015, declining to about $2,000 per EV and $1,000 per PHEV in 2030.

[15] Total EV/PHEV deployed in 2030: 4,100,000 = 5.7 mmt GHG benefit = 3.0% of 2011 baseline. MOU vehicles in 2030 not included in Fed Policies baseline (i.e., TCI-funded): 929,000 = 1.3 mmt = 0.7% of baseline. MOU target = 1,670,000 vehicles = 2.3 mmt = 1.2% of baseline. Differences = 1.0 mmt or 0.5%.

Table 3.4 EV/AFV Sensitivity Analysis

Assumptions[a]	2030 GHG Reduction (% of 2030 Baseline)	Cumulative MOU State EV's in 2025	% of MOU Target
Baseline as described in text (funding: 30% EV, 60% PHEV, 10% CNG/LNG)	2.7%	570,000	34%
Only light-duty (funding: 35% EV, 65% PHEV)	2.0%	632,000	38%
PHEV emphasis (funding: 10% EV, 80% PHEV, 10% CNG/LNG)	2.6%	592,000	35%
Only consider 5 years fuel savings	1.4%	447,000	27%
Reduce incremental EV/PHEV cost by 25%	4.4%	903,000	54%
Reduce incremental EV/PHEV cost by 40%	5.4%	1,421,000	85%
Double funding	5.4%	1,141,000	68%
Achieve MOU target (all EV/PHEV, no HDV)	4.5%	1,670,000	100%

[a]Each assumption is applied relative to the baseline set of assumptions shown in the first row – the assumptions are not applied cumulatively. Analysis is applied for funding from VMT fee of 0.6 cents/mile. Analysis is carried out independent of MOU EV sales goal/requirement. Reduction is based on a preliminary 2030 GHG baseline of 230 mmt. The numbers are based on a preliminary analysis and would vary slightly considering final assumptions.

The assumptions regarding the GHG intensity of fuels are taken from the 2011 NESCAUM report. These are fuel-cycle (well-to-wheel) intensities reflecting fuel production and transport as well as combustion. These assumptions are shown in Table 3.4b, expressed in grams of CO_2-equivalent per megajoule (MJ). Note that there are a variety of uncertainties in the upstream emissions associated with fuel, such as the carbon intensity of future petroleum extraction methods, methane leakage in production and distribution, and the mix of energy sources for electricity generation. Other conversion factors used include 116,090 BTU/GGE (low heating value from GREET 2011), 948 BTU/MJ, and 3.6 kWh/MJ.

Fuel-cycle GHG intensities are used in order to place electricity and natural gas on an even footing with gasoline and diesel. Otherwise, if only direct emissions were included, EVs would have zero emissions. However the use of fuel-cycle factors will overstate benefits compared to other strategies because benefits outside the normal transportation inventory (i.e., associated with fuel production and transport) are being considered only for this strategy. Fuel-cycle emissions for gasoline are typically 25 to 30 percent higher than direct emissions. To make the EV/AFV benefits more consistent with other strategies, a "direct equivalent" carbon intensity factor was used in the final analysis by scaling the fuel-cycle intensities back by a factor of 1.27 (the gasoline fuel-cycle scale factor from the GREET 2011 model). Using the full fuel-cycle factors would increase the benefits of the EV/AFV strategy from 2.84 to 3.61 mmt in 2030 or from 21.1 to 26.8 mmt cumulatively under the 1x pricing/100% reinvestment scenario.

Table 3.4b Carbon Intensity Assumptions

Fuel	Fuel-Cycle Carbon Intensity, g CO_2e/MJ	"Direct Equivalent" Carbon Intensity, g CO_2e/MJ	Notes
Gasoline	101	79.5	2022 value
Diesel	99	78.0	2022 value
Compressed Natural Gas	73	57.5	Midpoint of range in Table 2-3
Electricity	65	51.2	Midpoint of 2022 range; accounts for assumed 3.0 energy efficiency ratio for electric vs. gasoline vehicles

Source: Northeast States for Coordinated Air Use Management (2011), Economic Analysis of a Program to Promote Clean Transportation Fuels in the Northeast/Mid-Atlantic Region.

3.2 Transit

The basic approach for evaluating urban and intercity transit investment is to estimate the annual GHG benefit (in metric tons or tons) per dollar of capital investment. For example, if $500 million is expended on a project in year 2020, and the annual benefit is 50 tons per million dollars investment, the annual reduction in years 2021 and beyond would be 25,000 tons per year (500 * 50).

This parameter is related to, but not the same as, "cost effectiveness" ($ per ton reduced) as reported in other studies such as Moving Cooler[16] and the U.S. DOT Report to Congress.[17] Moving Cooler considered cost-effectiveness by dividing cumulative costs over a 40-year period (2010-2050) by cumulative GHG reductions over that period. The timeframe of this study is shorter so it is not possible to directly use those cost-effectiveness figures.

For this study, capital costs and GHG benefits were reviewed for a sample of proposed transit projects in the Northeast and Mid-Atlantic regions for which data were available from project studies. Estimates for four projects are shown in Table 3.5 for comparison. These estimates are also converted to $/ton and compared with the cost-effectiveness estimates from the literature.[18]

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[16] Cambridge Systematics, Inc. (2009), Moving Cooler, Prepared for Urban Land Institute.

[17] U.S. DOT (2010). "Transportation's Role in Reducing U.S. Greenhouse Gas Emissions." Report to Congress.

[18] Conversion to $/ton assumes a capital annualization factor of 7 percent, based on CS analysis of a number of transit projects for Transit Cooperative Research Program (TCRP) Project H-41 (TCRP Web-Only Document 55, Assessing and Comparing Environmental Performance of Major Transit Investments,

Table 3.5 Transit Project Cost-Effectiveness

Project	Type	Annual tons per millions of capital $	$/ton
South Coast Rail, Boston, MA	Commuter Rail	25	$3,500
Green Line Extension, Boston, MA	Light Rail	25	$3,900
Silver Line Gateway, Boston, MA	Diesel Hybrid BRT	6	$17,300
Springfield – New Haven improvements, MA – CT	Intercity Rail	6	$14,900
Red Line, Baltimore, MD	Heavy Rail	5	$19,300
Purple Line, suburban Washington, D.C.	Light Rail	18	$5,300
Moving Cooler	Urban transit expansion/ service improvements	54 (at midpoint)	$1,200-$2,000

The effectiveness of the projects is in the range of 10 to 50 percent of the Moving Cooler estimates. The South Coast and Green Line Extension projects were analyzed using the most robust modeling, with travel demand models used to forecast ridership and automobile VMT changes, with these changes linked to emission factors. The analysis for the other projects is somewhat more sketch-level. None of these estimates account for annual operating costs, which are typically in the range of 35 to 40 percent of annualized capital costs.

Considering the most robust project-level modeling results, 25 tons per capital dollar was taken as the effectiveness estimate for year 2030 (the modeling studies shown in Table 3.6 are for an analysis horizon in the 2030-2035 time frame). This estimate is more optimistic than some of the sketch-level project studies but more conservative than the Moving Cooler analysis, which looked at a comprehensive program of long-term transit investment. GHG effectiveness should be greater in earlier years because automobile fuel efficiency is not as high. Therefore, the 25 tons/$million value was increased in earlier years based on the ratio of Year X to 2030 automobile fuel efficiency, starting at a value of 35 tons/$ million in 2015.

2013). The annualization factor is a composite reflecting a discount rate and useful life spans of different transit project elements from the Federal Transit Administration's Standard Capital Cost worksheets.

Table 3.6 Transit Sensitivity Analysis

Tons/million dollars capital investment	2030 GHG Reduction (% of Baseline)
35 in 2015, decreasing to 25 in 2030 (baseline value)	0.15%
70 in 2015, decreasing to 50 in 2030 (comparable to Moving Cooler)	0.31%
Reducing effectiveness by 35% from baseline to account for annual operating costs	0.10%

Impact of Reduced Transit Usage

In the course of this study, the question was raised as to what effect reduced transit usage would have on VMT and GHG emissions if it led to a shift towards more driving (for example, as a result of an inability to continue funding at levels necessary for current levels of transit service and quality). Table 3.6b shows total transit passenger-miles in 2011 and 2030 under the baseline forecast, and then if transit passenger-miles were to be reduced by half (worst case) in 2030 compared to the forecast, or about 25 percent below current levels. The table shows transit CO_2e emissions using the efficiency levels assumed in this study, as well as new automobile emissions if 60 percent of the former passenger-miles are diverted to driving (consistent with national average mode shares, based on data from the 2009 National Household Travel Survey).[19] The net impact of the first-order effects of replacing transit trips with more automobile use is an additional 1.2 mmt CO_2e in 2030, or an increase of about 0.7 percent.

The results shown here are purely illustrative of an order-of-magnitude effect. They simply show the effect of trip substitution, if some transit trips are taken by automobile. They do not account for the additional emissions from increased congestion that would result from this shift to driving. Furthermore they do not account for any changes to urban form (e.g., greater sprawl, decreased economic growth) that could result in a feedback loop of longer trip lengths and more driving if a lack of transit access and increased roadway congestion results in disinvestment in the TCI region's urban core areas.

[19] Automobile and transit emission rates and other assumptions are provided in the documentation for the inventory and forecast developed for this study.

Table 3.6b First-Order GHG Impact of Reduced Transit Usage

Industry	2011	2030 Study Forecast	2030 with Reduced Transit Usage
Total transit passenger-miles (billions)	23.3	34.1	17.0
Total transit CO_2 (mmt)	2.7	3.1	1.5
New auto CO_2 from mode shift (mmt)			2.7
Baseline CO_2 – total (with Federal policies)	256.3	182.1	183.2
Change vs. study forecast			0.7%

3.3 Land Use/Smart Growth

Land use/smart growth strategies include infill, compact development, and transit-oriented development, which may be achieved through land use planning, public investment (e.g., complete streets projects, pedestrian infrastructure), and/or funding incentives to municipalities. Most analyses of the GHG benefits of these strategies assume that a certain amount of population or activity can be shifted into more transportation-efficient locations. Costs for administrative/planning activities are usually nominal compared to capital investment costs such as are required for most transportation strategies. However, additional costs may be incurred such as infrastructure investment in targeted growth areas, or incentives to cities and towns to encourage rezoning.

There has not been a comprehensive assessment of land use strategy costs on which to base a GHG effectiveness metric (tons per $, as used for other strategies).[20] Therefore, assumptions needed to be made for this analysis to tie funding to effectiveness. We use as our metric the **cost to shift one person or household from a dispersed land use type into a more compact land use type.** We use as a benchmark the Commonwealth of Massachusetts' Chapter 40R program (Smart Growth Zoning Overlay District Act), which since 2005 has offered cities and towns an incentive of up to $3,500 per new built dwelling unit in areas rezoned as "smart growth" districts meeting certain criteria.[21] This was intended to cover additional costs associated with schools and other local services but could serve as a proxy for other costs such as infrastructure investment. As of August 2014, 35 smart growth districts had been approved with a capacity for 12,744 zoned units and nearly 2,500 building permits

[20] Moving Cooler considered planning costs only, not infrastructure investment or fiscal incentives.

[21] The legislation set fixed payments ranging from $500 to $3,500 per unit depending upon the number of units built; $3,000 is the amount for a one-time density bonus payment. See: 760 CMR 59, http://www.mass.gov/hed/community/planning/chapter-40-r.html

issued.[22] We use $3,000 per dwelling unit which equates to **$1,200 per person** at an average of 2.5 persons per household.

Using Census data, we divided the population of the TCI region into five "place types," based on population density, consistent with those defined in the inventory and forecast. However, the place types in this case were defined at a Census tract level rather than a county level, for finer granularity. VMT per capita by place type was taken from the I&F (adjusted to match total VMT after the new geographic definition of place types). It was then assumed that smart growth infrastructure investment and incentives shifted a certain fraction of population from lower-density to higher-density place types. Total VMT was then compared for the smart growth vs. the business as usual scenario. The population shift at the baseline funding level and other key parameters are shown in Table 3.7. Funding of about $230 million annually for land use strategies is enough to shift about 3 million people or about 5 percent of the region's population. Emission factors were then applied to estimate GHG emissions. (The GHG change on a percentage basis is less than the VMT change because emission factors in high-density place types are higher due to lower traffic speeds.) This analysis was done for 2030, with interim years scaled in linear proportion.

[22] http://www.mass.gov/hed/docs/dhcd/cd/ch40r/40ractivitysummary.pdf

Table 3.7 Land Use Assumptions (2030)

Place Type:	Core	High Urban	Med. Urban	Suburban	Rural	Total
Persons per sq. mi.:	> 10,000	4,000 – 10,000	2,000 – 4,000	500 – 2,000	< 500	
VMT/capita (2030):	3,168	7,636	8,964	10,553	13,672	
Affected pop. (2030 BAU):	16,123,428	12,163,763	10,335,350	13,273,017	14,425,323	66,320,881
Pop shift fraction to:[a]	30%	30%	30%	10%		100%
Pop shift fraction from:			30%	60%	10%	100%
Pop shift to by 2030 (added):	930,879	930,879	930,879	310,293	-	3,102,929
Pop shift from by 2030 (subtracted):	-	-	930,879	1,861,758	310,293	3,102,929
Net pop loss/gain by 2030:	930,879	930,879	-	(1,551,465)	(310,293)	-
% change vs. BAU	6%	8%	0%	-12%	-2%	0%
VMT Change (millions)	2,949	7,108	-	(16,373)	(4,242)	(10,557) (-1.9%)
GHG Change (mmt)	0.87	2.15	-	(3.74)	(0.94)	(1.66) (-1.0%)

[a]The population shift fractions show that of the total population shifted (in this case, 3.1 million), 30% is shifted into core areas, 30% into high urban, etc.

3.4 Active Transportation

Active transportation is defined as non-motorized travel improvements, including bicycle and pedestrian infrastructure and supporting programs. This analysis focuses on bicycling improvements, as increases in walking are assumed to be considered under the land use strategy. Bicycling improvements may include various forms of infrastructure, such as bike lanes, cycle tracks, separated paths, bike boulevards, and parking; as well as supportive programs such as education, enforcement of traffic laws, and bike share programs.

The approach in this analysis is similar to that used in Moving Cooler and also a recent analysis of MassDOT's Capital Investment Program.[23] The approach is to assume an increase in bicycle mode share (percent of trips) between current conditions and full build-out of a robust bike network. The assumed mode share varies by place type and is highest in core/high density areas. A mix of facility types is assumed in each place type to achieve a complete, fully built-out network of facilities appropriate to that place type, and a cost per mile (from research performed for Moving Cooler) is associated with each facility type. For example, core areas are assumed to have bike lanes at ½ mile intervals (4 miles per square mile), and cycle tracks at 1 mile intervals (2 miles per square mile). A further assumption is made about the distribution of funding provided by place type; the percent of "build-out" network achieved by 2030 is calculated by place type, considering the total land area of census tracts in each place type and the corresponding mileage of facilities required in each place type. The change in bicycle mode share to reach the build-out mode share was then adjusted by the proportion of network that could be built out with the TCI generated funding.

Assumptions about build-out mode shares are informed by experience from other cities that have invested heavily in bicycle infrastructure, including European cities and Portland, Oregon. Many European cities have bicycle mode shares of 20 to 30 percent, although they also have much higher fuel and automobile prices and very restricted parking in core areas. In the U.S., Portland, Oregon has made extensive bicycle investments and has the highest bicycle mode share of any large city in the U.S., currently over 6 percent for commuting. A build-out mode share of 10 percent was assumed for the "core" place type, with proportionately lower shares for other place types.

The various assumptions by place type for the bicycle analysis are shown in Table 3.8. Other assumptions, based on CS analysis of the 2009 National Household Travel survey, include 4.7 trips per person per day, 2.3 miles per bicycle trip, and a 60 percent prior drive alone mode share.

[23] Cambridge Systematics, unpublished data

Table 3.8 Bicycle Investment Assumptions

Place Type:	Core	High Urban	Med. Urban	Suburban	Rural	Total
Persons per sq. mi.:	> 10,000	4,000 – 10,000	2,000 – 4,000	500 – 2,000	< 500	
Affected population (2030):	16,123,428	12,163,763	10,335,350	13,273,017	14,425,323	66,320,881
Land area (sq mi):	644	1,929	3,462	12,695	164,230	182,960
Bike Trip Mode Share						
Now	2.0%	1.5%	1.0%	0.5%	0.5%	
At Network Build-Out	10.0%	8.0%	6.0%	2.0%	1.0%	
Cost per Facility Mile:						
Mile of bike lane			$25,000			
Mile of boulevard			$200,000			
Mile of cycle track			$500,000			
Mile of sep. path			$750,000			
Facility Density at Build-Out (mi/sq mi):						
Bike lane	4.0	4.0	2.0	2.0	0.1	
Bike boulevard			2.0			
Cycle track	2.0	2.0				
Separated path				0.1	0.1	
Expenditure to Achieve Network Build-Out: ($M)	$709	$2,121	$1,558	$1,587	$12,728	
% Expenditure by Place Type:	15%	35%	25%	15%	10%	100%
Expenditure by 2030 ($M):	$537	$1,253	$895	$537	$358	$3,580
% of Build-Out Achieved by 2030:	**76%**	**59%**	**57%**	**34%**	**3%**	
VMT Change (millions)	(2,313)	(1,105)	(703)	(159)	(5)	(4,286) (-0.9%)
GHG Change (mmt)	(0.68)	(0.33)	(0.20)	(0.04)	(0.00)	(1.25) (-0.7%)

3.5 Travel Demand Management and Ecodriving

Travel demand management (TDM) includes strategies such as employer outreach, rideshare and vanpool programs, subsidized transit passes, development requirements, neighborhood trip reduction programs, etc. to encourage alternatives to automobile travel for commuting and potentially other purposes. Ecodriving includes programs to educate and encourage drivers of passenger and/or commercial vehicles to drive in a more fuel-efficient manner.

This analysis focuses on TDM, rather than ecodriving, as there is much more experience on using TDM to reduce VMT and GHG emissions and evidence on the benefits of such programs. While ecodriving has theoretically significant potential to reduce fuel use (on the order of 5 to 10 percent or more if implemented by all drivers), there are few examples of demonstrated programs successfully reaching a large population. Most successful ecodriving examples have focused on a small number of commercial fleets (e.g., Staples, UPS). Furthermore, feedback technology through instrumentation in vehicles or on mobile devices is increasingly being deployed, and while such feedback has been shown to increase driving efficiency,[24] the future role of public sector funding in complementing these technologies is not clear. Over the long-term, ecodriving benefits may occur through connected vehicles and infrastructure strategies. These benefits are potentially significant if they can help achieve the theoretical potential of ecodriving, but are not quantified in this study (either in the baseline or as a strategy benefit) due to uncertainty over the timeframe of deployment and the extent to which ecodriving practices will be implemented.

The basic approach for the TDM analysis is similar to other strategies, to assume a tons per dollar effectiveness based on evidence from the literature. However, unlike capital intensive strategies where a dollar invested now brings continuing returns in the future, TDM is assumed to have short-term effects. In this analysis, we assume that a dollar invested in Year X also brings returns only in Year X. Therefore, the tons per dollar metric is not comparable to the metric for other strategies.

Table 3.9 shows various cost-effectiveness estimates from the literature. General estimates are reported in Moving Cooler and the U.S. DOT Report to Congress. Estimates for specific types of projects can also be inferred from Congestion Mitigation and Air Quality Improvement Program (CMAQ) evaluation reports.[25] In addition to national studies, results are also available from careful evaluations of the Metro Washington Council of Governments (MWCOG) Commuter Connections program, providing an example for the TCI region. A wide range of values is observed. National studies report general estimates in the range of tens to low hundreds of dollars per ton of GHG reduced. The Commuter Connections program is at the most cost-effective end of the range, roughly $15-20 per ton.[26] Less cost-effective projects

[24] Kurani, K.S., T. Stillwater, M. Jones, and N. Caperello (2013). Ecodrive I-80: A Large Sample Fuel Economy Feedback Field Test. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-13-15

[25] Cambridge Systematics and Eastern Research Group (2010), Evaluate the Interactions between Transportation-Related Particulate Matter, Ozone, Air Toxics, Climate Change, and Other Air-Pollutant Control Strategies, Prepared for National Cooperative Highway Research Program Project NCHRP 25-25 Task 59; citing data in: Transportation Research Board Special Report 264, The CMAQ Program: Assessing 10 Years of Experience (2002), and ICF International (2008), SAFETEA-LU 1808: CMAQ Evaluation and Assessment: Phase I Final Report, prepared for Federal Highway Administration, FHWA-HEP-08-019.

[26] Cambridge Systematics and Sprinkle Consulting (2010), Transportation Demand Management Project Evaluation and Funding Methods in the Denver Region: Review and Recommendations, prepared for Colorado Department of Transportation; citing data in LDA Consulting et al (2009), Transportation Emission Reduction Analysis Report, FY 2006–2008, prepared for Metropolitan Washington Council of Governments.

(as observed in the CMAQ evaluations) can range into the thousands of dollars per ton. In this analysis, we select a value of **$100 per ton, which is equivalent to 10,000 tons reduced per million dollars spent annually**. We select a somewhat conservative value compared to the most cost-effective examples in Table 9; because most large urban areas – and many states – already have active TDM programs, we assume that these programs have taken the "low-hanging fruit" and additional spending will yield lower returns.

Table 3.9 TDM Cost-Effectiveness

Source	$/ton GHG reduced	Annual tons per annual $millions[c]
USDOT Report to Congress - Employer/Worksite TDM	$30 - $180	9,500
USDOT Report to Congress - Rideshare Programs	$80	12,500
Moving Cooler - Employer Based Commute	$290 - $420	2,800
MWCOG Commuter Connections	$16	62,500
2002 CMAQ Evaluation		
Regional Ridesharing	$3 - $19 - $41[a]	52,600
Vanpool Programs	$13 - $27 - $229	37,100
Employer Trip Reduction Programs	$15 - $58 - $452	17,100
Misc. TDM	$6 - $32 - $85	31,100
Transit - Modal Subsidies & Vouchers	$2 - $120 - $1,211	8,400
2008 CMAQ Evaluation		
Regional Ridesharing	$212 - $1,211[b]	1,400
Vanpool Programs	$82 - $410	4,100
Misc. TDM	$40 - $7,486	300
Values Selected for Analysis		
First Increment of Funding	$100	10,000
Subsequent Funding	$2,000	500

[a]Low – median – high
[b]Low - high
[c]At median or midpoint

Because the more cost-effective TDM results are obtained through outreach and administrative type programs, rather than infrastructure or operating investments, we also assume for TDM strategies that there is an upper limit beyond which additional spending becomes less cost-effective. We set this limit at $5 million per large metro area and $5 million per state (covering medium and small metro areas as well as rural areas), for a total of about $90 million for the TCI region annually.[27] At higher funding levels, we assume that additional funding goes into direct transit fare subsidies for commuters. Based on analysis for Moving Cooler using the EPA Commuter Model,[28] we estimate a cost-effectiveness of about **$2,000 per ton, or 500 annual tons per million dollars invested annually** for investments beyond $90 million per year.

3.6 System Efficiency/Operations

System efficiency/operations strategies include "intelligent transportation systems" strategies such as signal timing and coordination, adaptive signal control, ramp metering, incident response, traveler information, advanced traffic management systems, and integrated corridor management (the last two combining elements of the others). These strategies can reduce GHG emissions by reducing congestion and helping traffic flow more efficiently. However, if travel times are improved, there may be some offsetting effects of "induced demand" as it becomes easier to drive.

A similar approach to other capital investment strategies – GHG reductions per dollar of investment – was taken with this set of strategies. Project-specific information on the GHG benefits of these strategies is very limited. There are a number of reasons for this:

- Such projects typically require expensive simulation modeling to accurately estimate fuel consumption and emissions benefits.
- GHG reduction is usually not the focus of these projects, so in most instances it is not analyzed.
- Different types of ITS strategies may have significantly different cost-effectiveness. For example, signal retiming has been shown to be quite cost-effective, whereas the GHG benefits of traveler information strategies have been hard to discern.
- Induced demand, in particular, is difficult to model.

The U.S. DOT's ITS Benefits Database contains a few studies from the TCI region but these were done in the early days of ITS deployment (late 1990's, early 2000's) and do not reflect current vehicle technology standards, and also have very limited data published to do a comparison on a consistent basis. The Moving Cooler study used a relatively comprehensive approach to modeling ITS benefits on a nationwide basis that accounted for induced demand,

[27] $5 million is the approximate budget for the MWCOG Commuter Connections program.

[28] The Commuter Model predicts changes in VMT as a result of changes in travel costs (including daily transit fares), using coefficients derived from travel demand models. The VMT changes were used with emission factors from the I&F to estimate GHG impacts. The results used here are for large metro areas with good transit service; impacts for medium and small metro areas would be smaller.

so this study was instead used as a basis for tons/dollar estimates.[29] The data are shown in Table 3.10. A value of $250 is used in this analysis, which equates to a value of about **300 tons per million dollars of capital investment**.[30] This value is used for 2015 and scaled down over time to account for increasing fuel efficiency. The dollar per ton value from Moving Cooler is based on a time-stream of costs and benefits from 2010 through 2050; the cost per ton will be higher when a shorter investment period is used (such as the 2030 time horizon in this study).

Table 3.10 ITS Cost-Effectiveness Estimates[a]

ITS Strategy	$/ton
Ramp Metering	$40-50
Advanced traffic management/ integrated corridor management	$240-340
Traveler information	$160-500

[a]Source: Cambridge Systematics (2009), *Moving Cooler*, for Urban Land Institute.

The system efficiency/operations analysis did not account for any potential decreases in the effectiveness of this strategy due to broader penetration of electric-drive vehicles (hybrid, full battery electric, or fuel cell), whose energy consumption per mile is similar in congested and uncongested traffic.

3.7 Freight/Intermodal Infrastructure & Operations

Freight/intermodal infrastructure and operations strategies include investments to encourage freight modal shift from truck to rail or water, and more efficient freight operations. Examples include relieving capacity constraints at critical freight rail bottlenecks, particularly in access corridors to intermodal facilities and in high-volume freight corridors; address rail infrastructure constraints such as low clearance bridges and low railcar weight limits; and improving accessibility to intermodal facilities.

The basic approach to analyzing this strategy is similar to the analysis of transit investment. Cost-effectiveness data were taken from the national literature and from project studies conducted in the TCI region to estimate a tons per dollar value of capital investment. The level of uncertainty related to freight investment GHG benefits is perhaps even higher than for other strategies evaluated. There are few studies that quantify freight infrastructure GHG benefits,

[29] Moving Cooler used the FHWA Highway Economic Requirements System (HERS) model, which has built-in demand elasticities, to estimate that a systemwide average reduction in delay of one hour per 1,000 VMT results in a systemwide increase in VMT of 2.13 percent. This increase in VMT results in a proportionate increase in fuel consumption and GHG emissions. The short-run increase was assumed to be half of this long-run increase. See Appendix B of the Moving Cooler report for further discussion.

[30] Assuming a 7 percent annualization factor consistent with the transit analysis.

and freight analysis methods are not well-developed so broad assumptions about mode shift potential are generally employed.

The considerable uncertainty over the benefits of freight improvements is reflected in the wide range of GHG effectiveness shown in Table 3.11, which vary by two orders of magnitude. For this analysis, a value of **140 tons per million capital dollars** in 2015 was selected, which is the value from Moving Cooler for rail capacity improvements. This value splits the difference between low effectiveness observed in some state plans (MA, CT) and specific projects, and much higher effectiveness in the MAROps five-state study and one other project.

Table 3.11 Freight Project Cost-Effectiveness

Project/ Report	Description	Capital Cost ($millions)	Annual GHG Tons Reduced	$/ton	Annual tons per millions of capital $
USDOT Report to Congress	Intermodal infrastructure			$80 - $200	500
Moving Cooler	Rail capacity			$450 - $500	140
Moving Cooler	Marine system			$800 - $1,000	80
MAROps priority investment	5-state (Mid-Atlantic) rail improvements	$6,000	(6,893,000)		1,149
MA - State Freight Plan	4 sets of freight rail investments	$692	(8,000)		12
CT DEEP - Freight Air Quality Plan	Statewide rail/ intermodal improvements	$2,000	(83,000)		42
NY - Arlington Intermodal Yard	Capacity improvements to a rail yard	$9.0	(52,401)		5,822
PA - Norfolk Southern Rail Ext & Rehab	Track extension	$12.5	(748)		60
PA - Westmoreland Intermodal	Intermodal freight facility	$9.5	(402)		42

Sources: MA - MassDOT Freight Plan (2010), Table 46. CT - de la Torre Klausmeier Consulting, Inc., Cambridge Systematics, and Eastern Research Group (2013), Development of a Strategic Plan for Reducing Emissions Associated with Freight Movement in Connecticut, Prepared for Connecticut Department of Energy and Environmental Protection. MAROps - I-95 Corridor Coalition (2009), Mid-Atlantic Rail Operations Phase II Study Final Report. Tons per dollar calculations by Cambridge Systematics. NY and PA projects – ICF International (2008), SAFETEA-LU 1808: Congestion Mitigation and Air Quality Improvement Program Evaluation and Assessment - Phase 1 Final Report, Prepared for Federal Highway Administration.

3.8 Clean Fuels

The clean fuels standard (CFS) strategy is based on the approach, presented in a NESCAUM report, of a 10 percent reduction in the carbon intensity (CI) of transportation fuels over a 10-year period.[31] The reduction is measured vs. the CI of gasoline and diesel fuel. In this analysis we assume that the 10 percent CI reduction is met by 2025. Some reduction in CI is already assumed in the Federal Policies scenario as a result of the Renewable Fuels Standard (RFS-2) which sets nationwide volumetric targets for renewable fuels meeting minimum carbon intensity standards. For the 15 percent CFS, we assume that the 10 percent CI reduction is met in 2025 and then CI continues to be reduced through 2030.

Existing use of renewable fuel in our baseline year (2011) is already assumed to reduce CI by 1.5 percent compared to all gasoline/diesel fuel. This includes widespread use of corn ethanol to meet fuel formulation requirements for air quality, as well as smaller quantities of biodiesel, natural gas, and liquefied propane gas (LPG) which are primarily used in heavy vehicles. The same CI is assumed in 2015. The Federal RFS-2 standard (included in the Federal Policies scenario) is assumed to result in a further 4.2 percent CI reduction beyond 2011 levels by the year 2025. **The NESCAUM 10 percent CFS would result in a CI reduction of 8.5 percent** (10 – 1.5) beyond 2011 levels in the year 2025, while the 15 percent CFS would result in a CI reduction of 13.5 percent beyond 2011 levels in the year 2030.[32]

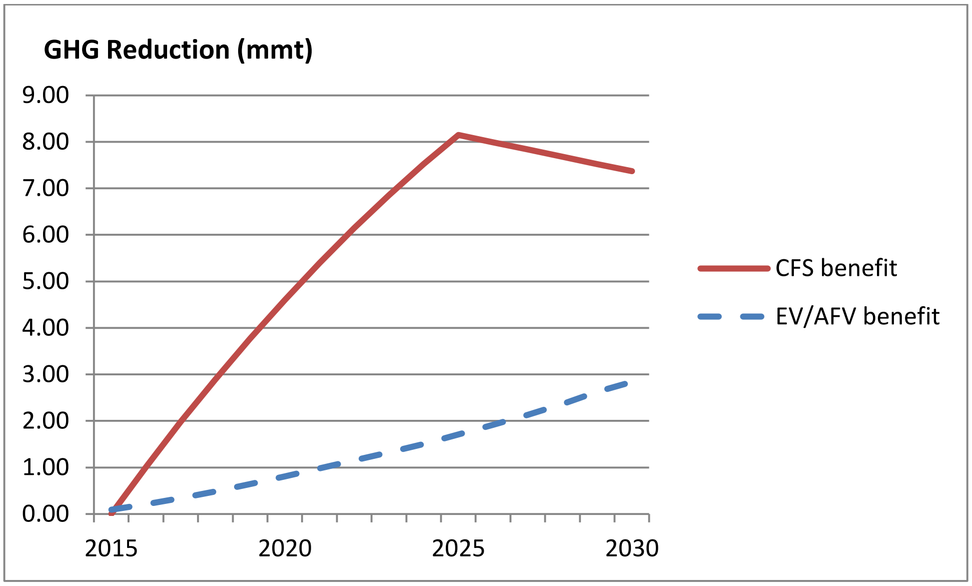
A clean fuels standard, if based on the carbon intensity of all fuels, will also have some overlap with strategies to introduce electric and other alternative fuel vehicles, since the fuels used by these vehicles (including electricity) will be less carbon-intensive than conventional fuels. Therefore, the benefits of the EV and alternative fuel vehicles in each year were subtracted from the CFS benefits when combining the strategies into scenarios. Under this analysis, the 10 percent CFS provides a larger benefit in the mid-range years, when EVs are just ramping up, but the benefit decreases in 2030 as EV sales accelerate while the CFS holds level.[33] Figure 3.1 shows how the incremental benefit of the CFS declines after 2025 because of the overlap between the CFS and EV/AFV strategies.

[31] Northeast States for Coordinated Air Use Management (2011), Economic Analysis of a Program to Promote Clean Transportation Fuels in the Northeast/Mid-Atlantic Region.

[32] The baseline and RFS2 CI analyses are based on the work conducted by CS for the Oregon DOE.

[33] Actually the absolute benefit of the CFS declines slightly after 2025 because the standard as expressed in terms of carbon intensity is the same after this point, but total fuel use is declining.

Figure 3.1 Relative Benefits of Clean Fuels and EV/AFV Strategies



3.9 Pricing Options

In the comprehensive policy bundle approach that combines investment strategies with pricing policies, the primary scenario assumes a pricing policy that generates approximately $3 billion a year for the TCI region, or $50 billion cumulatively for the 2015-2030 period. This level of pricing would be consistent with a new carbon price increasing from $5/ton of CO_2 in 2015 to $10/ton in 2020 to $30/ton in 2030, a new VMT fee of 0.6 cents/mile, <u>or</u> an additional motor fuels tax of $0.137 per gallon. An alternate scenario with pricing at twice these levels was also tested.

The pricing options evaluated here can affect GHG emissions in three ways – (1) reducing VMT, (2) encouraging consumers to buy more fuel-efficient vehicles, and/or (3) encouraging a shift to lower-carbon fuels. Other pricing strategies (such as congestion pricing) can also reduce emissions by reducing congestion. Table 3.1 shows how the pricing options evaluated may affect GHG emissions.

Table 3.1 Pricing Option Effects on GHG

Pricing Option	Reduce VMT	Increase Vehicle Efficiency	Shift to Low-Carbon Fuels
VMT Fee	X		
Motor Fuel Tax	X	X	
Carbon Price	X	X	X

For this analysis, **elasticities of travel or vehicle efficiency with respect to fuel price** were derived from the 2014 Annual Energy Outlook (AEO) published by the U.S. Department of Energy (DOE). This was done by comparing fuel prices, light-duty vehicle VMT, and light-duty vehicle stock efficiency under the "High Price" scenario with the "Reference" scenario. The percent change in VMT or stock efficiency with respect to the percent change in fuel price was used as the elasticity. This was done for every year from 2015 through 2030. The AEO forecasts reflect the latest Federal vehicle fuel efficiency standards and therefore may be more appropriate to use than elasticities from older sources. (Vehicle efficiency should be less sensitive to fuel price when stringent standards are already in place, since the marginal cost of increasing efficiency beyond the standards is greater.) The elasticities derived from AEO were compared to published elasticities and found to be comparable in magnitude, although the AEO does give a lower response for vehicle efficiency than for VMT, as expected because of the high fuel efficiency standards already in place.

Table 3.2 shows the elasticities used in five-year increments. The vehicle efficiency elasticity is applied to the motor fuel tax and carbon price options only, while the VMT elasticity is applied to all three options. The elasticities are applied only to light-duty VMT and fuel consumption, as the AEO shows virtually no effect of higher oil prices on heavy-duty vehicle travel and efficiency.[34]

Table 3.2 Elasticities with Respect to Fuel Price

Pricing Option	2015	2020	2025	2030
Light-duty VMT	-0.05	-0.16	-0.21	-0.20
Light-duty efficiency[a]	0.00	-0.02	-0.07	-0.07

Source: Analysis by Cambridge Systematics based on data from 2014 Annual Energy Outlook

No information is available on the sensitivity of fuel carbon content to a carbon price, since until recently there has been very little use of low-carbon fuels, and its introduction has primarily been driven by regulation rather than pricing. Therefore, the carbon price option is not assumed to have an additional effect on fuel carbon content beyond what will be achieved through the Federal Renewable Fuel Standard (RFS-2) and any regionally adopted clean fuels programs.

A sensitivity test was performed in which the elasticities were decreased to 50 percent of the AEO inferred elasticities and then increased to 150 percent of the values shown in Table 3.2. With an elasticity of half the value, the GHG benefits would be cut in half, from 1.5 – 2.8 mmt in 2030 to 0.8 – 1.4 mmt.[35] With an elasticity 50 percent higher, the GHG benefits would

[34] In some cases, truck VMT actually increases under the "high oil price" scenario. This may be a result of shifting trade patterns, e.g., more sourcing of goods within the U.S. vs. overseas, as companies work to minimize total transportation costs. It may also reflect limitations of the underlying model.

[35] The lower end of the range corresponds to a VMT fee or motor fuels tax, and the upper end to a carbon price, which would have lower benefits in early years but a greater annual impact in 2030 due to the increasing nature of the price.

increase correspondingly to 2.4 – 4.1 mmt in 2030. For the motor fuel tax, the 0.8 percent reduction due to the pricing effects vs. the Federal Policies scenario could be reduced to 0.4 percent or increased to 1.2 percent with this range of elasticities.

4.0 Other GHG Analysis Issues

4.1 Economies or Diseconomies of Scale

(Applies to both Transportation Investment Approach and Comprehensive Policy Bundle Approach)

A question that is relevant to this GHG strategy evaluation is the degree to which additional funding for a strategy may lead to economies of scale, or conversely, diminishing returns as the most cost-effective investments are made. Scale economies/diseconomies were considered to some degree in two strategies – active transportation, and TDM. They were not considered in others due to lack of data, and/or judgment that they would not be relevant at the levels of investment being contemplated. The following is a qualitative discussion of the extent to which scale economies/diseconomies would be expected, and how they were treated in this analysis.

Electric/alternative fuel vehicles – Economies of scale would be expected, as more investment leads to more vehicle purchases which leads to lower per-vehicle costs for manufacturers and spreads infrastructure costs across a wider population base. However, there is a wide variety of complex factors that will drive future EV/AFV costs and this impact is difficult or impossible to estimate quantitatively at this point in time, given the evolving nature of technology and consumer markets. The transition to a future reliant on alternative fuels will be dependent on many factors, such as learning by doing, overcoming risk aversion of consumers, and breaking through the chicken-or-egg barrier of having a critical mass of vehicles and supporting infrastructure.

TCI policies will be one factor affecting EV/AFV demand, but the region still represents a relatively small fraction of the vehicle market. Still, the transition process induces positive feedbacks and is therefore path-dependent with tipping points; even small contributions can be significant at certain points of the process. Economies of scale could be tested by adjusting the price differential between alternative and conventional vehicles at higher funding levels.

Transit – Theory also conflicts on this topic. On the one hand, the most cost-effective projects could be done first, serving the most densely populated areas and most densely traveled corridors. On the other hand, more transit investment can disproportionately increase ridership as network benefits are achieved and service reaches more areas – especially if supportive land use policies are also implemented. There are many transit investments on the "wish list" for the TCI region (more than can be created with the contemplated funding levels) so a constant return to scale is assumed in this analysis.

Land Use/Smart Growth – It might be expected that the first increment of population is easier to shift into compact/smart growth areas, for people who are already on the margin, and later increments are harder to shift as other people may be less willing to change lifestyles. This could be accounted for by increasing the cost per person factor in the analysis at higher investment levels. However, there is no evidence to support a particular quantitative value or threshold for this increase, and so constant returns to scale are assumed at the contemplated population shift levels (around 10 percent of the TCI region at baseline funding).

Active Transportation – Up to a certain point, economies of scale might be expected, as a comprehensive, well-connected bicycle network should have greater mode share impacts than individual segments that may not connect well. On the other hand, the marginal cost of making a connected network becomes increasingly expensive as the network is built-out. In this analysis, constant returns are assumed up to the point where the network is built-out in each place type. Under the baseline funding scenario network buildout is not assumed in any place type. At higher levels, however (such as the Double Funding Scenario), the most dense place types become built-out and funding must therefore be shifted into lower-density areas where mode shift impacts are lower. This implies decreasing returns.

TDM and Ecodriving – As explained in Section 3.5, it is assumed that the first increment of funding goes to more cost-effective "soft" activities such as outreach programs. Beyond a certain point, these programs are developed to their fullest extent and additional funding is directed towards less cost-effective direct subsidies.

System Efficiency/Operations – Constant returns are assumed for this strategy. The benefits should generally be additive across roadway segments or transportation corridors.

Freight/Intermodal Infrastructure and Operations – The considerations here are similar as those for transit, with low-hanging fruit contrasting against network-level benefits. There are many freight investments on the "wish list" for the TCI region (more than can be created with the contemplated funding levels) so a constant return to scale is assumed.

Pricing options – While not technically an "economy of scale" issue, a related question is whether response to pricing will increase or decrease as the price is raised. There is conflicting evidence on this. The first increment of pricing could be more effective, as travelers shift the "easiest" trips first. On the other hand, there is discussion in the literature over whether small changes are noticed to the same extent as large changes in price. In addition, the energy price elasticity of VMT most likely increases with increasing energy price because energy becomes a larger fraction of the total private cost of vehicle travel. Furthermore, elasticities should be larger as alternatives to driving are developed. Since the price changes proposed in this report are relatively modest and there is limited evidence to quantify how elasticities might change within the range of pricing proposed here, constant response is assumed.

4.2 Effects of Revenue Feedback and Diversion

(Applies only to Comprehensive Policy Bundle Approach)

The decrease in VMT and fuel consumption due to investments in GHG reduction strategies would lead to a reduction in funding obtained through all three potential pricing mechanisms analyzed here. This "pricing policy source revenue loss" would slightly reduce the overall benefits of the strategies. The cumulative reductions in new pricing policy funding (2015-2030) with feedback under the baseline funding scenario are shown in Table 4.1.[36] They range from just over 2 percent for the VMT fee to nearly 5 percent for the carbon price. However, the GHG reduction is only affected by a small amount, declining by one or two tenths of a percentage point. This does not show the reduction in revenue as a result of the most recent Federal fuel efficiency and renewable fuel standards (compared to a "business as usual" baseline without these standards), which will happen in any of the scenarios analyzed.

Table 4.1 Impacts of Revenue Feedback on Pricing Policy Proceeds

Pricing Strategy	Cum. Revenue – Base (millions)	Cum. Revenue – w/ Feedback (millions)	2030 GHG Reduction – Base	2030 GHG Reduction – w/Feedback
VMT Fee, 0.6 c/mi	$50,826	$49,628 (-2.4%)	33.4%	33.3%
Motor Fuels Tax, $0.137/gal	$50,869	$49,064 (-3.5%)	33.2%	33.1%
Carbon Price, $5 – 30/ton	$50,665	$48,403 (-4.5%)	33.9%	33.7%

In addition, state transportation agencies would expect to see some loss in revenue from traditional sources (state motor fuel taxes, and Federal motor fuel taxes as distributed to states through the Federal-aid Highway Funding program) as a result of the VMT reductions and fuel efficiency increases from the proposed GHG reduction strategies. If this revenue were not made up through other sources, states might look to divert some of the new revenue from the pricing policy to fill the gap.[37] This diversion to cover "all-sector revenue loss" would reduce the funds available for spending on GHG reduction strategies, and correspondingly reduce the GHG benefits of the program. Evaluation of the effects of this "feedback"

[36] The VMT reduction would potentially reduce maintenance costs for state and local transportation agencies, by about $340 million annually under the 1x pricing + 100% reinvestment scenario (see Section 6.6 and Appendix C). This cost savings would somewhat offset the revenue reduction.

[37] The "gap" and corresponding diversion would have to be based on an *estimate* of lost revenue, since this revenue loss cannot be directly measured. It would be impossible to distinguish the effects of TCI-generated VMT and fuel consumption reductions from the variety of other factors that will influence future VMT and fuel consumption.

mechanism requires multiple iterations to arrive at a converging solution where revenue and investment is balanced.

A sensitivity analysis was conducted to test the effects of reducing the new revenue available for GHG strategies to fill the revenue gap created from existing transportation sources. The effects of the feedback vary by pricing mechanism (VMT fee, motor fuels tax, or carbon fee) since VMT fees only affect travel rates, but motor fuel taxes and carbon fees also affect vehicle efficiency and fuel choice. The effect increases over time. At the primary pricing levels and 100% reinvestment, the GHG benefits are reduced by up to 12 percent (in 2030) with the VMT fee, 21 percent with the motor fuels tax, and 28 percent with the carbon fee. The net effects on total state revenue for transportation are shown graphically in Figure 4.1 and in tabular format in Table 4.2, which also show the loss in revenue over the 2015-2030 time period as a result of existing Federal policies (fuel economy and renewable fuel standards). Figure 4.1 and Table 4.2 show:

- At 2011 fuel economy and tax levels, Federal and state motor fuel tax revenue to the TCI region would increase from just under $12 billion in 2012 to about $13 billion in 2030 (dotted line).
- With existing Federal policies, revenue would decrease to just over $9 billion in 2030 (black line).
- The modeled pricing policy would increase revenue to over $14 billion in 2016, but it would then decline to around $12 billion (current levels) in 2030 due to Federal fuel efficiency improvements as well as new TCI region GHG reduction strategies. The three colored lines show the effects of each pricing mechanism.

Figure 4.1 Revenue Effects of Federal Policies and Modeled Pricing Policies

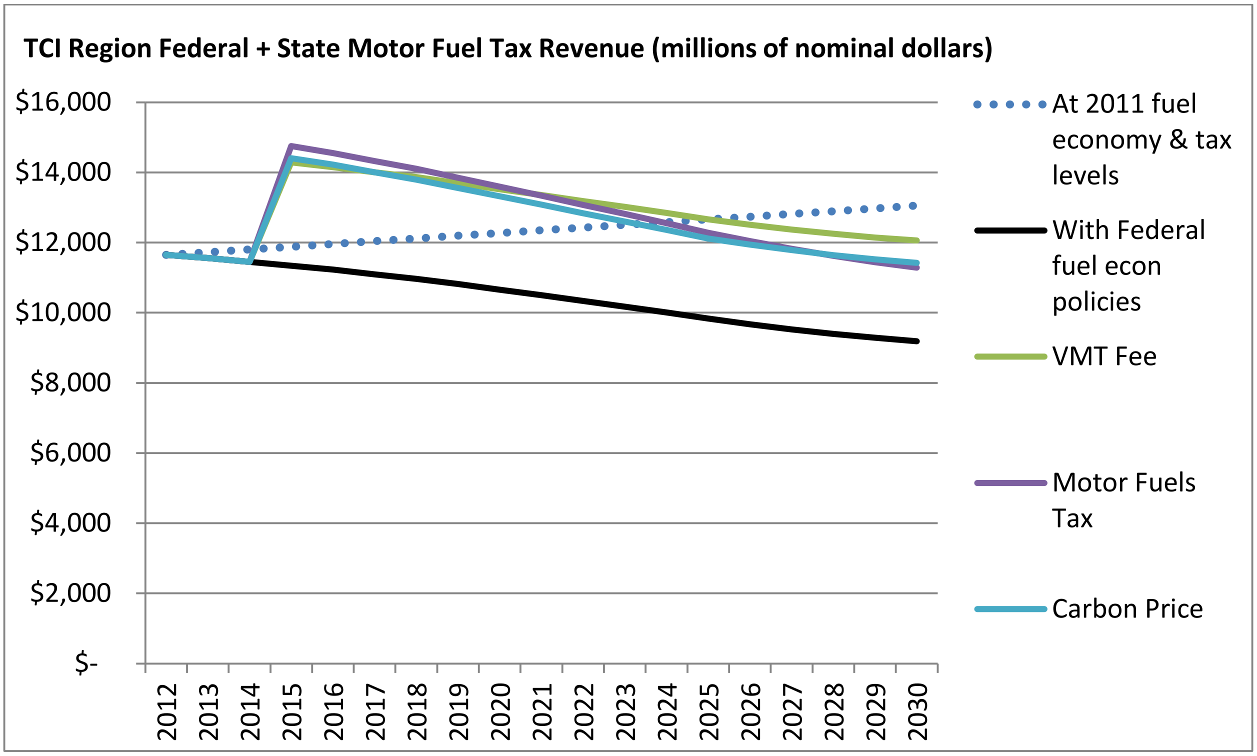


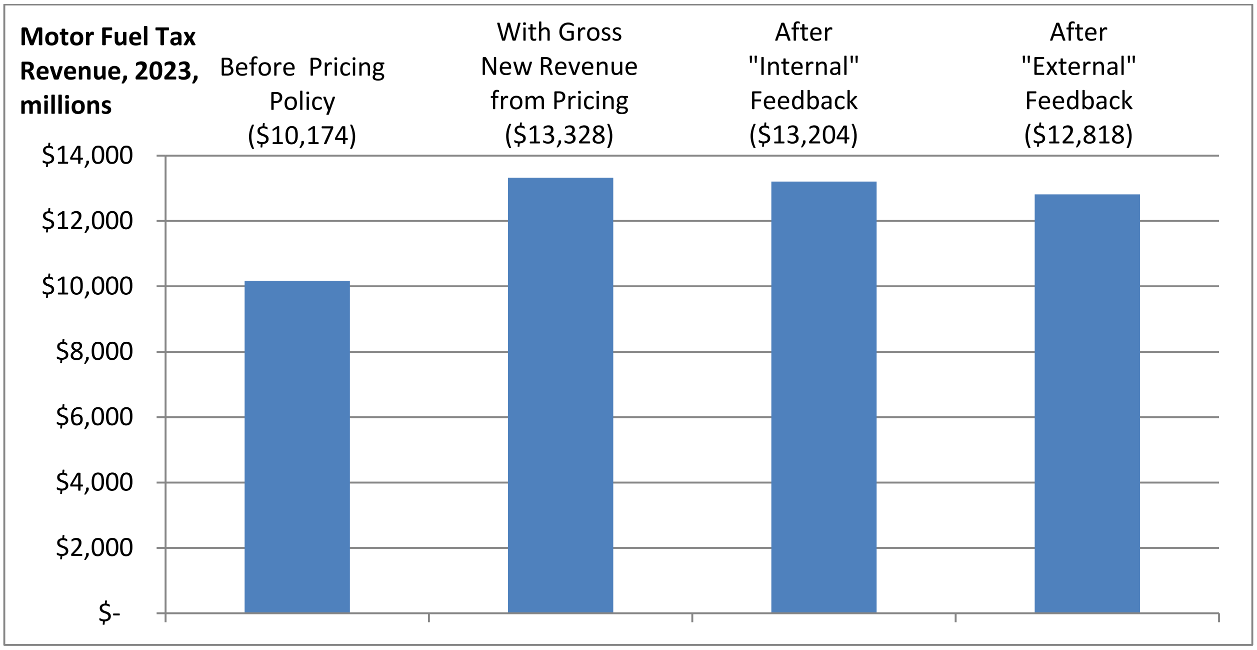
Table 4.2 Revenue Effects of Federal Policies and Modeled Strategies – By Year (millions of current dollars)

Year	At 2011 fuel economy & tax levels	With Federal fuel economy policies	With Additional MF Tax Before Feedback	VMT Fee w/ Feedback	MF Tax w/ Feedback	Carbon Price w/ Feedback
2012	$11,649	$11,649				
2013	$11,727	$11,562				
2014	$11,805	$11,452				
2015	$11,883	$11,340	$14,879	$14,285	$14,754	$14,409
2016	$11,961	$11,227	$14,729	$14,154	$14,550	$14,220
2017	$12,038	$11,098	$14,558	$14,007	$14,326	$14,004
2018	$12,116	$10,970	$14,388	$13,862	$14,103	$13,791
2019	$12,194	$10,816	$14,183	$13,693	$13,848	$13,555
2020	$12,272	$10,660	$13,976	$13,523	$13,592	$13,320
2021	$12,350	$10,499	$13,762	$13,355	$13,334	$13,078
2022	$12,428	$10,337	$13,546	$13,186	$13,076	$12,837
2023	$12,506	$10,174	$13,328	$13,017	$12,818	$12,598
2024	$12,583	$10,008	$13,107	$12,846	$12,556	$12,359
2025	$12,661	$9,832	$12,873	$12,666	$12,282	$12,114
2026	$12,739	$9,671	$12,658	$12,511	$12,041	$11,940
2027	$12,817	$9,526	$12,464	$12,372	$11,820	$11,783
2028	$12,895	$9,398	$12,293	$12,250	$11,620	$11,644
2029	$12,973	$9,286	$12,143	$12,146	$11,439	$11,524
2030	$13,051	$9,189	$12,013	$12,057	$11,281	$11,419
2015-2030	**$199,466**	**$164,031**	**$214,899**	**$209,929**	**$207,440**	**$204,596**

The net result over the 2015-2030 period is a loss of $35 billion from Federal policies (compared to a 2011 policies baseline projection of nearly $200 billion for the 2011 policies baseline), but an initial gain of $51 billion from modeled pricing (not considering feedback), which is reduced by $5-10 billion cumulatively after accounting for GHG strategy-generated efficiency improvements.

Figure 4.2 further illustrates the effects of feedback on revenue, using the motor fuel tax in 2023 as an example. Of a total of $13.3 billion in revenue, about $500 million (3.8 percent) is lost to "feedback" – i.e., reduced fuel consumption due to new GHG reduction strategies.

Figure 4.2 Illustration of Effects of Feedback on Revenue



4.3 Future Opportunities

This report provides an illustration of the GHG reduction benefits that could be achieved through a variety of commonly considered strategies. However, it does not necessarily reflect the universe of all potential GHG reduction measures. There are other strategies or technologies that could have larger impacts in the future than quantified here. For example, these might include:

- Fuel economy and GHG emission reduction standards beyond the current adopted Federal standards;
- Other advanced technologies including fuel cell vehicles or hybrid and electric heavy-duty vehicles;
- Efficiency benefits of connected and/or autonomous vehicle operations, which have the potential to improve efficiency (energy or GHG per mile) on both the level of the individual vehicle and the transportation network or system; and
- "Shared mobility" strategies such as expanded car-sharing, bike-sharing, ride-hailing and ride-sharing services, and other services that support reduced car ownership and use and complement public transportation in urban areas.

At the same time, some technological advances, such as autonomous vehicles, could increase VMT and GHG emissions. The future is not entirely knowable and any projections of baseline GHG emissions and strategy impacts are subject to considerable uncertainty.

5.0 Economic Analysis

(Applies only to Comprehensive Policy Bundle Approach)

The purpose of the economic analysis is to estimate the costs and benefits of implementing the GHG reduction strategies described in this report, as well as the net economic benefits to the TCI region. Economic benefits are measured in terms of new jobs, additional gross regional product (GRP), and additional disposable income over the analysis period (2015-2030). These benefits may accrue due to factors such as travel time savings, reduced vehicle operating costs, and increasing the share of business and consumer income that is spent within the TCI region.

Impacts are evaluated for two comprehensive policy bundles that include pricing policies and investment scenarios, one 100 percent reinvestment policy bundle and one 50/50 policy bundle, with and without diversion of funds to cover potential all-sector revenue loss.

The two policy bundles modeled are as follows:

- The **First Policy Bundle (100 percent policy bundle)** assumes a transportation pricing policy raising approximately $3 billion per year, and 100 percent of the proceeds of this policy are assumed to fund a Moderate Investment Scenario of $3 billion per year where all of the funded strategies are assumed to achieve additional GHG emission reductions.
- The **Second Policy Bundle (50/50 policy bundle)** assumes a transportation pricing policy raising approximately $3 billion per year. Half of these proceeds—$1.5 billion per year—are used to fund a Modest Investment Scenario of $1.5 billion per year. The other half of the proceeds—an additional $1.5 billion per year—is assumed to fund other programs that support clean transportation, specifically existing transit operations and maintaining the existing transportation system.

5.1 The Economic Model

The Regional Economic Models, Inc. (REMI) Policy Insight (PI+) model (v1.6.8) was used for this analysis. REMI is the premier economic simulation model in the U.S. and is a dynamic model, measuring interactions among all sectors of the economy over time. The model includes historical data through 2012 and provides forecasts on a year-by-year basis through 2050. REMI has been used for other transportation and energy analysis applications in the region, such as the NESCAUM Clean Fuels Study and various projects of the New York State Energy Research and Development Authority (NYSERDA). For this project, the model was set up with data from each of the 11 TCI states plus the District of Columbia (Maryland and D.C. were analyzed as one unit) along with the rest of the U.S., for 23 economic sectors.

The REMI model analyzes *changes in monetary flows* through the economy, and the resulting impacts on jobs, GRP, income, and various other metrics. Thus, the analysis only considers benefits and costs that can be directly monetized. For example, time savings for truckers are considered because truck operating costs (including driver hourly wages) are a direct cost to businesses. However, time savings for personal travel are not considered because such savings do not directly provide travelers with more money to spend. The economic analysis therefore differs from a *benefit-cost analysis*, which places a value on all benefits and impacts in monetary terms, even if these benefits or impacts are not "spent."

5.2 How GHG Reduction Strategies Affect the Economy

The economic analysis considered the net economic effects to the region from the following impacts:

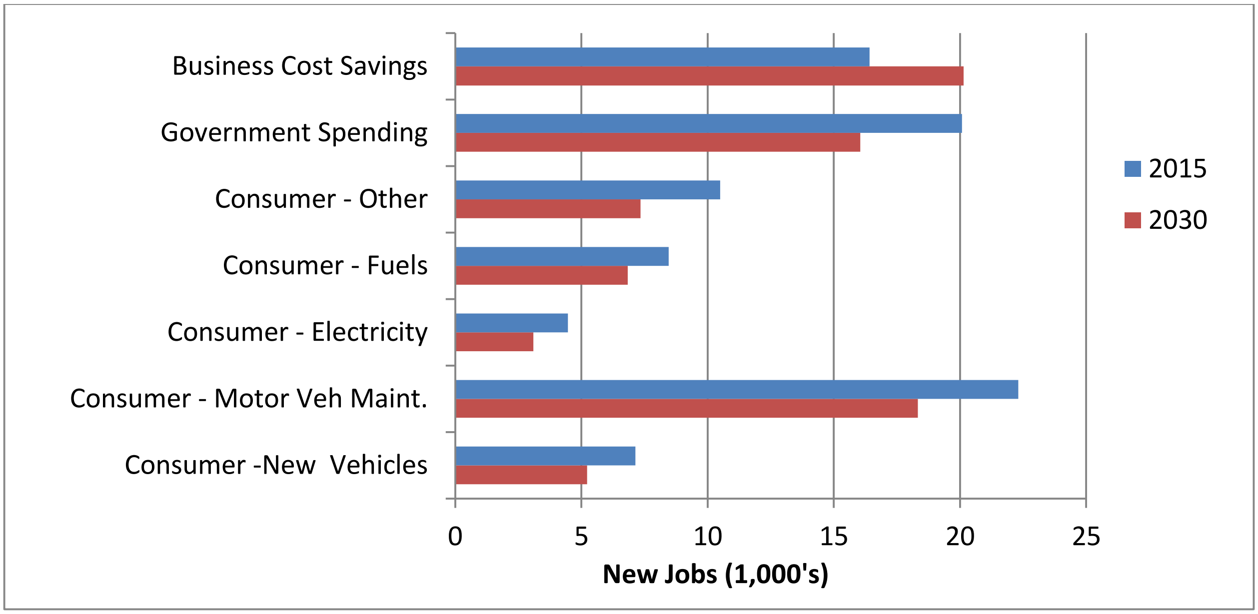
- **Travel time savings** accruing to businesses, due to reductions in congestion and delay. These include time savings for truckers, other commercial vehicle operators, and other "on-the-clock" travel. Congestion and delay are reduced through investments in traffic flow improvements; reducing VMT also reduces congestion.
- **Savings in fuel and vehicle maintenance** (for businesses and consumers), as a result of strategies (such as investment in transit and nonmotorized infrastructure) that allow travelers to reduce VMT.
- **Shipping cost savings** for businesses that can ship by rail rather than truck, as a result of improved freight rail infrastructure.
- **Increased spending on vehicles** (for electric vehicle and natural gas truck purchases) and electricity and natural gas to run these vehicles; these spending increases are offset by reduced petroleum fuel costs.
- **New government investment** in transportation infrastructure and services, made possible by the new funding mechanisms.
- **Changes in consumer spending** on non-transportation goods and services. Consumers will pay more in VMT, fuel, or carbon taxes or fees and for electric vehicles. However these costs will be offset by the above monetary cost savings. The net of these two effects is an increase or decrease in money available to spend on other items.[38]

Money transfers (such as paying taxes to support increased infrastructure investment) do not by themselves increase or decrease wealth or jobs, they just transfer wealth from one entity to another. However, they can shift the balance of where money is spent in the economy, which can affect the benefits captured within the TCI region. For example, as shown in Figure 5.1, every dollar spent by government on infrastructure, or realized by businesses through cost savings, has about twice the impact on the regional economy as money spent on motor fuels and new vehicles (although the regional benefits of every dollar spent on motor vehicle repair are even greater). Figure 5.1 shows the new jobs created in the TCI region per billion dollars of

[38] Changes in consumer spending in other sectors of the economy could increase or decrease GHG emissions in these sectors. Accounting for changes in non-transportation GHG emissions was beyond the scope of this analysis.

spending (or cost savings) in different categories, to compare the relative benefits of spending or cost savings each category.

Figure 5.1 TCI Region Impact of $1 Billion in Annual New Spending or Cost Savings



Source: Cambridge Systematics, Inc. analysis using REMI PI+.

Other impacts of the GHG strategies can be monetized but were not included in the REMI analysis. Such impacts are often included in benefit-cost analysis. These include:

- Time savings for personal/off-the-clock travel. As noted above, such time savings are not directly reinvested in the form of spending.
- Crash reductions and associated cost savings (medical, lost wages, etc.). Reducing VMT should reduce motor vehicle crashes. However, there may be an offsetting increase in crashes and incidents by transit and nonmotorized modes. There is considerable uncertainty over how pedestrian and bicycle crash and injury rates will change in the future as infrastructure for these modes is improved. Also, some types of crash costs are difficult or impossible to translate into monetary flows.
- Air pollution reductions. Reductions of criteria pollutants can result in health benefits and other savings such as reduced crop damage. While studies have placed monetary values on the benefits of reducing different pollutants, it is more difficult to translate these benefits into direct monetary flows in the economy.

Finally, there are potential impacts that could not be monetized due to lack of good data or methods for doing so:

- Health benefits related to physical activity. Benefits of physical activity (including bicycling and walking) have been shown to be significant. Tools (such as the World Health Organization's Health Economic Assessment Tool, or HEAT) are emerging to monetize these benefits, but they have not been widely applied in transportation practice and methods for translating benefits into economic flows are not well demonstrated.

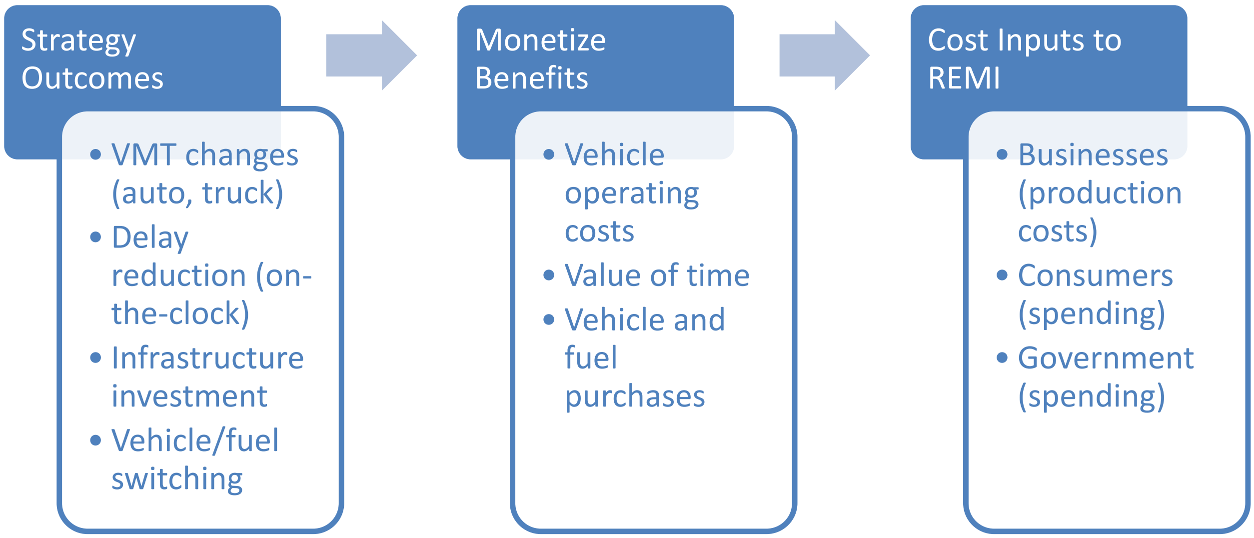
- Consumer welfare and "intangibles" – Travelers may experience various other benefits or impacts as a result of changes in transportation investment and costs by various modes, such as comfort and convenience, or the ability to access jobs and essential services. These are difficult to measure and even more difficult to translate into monetary flows.

5.3 Key Assumptions

The analysis of GHG strategies described here was by necessity "high-level" since it was not possible to define and model specific transportation investments across the entire TCI region and analysis period. As described in Section 3.0 for the GHG strategy analysis, various simplifying assumptions and general approximations had to be made. The reader should keep in mind that the results are therefore representative of an "order of magnitude" of effects rather than a precise estimate.

Figure 5.2 shows the basic analysis approach. Strategy outcomes (some computed for the GHG estimates, others which needed to be computed for the economic analysis) are first tabulated. These are then monetized using various factors such as value of time. Finally, the monetary costs are tabulated in a form that can be input to REMI. The inputs include changes in business production costs, consumer spending, and government spending.

Figure 5.2 Economic Analysis Approach



The assumptions described here are for the "base scenario" pricing policy generating $3 billion per year for the TCI region through a carbon fee, VMT fee, or motor fuel tax, with 100 percent reinvestment in GHG mitigation strategies.

5.3.1 VMT Changes

Light-duty VMT reductions result from pricing policy, transit investment, land use/smart growth, active transportation investment, and TDM programs.

VMT changes were needed to estimate GHG emissions. Therefore the methods for computing VMT changes are described in Section 3.0 of this document. To assist in monetizing, VMT changes were broken out by light-duty vs. heavy-duty vehicles.

To monetize the VMT changes, the following values from sources widely accepted in transportation analysis were used:

- Fuel costs – based on the fuel efficiency and fuel price assumptions used in the GHG analysis, which are consistent with the Annual Energy Outlook 2014 Reference Case. These decrease from **$0.14 per mile in 2015 to $0.105 per mile in 2030** for light-duty vehicles.

- Maintenance costs – **$0.10 per mile** for light-duty vehicles, based on the FHWA Highway Economic Requirements System (HERS) model Technical Report (2005).[39]

[39] HERS is used as the basis for the U.S. DOT's annual "Conditions and Performance" Report which describes the status of the nation's highways, bridges, and transit and describes investment needs.

Note that VMT and associated fuel and maintenance cost savings for trucks are not considered separately. These are already considered in the changes in shipping costs as a result of truck-rail mode shifts described in Section 5.3.2.

For comparison, other costs estimated but not used in the economic analysis include:

- Air pollution costs – For automobiles, $0.027 per mile in 2015, declining to $0.015 in 2030, based on values developed by Cambridge Systematics and used by the Federal Transit Administration (FTA) in its New Starts evaluation process for transit investments. These costs primarily represent health impacts. For heavy trucks, these values were factored by the ratio of diesel bus to automobile emissions (diesel buses must meet the same emissions standards as heavy trucks) - $0.412 per mile in 2015, declining to $0.297 in 2030. Air pollution benefits include the benefits of VOC, CO, NOx, and PM2.5 reductions.

- Motor vehicle crash costs - $0.141 per vehicle-mile, also the value used by FTA.

- Pavement damage costs -- $0.001 per mile for automobiles or $0.18 per mile for trucks, based on the 1997 FHWA Highway Cost Allocation Study and 2010 MassDOT Freight Plan.

5.3.2 Changes in Truck and Rail Ton-Miles

Freight/intermodal infrastructure investment supports a shift in freight ton-miles from truck to rail.

To estimate this shift, a *change in rail ton-miles per capital dollar invested* was estimated. This estimate was based on the Mid-Atlantic Rail Operations (MAROps) study of rail improvements in five mid-Atlantic states.[40] This study estimated that a $6 billion investment in rail infrastructure could result in an annual reduction of 3.6 billion truck VMT and an increase of 51 billion rail ton-miles. The resulting factor is an increase **of 8.5 million ton-miles per millions of capital dollars invested**. With an investment of about $460 million per year, rail ton-miles would increase by about 3.8 billion per year, for an increase of 63 billion annual ton-miles by 2030.

To monetize the benefits of a shift in traffic, a value of $0.04 in shipper savings per ton-mile shifted from truck to rail was used. This value was taken from the Massachusetts Department of Transportation Freight Plan (2010, p. 4-10).

5.3.3 Time Savings

Time savings from two sources were estimated:

- Investment in system operations/efficiency strategies for GHG reduction, such as ITS, traffic signal coordination, etc. to reduce delay.

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[40] I-95 Corridor Coalition, Mid-Atlantic Rail Operations Phase II Study Final Report, 2009

- Reduced congestion as a result of reduced VMT (section 5.3.1).

Hours of delay reduced per VMT reduced were estimated based on the Texas Transportation Institute's 2012 Urban Mobility Report (UMR), which estimates the cost of congestion nationwide. This report is released annually and widely cited. Recent editions of this report have also estimated the time savings and delay reduction benefits of existing public transportation and system operations strategies.

To analyze reduced congestion as a result of reduced VMT, the UMR-reported nationwide hours of delay reduced from public transportation (865 million in 2012) was divided by the estimated VMT reduced from public transportation (44.8 billion) to obtain a factor of **0.02 hours of delay reduced per VMT reduced**. This was then multiplied by the VMT change estimated for the TCI strategy analysis to obtain an overall delay reduction of 96 million hours in 2015, increasing to 530 million hours in 2030.

For system operations/efficiency, the UMR reported that nationwide, operational improvements implemented through 2012 were saving 374 million hours of delay and 194 million gallons of fuel annually, for a savings of 0.52 gallons of fuel per hour of delay reduced. This equates to about 4.7 kg of CO_2 per hour of delay. With a factor of 280 annual tons CO_2 saved per capital millions invested (Section 3.7), this equates to about **58,000 annual hours saved per millions of capital dollars invested**. With annual investment of about $460 million this yields an overall delay reduction of 27 million hours in 2015, increasing to 436 million hours in 2030.

Time savings (delay reductions) were allocated between personal light-duty VMT, commercial light-duty VMT, and truck VMT in proportion to the VMT by each mode in the TCI region. They were then monetized using a value of $24.90 per vehicle-hour, based on U.S. DOT guidance.[41]

For commercial light and heavy truck VMT, all time savings are assumed to accrue to businesses. For passenger travel VMT, 6.3 percent of travel was assumed to be "on-the-clock."[42]

5.3.4 Alternative Fuel Vehicle Costs

Additional vehicle purchase costs for EVs and natural gas trucks are described in Section 3.1. Costs of electricity and natural gas are also estimated based on efficiency assumptions as described in the GHG analysis and unit costs from 2014 AEO.

[41] USDOT "Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis (Revision 2 – corrected)" (2012)

[42] Cambridge Systematics, REMI Vulnerability Analysis for Hillsborough County (2014) –sourced from travel survey data

5.3.5 Modeling Supportive Strategies for "50/50" Scenarios

To model the "50/50" scenarios (Scenario 2, where 50 percent of new TCI revenue is directed to strategies that are assumed not to achieve additional GHG emission reductions beyond the baseline but support a clean and resilient transportation system), assumptions were needed about the economic benefits of the preservation spending assumed in these scenarios. The use of this spending was determined with input from participating states through a survey that asked about how this study should assume the proceeds would be spent in this hypothetical scenario. The key assumptions are as follows:

- 65 percent of the "supportive" spending is for highway preservation;
- 35 percent of the "supportive" spending is for transit operations.

Highway Preservation

Benefit data are derived from the 2013 FHWA Conditions and Performance Report, pp. 7-20 and 7-21. The report includes highway investment scenarios analyzed at a national level using the Highway Economic Requirements System (HERS) model. Multiple investment scenarios are shown for average annual spending (2010 $billions) and total user costs ($/VMT). The differences between successive scenarios shown in these tables are used to derive an average cost savings ($/VMT) per $billion invested.

The scenarios are a mix of capacity expansion, preservation, ITS, and safety. This mix is internally determined by HERS algorithms. The report does not have scenarios that only include preservation, so the impacts of the different investment types cannot be distinguished. Instead, spending on highway preservation is assumed to have the same economic benefit per dollar as the other types of investment assumed in HERS.

The report states that 44.9 percent of user costs are time, and 41.5 percent are vehicle operating (the remainder are crash costs). The resulting values are $412 in time savings and $381 in VOC savings per million VMT. These savings are multiplied by TCI region VMT and allocated amongst business and personal travel consistent with the other elements of the analysis as described above.

Transit Operations

Economic benefits of transit operations were not modeled directly in REMI. Instead, they were taken from Transit Cooperative Research Program (TCRP) Report J-11.[43] The report authors used the TREDIS model, which has many similarities to REMI, to evaluate the benefits of nationwide transit investment. These benefits were estimated at 36,000 jobs and $3.5 billion GDP annually per $billion of investment, over the long term. The analysis accounts for the impacts of new government spending, productivity benefits to businesses due to time savings, cost savings to travelers reflecting changes in vehicle operating and ownership costs and

[43] Economic Impacts of Public Transportation Investment, EDRG and Cambridge Systematics, 2009.

transit fares, and benefits of reduced congestion. Modeling all of these factors for transit spending at the level of detail in the TCRP study would be beyond the scope of this study, so the TCRP study results were used directly for expediency.

For comparison, REMI (based on our analysis) predicts 16,000 to 20,000 jobs per year from government spending. The Council of Economic Advisers estimated that every $1 billion in Federal highway and transit investment funded by the American Jobs Act would support 13,000 jobs for one year.[44] (An older FHWA estimate cited in the TCRP report was 30,000 jobs per $billion.) These figures do not account for transportation user benefits.

The TCRP analysis is nationwide. It assumes a mix of current annual spending on public transportation of operations (71 percent) and capital (29 percent), so the benefits in this analysis are assumed to be similar. The TCRP report also implies that these are long-run benefits, so they are applied to 2030 in our study, and earlier year benefits are scaled proportional to benefits from our scenario modeling in REMI. Personal income is not reported, so estimates in our study are scaled from GDP benefits, based on the ratio of personal income to GDP benefits from other scenarios modeled.

5.4 REMI Inputs

The monetized benefits described above, as well as transfers between different entities (taxes/fees and incentives), were translated into the following REMI inputs for businesses, consumers, and the government.

5.4.1 State Government Revenues and Expenditures

Government agencies receive just over $3 billion annually (averaged over the 2015-2030 period) in new revenue from pricing. This amount considers decreased fuel use due to the GHG reduction strategies ("Pricing policy source revenue loss"), which reduces the new revenue by about $75 to $141 million per year on average (depending upon the pricing mechanism) compared to what it would be at the same (baseline) levels of fuel consumption. This impact, however, does not consider loss in revenue from *existing* motor fuel tax sources due to the reduced fuel consumption from the implemented GHG reduction strategies (as discussed in Section 4.2). With the primary pricing and 100% reinvestment scenario, the average annual motor fuel tax revenue loss would be about $308 million for the VMT fee, $466 million for the additional motor fuel tax, or $631 million for the carbon price. If enough new revenue from potential pricing policies to fully make up this shortfall was diverted to other transportation sector uses, the money available for reinvestment in GHG strategies would be reduced by 10 to 20 percent. However, this diverted revenue would still have economic benefits as long as it was being spent on productive investments.

The $3 billion in new revenue is assumed to be spent primarily on transportation infrastructure and services (about $2.2 billion annual average), with a small amount for electric utility infrastructure (about $120 million annual average). It is also assumed that just over $700

[44] http://www.whitehouse.gov/blog/2011/09/09/american-jobs-act-state-sta

million is returned to consumers each year in the form of EV incentives and transit subsidies. The bottom line is new government spending of about $2.3 billion per year that is entered in the "government spending" category in REMI. This is an annual average, and the actual time stream will vary somewhat depending upon the revenue mechanism.

The various government revenues and expenditures are shown in Figures 5.3a and 5.3b for all years (100% reinvestment and 50/50 scenarios, respectively), and Tables 5.1a and 5.1b for a snapshot (2015 and 2030) and cumulatively over the time horizon. (Detailed results for each year over the analysis period are presented in Tables A.1 and A.2.) The motor fuel tax is used for this illustrative data for two reasons – first, it causes the midrange revenue loss (VMT fee causes the lowest, and carbon price the highest) and second, it is the existing revenue mechanism for transportation funding. Both the 100% reinvestment and the 50/50 scenario have similar revenue streams. The differences less spending on consumer incentives and utilities and more on transportation infrastructure under the 50/50 scenario, and lower revenue loss under the 50/50 scenario since there is less impact on fuel consumption from the mix of spending in this scenario.

Figure 5.3a New State Government Revenues and Expenditures: 100% Reinvestment Scenario

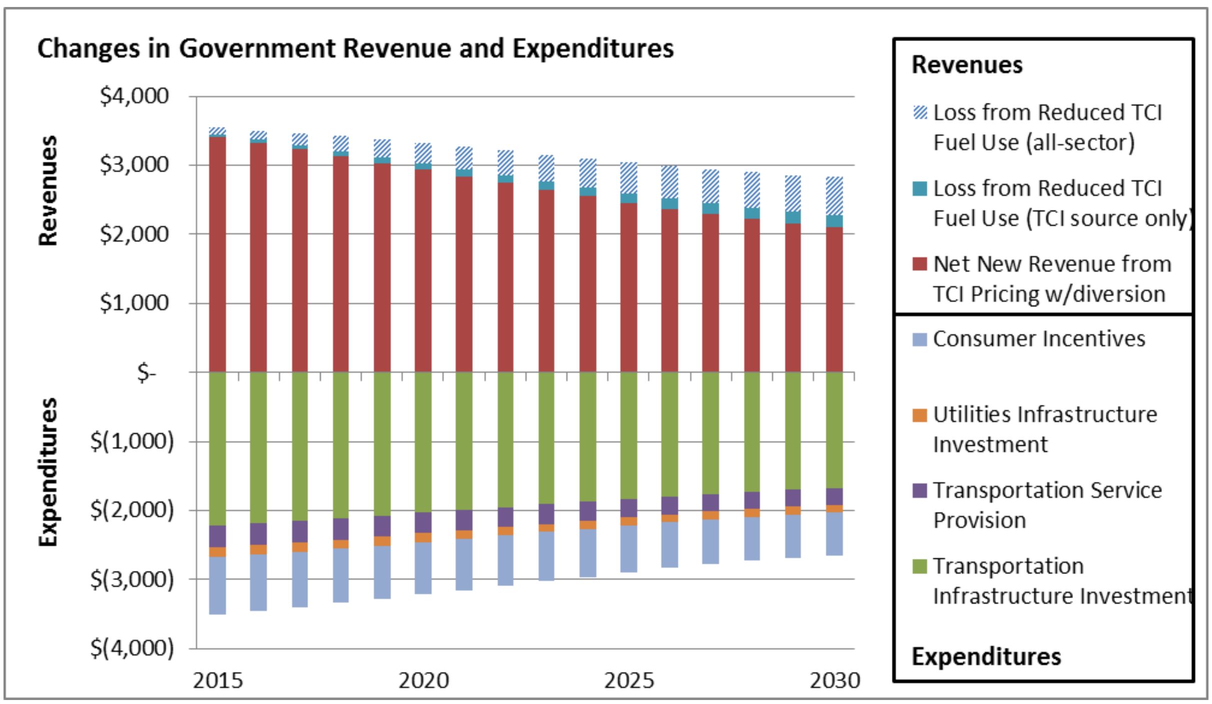
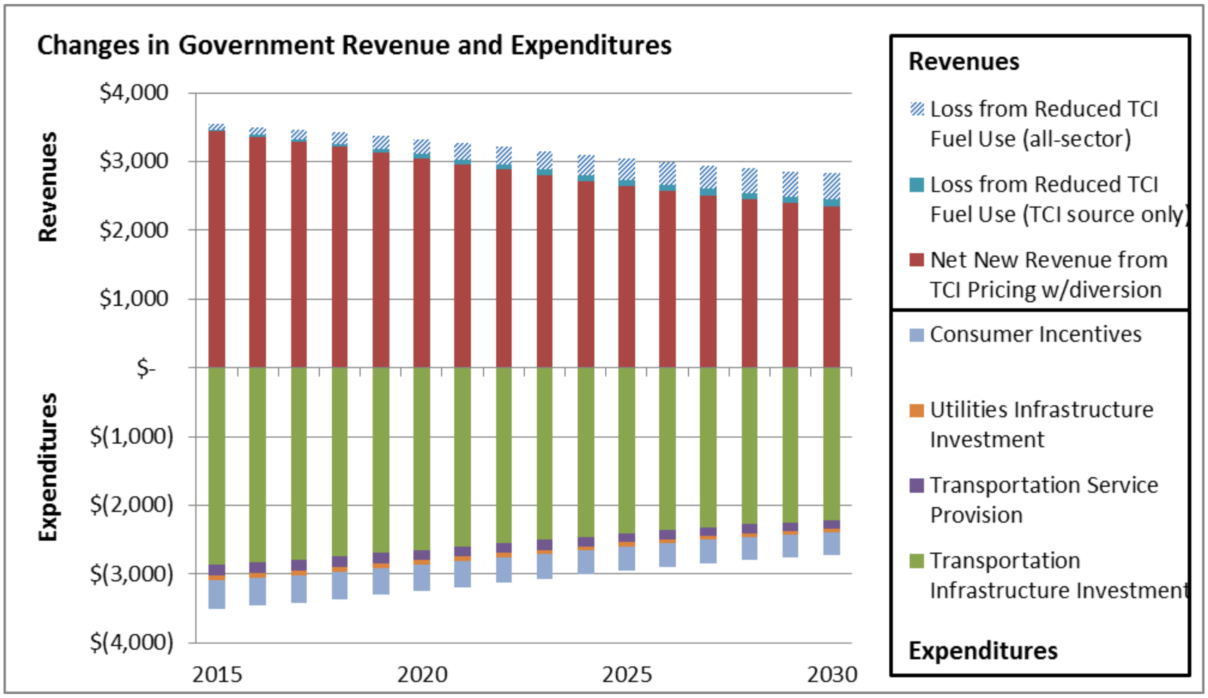


Figure 5.3b New State Government Revenues and Expenditures: 50/50 Scenario



Note: Illustrative revenues and expenditures shown for motor fuel tax. Total new expenditures are sum of gross new revenue from pricing policy and pricing policy -source revenue loss (i.e., not accounting for any diversion to cover all-sector revenue loss).

Table 5.1a New State Government Revenues and Expenditures, $millions (100% Reinvestment Scenario)

	2015	2030	2015 - 2030
New Revenues			
Gross New Revenue from Pricing	$3,539	$2,824	$50,869
Loss in Revenue from Reduced Fuel Consumption	$(32) - $(94)	$(173) - $(558)	$(1,804) - $(5,655)
Net New Revenue	**$3,414 - $3,508**	**$2,092 - $2,650**	**$43,409 - $49,064**
New Expenditures			
Transportation Infrastructure	$2,159 - $2,219	$1,323 - $1,676	$27,456 - $31,032
Transportation Services	$316 - $325	$194 - $245	$4,016 - $4,539
Utilities Infrastructure	$137 - $140	$84 - $106	$1,736 - $1,963
Consumer Incentives	$802 - $824	$492 - $623	$10,201 - $11,530
Net New Expenditures	**$3,414 - $3,508**	**$2,092 - $2,650**	**$43,409 - $49,064**

Note: Illustrative revenues and expenditures shown for motor fuel tax. Smaller loss value (larger revenue or expenditure value) accounts for pricing policy-source revenue loss only. Larger loss value (smaller revenue or expenditure value) accounts for all-sector revenue loss.

Table 5.1b New State Government Revenues and Expenditures, $millions (50/50 Scenario)

	2015	2030	2015 - 2030
New Revenues			
Gross New Revenue from Pricing	$3,539	$2,824	$50,869
Loss in Revenue from Reduced Fuel Consumption	$(25) - $(77)	$(104) - $(380)	$(1,167) - $(4,018)
Net New Revenue	**$3,436 - $3,514**	**$2,340 - $2,720**	**$45,684 - $49,702**
New Expenditures			
Transportation Infrastructure	$2,805 - $2,868	$1,910 - $2,220	$37,289 - $40,569
Transportation Services	$159 - $163	$108 - $126	$2,113 - $2,299
Utilities Infrastructure	$69 - $70	$47 - $54	$914 - $994
Consumer Incentives	$404 - $413	$275 - $320	$5,368 - $5,840
Net New Expenditures	**$3,436 - $3,514**	**$2,340 - $2,720**	**$45,684 - $49,702**

Note: Illustrative revenues and expenditures shown for motor fuel tax. Smaller loss value (larger revenue or expenditure value) accounts for pricing policy-source revenue loss only. Larger loss value (smaller revenue or expenditure value) accounts for all-sector revenue loss.

5.4.2 Business Costs and Cost Savings

All changes accruing to businesses, including commercial vehicle time savings, shipping cost savings, incremental costs of natural gas truck purchase, fuel savings associated with natural gas use, the value of "on-the-clock" travel time in personal vehicles saved, and the commercial vehicle share of increases in taxes/fees, are summed to obtain a **net change in business production costs**. The result is a $131 to $170 million region-wide increase in business production costs in 2015, changing to a cost savings in 2016 which increases to a net cost savings of $3.7 to $6.9 billion in 2030 (ranges reflect the 50/50 and 100% reinvestment scenarios). The net savings over the 2015-2030 time period is $29 to $55 billion. The components of costs and cost savings are shown in Figures 5.4a and 5.4b (all years) and Table 5.2 (snapshot and cumulative). (Detailed results for each year over the analysis period are presented in Tables A.3 and A.4.) Note that a positive number denotes a cost increase, while a negative number denotes a cost savings. The motor fuel tax is used for illustrative purposes.

The business production costs needed to be allocated across 23 industry sectors. This was done by considering the proportion of the economy made up by each sector, and the proportion of each sector's cost that is for transportation, as determined from data embedded in the REMI model. While these proportions vary by state, an example for New York State is shown in Table 5.3.

Table 5.2 Business Production Costs and Savings ($millions)

	2015	2030	2015 - 2030
100% Reinvestment Scenario			
Time (Productivity)	$(572)	$(4,613)	$(42,940)
Fuel (Petroleum) + Electricity	$(65)	$(1,014)	$(8,853)
Vehicle Purchase	$242	$649	$9,759
Vehicle Maintenance/Repair	$(29)	$(153)	$(1,522)
Transportation Services (Shipping)	$(179)	$(2,502)	$(22,304)
Fees, Taxes, Tolls, Fares	$733	$702	$11,269
Net Business Production Cost Change	$131	$(6,932)	$(54,591)
50/50 Scenario			
Time (Productivity)	$(500)	$(2,791)	$(27,557)
Fuel (Petroleum)	$(46)	$(542)	$(4,860)
Vehicle Purchase	$121	$333	$4,952
Vehicle Maintenance/Repair	$(49)	$(124)	$(1,461)
Transportation Services (Shipping)	$(90)	$(1,267)	$(11,254)
Fees, Taxes, Tolls, Fares	$734	$720	$11,422
Net Business Production Cost Change	$170	$(3,672)	$(28,757)

Note: Business cost savings for the 50/50 scenario do not include benefits related to investment in operations and maintenance of the existing public transportation system. The economic benefits of such investment were taken from another study and cost data are not available in a format consistent with the costs developed for this study.

Figure 5.4a Business Production Costs and Savings: 100% Scenario ($millions)

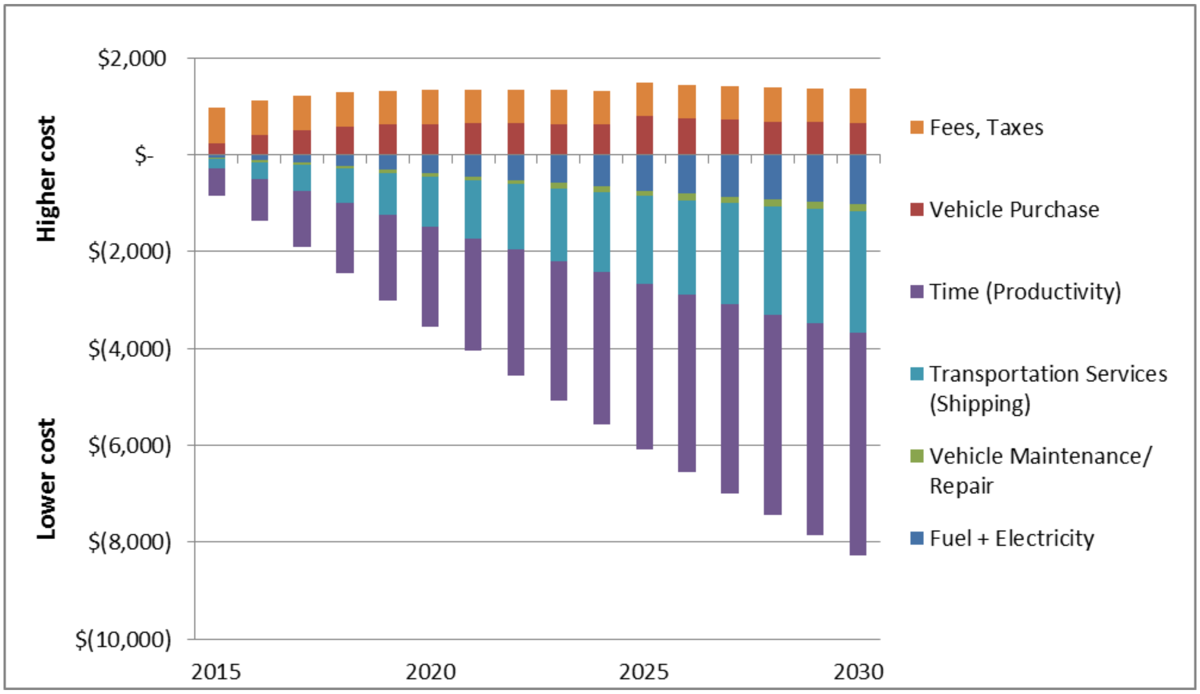
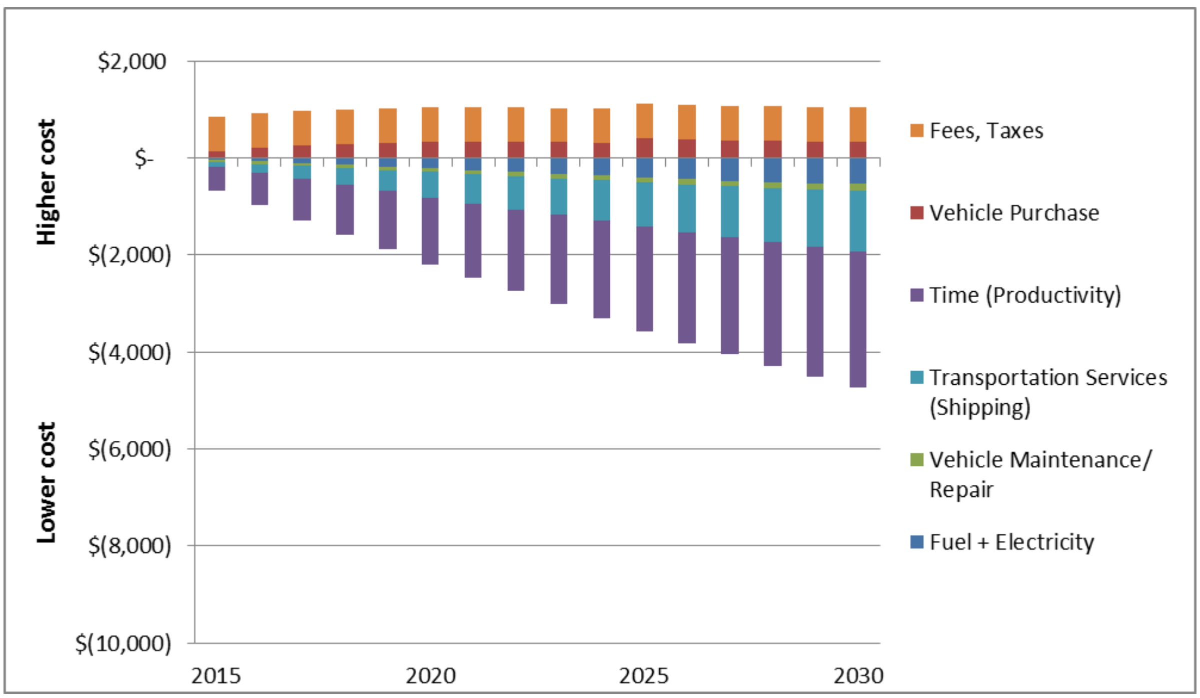


Figure 5.4b Business Production Costs and Savings: 50/50 Scenario ($millions)



Note: Business cost savings for the 50/50 scenario do not include benefits related to investment in operations and maintenance of the existing public transportation system. The economic benefits of such investment were taken from another study and cost data are not available in a format consistent with the costs developed for this study.

Table 5.3 Share of Transportation Costs by Industry, New York State

Industry	Industry Spending ($billions)	Transportation Expenses per Dollar of Spending	Industry Share of Transportation Costs
Forestry, Fishing, and Related Activities	0.50	0.0023	0.02%
Mining	2.50	0.0179	0.60%
Utilities	24.69	0.0024	0.78%
Construction	60.01	0.0147	11.77%
Manufacturing	200.83	0.0183	48.99%
Wholesale Trade	77.78	0.0011	1.18%
Retail Trade	86.39	0.0016	1.86%
Transportation and Warehousing	40.07	0.0179	9.54%
Information	136.55	0.0016	2.85%
Finance and Insurance	361.79	0.0003	1.59%
Real Estate and Rental and Leasing	271.07	0.0009	3.36%
Professional, Scientific, and Technical Services	138.56	0.0011	2.07%
Management of Companies and Enterprises	35.04	0.0008	0.35%
Administrative and Waste Management Services	46.03	0.0061	3.77%
Educational Services	26.12	0.0022	0.76%
Health Care and Social Assistance	146.69	0.0022	4.39%
Arts, Entertainment, and Recreation	22.17	0.0015	0.44%
Accommodation and Food Services	53.55	0.0048	3.46%
Other Services, except Public Administration	38.36	0.0043	2.22%
Total	**1,768.69**		**100.00%**

5.4.3 Consumer Spending

Spending changes were entered for petroleum fuel, electricity, vehicle purchase (EVs), and vehicle maintenance/repair. Consumers also paid more in taxes/fees, but were assumed to receive some government incentives (for EV purchase and transit subsidies for the TDM strategy). The net costs and cost savings to consumers were summed to obtain a "bottom line" available for spending on other (non-transportation) items, which is entered in REMI as the consumer reallocation variable. The net impact of the cost and cost savings is that consumers have between $1.3 and $1.5 billion less to spend in 2015; by 2019 to 2021, however, they receive a net benefit, which increases to $1.6 to $3.2 billion available to spend on non-transportation items in 2030 (ranges reflect the 50/50 vs. 100% reinvestment scenarios). The components of consumer spending and savings are shown in Figures 5.5a and 5.5b (all years) and Table 5.4 (snapshot and cumulative). (Detailed results for each year over the analysis period are presented in Tables A.5 and A.6.) Note that a positive number denotes a higher cost or spending level, while a negative number denotes a lower cost or spending level. Incentives provided to consumers are also shown as negative values (since this represents new money just like a cost savings). These cost savings do not reflect any diversion of funds to cover all-sector revenue loss; if this were considered, the cost savings could be reduced by 10 to 20 percent, not accounting for any benefits that would accrue to consumers from the diverted revenue. Vehicle purchase and electricity costs would also be reduced by a similar amount.

Table 5.4 Consumer Costs and Savings ($millions)

	2015	2030	2015 - 2030
100% Reinvestment Scenario			
Transportation-Related Expenditures			
Fuel (Petroleum)	$(622)	$(2,801)	$(29,068)
Electricity	$5	$151	$1,012
Vehicle Purchase	$376	$393	$5,880
Vehicle Maintenance/Repair	$(430)	$(2,274)	$(22,653)
Fees, Taxes, Tolls, Fares	$2,775	$1,948	$37,795
Total Change in Expenditures	**$2,103**	**$(2,583)**	**$(7,033)**
Incentives and Discounts	$(824)	$(623)	$(11,530)
Money Available for Spending on Other Items	**$(1,278)**	**$3,206**	**$18,563**
50/50 Scenario			
Transportation-Related Expenditures			
Fuel (Petroleum)	$(522)	$(1,830)	$(20,413)
Electricity	$2	$77	$512
Vehicle Purchase	$188	$201	$2,981
Vehicle Maintenance/Repair	$(561)	$(1,701)	$(19,161)
Fees, Taxes, Tolls, Fares	$2,780	$2,000	$38,280
Total Change in Expenditures	**$1,888**	**$(1,253)**	**$(2,198)**
Incentives and Discounts	$(413)	$(320)	$(3,641)
Money Available for Spending on Other Items	**$(1,475)**	**$1,573**	**$5,839**

Note: Consumer cost savings for the 50/50 scenario do not include benefits related to investment in operations and maintenance of the existing public transportation system. The economic benefits of such investment were taken from another study and cost data are not available in a format consistent with the costs developed for this study.

Figure 5.5a Consumer Costs and Savings: 100% Reinvestment ($millions)

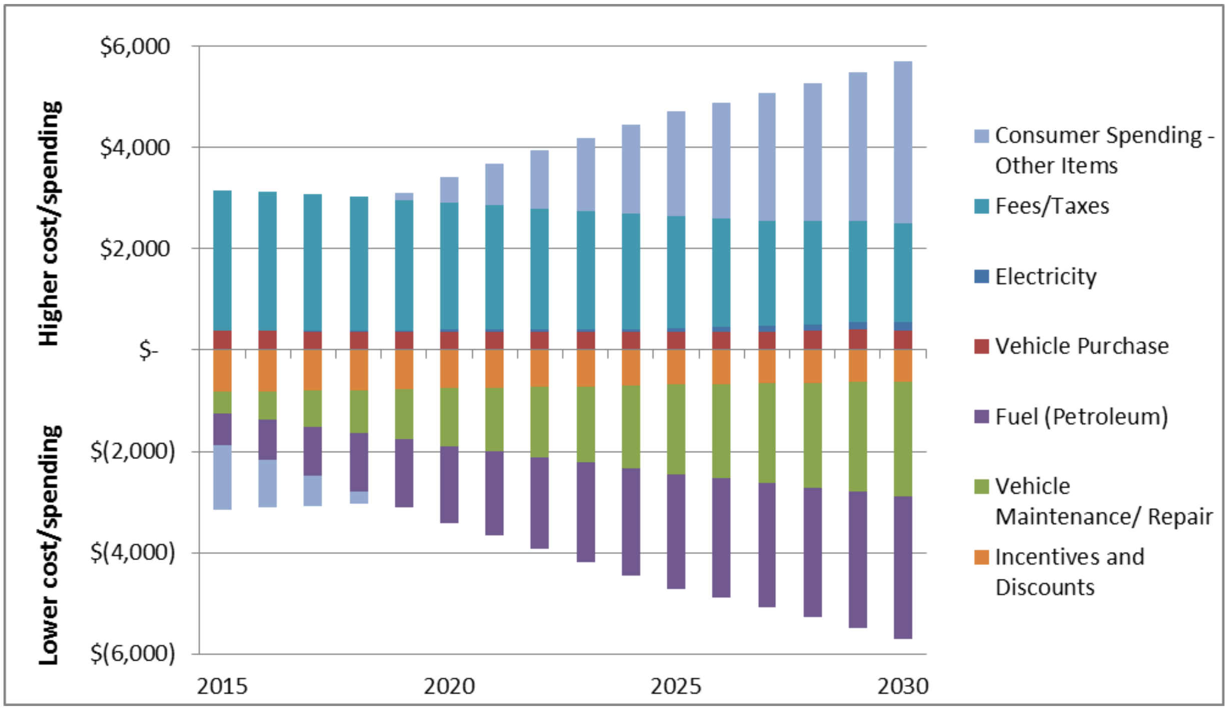
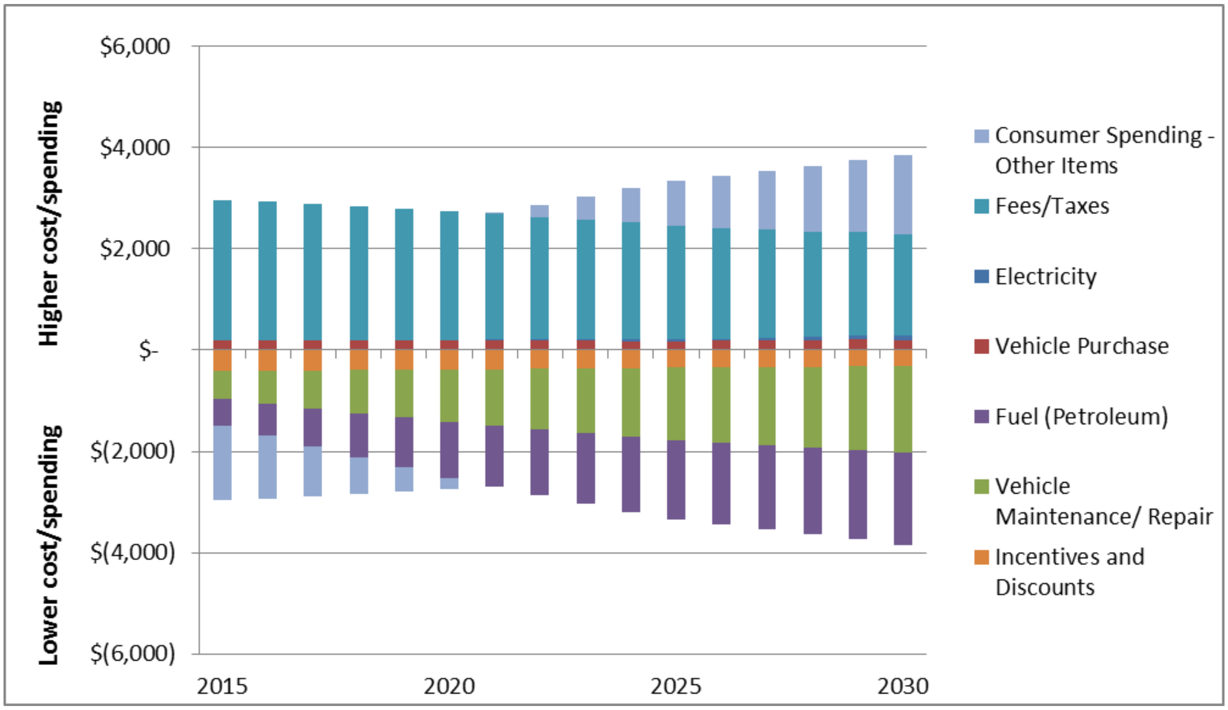


Figure 5.5b Consumer Costs and Savings: 50/50 Scenario ($millions)



Note: Consumer cost savings for the 50/50 scenario do not include benefits related to investment in operations and maintenance of the existing public transportation system. The economic benefits of such investment were taken from another study and cost data are not available in a format consistent with the costs developed for this study.

5.4.4 Net Cost and Expenditure Changes

The net annual cost or expenditure changes for all sectors – government, business, and consumer – are shown in Figure 5.6. Consumer spending is distinguished for transportation-related expenditures (including vehicle purchases, fuel, electricity, and maintenance and repair, and taxes/fees, less government incentives) and non-transportation-related expenditures, which represents new money that consumers have to spend on other items.

Figure 5.6a Net Annual Cost/Expenditure Changes: 100% Reinvestment Scenario

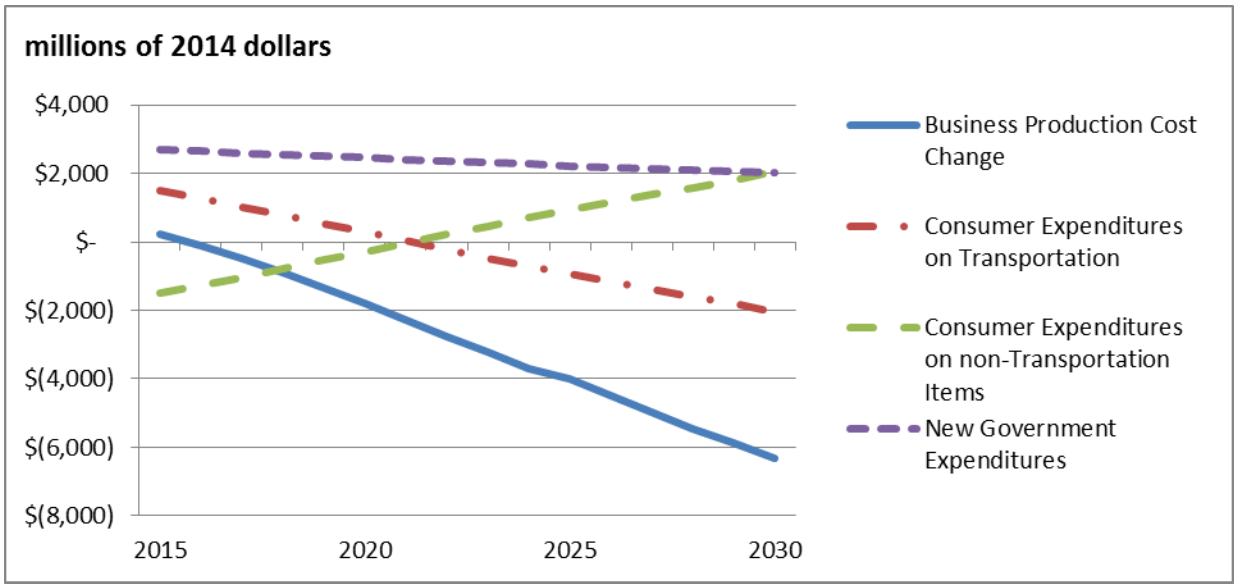
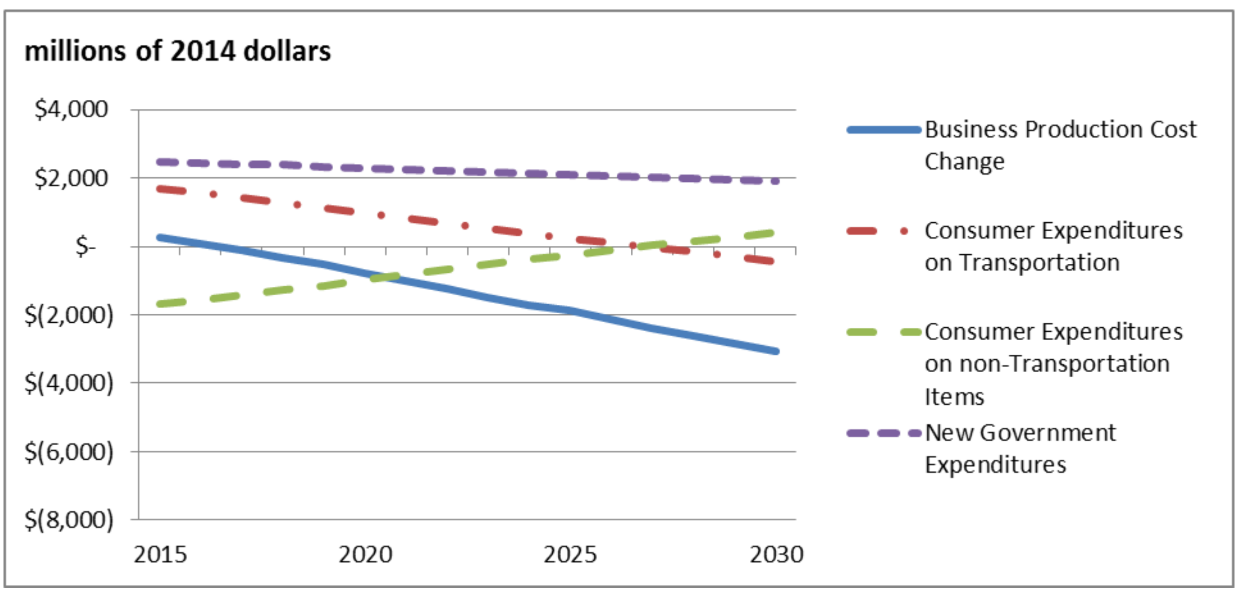


Figure 5.6b Net Annual Cost/Expenditure Changes: 50/50 Scenario



5.5 Results

5.5.1 First Policy Bundle or Scenario 1 (100% Mitigation)

Table 5.5 summarizes the results of the First Policy Bundle, or Scenario 1, economic impact analysis in terms of new jobs, gross regional product, and disposable personal income. The results shown here are for the primary pricing scenario generating $3 billion per year for the TCI region through a carbon fee, VMT fee, or motor fuel tax, with 100 percent reinvestment in GHG mitigation strategies. Detailed results by state and year are presented in Tables A.7, A.9, and A.11.

Scenario 1a is without considering any diversion of new revenue to cover all-sector funding losses. The pricing and reinvestment strategies are projected to result in an annual increase in 125,000 jobs, nearly $18 billion in GRP, and over $14 billion in disposable income by 2030. These figures represent increases of one-quarter to one-third of a percent over baseline projected levels. Cumulatively over the next 15 years, about 1.2 million jobs (i.e., job-years) would be added to the regional economy, about $144 billion in GRP, and $109 billion in disposable income.

Table 5.5 Economic Benefits of GHG Pricing and Reinvestment Scenario #1a

Industry	2030	2030 Percent of Region	Cumulative, 2015-2030
Change in Regional Employment	125,000	0.31%	1,167,000
Change in Gross Regional Product ($Billions, 2009)	17.7	0.38%	144
Change in Disposable Personal Income ($Billions, 2009)	14.4	0.28%	109

Scenario 1b considers diversion of new revenue to cover all-sector funding losses. As described previously, state transportation agencies would expect to see some loss in revenue from traditional sources as a result of the VMT reductions and fuel efficiency increases from the proposed GHG reduction strategies. If this revenue were not made up through other sources, states might look to divert some of the new revenue from the pricing policy to fill the gap. This would reduce the funds available for spending on GHG reduction strategies, which would correspondingly reduce the user benefits related to these strategies. Table 5.6 shows the benefits of Scenario 1b.

Table 5.6 Economic Benefits of GHG Pricing and Reinvestment Scenario #1b

Industry	2030	2030 Percent of Region	Cumulative, 2015-2030
Change in Regional Employment	117,000	0.29%	1,100,000
Change in Gross Regional Product ($Billions, 2009)	16.5	0.35%	137
Change in Disposable Personal Income ($Billions, 2009)	13.4	0.26%	103

Figures 5.7, 5.8, and 5.9 show the effects on jobs, GRP, and income by year for Scenario 1a. The effects of government spending, reduced business costs, and consumer spending (transportation and non-transportation) are shown separately, with the solid black line representing the net change. The corresponding figures for Scenario 1b would look similar, only with a slightly smaller magnitude of impacts.

The differences between Scenarios 1a and 1b should be taken as an illustration of a range of uncertainty in the analysis of overall economic benefits, rather than a difference between the two scenarios. For example, Scenario 1a does not account for any economic loss due to reduced transportation spending outside of the new pricing policy and reinvestment. Other factors in the analysis could lead to a greater range of uncertainty than illustrated just with these two scenarios.

Figure 5.7 Net Effects on Employment (Scenario 1a)

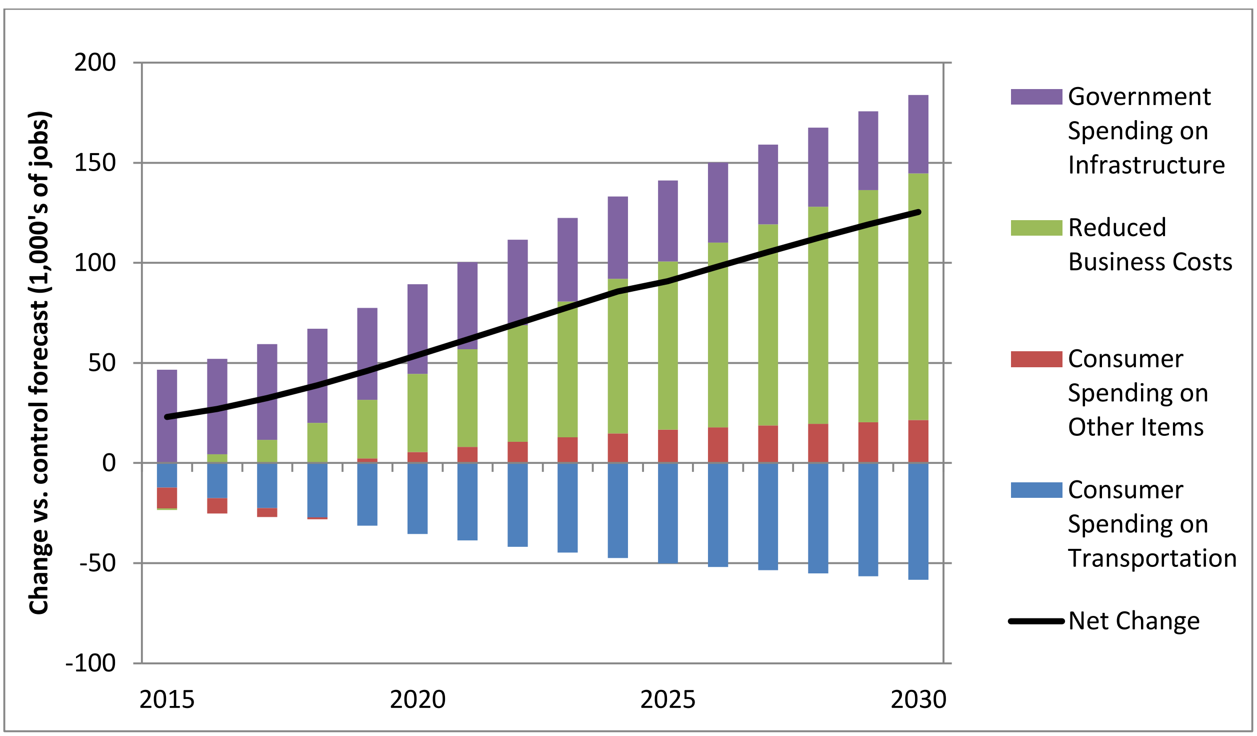


Figure 5.8 Net Effects on Gross Regional Product (Scenario 1a)

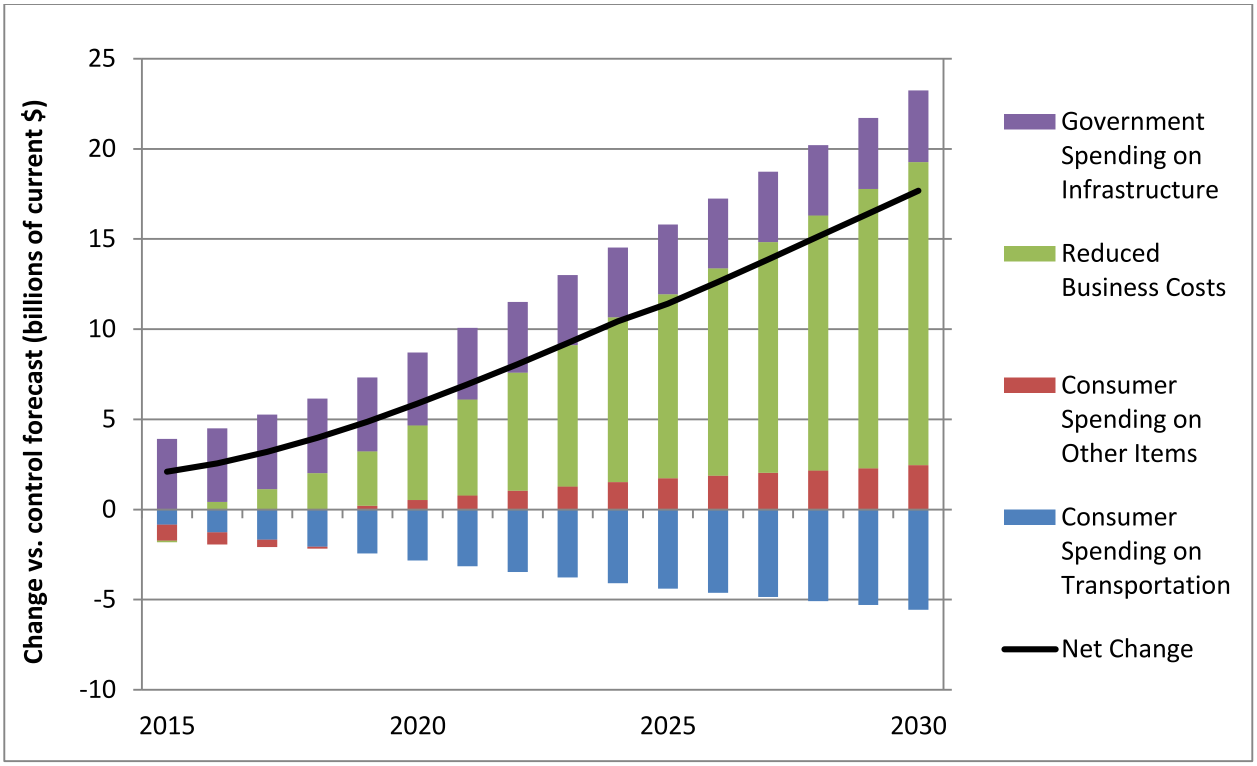
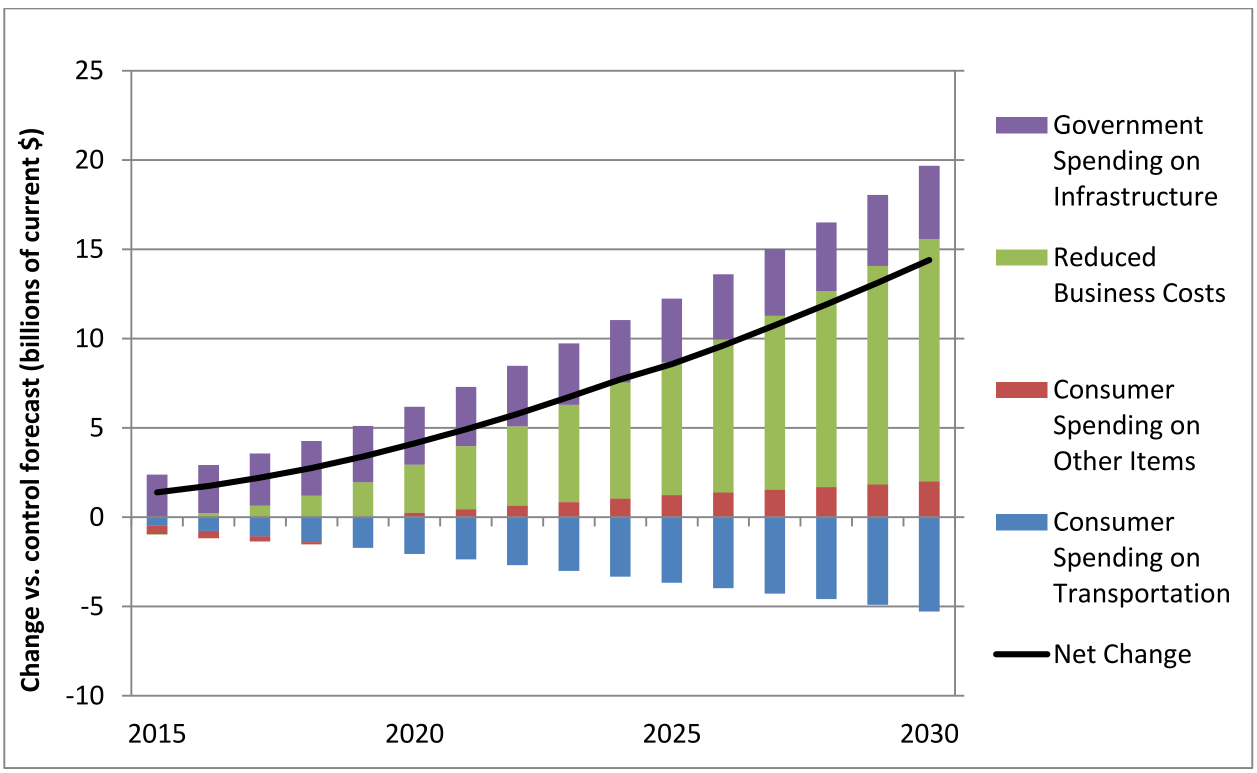


Figure 5.9 Net Effects on Personal Disposable Income (Scenario 1a)



5.5.2 Second Policy Bundle or Scenario 2 (50/50)

Table 5.7 summarizes the results of the Second Policy Bundle, or Scenario 2, economic impact analysis in terms of new jobs, gross regional product, and disposable personal income. The results shown here are for the primary pricing scenario generating $3 billion per year for the TCI region through a carbon fee, VMT fee, or motor fuel tax, with 50 percent reinvestment in GHG mitigation strategies and 50 percent in other transportation strategies. Detailed results by state and year are presented in Tables A.8, A.10, and A.12.

Scenario 2a is without considering any diversion of new revenue to cover all-sector funding losses. The pricing and reinvestment strategies are projected to result in an annual increase in 97,000 jobs, $12 billion in GRP, and over $10 billion in disposable income by 2030. Cumulatively over the next 15 years, about 829,000 jobs (i.e., job-years) would be added to the regional economy, about $95 billion in GRP, and $75 billion in disposable income.

Table 5.7 Economic Benefits of GHG Pricing and Reinvestment Scenario #2a

Industry	2030	2030 Percent of Region	Cumulative, 2015-2030
Change in Regional Employment	97,000	0.24%	829,000
Change in Gross Regional Product ($Billions, 2009)	12.1	0.26%	95
Change in Disposable Personal Income ($Billions, 2009)	10.5	0.20%	75

Scenario 2b considers diversion of new revenue to cover all-sector funding losses. As described previously, state transportation agencies would expect to see some loss in revenue from traditional sources as a result of the VMT reductions and fuel efficiency increases from the proposed GHG reduction strategies. If this revenue were not made up through other sources, states might look to divert some of the new revenue from the pricing policy to fill the gap. This would reduce the funds available for spending on GHG reduction strategies, which would correspondingly reduce the user benefits related to these strategies. Table 5.8 shows the benefits of Scenario 2b. Again, Scenarios 2a and 2b together should be taken as an illustration of the range of benefits that might be achieved through a 50/50 scenario.

Table 5.8 Economic Benefits of GHG Pricing and Reinvestment Scenario #2b

Industry	2030	2030 Percent of Region	Cumulative, 2015-2030
Change in Regional Employment	91,000	0.22%	794,000
Change in Gross Regional Product ($Billions, 2009)	11.7	0.25%	92
Change in Disposable Personal Income ($Billions, 2009)	9.9	0.19%	71

The estimated benefits of Scenario 2 are slightly smaller than Scenario 1 but still significant. They are smaller because the traveler time and cost savings associated with the GHG mitigation strategies would be smaller, and because of the specific assumptions used for the impacts of spending to maintain highway and transit operations, vs. investing in new infrastructure. It should be noted that the estimates are based on somewhat different methodologies and assumptions due to different data sources and the broad-brush (i.e., regionwide) nature of the analysis. The benefits of any specific mix of investments or types of spending may vary greatly depending upon the specific projects selected and their short-term as well as long-term effects. Therefore the analysis findings should not be used to directly compare the benefits of a 50/50 investment scenario with a 100 percent mitigation scenario. Instead, they simply support the observation that spending directed at *productive transportation benefits* (i.e., those that benefit consumers and businesses through time, cost, and savings) have clear net economic benefits to society.

5.5.3 Impacts by State

Tables A.7 through A.12 in Appendix A summarize the impacts on jobs, GRP, and income by state, for 2030 and cumulatively over the 2015-2030 time period. In the underlying analysis, revenues and expenditures by state are assumed to be proportional to the amount of vehicle-miles of travel in each state. State-level economic benefits will be roughly proportional, but will vary depending upon the structure of the state's economy as well as how the actual benefits of each strategy are distributed among states.

6.0 Other Benefits

Investing in transportation options that reduce GHG emissions has the potential to support a variety of other benefits, most of which are not reflected in the economic analysis. The benefits that were quantified in this analysis include:

- Energy independence – A reduction in petroleum fuel use;[45]
- Time savings – For personal or "off-the-clock" travel (the economic benefits reflect savings in business or "on-the-clock" travel);
- Safety – A reduction in fatalities and injuries due to reduced motor vehicle crashes;
- Air pollution – A reduction in a variety of negative health outcomes associated with emissions from motor vehicles (changes in premature deaths and asthma cases are shown here);
- Physical activity – Reduced mortality as a result of greater participation in "active" transportation options including walking and bicycling; and
- Pavement damage – Reduced wear and tear on the region's highways.

While some of these benefits are quantified here in monetary terms (e.g., based on value of statistical life saved or health outcomes), these cost savings were not included in the economic analysis since they may affect the economy in complex ways which were beyond the scope of this analysis to assess. The key assumptions used to quantify these other benefits are described below. (Uncertainties are inherent in these estimates, just as they are in the estimates of GHG reductions and economic benefits.) "Other benefits" results are provided in Appendix C for 12 scenario combinations, including 1x funding with 100% and 50/50 reinvestment and 0% and 10% clean fuels, and 2x funding with 100% reinvestment and 0% and 15% clean fuels.

6.1 Energy Independence

Energy independence benefits are measured in terms of a reduction in petroleum consumption. To calculate this reduction, total fuel and petroleum consumption under the "Federal policies" scenario were first calculated. Energy consumed by motor vehicles –expressed in gallons of gasoline-equivalent (GGE) – was calculated by dividing total vehicle-miles traveled by light duty vehicles, commercial light trucks, and heavy trucks and buses by average fuel efficiency for each of these three vehicle classes as taken from the 2014 AEO Reference Case. Petroleum consumed was then estimated by adjusting total energy consumption by the fraction of energy provided by petroleum in each year (see Section 3.9), accounting for Federal renewable fuel

[45] The *economic* benefits of reduced spending on energy are accounted for in the economic analysis; this section directly presents the energy and petroleum reductions.

(RFS2) standards. For simplicity, all light-duty vehicles were assumed to consume gasoline and all heavy-duty vehicles to consume diesel fuel. Energy and petroleum consumption and their contributing factors under the "Federal policies" scenario are shown in Table 6.1 for 2015, 2022, 2030, and cumulative.

Table 6.1 Energy and Petroleum Consumption – Federal Policies Scenario

Parameter	2015	2022	2030	2015 - 2030
VMT (millions)				
Light duty vehicle	446,023	461,385	478,940	7,399,709
Commercial light truck	35,673	37,377	39,324	599,981
Heavy duty vehicle (truck, bus)	26,884	29,290	32,040	471,389
Fuel Efficiency (mi/gal)				
Light duty vehicle	22.7	26.4	32.6	
Commercial light truck	16.1	18.9	22.5	
Heavy duty vehicle (truck, bus)	6.8	7.4	7.7	
Energy Consumed (million GGE)				
Gasoline + substitutes	21,906	19,454	16,444	307,218
Diesel + substitutes	3,927	3,969	4,168	64,086
Total	25,834	23,423	20,611	371,304
Petroleum Fraction of Energy				
Light duty	91.6%	88.0%	88.0%	
Heavy duty	91.5%	86.1%	86.1%	
Petroleum Consumed (million GGE)				
Gasoline + substitutes	20,076	17,116	14,467	273,410
Diesel + substitutes	3,593	3,417	3,589	56,030
Total	**23,669**	**20,533**	**18,056**	**329,440**

The change in petroleum consumption in each scenario was then calculated from four effects:

- The change in energy consumption (in GGE) from reduced auto and truck VMT; [46]
- The change in energy consumption (in GGE) from improved system operational efficiency;
- The change in energy consumption (in GGE) from increased freight rail ton-miles; and
- The change in fuel carbon intensity due to clean fuels policies.

The calculation involved the following steps:

1. The change in energy from reduced auto and truck VMT was calculated similarly to the baseline estimate – by dividing VMT by fuel efficiency for each vehicle type and year.
2. The change in energy from improved system operational efficiency was calculated from the change in vehicle-hours of delay (Section 5.3.3), using a factor of 0.52 gallons per hour of delay saved from the Texas Transportation Institute 2012 Urban Mobility Report.
3. The change in energy from rail was calculated using a factor of 0.00226 gallons per ton-mile (based on 3.51 ton-miles per million BTU per 2014 AEO and 126,000 BTU/gallon).
4. The change in petroleum consumption for reduced VMT, system efficiency, and new rail was calculated by adjusting the change in energy consumption for the difference in petroleum fractions of the fuel mix (Federal policies vs. analysis scenario) for each year and vehicle/fuel type (light duty/gasoline & substitutes and heavy duty/diesel & substitutes) under the scenario being analyzed.
5. The change in petroleum consumption as a result of additional clean fuels policies was calculated by multiplying total energy consumption by the difference in petroleum fractions in each year for the analysis scenario vs. the Federal policies scenario.

Table 6.2 shows illustrative results for these factors for the 1x funding scenario, 100% reinvestment, and 10% clean fuels policy. Note that the *economic* benefits of reduced energy and petroleum use are included in the economic analysis results shown in Section 5; this table quantifies these benefits in non-economic form.

[46] The increased fuel consumption from expanded transit service is also calculated and included in the estimate of net change in heavy-duty VMT. The impact is small (11 million new transit-miles in 2030 vs. 4 billion truck-miles reduced). This is calculated based on a ratio of a 3% increase in transit VMT per auto VMT reduced as calculated from a sample of nine New Starts projects reviewed by Cambridge Systematics in prior research for FTA.

Table 6.2 Illustrative Energy and Petroleum Savings

Parameter	2015	2022	2030	2015 - 2030
Change in energy (millions of GGE)				
Auto and truck VMT reduction	(167)	(583)	(1,150)	(10,116)
System efficiency	(41)	(191)	(458)	(3,556)
New rail energy	4	45	140	933
Petroleum fraction of energy (GGE basis)				
Light-duty	91.6%	82.8%	80.6%	
Heavy-duty	91.5%	67.5%	59.5%	
Change in petroleum consumption (millions of gallons)				
Auto and truck VMT reduction	(153)	(454)	(808)	(7,602)
System efficiency	(38)	(148)	(322)	(2,649)
New rail energy	3	30	83	586
Clean fuels	-	(1,684)	(2,138)	(24,963)
Total	**(187)**	**(2,256)**	**(3,185)**	**(34,629)**
% change vs. Fed Policies	-0.8%	-11.0%	-17.6%	-10.5%

6.2 Time Savings

The methods for estimating the value of time savings are described in Section 5.3.3. For commercial light and heavy truck VMT, all time savings are assumed to accrue to businesses, and are therefore included in the economic benefits analysis. For passenger travel VMT, 6.3 percent of travel was assumed to be "on-the-clock" and included in the economic analysis. The remaining 93.7 percent of travel was assumed to be "off-the-clock" and is therefore reported under "other benefits" as "personal time savings."

6.3 Safety

For safety benefits, fatality and injury motor vehicle crashes are assumed to be reduced in proportion to VMT reduced. Average rates of 0.013 fatalities and 0.195 injuries per million vehicle-miles are used, based on Fatality Analysis Reporting System (FARS) fatality data from 2000-2009 and injury rates reported by the Bureau of Transportation Statistics (BTS) in National Transportation Statistics (Table 2-17: "Motor Vehicle Safety Data"). These rates were developed by Cambridge Systematics for the Federal Transit Administration and are applied by FTA for use in New Starts and Small Starts project evaluation.[47]

[47] See: Federal Transit Administration, New Starts Environmental Benefits Template, available at http://www.fta.dot.gov/12304.html

6.4 Air Pollution

Reductions in emissions of air pollutants from motor vehicles are also assumed to be proportional to reductions in VMT. Separate emission factors are applied to light-duty and heavy-duty vehicle VMT. These factors also vary by analysis year, reflecting decreasing emissions per-vehicle over time as vehicles meeting more stringent Federal emissions standards are phased in.

Emissions of fine particulate matter ($PM_{2.5}$) are reported, since these are responsible for the large majority of health effects from motor vehicle air pollution.[48,49] Emission factors for light-duty vehicles were developed by Cambridge Systematics for the Federal Transit Administration for use in New Starts and Small Starts project evaluation. Emission factors for heavy-duty vehicles were developed by Cambridge Systematics from MOVES runs conducted for two National Cooperative Highway Research Program (NCHRP) research projects[50] and were interpolated for interim years over this project's study period. These are averages for all heavy-duty vehicle types (weighted by VMT fractions). These estimates should provide a reasonable order of magnitude of emission reductions. More precise estimates could be obtained by running MOVES with TCI-region specific setups (individual states or counties) for all years in the study period. However, doing so was beyond the scope of this analysis. The $PM_{2.5}$ emission factors used are shown in Table 6.3.

[48] EPA (2011). "Final rulemaking to establish greenhouse gas emissions standards and fuel efficiency standards for medium and heavy-duty engines and vehicles - Regulatory impact analysis." Report. Office of Transportation and Air Quality, US EPA and National Highway Traffic Safety Administration, US DOT.

[49] EPA (2012). "Regulatory Impact Analysis: Final Rulemaking for 2017-2025 light-duty vehicle greenhouse gas emission standards and corporate average fuel economy standards". EPA-420-R-12-016. Office of Transportation and Air Quality, US EPA and National Highway Traffic Safety Administration, US DOT.

[50] Cambridge Systematics, Inc., and ERG, Inc. (2015). Web-Only Document 210: Input Guidelines for Motor Vehicle Emissions Simulator Model, prepared for NCHRP Project 25-38; Cambridge Systematics, Inc., Cambridge Environmental, Inc., and Sonoma Technology, Inc. (2012). NCHRP 25-25 Task 70: Assessment of Quantitative Mobile Source Air Toxics in Environmental Documents.

Table 6.3 $PM_{2.5}$ Emission Factors (g/mi)

Calendar Year	Autos and Light Trucks	Heavy Trucks
2015	0.010	0.1766
2016	0.010	0.1687
2017	0.010	0.1608
2018	0.010	0.1529
2019	0.010	0.1450
2020	0.010	0.1371
2021	0.010	0.1292
2022	0.010	0.1212
2023	0.010	0.1133
2024	0.010	0.1054
2025	0.010	0.0975
2026	0.010	0.0896
2027	0.010	0.0817
2028	0.010	0.0738
2029	0.010	0.0659
2030	0.010	0.0580

Changes in key health outcomes – including premature deaths for adults age 30+, cases of chronic bronchitis for adults 26+, emergency room visits for asthma for children, and asthma symptoms/exacerbation – are estimated based on the $PM_{2.5}$ emission reductions. This was done using information from the Regulatory Impact Analyses for the EPA/NHTSA joint rulemaking for Model Year 2017-2025 light-duty vehicle GHG emissions and fuel economy, and for the agencies' joint rulemaking for Model Year 2014-2018 heavy-duty vehicle GHG emissions and fuel economy (U.S. EPA & NHTSA, 2011, 2012). The nationwide air pollution benefits in year 2030 (Table 8-12, EPA & NHTSA 2011; Table 6.3-3, EPA & NHTSA 2012) were divided by the nationwide emission reductions in year 2030 (Table 5-12, EPA & NHTSA 2011; Table 4.3-19, EPA & NHTSA 2012) to obtain a health benefit per unit of emissions reduced. These values are shown in Table 6.4, which shows a complete list of the health outcomes estimated in the EPA/NHTSA documents. Table 6.4 also shows the 5^{th} and 95^{th} percentile of each estimate in addition to the average annual estimate. Selected outcomes, using the average value (shown in boldface), are reported in the summary of this analysis.

These outcomes are based on nationwide rather than TCI region-specific analysis and include powerplant as well as vehicle tailpipe emissions. While they should provide a reasonable order-of-magnitude estimate of the health benefits of motor vehicle emission reductions in the TCI region, region-specific modeling considering the location of emissions, regional meteorology, and population exposure would be required for a more precise estimate. Such modeling was beyond the scope of this analysis.

Table 6.4 Air Pollution Health Impact Factors (per 100 short tons $PM_{2.5}$)

Health Outcome	Auto - Average Annual, 2030	5th %ile	95th %ile	Truck - Average Annual, 2030	5th %ile	95th %ile
Premature mortality cases						
Adult, age 30+, ACS Cohort study (Pope et al., 2002)	9	2	15	6	2	9
Adult, age 25+, Six Cities Study (Laden et al., 2006)	**22**	10	35	**15**	8	21
Infant, age<1 year (Woodruff et al., 1997)	0	0	0	0	0	0
Cases of chronic bronchitis (adult, age 26 and over)	**6**	0	12	**4**	1	7
Non-fatal myocardial infarction (adult, age 18 and over)	10	3	18	11	4	17
Hospital admissions- respiratory (all ages)	2	1	3	1	1	2
Hospital admissions- cardiovascular (adults, age>18)	4	3	5	3	2	4
Emergency room visits for asthma (age <=18)	**6**	3	9	**6**	3	9
Acute bronchitis (children, age 8-12)	13	-3	30	9	0	20
Lower respiratory symptoms (children, age 7-14)	167	61	271	116	54	174
Upper respiratory symptoms (asthmatic children, age 9-18)	128	21	231	87	27	145
Cases of asthma exacerbation (asthmatic children, age 6-18)	**279**	-10	774	**102**	12	290

Source: Cambridge Systematics analysis of EPA/NHTSA (2011,2012)

6.5 Physical Activity

The World Health Organization (WHO) Health Economic Assessment Tool (HEAT) was used to estimate the benefits of increased bicycling and walking.[51] HEAT provides estimates of benefits in terms of reduced mortality and the statistical value of lives saved.

The additional bicycling was estimated using the method described in Section 3.5, which accounts for new bicycling due to investment in bicycle facilities. The additional walking was estimated based on the number of people shifting into more "compact" (higher density) land use areas as described in Section 3.4, as a result of land use/smart growth policies. The estimates are therefore conservative, as additional walk and bike trips may be encouraged as a

[51] http://www.heatwalkingcycling.org/

result of pricing, TDM, and transit investments. These additional "active transportation" trips due to these other strategies are not estimated.[52]

Estimated benefits in the year 2036 from increased walking and cycling were separately calculated using the HEAT tool, based on estimated changes in walking and cycling levels in 2030 as a result of TCI investments, a 15 year build up for uptake of walking and biking (over the project study period as investments are made) and an additional five-year build up until full benefits are achieved (as built into the HEAT tool).

Key assumptions in the HEAT tool include a value of statistical life of $9.2 million, based on the latest U.S. DOT guidance,[53] and a mortality rate of 679 per 100,000 population, based on Massachusetts data.[54]

The assumptions used for calculating the benefits associated with increased walking were based on data on the proportion of total trips that are walk trips by population density, as taken from the 2009 National Household Travel Survey (NHTS) as shown in Table 6.5. In addition, the average person living in the northeast was assumed to take an average of 1,385 total trips per year, as well as walk an average of 14.1 minutes per trip for the proportion of trips attributed to walking, based on the NHTS data. Benefits for increased walking were calculated for a subset of the population assumed to have shifted from low density areas to core and high density urban areas as a result of implemented land use policies – about 1.8 million people in the 1x funding and 100% reinvestment scenario. This population shift increased the total number of walk trips by this subset from 220 million to 579 million trips in 2030, producing a benefit of $3.98 billion in year 2036 when both health benefits and uptake of walking reach maximum levels. The model results for walking are shown in Table 6.6.

[52] Good information is not available as to the extent to which pricing and TDM will increase walking trips vs. reduce VMT through other means (shorter trips, fewer trips, transit, bicycling, etc.) Additional transit use is estimated to add about 8 million walk trips in 2030, which would add incrementally to the walk trips from compact land use shown here.

[53] Memorandum from Peter Rogoff, U.S. Department of Transportation – Office of the Secretary, to Secretarial Officers and Modal Administrators. "Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analysis – 2014 Adjustment." June 13, 2014.

[54] Massachusetts Department of Public Health (2013). MassCHIP: Massachusetts Community Health Information Profile, Mortality Standard Report, http://www.mass.gov/eohhs/researcher/community-health/masschip/mortality-standard-report.html

Table 6.5 Average Percent Walk Trips by Density for the Northeast

Density (census tract, persons per square mile)	Share of walk trips (%)
>10,000	29.5
4,000-10,000	15.3
2,000 – 4,000	10.4
500-2,000	8.7
< 500	7.9

Table 6.6 HEAT Model Key Inputs and Outputs for Increased Walking

Parameter	Value
2030 affected population	1,861,758
Existing 2030 walk trips	219,525,936
New 2030 walk trips	579,316,488
Avoided deaths per year in 2030+	432
Decrease in avg. mortality risk for pop.	3%
Max. benefit realized in 2036 ($millions)	$3,976

For bicycling, the number of new bicycle-miles of travel had to be spread over an assumed affected population for purposes of HEAT inputs. Different assumptions could be made about the baseline and new amount of bicycling (measured in trips or miles per week) and the size of the affected population group. E.g., the new BMT could be spread over a larger population group with fewer new trips per week, or a smaller group with more new trips per week.

A sensitivity analysis was conducted to compare the HEAT benefits estimates under varying assumptions. The baseline number of bicycle trips per week for the affected population was varied from zero to four, with an additional four to six trips per week after the TCI funded investments are made. The "affected population" therefore varies between 1.8 million and 2.8 million. The average nationwide bicycle trip length of 2.3 miles from the 2009 NHTS was used.

Table 6.7 shows the various scenario inputs and outputs for bicycling-related benefits from HEAT. The largest benefits were observed for scenarios 1 and 2, where the average number of bike trips increased from zero to six and four trips per week respectively. To be conservative, we use the smaller benefits found in scenario 5, which results in a still very significant benefit of 394 avoided deaths per year and a maximum annual benefit (value of statistical lives saved) of $3.6 billion in 2036 and beyond once benefits are fully realized.

Table 6.7 HEAT Model Key Inputs and Outputs for Increased Bicycling

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Avg trip length (mi/trip)	2.3	2.3	2.3	2.3	2.3
Bike trips per week:					
Baseline	0	0	2	2	4
Additional	6	4	6	4	6
Affected population in 2030	1,846,075	2,769,113	1,846,075	2,769,113	1,846,075
Decrease in avg. mortality risk for pop.	9%	7%	6%	3%	3%
Avoided deaths per year	1,177	1,221	787	636	394
Max. benefit realized in 2036 ($millions)	$10,832	$11,232	$7,244	$5,851	$3,622

To estimate benefits over the study period (2015 – 2030), the walking and bicycling benefits in 2036 were summed and then discounted proportionately to provide a linearly increasing stream of benefits (starting from zero) over the 2015-2030 study period. The HEAT tool was run with the baseline scenario estimates of 1.8 million people shifted from lower-density to higher-density areas, and 2,608 million new BMT in 2030. To estimate benefits for scenarios with different investment levels (50/50 reinvestment and 2x funding levels), the HEAT outputs were scaled proportionately to the amount of population shift and BMT under each alternative investment scenario.

6.6 Pavement Damage

Pavement damage costs are taken from the Addendum to the 1997 Federal Highway Cost Allocation Study Final Report and the Massachusetts Department of Transportation Freight Plan (2010). The FHWA value of 0.1 cents per mile for light-duty vehicles on urban interstates was applied to the reduction in light-duty VMT. FHWA gives a range of 1.0 to 40 cents per mile for trucks, depending upon size class and axle configuration, but does not provide a weighted average. The value of 18 cents per mile cited in the MassDOT Freight Plan was used as representative of the damage cost from heavy-duty vehicles and was applied to the reduction in truck VMT under each scenario.

Appendix A Economic Modeling Results: Detail

Table A.1 Government Revenue and Expenditures: 100% Reinvestment Scenario (Scenario 1)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Cum.
New Revenues																	
Gross New Revenue from Pricing Policy	$3,539	$3,502	$3,460	$3,418	$3,367	$3,316	$3,263	$3,209	$3,155	$3,099	$3,041	$2,987	$2,938	$2,895	$2,857	$2,824	$50,869
Loss from Reduced TCI Fuel Use (TCI source only)	$32	$45	$58	$71	$84	$95	$105	$115	$124	$133	$141	$147	$153	$160	$167	$173	$1,804
Loss from Reduced TCI Fuel Use (all-sector)	$94	$134	$174	$213	$252	$289	$323	$355	$387	$418	$449	$470	$491	$513	$537	$558	$5,655
Net New Revenue w/internal feedback only	$3,508	$3,457	$3,401	$3,347	$3,284	$3,221	$3,157	$3,094	$3,030	$2,966	$2,900	$2,840	$2,785	$2,735	$2,690	$2,650	$49,064
Net New Revenue w/all-sector feedback	$3,414	$3,323	$3,228	$3,133	$3,032	$2,932	$2,835	$2,739	$2,644	$2,549	$2,450	$2,370	$2,294	$2,222	$2,153	$2,092	$43,409
New Expenditures: Internal Loss Only (1a)																	
Transportation Infrastructure Investment	$2,219	$2,186	$2,151	$2,117	$2,077	$2,037	$1,997	$1,957	$1,917	$1,876	$1,834	$1,796	$1,761	$1,730	$1,701	$1,676	$31,032
Transportation Service Provision	$325	$320	$315	$310	$304	$298	$292	$286	$280	$274	$268	$263	$258	$253	$249	$245	$4,539
Utilities Infrastructure Investment	$140	$138	$136	$134	$131	$129	$126	$124	$121	$119	$116	$114	$111	$109	$108	$106	$1,963
Consumer Incentives	$824	$812	$799	$786	$772	$757	$742	$727	$712	$697	$681	$667	$654	$643	$632	$623	$11,530
Net New Expenditures	$3,508	$3,457	$3,401	$3,347	$3,284	$3,221	$3,157	$3,094	$3,030	$2,966	$2,900	$2,840	$2,785	$2,735	$2,690	$2,650	$49,064
New Expenditures: w/All-Sector Feedback (1b)																	
Transportation Infrastructure Investment	$2,159	$2,102	$2,042	$1,982	$1,918	$1,854	$1,793	$1,732	$1,672	$1,612	$1,550	$1,499	$1,451	$1,405	$1,362	$1,323	$27,456
Transportation Service Provision	$316	$307	$299	$290	$281	$271	$262	$253	$245	$236	$227	$219	$212	$206	$199	$194	$4,016
Utilities Infrastructure Investment	$137	$133	$129	$125	$121	$117	$113	$110	$106	$102	$98	$95	$92	$89	$86	$84	$1,736
Consumer Incentives	$802	$781	$759	$736	$713	$689	$666	$644	$621	$599	$576	$557	$539	$522	$506	$492	$10,201
Net New Expenditures	$3,414	$3,323	$3,228	$3,133	$3,032	$2,932	$2,835	$2,739	$2,644	$2,549	$2,450	$2,370	$2,294	$2,222	$2,153	$2,092	$43,409

Table A.2 Government Revenue and Expenditures: 50/50 Scenario (Scenario 2)

Category	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Cum.
New Revenues																	
Gross New Revenue from Pricing Policy	$3,539	$3,502	$3,460	$3,418	$3,367	$3,316	$3,263	$3,209	$3,155	$3,099	$3,041	$2,987	$2,938	$2,895	$2,857	$2,824	$50,869
Loss from Reduced TCI Fuel Use (TCI source only)	$25	$34	$42	$50	$58	$65	$70	$76	$81	$86	$90	$93	$95	$98	$101	$104	$1,167
Loss from Reduced TCI Fuel Use (all-sector)	$77	$105	$132	$160	$186	$211	$233	$255	$276	$296	$317	$329	$340	$353	$367	$380	$4,018
Net New Revenue w/internal feedback only	$3,514	$3,468	$3,418	$3,368	$3,310	$3,251	$3,192	$3,133	$3,074	$3,014	$2,951	$2,894	$2,843	$2,797	$2,756	$2,720	$49,702
Net New Revenue w/all-sector feedback	$3,436	$3,363	$3,285	$3,208	$3,124	$3,040	$2,959	$2,878	$2,798	$2,717	$2,633	$2,566	$2,503	$2,444	$2,389	$2,340	$45,684
New Expenditures: Internal Loss Only (2a)																	
Transportation Infrastructure Investment	$2,868	$2,831	$2,790	$2,749	$2,701	$2,654	$2,605	$2,557	$2,509	$2,460	$2,408	$2,363	$2,321	$2,283	$2,250	$2,220	$40,569
Transportation Service Provision	$163	$160	$158	$156	$153	$150	$148	$145	$142	$139	$136	$134	$132	$129	$127	$126	$2,299
Utilities Infrastructure Investment	$70	$69	$68	$67	$66	$65	$64	$63	$61	$60	$59	$58	$57	$56	$55	$54	$994
Consumer Incentives	$413	$407	$402	$396	$389	$382	$375	$368	$361	$354	$347	$340	$334	$329	$324	$320	$5,840
Net New Expenditures	$3,514	$3,468	$3,418	$3,368	$3,310	$3,251	$3,192	$3,133	$3,074	$3,014	$2,951	$2,894	$2,843	$2,797	$2,756	$2,720	$49,702
New Expenditures: w/All-Sector Feedback (2b)																	
Transportation Infrastructure Investment	$2,805	$2,745	$2,682	$2,619	$2,550	$2,481	$2,415	$2,349	$2,284	$2,218	$2,149	$2,094	$2,043	$1,995	$1,950	$1,910	$37,289
Transportation Service Provision	$159	$156	$152	$148	$144	$141	$137	$133	$129	$126	$122	$119	$116	$113	$111	$108	$2,113
Utilities Infrastructure Investment	$69	$67	$66	$64	$62	$61	$59	$58	$56	$54	$53	$51	$50	$49	$48	$47	$914
Consumer Incentives	$404	$395	$386	$377	$367	$357	$348	$338	$329	$319	$309	$301	$294	$287	$281	$275	$5,368
Net New Expenditures	$3,436	$3,363	$3,285	$3,208	$3,124	$3,040	$2,959	$2,878	$2,798	$2,717	$2,633	$2,566	$2,503	$2,444	$2,389	$2,340	$45,684

Table A.3 Business Expenditures: 100% Reinvestment Scenario (Scenario 1)

Category	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Cum.
100% Reinvestment Scenario w/Internal Feedback (1a)																	
Time (Productivity)	$(572)	$(868)	$(1,166)	$(1,463)	$(1,760)	$(2,055)	$(2,328)	$(2,600)	$(2,872)	$(3,145)	$(3,420)	$(3,662)	$(3,899)	$(4,140)	$(4,377)	$(4,613)	$(42,940)
Fuel + Electricity	$(65)	$(114)	$(174)	$(239)	$(308)	$(380)	$(450)	$(521)	$(592)	$(659)	$(740)	$(812)	$(876)	$(931)	$(978)	$(1,014)	$(8,853)
Vehicle Purchase	$242	$395	$500	$570	$613	$636	$643	$641	$632	$617	$803	$755	$715	$685	$663	$649	$9,759
Vehicle Maintenance/ Repair	$(29)	$(38)	$(48)	$(57)	$(67)	$(77)	$(85)	$(93)	$(102)	$(110)	$(119)	$(126)	$(132)	$(139)	$(146)	$(153)	$(1,522)
Transportation Services (Shipping)	$(179)	$(355)	$(529)	$(699)	$(867)	$(1,031)	$(1,192)	$(1,350)	$(1,504)	$(1,656)	$(1,804)	$(1,948)	$(2,090)	$(2,230)	$(2,367)	$(2,502)	$(22,304)
Fees, Taxes	$733	$722	$711	$710	$708	$706	$704	$702	$700	$698	$695	$693	$693	$695	$697	$702	$11,269
Net Change	$131	$(259)	$(705)	$(1,179)	$(1,681)	$(2,201)	$(2,708)	$(3,221)	$(3,738)	$(4,255)	$(4,586)	$(5,100)	$(5,589)	$(6,061)	$(6,507)	$(6,932)	$(54,591)
100% Reinvestment Scenario w/All-Sector Feedback (1b)																	
Time (Productivity)	$(557)	$(836)	$(1,114)	$(1,390)	$(1,664)	$(1,935)	$(2,181)	$(2,426)	$(2,669)	$(2,912)	$(3,157)	$(3,367)	$(3,573)	$(3,782)	$(3,986)	$(4,190)	$(39,741)
Fuel + Electricity	$(63)	$(110)	$(166)	$(226)	$(290)	$(354)	$(418)	$(481)	$(543)	$(601)	$(671)	$(732)	$(785)	$(831)	$(868)	$(896)	$(8,033)
Vehicle Purchase	$235	$377	$470	$529	$561	$574	$574	$567	$553	$534	$687	$643	$605	$576	$553	$538	$8,575
Vehicle Maintenance/ Repair	$(28)	$(37)	$(46)	$(55)	$(64)	$(73)	$(80)	$(88)	$(95)	$(103)	$(112)	$(118)	$(124)	$(130)	$(136)	$(142)	$(1,428)
Transportation Services (Shipping)	$(173)	$(341)	$(504)	$(663)	$(816)	$(964)	$(1,108)	$(1,248)	$(1,383)	$(1,514)	$(1,640)	$(1,763)	$(1,884)	$(2,001)	$(2,115)	$(2,227)	$(20,345)
Fees, Taxes	$709	$689	$668	$659	$648	$638	$629	$620	$612	$603	$595	$590	$587	$584	$582	$582	$9,995
Net Change	$123	$(258)	$(691)	$(1,146)	$(1,625)	$(2,114)	$(2,584)	$(3,055)	$(3,526)	$(3,993)	$(4,298)	$(4,748)	$(5,174)	$(5,584)	$(5,970)	$(6,334)	$(50,977)

Table A.4 Business Expenditures: 50/50 Scenario (Scenario 2)

Category	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Cum.
50/50 Scenario w/Internal Feedback (2a)																	
Time (Productivity)	$(500)	$(674)	$(849)	$(1,026)	$(1,203)	$(1,379)	$(1,533)	$(1,688)	$(1,843)	$(2,000)	$(2,161)	$(2,289)	$(2,413)	$(2,541)	$(2,666)	$(2,791)	$(27,557)
Fuel + Electricity	$(46)	$(73)	$(105)	$(140)	$(176)	$(215)	$(251)	$(288)	$(325)	$(361)	$(403)	$(439)	$(471)	$(500)	$(524)	$(542)	$(4,860)
Vehicle Purchase	$121	$198	$251	$287	$309	$321	$325	$325	$321	$313	$408	$385	$365	$350	$340	$333	$4,952
Vehicle Maintenance/ Repair	$(49)	$(56)	$(62)	$(68)	$(75)	$(81)	$(86)	$(91)	$(96)	$(102)	$(107)	$(111)	$(114)	$(117)	$(121)	$(124)	$(1,461)
Transportation Services (Shipping)	$(90)	$(178)	$(265)	$(351)	$(435)	$(518)	$(600)	$(680)	$(758)	$(835)	$(910)	$(984)	$(1,056)	$(1,128)	$(1,198)	$(1,267)	$(11,254)
Fees, Taxes	$734	$725	$714	$715	$714	$713	$712	$711	$710	$709	$707	$707	$708	$710	$715	$720	$11,422
Net Change	$170	$(58)	$(316)	$(583)	$(867)	$(1,159)	$(1,434)	$(1,712)	$(1,992)	$(2,275)	$(2,466)	$(2,731)	$(2,982)	$(3,226)	$(3,454)	$(3,672)	$(28,757)
50/50 Scenario w/All-Sector Feedback (2b)																	
Time (Productivity)	$(492)	$(660)	$(829)	$(997)	$(1,166)	$(1,334)	$(1,479)	$(1,624)	$(1,769)	$(1,917)	$(2,067)	$(2,184)	$(2,298)	$(2,416)	$(2,530)	$(2,644)	$(26,407)
Fuel + Electricity	$(46)	$(71)	$(102)	$(135)	$(170)	$(206)	$(240)	$(274)	$(308)	$(340)	$(379)	$(412)	$(440)	$(466)	$(487)	$(503)	$(4,577)
Vehicle Purchase	$118	$191	$240	$272	$290	$299	$301	$299	$294	$285	$370	$348	$329	$315	$305	$298	$4,555
Vehicle Maintenance/ Repair	$(48)	$(54)	$(60)	$(66)	$(72)	$(78)	$(83)	$(88)	$(92)	$(97)	$(103)	$(106)	$(109)	$(112)	$(115)	$(118)	$(1,403)
Transportation Services (Shipping)	$(87)	$(173)	$(256)	$(337)	$(417)	$(494)	$(569)	$(643)	$(715)	$(785)	$(853)	$(920)	$(985)	$(1,049)	$(1,112)	$(1,174)	$(10,568)
Fees, Taxes	$715	$699	$683	$678	$671	$665	$660	$655	$650	$645	$640	$639	$638	$639	$641	$645	$10,561
Net Change	$159	$(68)	$(323)	$(586)	$(863)	$(1,147)	$(1,410)	$(1,675)	$(1,941)	$(2,209)	$(2,392)	$(2,635)	$(2,865)	$(3,089)	$(3,299)	$(3,497)	$(27,840)

Table A.5 Consumer Expenditures: 100% Reinvestment Scenario (Scenario 1)

Category	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Cum.
100% Reinvestment Scenario w/Internal Feedback (1a)																	
Fuel (Petroleum)	$(622)	$(795)	$(970)	$(1,148)	$(1,326)	$(1,510)	$(1,665)	$(1,819)	$(1,973)	$(2,121)	$(2,258)	$(2,354)	$(2,463)	$(2,561)	$(2,682)	$(2,801)	$(29,068)
Electricity	$5	$10	$16	$22	$28	$35	$42	$50	$59	$68	$79	$91	$105	$119	$135	$151	$1,012
Vehicle Purchase	$376	$371	$368	$365	$363	$361	$361	$356	$353	$351	$351	$355	$364	$381	$412	$393	$5,880
Vehicle Maintenance/ Repair	$(430)	$(569)	$(711)	$(854)	$(998)	$(1,142)	$(1,264)	$(1,388)	$(1,513)	$(1,641)	$(1,774)	$(1,874)	$(1,971)	$(2,074)	$(2,174)	$(2,274)	$(22,653)
Fees/Taxes	$2,775	$2,735	$2,691	$2,636	$2,575	$2,514	$2,453	$2,392	$2,331	$2,269	$2,205	$2,146	$2,092	$2,040	$1,992	$1,948	$37,795
Incentives and Discounts	$(824)	$(812)	$(799)	$(786)	$(772)	$(757)	$(742)	$(727)	$(712)	$(697)	$(681)	$(667)	$(654)	$(643)	$(632)	$(623)	$(11,530)
Consumer Spending - Other Items	$(1,278)	$(939)	$(595)	$(235)	$129	$499	$816	$1,136	$1,456	$1,771	$2,079	$2,303	$2,528	$2,738	$2,948	$3,206	$18,563
100% Reinvestment Scenario w/All-Sector Feedback (1b)																	
Fuel (Petroleum)	$(607)	$(766)	$(928)	$(1,093)	$(1,257)	$(1,428)	$(1,569)	$(1,709)	$(1,849)	$(1,982)	$(2,106)	$(2,189)	$(2,284)	$(2,369)	$(2,472)	$(2,574)	$(27,183)
Electricity	$5	$10	$15	$21	$26	$32	$39	$46	$53	$62	$71	$81	$94	$105	$119	$131	$908
Vehicle Purchase	$363	$354	$346	$339	$332	$326	$322	$315	$308	$304	$300	$302	$308	$320	$344	$326	$5,210
Vehicle Maintenance/ Repair	$(420)	$(549)	$(680)	$(813)	$(947)	$(1,081)	$(1,193)	$(1,306)	$(1,421)	$(1,539)	$(1,662)	$(1,751)	$(1,838)	$(1,930)	$(2,020)	$(2,109)	$(21,259)
Fees/Taxes	$2,685	$2,609	$2,531	$2,445	$2,357	$2,272	$2,191	$2,113	$2,037	$1,963	$1,888	$1,827	$1,770	$1,715	$1,663	$1,616	$33,681
Incentives and Discounts	$(798)	$(775)	$(752)	$(730)	$(706)	$(684)	$(663)	$(642)	$(622)	$(603)	$(583)	$(568)	$(554)	$(540)	$(528)	$(517)	$(10,264)
Consumer Spending - Other Items	$(1,229)	$(883)	$(532)	$(169)	$196	$563	$873	$1,185	$1,493	$1,796	$2,092	$2,299	$2,504	$2,699	$2,894	$3,127	$18,907

Table A.6 Consumer Expenditures: 50/50 Scenario (Scenario 2)

Category	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Cum.
50/50 Scenario w/Internal Feedback (2a)																	
Fuel (Petroleum)	$(522)	$(633)	$(748)	$(867)	$(986)	$(1,110)	$(1,205)	$(1,299)	$(1,394)	$(1,484)	$(1,569)	$(1,614)	$(1,666)	$(1,713)	$(1,772)	$(1,830)	$(20,413)
Electricity	$2	$5	$8	$11	$14	$17	$21	$25	$30	$34	$40	$46	$53	$60	$69	$77	$512
Vehicle Purchase	$188	$186	$185	$184	$183	$182	$182	$180	$179	$178	$178	$181	$186	$195	$211	$201	$2,981
Vehicle Maintenance/ Repair	$(561)	$(655)	$(751)	$(848)	$(946)	$(1,043)	$(1,119)	$(1,195)	$(1,273)	$(1,354)	$(1,439)	$(1,491)	$(1,541)	$(1,596)	$(1,648)	$(1,701)	$(19,161)
Fees/Taxes	$2,780	$2,743	$2,704	$2,653	$2,596	$2,538	$2,480	$2,422	$2,364	$2,305	$2,244	$2,188	$2,135	$2,087	$2,042	$2,000	$38,280
Incentives and Discounts	$(413)	$(407)	$(402)	$(396)	$(389)	$(382)	$(375)	$(368)	$(361)	$(354)	$(347)	$(340)	$(334)	$(329)	$(324)	$(320)	$(5,840)
Consumer Spending - Other Items	$(1,475)	$(1,240)	$(996)	$(737)	$(472)	$(202)	$15	$235	$456	$675	$894	$1,031	$1,167	$1,296	$1,422	$1,573	$3,641
50/50 Scenario w/External Feedback (2b)																	
Fuel (Petroleum)	$(517)	$(623)	$(734)	$(848)	$(963)	$(1,082)	$(1,172)	$(1,262)	$(1,351)	$(1,437)	$(1,518)	$(1,558)	$(1,605)	$(1,647)	$(1,701)	$(1,754)	$(19,772)
Electricity	$2	$5	$8	$10	$13	$17	$20	$24	$28	$32	$37	$43	$49	$55	$63	$70	$476
Vehicle Purchase	$183	$180	$177	$174	$172	$170	$169	$166	$164	$162	$162	$163	$168	$175	$189	$180	$2,754
Vehicle Maintenance/ Repair	$(552)	$(641)	$(732)	$(824)	$(917)	$(1,010)	$(1,081)	$(1,154)	$(1,227)	$(1,304)	$(1,385)	$(1,434)	$(1,480)	$(1,531)	$(1,580)	$(1,629)	$(18,481)
Fees/Taxes	$2,707	$2,647	$2,585	$2,515	$2,440	$2,368	$2,298	$2,231	$2,164	$2,099	$2,032	$1,977	$1,926	$1,877	$1,831	$1,789	$35,485
Incentives and Discounts	$(402)	$(393)	$(384)	$(375)	$(366)	$(356)	$(348)	$(339)	$(331)	$(322)	$(314)	$(307)	$(301)	$(296)	$(290)	$(286)	$(5,410)
Consumer Spending - Other Items	$(1,422)	$(1,175)	$(920)	$(652)	$(380)	$(106)	$113	$334	$553	$771	$987	$1,116	$1,244	$1,367	$1,487	$1,628	$4,947

Table A.7 Change in Jobs by State (1,000's): 100% Reinvestment Scenario (Scenario 1)

Region	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Cum.
With Internal Feedback (1a)																	
Connecticut	2.65	2.90	3.24	3.63	4.06	4.53	5.00	5.49	5.98	6.46	6.78	7.23	7.67	8.11	8.51	8.90	91.2
Delaware	1.38	1.45	1.54	1.62	1.72	1.82	1.93	2.04	2.16	2.28	2.35	2.47	2.58	2.70	2.81	2.91	33.8
Maine	0.84	0.95	1.10	1.29	1.50	1.74	1.98	2.23	2.48	2.73	2.90	3.13	3.36	3.58	3.80	4.01	37.6
D.C. & Maryland	2.37	2.72	3.23	3.84	4.52	5.25	6.00	6.76	7.52	8.27	8.75	9.44	10.12	10.78	11.40	11.99	113.0
Massachusetts	2.46	2.99	3.72	4.57	5.50	6.49	7.48	8.47	9.46	10.44	11.07	11.94	12.81	13.66	14.46	15.22	140.7
New Hampshire	1.17	1.29	1.46	1.66	1.87	2.10	2.33	2.56	2.80	3.03	3.18	3.39	3.60	3.81	4.00	4.19	42.4
New Jersey	4.01	4.57	5.38	6.33	7.40	8.54	9.72	10.91	12.10	13.30	14.10	15.20	16.30	17.36	18.36	19.32	182.9
New York	1.92	3.10	4.71	6.62	8.71	10.94	13.19	15.45	17.70	19.94	21.42	23.48	25.48	27.42	29.25	31.00	260.3
Pennsylvania	5.32	5.91	6.79	7.88	9.11	10.46	11.87	13.31	14.77	16.22	17.20	18.54	19.88	21.19	22.44	23.62	224.5
Rhode Island	0.59	0.66	0.76	0.88	1.01	1.14	1.28	1.43	1.57	1.71	1.81	1.94	2.07	2.19	2.31	2.43	23.8
Vermont	0.37	0.42	0.49	0.58	0.68	0.79	0.90	1.02	1.14	1.25	1.33	1.44	1.55	1.66	1.76	1.85	17.2
Total	**23.1**	**27.0**	**32.4**	**38.9**	**46.1**	**53.8**	**61.7**	**69.7**	**77.7**	**85.6**	**90.9**	**98.2**	**105**	**112**	**119**	**125**	**1167.4**
With External Feedback (1b)																	
Connecticut	2.58	2.81	3.12	3.48	3.88	4.31	4.76	5.20	5.65	6.09	6.38	6.79	7.19	7.58	7.94	8.29	86.04
Delaware	1.34	1.41	1.48	1.56	1.64	1.74	1.83	1.93	2.04	2.14	2.22	2.32	2.42	2.52	2.62	2.71	31.92
Maine	0.82	0.92	1.06	1.24	1.44	1.66	1.88	2.12	2.35	2.57	2.73	2.94	3.14	3.35	3.54	3.73	35.47
D.C. & Maryland	2.31	2.63	3.11	3.68	4.32	5.01	5.71	6.41	7.11	7.79	8.24	8.86	9.48	10.07	10.63	11.16	106.50
Massachusetts	2.40	2.89	3.58	4.38	5.26	6.18	7.11	8.03	8.94	9.84	10.41	11.21	12.00	12.76	13.48	14.17	132.65
New Hampshire	1.14	1.25	1.41	1.59	1.79	2.00	2.21	2.43	2.64	2.85	2.99	3.18	3.37	3.56	3.73	3.90	40.04
New Jersey	3.90	4.42	5.18	6.07	7.07	8.14	9.23	10.34	11.44	12.53	13.26	14.27	15.26	16.22	17.12	17.98	172.45
New York	1.87	2.99	4.53	6.34	8.33	10.43	12.53	14.64	16.73	18.79	20.16	22.04	23.87	25.63	27.27	28.86	245.02
Pennsylvania	5.18	5.71	6.54	7.55	8.70	9.96	11.28	12.61	13.96	15.29	16.18	17.40	18.62	19.81	20.92	21.99	211.71
Rhode Island	0.57	0.64	0.73	0.84	0.96	1.09	1.22	1.35	1.48	1.61	1.70	1.82	1.94	2.05	2.16	2.26	22.42
Vermont	0.36	0.40	0.47	0.55	0.65	0.75	0.86	0.97	1.07	1.18	1.26	1.35	1.45	1.55	1.64	1.73	16.24
Total	**22.5**	**26.1**	**31.2**	**37.3**	**44.0**	**51.3**	**58.6**	**66.0**	**73.4**	**80.7**	**85.5**	**92.2**	**98.7**	**105.1**	**111.1**	**116.8**	**1100.5**

Table A.8 Change in Jobs by State (1,000's): 50/50 Scenario (Scenario 2)

Region	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Cum.
With Internal Feedback (2a)																	
Connecticut	2.11	2.19	2.39	2.64	2.93	3.25	3.57	3.90	4.23	4.57	4.79	5.09	5.39	5.68	5.95	6.21	64.91
Delaware	1.10	1.10	1.13	1.18	1.24	1.31	1.38	1.45	1.53	1.61	1.66	1.74	1.81	1.89	1.96	2.03	24.12
Maine	0.67	0.72	0.81	0.94	1.08	1.25	1.42	1.59	1.76	1.93	2.05	2.20	2.36	2.51	2.66	2.79	26.73
D.C. & Maryland	1.88	2.05	2.38	2.79	3.26	3.77	4.29	4.81	5.33	5.84	6.19	6.65	7.11	7.55	7.97	8.36	80.24
Massachusetts	1.96	2.26	2.74	3.32	3.97	4.66	5.34	6.02	6.70	7.38	7.82	8.42	9.00	9.57	10.11	10.62	99.88
New Hampshire	0.93	0.98	1.08	1.20	1.35	1.51	1.66	1.82	1.98	2.14	2.25	2.39	2.53	2.67	2.80	2.92	30.20
New Jersey	3.19	3.45	3.96	4.61	5.33	6.14	6.94	7.75	8.58	9.40	9.96	10.71	11.45	12.16	12.84	13.48	129.94
New York	1.53	2.34	3.47	4.81	6.28	7.86	9.41	10.98	12.54	14.09	15.14	16.54	17.90	19.22	20.45	21.63	184.20
Pennsylvania	4.23	4.46	5.01	5.73	6.57	7.51	8.47	9.46	10.46	11.46	12.16	13.06	13.97	14.85	15.69	16.48	159.57
Rhode Island	0.47	0.50	0.56	0.64	0.73	0.82	0.92	1.01	1.11	1.21	1.28	1.36	1.45	1.54	1.62	1.69	16.90
Vermont	0.29	0.32	0.36	0.42	0.49	0.56	0.64	0.72	0.81	0.89	0.94	1.02	1.09	1.16	1.23	1.29	12.23
Total	**18.3**	**20.4**	**23.9**	**28.3**	**33.2**	**38.6**	**44.0**	**49.5**	**55.0**	**60.5**	**64.2**	**69.2**	**74.1**	**78.8**	**83.3**	**87.5**	**828.9**
With External Feedback (2b)																	
Connecticut	2.08	2.15	2.33	2.57	2.84	3.14	3.44	3.75	4.06	4.37	4.58	4.86	5.13	5.40	5.65	5.89	62.25
Delaware	1.08	1.08	1.11	1.15	1.20	1.26	1.33	1.39	1.47	1.54	1.59	1.66	1.73	1.80	1.86	1.93	23.17
Maine	0.66	0.70	0.79	0.91	1.05	1.21	1.37	1.53	1.69	1.85	1.96	2.10	2.25	2.39	2.52	2.65	25.61
D.C. & Maryland	1.86	2.01	2.32	2.72	3.16	3.65	4.13	4.62	5.11	5.59	5.91	6.34	6.77	7.18	7.56	7.93	76.87
Massachusetts	1.93	2.22	2.68	3.23	3.85	4.50	5.15	5.79	6.43	7.06	7.47	8.03	8.57	9.10	9.59	10.06	95.66
New Hampshire	0.91	0.96	1.05	1.17	1.31	1.46	1.60	1.75	1.90	2.05	2.15	2.28	2.41	2.54	2.66	2.77	28.96
New Jersey	3.14	3.38	3.87	4.48	5.17	5.93	6.69	7.46	8.23	9.00	9.52	10.22	10.90	11.56	12.18	12.77	124.50
New York	1.51	2.29	3.39	4.68	6.09	7.60	9.08	10.56	12.03	13.49	14.47	15.78	17.05	18.27	19.40	20.50	176.17
Pennsylvania	4.16	4.38	4.89	5.57	6.37	7.26	8.17	9.10	10.04	10.97	11.61	12.46	13.30	14.12	14.89	15.61	152.90
Rhode Island	0.46	0.49	0.55	0.62	0.70	0.79	0.88	0.98	1.07	1.16	1.22	1.30	1.38	1.46	1.53	1.60	16.20
Vermont	0.29	0.31	0.35	0.41	0.47	0.55	0.62	0.70	0.77	0.85	0.90	0.97	1.04	1.10	1.17	1.23	11.72
Total	**18.1**	**20.0**	**23.3**	**27.5**	**32.2**	**37.3**	**42.5**	**47.6**	**52.8**	**57.9**	**61.4**	**66.0**	**70.5**	**74.9**	**79.0**	**82.9**	**794.0**

Table A.9 Change in Gross Regional Product by State (billions of 2009$): 100% Reinvestment Scenario

Region	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Cum.
With Internal Feedback (1a)																	
Connecticut	0.23	0.26	0.30	0.35	0.41	0.47	0.54	0.61	0.68	0.76	0.82	0.90	0.98	1.07	1.15	1.23	10.76
Delaware	0.10	0.11	0.12	0.13	0.14	0.16	0.17	0.18	0.20	0.22	0.23	0.25	0.27	0.29	0.31	0.33	3.22
Maine	0.05	0.06	0.07	0.09	0.11	0.13	0.15	0.18	0.21	0.23	0.26	0.28	0.31	0.34	0.37	0.40	3.26
D.C. & Maryland	0.21	0.25	0.31	0.38	0.46	0.55	0.64	0.74	0.84	0.95	1.03	1.14	1.25	1.36	1.47	1.58	13.13
Massachusetts	0.24	0.30	0.39	0.50	0.62	0.75	0.89	1.04	1.19	1.35	1.48	1.64	1.80	1.96	2.13	2.29	18.58
New Hampshire	0.08	0.09	0.11	0.13	0.15	0.17	0.20	0.23	0.26	0.29	0.32	0.35	0.38	0.41	0.45	0.48	4.09
New Jersey	0.38	0.44	0.54	0.65	0.78	0.93	1.08	1.25	1.42	1.60	1.75	1.93	2.11	2.30	2.49	2.68	22.33
New York	0.28	0.43	0.64	0.89	1.17	1.48	1.81	2.15	2.50	2.87	3.15	3.52	3.89	4.26	4.63	5.01	38.68
Pennsylvania	0.45	0.52	0.62	0.74	0.89	1.06	1.25	1.45	1.65	1.87	2.04	2.26	2.48	2.71	2.94	3.17	26.11
Rhode Island	0.05	0.06	0.07	0.08	0.09	0.11	0.13	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	2.55
Vermont	0.03	0.03	0.04	0.04	0.05	0.06	0.08	0.09	0.10	0.12	0.13	0.14	0.16	0.17	0.18	0.20	1.61
Total	**2.10**	**2.56**	**3.19**	**3.97**	**4.87**	**5.87**	**6.93**	**8.05**	**9.23**	**10.44**	**11.41**	**12.62**	**13.87**	**15.13**	**16.40**	**17.67**	**144.33**
With External Feedback (1b)																	
Connecticut	0.22	0.25	0.29	0.34	0.39	0.45	0.51	0.58	0.65	0.72	0.78	0.85	0.93	1.00	1.08	1.15	10.18
Delaware	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.18	0.19	0.21	0.22	0.24	0.25	0.27	0.29	0.31	3.05
Maine	0.05	0.06	0.07	0.09	0.10	0.12	0.15	0.17	0.20	0.22	0.24	0.27	0.29	0.32	0.35	0.38	3.08
D.C. & Maryland	0.21	0.24	0.30	0.36	0.44	0.52	0.61	0.70	0.80	0.90	0.97	1.07	1.17	1.27	1.37	1.47	12.42
Massachusetts	0.23	0.29	0.38	0.48	0.59	0.72	0.85	0.99	1.13	1.28	1.40	1.54	1.69	1.84	1.99	2.14	17.57
New Hampshire	0.08	0.09	0.10	0.12	0.14	0.17	0.19	0.22	0.25	0.28	0.30	0.33	0.36	0.39	0.42	0.45	3.87
New Jersey	0.37	0.43	0.52	0.62	0.75	0.89	1.03	1.19	1.35	1.52	1.65	1.82	1.99	2.16	2.34	2.51	21.12
New York	0.28	0.42	0.62	0.85	1.12	1.42	1.72	2.04	2.37	2.72	2.98	3.32	3.66	4.00	4.34	4.68	36.54
Pennsylvania	0.44	0.50	0.59	0.72	0.86	1.02	1.19	1.37	1.57	1.77	1.93	2.13	2.34	2.55	2.76	2.97	24.69
Rhode Island	0.05	0.06	0.06	0.08	0.09	0.10	0.12	0.14	0.15	0.17	0.19	0.20	0.22	0.24	0.26	0.28	2.41
Vermont	0.03	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.10	0.11	0.12	0.13	0.15	0.16	0.17	0.19	1.52
Total	**2.05**	**2.48**	**3.08**	**3.82**	**4.67**	**5.62**	**6.61**	**7.66**	**8.76**	**9.89**	**10.79**	**11.90**	**13.05**	**14.21**	**15.37**	**16.53**	**136.5**

Table A.10 Change in Gross Regional Product by State (billions of 2009$): 50/50 Scenario

Region	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Cum.
With Internal Feedback (2a)																	
Connecticut	0.25	0.24	0.25	0.26	0.28	0.32	0.35	0.39	0.44	0.49	0.53	0.57	0.63	0.68	0.73	0.78	7.18
Delaware	0.11	0.10	0.10	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.20	0.21	2.18
Maine	0.06	0.06	0.06	0.07	0.08	0.09	0.10	0.12	0.13	0.15	0.16	0.18	0.20	0.22	0.24	0.26	2.15
D.C. & Maryland	0.23	0.23	0.25	0.28	0.32	0.37	0.42	0.48	0.54	0.61	0.66	0.72	0.79	0.86	0.93	1.00	8.70
Massachusetts	0.26	0.28	0.32	0.37	0.43	0.51	0.59	0.68	0.77	0.87	0.94	1.04	1.14	1.25	1.35	1.45	12.25
New Hampshire	0.09	0.08	0.09	0.09	0.10	0.12	0.13	0.15	0.17	0.19	0.20	0.22	0.24	0.26	0.28	0.30	2.73
New Jersey	0.41	0.41	0.44	0.49	0.55	0.63	0.71	0.81	0.91	1.02	1.11	1.23	1.34	1.46	1.58	1.70	14.81
New York	0.31	0.40	0.52	0.66	0.82	1.00	1.19	1.39	1.61	1.83	2.01	2.24	2.47	2.71	2.94	3.17	25.29
Pennsylvania	0.48	0.48	0.51	0.56	0.63	0.72	0.82	0.94	1.06	1.19	1.30	1.44	1.58	1.72	1.87	2.01	17.31
Rhode Island	0.05	0.05	0.05	0.06	0.07	0.07	0.08	0.09	0.10	0.12	0.13	0.14	0.15	0.16	0.18	0.19	1.70
Vermont	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.07	0.07	0.08	0.09	0.10	0.11	0.12	0.13	1.07
Total	**2.27**	**2.37**	**2.62**	**2.97**	**3.42**	**3.97**	**4.57**	**5.23**	**5.93**	**6.67**	**7.27**	**8.04**	**8.82**	**9.61**	**10.41**	**11.19**	**95.38**
With External Feedback (2b)																	
Connecticut	0.18	0.19	0.21	0.24	0.27	0.31	0.35	0.39	0.44	0.48	0.52	0.57	0.62	0.66	0.71	0.76	6.89
Delaware	0.08	0.08	0.08	0.09	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20	2.07
Maine	0.04	0.04	0.05	0.06	0.07	0.09	0.10	0.12	0.13	0.15	0.16	0.18	0.20	0.21	0.23	0.25	2.08
D.C. & Maryland	0.16	0.18	0.21	0.26	0.30	0.36	0.42	0.48	0.54	0.60	0.65	0.72	0.78	0.84	0.91	0.97	8.38
Massachusetts	0.19	0.22	0.27	0.34	0.41	0.50	0.58	0.67	0.76	0.86	0.94	1.03	1.12	1.22	1.32	1.41	11.84
New Hampshire	0.06	0.07	0.07	0.09	0.10	0.11	0.13	0.15	0.17	0.19	0.20	0.22	0.24	0.26	0.28	0.30	2.62
New Jersey	0.29	0.32	0.37	0.44	0.52	0.61	0.71	0.80	0.91	1.02	1.11	1.21	1.32	1.43	1.54	1.65	14.26
New York	0.22	0.31	0.44	0.60	0.78	0.98	1.18	1.38	1.60	1.82	2.00	2.21	2.43	2.65	2.86	3.08	24.56
Pennsylvania	0.35	0.37	0.43	0.50	0.60	0.70	0.81	0.93	1.06	1.19	1.30	1.42	1.55	1.69	1.82	1.95	16.67
Rhode Island	0.04	0.04	0.05	0.05	0.06	0.07	0.08	0.09	0.10	0.12	0.13	0.14	0.15	0.16	0.17	0.18	1.63
Vermont	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.06	0.07	0.07	0.08	0.09	0.10	0.11	0.11	0.12	1.03
Total	**1.63**	**1.85**	**2.22**	**2.70**	**3.25**	**3.87**	**4.52**	**5.19**	**5.90**	**6.64**	**7.23**	**7.94**	**8.67**	**9.41**	**10.14**	**10.87**	**92.03**

Table A.11 Change in Personal Disposable Income by State (billions of 2009$): 100% Reinvest. Scenario

Region	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Cum.
With Internal Feedback (1a)																	
Connecticut	0.15	0.18	0.21	0.25	0.29	0.34	0.40	0.46	0.52	0.59	0.65	0.72	0.80	0.88	0.96	1.05	8.43
Delaware	0.06	0.07	0.08	0.09	0.10	0.11	0.13	0.14	0.15	0.17	0.18	0.20	0.22	0.24	0.26	0.28	2.48
Maine	0.04	0.05	0.06	0.07	0.08	0.10	0.12	0.14	0.16	0.18	0.21	0.23	0.26	0.29	0.32	0.35	2.64
D.C. & Maryland	0.14	0.18	0.23	0.29	0.37	0.45	0.54	0.63	0.73	0.84	0.93	1.04	1.17	1.29	1.42	1.56	11.81
Massachusetts	0.16	0.20	0.26	0.33	0.41	0.50	0.59	0.70	0.81	0.93	1.03	1.16	1.29	1.43	1.58	1.73	13.10
New Hampshire	0.06	0.07	0.09	0.11	0.13	0.15	0.17	0.20	0.23	0.26	0.29	0.32	0.35	0.39	0.43	0.47	3.70
New Jersey	0.27	0.33	0.41	0.50	0.61	0.74	0.88	1.03	1.19	1.37	1.52	1.71	1.91	2.11	2.33	2.55	19.46
New York	0.18	0.26	0.37	0.50	0.67	0.85	1.05	1.27	1.51	1.76	1.98	2.24	2.52	2.82	3.12	3.44	24.54
Pennsylvania	0.31	0.37	0.44	0.54	0.64	0.76	0.90	1.04	1.20	1.37	1.53	1.71	1.90	2.11	2.32	2.54	19.69
Rhode Island	0.03	0.04	0.05	0.06	0.07	0.08	0.10	0.11	0.13	0.14	0.16	0.18	0.20	0.22	0.24	0.26	2.05
Vermont	0.02	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.13	0.14	0.16	0.17	1.31
Total	**1.40**	**1.75**	**2.21**	**2.76**	**3.41**	**4.13**	**4.93**	**5.79**	**6.72**	**7.71**	**8.57**	**9.62**	**10.74**	**11.91**	**13.13**	**14.40**	**109.2**
With External Feedback (1b)																	
Connecticut	0.14	0.17	0.20	0.24	0.28	0.33	0.38	0.43	0.49	0.56	0.61	0.68	0.75	0.82	0.90	0.98	7.96
Delaware	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.15	0.16	0.17	0.19	0.21	0.22	0.24	0.26	2.34
Maine	0.04	0.04	0.05	0.07	0.08	0.09	0.11	0.13	0.15	0.17	0.19	0.22	0.24	0.27	0.30	0.33	2.49
D.C. & Maryland	0.13	0.17	0.22	0.28	0.35	0.43	0.51	0.60	0.69	0.79	0.88	0.98	1.09	1.21	1.33	1.45	11.13
Massachusetts	0.15	0.19	0.25	0.31	0.39	0.47	0.56	0.66	0.77	0.88	0.98	1.09	1.21	1.34	1.47	1.61	12.35
New Hampshire	0.06	0.07	0.08	0.10	0.12	0.14	0.17	0.19	0.22	0.25	0.27	0.30	0.33	0.37	0.40	0.44	3.49
New Jersey	0.26	0.32	0.39	0.48	0.59	0.71	0.84	0.98	1.13	1.29	1.44	1.61	1.79	1.98	2.18	2.38	18.36
New York	0.17	0.25	0.35	0.48	0.64	0.81	1.00	1.21	1.43	1.66	1.87	2.11	2.37	2.64	2.92	3.21	23.12
Pennsylvania	0.30	0.36	0.43	0.51	0.61	0.73	0.85	0.99	1.14	1.30	1.44	1.61	1.78	1.97	2.17	2.37	18.57
Rhode Island	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.12	0.14	0.15	0.17	0.18	0.20	0.22	0.24	1.93
Vermont	0.02	0.02	0.03	0.03	0.04	0.05	0.06	0.06	0.08	0.09	0.10	0.11	0.12	0.13	0.15	0.16	1.23
Total	**1.36**	**1.70**	**2.13**	**2.65**	**3.26**	**3.94**	**4.69**	**5.50**	**6.37**	**7.29**	**8.09**	**9.05**	**10.08**	**11.16**	**12.28**	**13.44**	**103.0**

Table A.12 Change in Personal Disposable Income by State (billions of 2009$): 50/50 Scenario

Region	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Cum.
With Internal Feedback (2a)																	
Connecticut	0.13	0.14	0.16	0.18	0.21	0.24	0.28	0.32	0.36	0.40	0.44	0.49	0.53	0.58	0.64	0.69	5.79
Delaware	0.05	0.06	0.06	0.07	0.07	0.08	0.09	0.10	0.11	0.12	0.12	0.13	0.15	0.16	0.17	0.18	1.71
Maine	0.03	0.04	0.04	0.05	0.06	0.07	0.08	0.10	0.11	0.13	0.14	0.16	0.17	0.19	0.21	0.23	1.81
D.C. & Maryland	0.12	0.14	0.18	0.22	0.26	0.32	0.38	0.44	0.50	0.57	0.63	0.70	0.78	0.86	0.94	1.03	8.06
Massachusetts	0.13	0.16	0.20	0.24	0.29	0.35	0.42	0.48	0.56	0.63	0.70	0.78	0.87	0.95	1.05	1.14	8.95
New Hampshire	0.05	0.06	0.07	0.08	0.09	0.11	0.12	0.14	0.16	0.18	0.19	0.21	0.24	0.26	0.28	0.31	2.54
New Jersey	0.23	0.26	0.31	0.37	0.44	0.53	0.62	0.71	0.82	0.93	1.03	1.15	1.28	1.41	1.54	1.69	13.31
New York	0.15	0.21	0.28	0.37	0.48	0.60	0.74	0.88	1.03	1.20	1.34	1.51	1.69	1.88	2.07	2.27	16.69
Pennsylvania	0.26	0.29	0.34	0.40	0.46	0.54	0.63	0.72	0.83	0.93	1.03	1.15	1.27	1.40	1.54	1.68	13.48
Rhode Island	0.03	0.03	0.04	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.16	0.17	1.40
Vermont	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.07	0.08	0.09	0.09	0.10	0.11	0.89
Total	**1.19**	**1.39**	**1.68**	**2.04**	**2.46**	**2.94**	**3.45**	**4.01**	**4.61**	**5.25**	**5.81**	**6.48**	**7.19**	**7.93**	**8.70**	**9.50**	**74.6**
With External Feedback (2b)																	
Connecticut	0.12	0.14	0.15	0.18	0.20	0.23	0.27	0.30	0.34	0.38	0.42	0.46	0.51	0.55	0.60	0.65	5.53
Delaware	0.05	0.05	0.06	0.06	0.07	0.08	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	1.63
Maine	0.03	0.04	0.04	0.05	0.06	0.07	0.08	0.09	0.11	0.12	0.13	0.15	0.16	0.18	0.20	0.22	1.73
D.C. & Maryland	0.11	0.14	0.17	0.21	0.26	0.31	0.36	0.42	0.48	0.55	0.60	0.67	0.74	0.82	0.89	0.97	7.70
Massachusetts	0.13	0.16	0.19	0.23	0.28	0.34	0.40	0.46	0.53	0.61	0.67	0.74	0.82	0.91	0.99	1.08	8.54
New Hampshire	0.05	0.06	0.06	0.08	0.09	0.10	0.12	0.13	0.15	0.17	0.19	0.20	0.22	0.25	0.27	0.29	2.42
New Jersey	0.22	0.25	0.30	0.36	0.43	0.51	0.59	0.68	0.78	0.89	0.98	1.10	1.21	1.34	1.46	1.60	12.71
New York	0.15	0.20	0.27	0.36	0.46	0.58	0.71	0.84	0.99	1.14	1.28	1.44	1.61	1.78	1.96	2.15	15.93
Pennsylvania	0.26	0.29	0.33	0.38	0.45	0.52	0.60	0.69	0.79	0.89	0.99	1.09	1.21	1.33	1.46	1.59	12.88
Rhode Island	0.03	0.03	0.04	0.04	0.05	0.06	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.14	0.15	0.16	1.34
Vermont	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.07	0.07	0.08	0.09	0.10	0.11	0.85
Total	**1.16**	**1.36**	**1.64**	**1.98**	**2.37**	**2.83**	**3.32**	**3.84**	**4.41**	**5.01**	**5.55**	**6.17**	**6.84**	**7.53**	**8.25**	**9.00**	**71.3**

Appendix B Emission Reductions Relative to Different Baseline Years

Table B.1 Emission Reductions Relative to Year X Baseline

Scenario	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Total TCI Emissions, mmt											
TCI Transportation Sector Emissions from SEDS	275.0	272.9	273.2	274.3	277.8	281.6	286.3	292.1	296.9	302.3	310.8
Surface Transportation Emissions	233.2	231.5	231.8	232.7	235.7	238.9	242.9	247.8	251.9	256.4	263.6
GHG Emissions Change in 2030 Relative to Baseline in Year X											
With Pricing Effects											
Baseline (pre-MY2025 standards)	103.9%	104.6%	104.5%	104.1%	102.8%	101.4%	99.7%	97.8%	96.2%	94.5%	91.9%
Federal Policies	78.6%	79.2%	79.1%	78.8%	77.8%	76.8%	75.5%	74.0%	72.8%	71.5%	69.6%
Fed Policies + MOU State ZEVs	78.0%	78.6%	78.5%	78.2%	77.2%	76.2%	74.9%	73.5%	72.2%	71.0%	69.0%
1x Funding + 50/50 Reinv.	75.2%	75.8%	75.7%	75.4%	74.5%	73.5%	72.2%	70.8%	69.7%	68.4%	66.6%
1x Funding + 50/50 Reinv. + CFS 10%	73.2%	73.8%	73.7%	73.4%	72.5%	71.5%	70.3%	68.9%	67.8%	66.6%	64.8%
1x Funding + 100% Reinv.	73.5%	74.0%	74.0%	73.7%	72.7%	71.7%	70.6%	69.2%	68.0%	66.8%	65.0%
1x Funding + 100% Reinv. + CFS 10%	72.1%	72.6%	72.5%	72.3%	71.3%	70.4%	69.2%	67.9%	66.7%	65.6%	63.8%
1x Funding + 100% Reinv. + CFS 15%	68.4%	68.9%	68.8%	68.6%	67.7%	66.8%	65.7%	64.4%	63.3%	62.2%	60.5%
2x Funding + 50/50 Reinv. + CFS 10%	71.6%	72.1%	72.0%	71.7%	70.8%	69.9%	68.7%	67.4%	66.3%	65.1%	63.3%
2x Funding + 100% Reinv. + CFS 15%	65.9%	66.4%	66.3%	66.1%	65.2%	64.4%	63.3%	62.0%	61.0%	59.9%	58.3%
Without Pricing Effects											
1x Funding + 50/50 Reinv.	75.9%	76.4%	76.4%	76.1%	75.1%	74.1%	72.9%	71.4%	70.3%	69.0%	67.1%
1x Funding + 50/50 Reinv. + CFS 10%	73.8%	74.4%	74.3%	74.0%	73.1%	72.1%	70.9%	69.5%	68.4%	67.2%	65.3%
1x Funding + 100% Reinv.	74.1%	74.7%	74.6%	74.3%	73.4%	72.4%	71.2%	69.8%	68.6%	67.4%	65.6%
1x Funding + 100% Reinv. + CFS 10%	72.7%	73.2%	73.2%	72.9%	71.9%	71.0%	69.8%	68.4%	67.3%	66.1%	64.3%
1x Funding + 100% Reinv. + CFS 15%	69.0%	69.5%	69.4%	69.2%	68.3%	67.4%	66.2%	64.9%	63.9%	62.7%	61.0%
2x Funding + 50/50 Reinv. + CFS 10%	72.8%	73.3%	73.3%	73.0%	72.0%	71.1%	69.9%	68.5%	67.4%	66.2%	64.4%
2x Funding + 100% Reinv. + CFS 15%	67.1%	67.6%	67.5%	67.2%	66.4%	65.5%	64.4%	63.1%	62.1%	61.0%	59.3%

Table B.1 Emission Reductions Relative to Year X Baseline (continued)

Scenario	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2030 MMT
Total TCI Emissions, mmt												
TCI Transportation Sector Emissions from SEDS	307.8	312.2	316.1	327.0	332.2	330.3	333.6	325.6	309.7	308.6	302.1	
Surface Transportation Emissions	261.1	264.9	268.1	277.4	281.8	280.2	283.0	276.2	262.7	261.8	256.3	
GHG Emissions Change in 2030 Relative to Baseline in Year X												
With Pricing Effects												
Baseline (pre-MY2025 standards)	92.8%	91.5%	90.4%	87.3%	86.0%	86.5%	85.6%	87.7%	92.2%	92.5%	94.5%	242.3
Federal Policies	70.2%	69.2%	68.4%	66.1%	65.1%	65.4%	64.8%	66.4%	69.8%	70.0%	71.6%	183.4
Fed Policies + MOU State ZEVs	69.7%	68.7%	67.9%	65.6%	64.6%	64.9%	64.3%	65.9%	69.3%	69.5%	71.0%	182.0
1x Funding + 50/50 Reinv.	67.2%	66.3%	65.5%	63.3%	62.3%	62.6%	62.0%	63.5%	66.8%	67.0%	68.5%	175.5
1x Funding + 50/50 Reinv. + CFS 10%	65.4%	64.5%	63.7%	61.6%	60.6%	61.0%	60.4%	61.8%	65.0%	65.2%	66.6%	170.8
1x Funding + 100% Reinv.	65.6%	64.7%	63.9%	61.8%	60.8%	61.2%	60.6%	62.1%	65.2%	65.5%	66.9%	171.4
1x Funding + 100% Reinv. + CFS 10%	64.4%	63.5%	62.7%	60.6%	59.7%	60.0%	59.4%	60.9%	64.0%	64.2%	65.6%	168.1
1x Funding + 100% Reinv. + CFS 15%	61.1%	60.2%	59.5%	57.5%	56.6%	56.9%	56.4%	57.8%	60.7%	60.9%	62.2%	159.5
2x Funding + 50/50 Reinv. + CFS 10%	63.9%	63.0%	62.3%	60.2%	59.2%	59.6%	59.0%	60.4%	63.5%	63.8%	65.1%	166.9
2x Funding + 100% Reinv. + CFS 15%	58.9%	58.0%	57.3%	55.4%	54.6%	54.9%	54.3%	55.7%	58.5%	58.7%	60.0%	153.7
Without Pricing Effects												
1x Funding + 50/50 Reinv.	67.8%	66.8%	66.0%	63.8%	62.8%	63.2%	62.5%	64.1%	67.4%	67.6%	69.1%	177.0
1x Funding + 50/50 Reinv. + CFS 10%	66.0%	65.0%	64.2%	62.1%	61.1%	61.5%	60.9%	62.4%	65.6%	65.8%	67.2%	172.2
1x Funding + 100% Reinv.	66.2%	65.3%	64.5%	62.3%	61.4%	61.7%	61.1%	62.6%	65.8%	66.0%	67.5%	172.9
1x Funding + 100% Reinv. + CFS 10%	64.9%	64.0%	63.2%	61.1%	60.2%	60.5%	59.9%	61.4%	64.5%	64.8%	66.2%	169.5
1x Funding + 100% Reinv. + CFS 15%	61.6%	60.7%	60.0%	58.0%	57.1%	57.4%	56.8%	58.3%	61.2%	61.5%	62.8%	160.9
2x Funding + 50/50 Reinv. + CFS 10%	65.0%	64.1%	63.3%	61.2%	60.3%	60.6%	60.0%	61.5%	64.6%	64.9%	66.3%	169.8
2x Funding + 100% Reinv. + CFS 15%	59.9%	59.1%	58.4%	56.4%	55.5%	55.8%	55.3%	56.6%	59.5%	59.8%	61.0%	156.5

Note: Line 1 is CO_2 emissions from SEDS (U.S. DOE, Energy Information Administration, State Energy Data Systems). Line 2 is the 2011 surface transportation inventory estimated for this study (256.3 mmt), proportioned by ratio of year X to 2011 SEDS emissions = estimated surface transportation emissions in year X, where year X is 1990 through 2011 (table columns). "GHG Emissions Change" is the year 2030 percent reduction from year X "Surface Transportation Emissions" for each scenario. Percent reduction for year 2011 is reported in the main document, Table 2.1.

Appendix C "Other Benefits" Results

Table C.1 Other Benefits: 1x Funding, 100% Reinvestment Scenarios

Scenario Information												
Clean fuels	0%			0%			10%			10%		
Pricing effects included?	Y			N			Y			N		
Other Benefits	**2030**	**2015 - 2030**	**Average Annual**	**2030**	**2015 - 2030**	**Average Annual**	**2030**	**2015 - 2030**	**Average Annual**	**2030**	**2015 - 2030**	**Average Annual**
Energy Independence												
Reduction in petroleum fuel consumption (millions of gallons)	1,434	13,492	843	1,279	11,168	698	3,307	36,599	2,287	3,185	34,629	2,164
% of regional consumption	7.9%	4.1%	4.1%	7.1%	3.4%	3.4%	18.3%	11.1%	11.1%	17.6%	10.5%	10.5%
Time Savings												
Personal time savings (millions of hours)	786	6,493	406	718	5,590	349	786	6,493	406	718	5,590	349
Safety/Crashes												
Fatalities prevented	350	3,318	207	296	2,601	163	350	3,318	207	296	2,601	163
Injuries prevented	5,255	49,768	3,110	4,442	39,008	2,438	5,255	49,768	3,110	4,442	39,008	2,438
Monetary valuation ($millions)	$3,188	$31,901	$1,994	$2,600	$24,118	$1,507	$3,188	$31,901	$1,994	$2,600	$24,118	$1,507
Air Pollution												
Premature deaths prevented	39	399	25	35	344	22	39	399	25	35	344	22
Asthma cases prevented	2,275	23,191	1,449	2,011	19,703	1,231	2,275	23,191	1,449	2,011	19,703	1,231
Monetary valuation ($millions)	$325	$3,949	$247	$265	$2,966	$185	$325	$3,949	$247	$265	$2,966	$185
Physical Activity												
Deaths prevented	826	7,021	439	826	7,021	439	826	7,021	439	826	7,021	439
Statistical value of lives saved ($millions)	$5,789	$49,210	$3,076	$5,789	$49,210	$3,076	$5,789	$49,210	$3,076	$5,789	$49,210	$3,076
Pavement Damage												
Roadway maintenance cost savings ($millions)	$805	$5,454	$341	$801	$5,399	$337	$805	$5,454	$341	$801	$5,399	$337

Table C.2 Other Benefits: 1x Funding, 50/50 Reinvestment Scenarios

Scenario Information												
Clean fuels	0%			0%			10%			10%		
Pricing effects included?	Y			N			Y			N		
Other Benefits	**2030**	**2015 - 2030**	**Average Annual**	**2030**	**2015 - 2030**	**Average Annual**	**2030**	**2015 - 2030**	**Average Annual**	**2030**	**2015 - 2030**	**Average Annual**
Energy Independence												
Reduction in petroleum fuel consumption (millions of gallons)	850	8,720	545	695	6,395	400	2,918	33,076	2,067	2,795	31,107	1,944
% of regional consumption	4.7%	2.6%	2.6%	3.9%	1.9%	1.9%	16.2%	10.0%	10.0%	15.5%	9.4%	9.4%
Time Savings												
Personal time savings (millions of hours)	453	4,016	251	385	3,114	195	453	4,016	251	385	3,114	195
Safety/Crashes												
Fatalities prevented	221	2,260	141	166	1,543	96	221	2,260	141	166	1,543	96
Injuries prevented	3,309	33,900	2,119	2,495	23,141	1,446	3,309	33,900	2,119	2,495	23,141	1,446
Monetary valuation ($millions)	$2,082	$22,448	$1,403	$1,494	$14,666	$917	$2,082	$22,448	$1,403	$1,494	$14,666	$917
Air Pollution												
Premature deaths prevented	23	246	15	19	191	12	23	246	15	19	191	12
Asthma cases prevented	1,363	14,554	910	1,099	11,066	692	1,363	14,554	910	1,099	11,066	692
Monetary valuation ($millions)	$212	$2,806	$175	$152	$1,823	$114	$212	$2,806	$175	$152	$1,823	$114
Physical Activity												
Deaths prevented	420	3,567	223	420	3,567	223	420	3,567	223	420	3,567	223
Statistical value of lives saved ($millions)	$2,941	$25,001	$1,563	$2,941	$25,001	$1,563	$2,941	$25,001	$1,563	$2,941	$25,001	$1,563
Pavement Damage												
Roadway maintenance cost savings ($millions)	$412	$2,803	$175	$408	$2,748	$172	$412	$2,803	$175	$408	$2,748	$172

Table C.3 Other Benefits: 2x Funding, 100% Reinvestment Scenarios

Scenario Information												
Clean fuels	0%			0%			15%			15%		
Pricing effects included?	Y			N			Y			N		
Other Benefits	**2030**	**2015 - 2030**	**Average Annual**	**2030**	**2015 - 2030**	**Average Annual**	**2030**	**2015 - 2030**	**Average Annual**	**2030**	**2015 - 2030**	**Average Annual**
Energy Independence												
Reduction in petroleum fuel consumption (millions of gallons)	2,696	24,606	1,538	2,386	19,957	1,247	5,039	47,528	2,971	4,838	43,760	2,735
% of regional consumption	14.9%	7.5%	7.5%	13.2%	6.1%	6.1%	27.9%	14.4%	14.4%	26.8%	13.3%	13.3%
Time Savings												
Personal time savings (millions of hours)	1,496	12,072	754	1,360	10,266	642	1,496	12,072	754	1,360	10,266	642
Safety/Crashes												
Fatalities prevented	640	5,910	369	532	4,475	280	640	5,910	369	532	4,475	280
Injuries prevented	9,602	88,644	5,540	7,975	67,126	4,195	9,602	88,644	5,540	7,975	67,126	4,195
Monetary valuation ($millions)	$5,720	$55,923	$3,495	$4,543	$40,359	$2,522	$5,720	$55,923	$3,495	$4,543	$40,359	$2,522
Air Pollution												
Premature deaths prevented	73	743	46	65	633	40	73	743	46	65	633	40
Asthma cases prevented	4,256	42,850	2,678	3,728	35,874	2,242	4,256	42,850	2,678	3,728	35,874	2,242
Monetary valuation ($millions)	$583	$6,874	$430	$463	$4,907	$307	$583	$6,874	$430	$463	$4,907	$307
Physical Activity												
Deaths prevented	1,455	12,367	773	1,455	12,367	773	1,455	12,367	773	1,455	12,367	773
Statistical value of lives saved ($millions)	$10,199	$86,692	$5,418	$10,199	$86,692	$5,418	$10,199	$86,692	$5,418	$10,199	$86,692	$5,418
Pavement Damage												
Roadway maintenance cost savings ($millions)	$1,605	$10,853	$678	$1,596	$10,742	$671	$1,605	$10,853	$678	$1,596	$10,742	$671