Presentation to REMI 2022 Users' Conference

Energy Supply and Demand for Deep Decarbonization

FTI and MIT

FTI CONSULTING

October 2022

Introduction

FTI CONSULTING

Disclaimer

The views in this presentation do not reflect the views of FTI Consulting. The analysis contained in this presentation are for illustrative purposes only and are subject to uncertainty.

FTI Consulting | Overview

FTI Consulting ("FTI") is an independent global business advisory firm dedicated to helping organizations manage change, mitigate risk, and resolve disputes. Due to our unique mix of EXPERTISE, CULTURE, BREADTH OF SERVICES, and INDUSTRY EXPERIENCE, we have a tangible impact on our clients' most complex opportunities and challenges.

Definitive Expertise

- **Who's Who Legal: Consulting Experts (Most Recognized),** *Law Business Research Ltd.* (2016 – 2019)
- **Best Of National Law Journal: Hall of Fame** *National Law Journal* (2017 – 2019)
- **#1 Restructuring Advisor,** *The Deal* (2007 – 2019)
- **Gold SABRE Award, Healthcare Providers,** *The Holmes Report* (2019)

A Culture That Delivers

- **Practical** in our communication and approach to outcomes
- **Judicious** in complex, multi-party situations
- **Collaborative** with clients and colleagues
- **Professional** in our commitment to work with the highest caliber

5,700+ Employees	**570+** SMDs	**$4.7B** Market Cap.[1]
82 Cities		**27** Countries
Advisor to **96** of the world's top **100** law firms	**53** of Fortune Global **100** corporations are clients	Advisor to **8** of the world's top **10** bank holding companies

Comprehensive Services

- Financial
- Operational
- Reputational

Industry Experience

- Aerospace & Defense
- Agriculture
- Automotive
- Construction
- Energy, Power & Products ("EPP")
- Environmental
- Financial Institutions
- Healthcare & Life Sciences
- Hospitality, Gaming & Leisure
- Insurance
- Mining
- Public Sector & Government Contracts
- Real Estate
- Retail & Consumer Products
- Telecom, Media & Technology
- Transportation

Economic Impacts Group ("EIG") | Overview

EIG is a functional group within FTI Consulting that answers "What If?" questions about the economy and public policy. We prefer to use third-party, documented models, not proprietary tools.

ECONOMIC IMPACTS GROUP OVERVIEW

- EIG examines how the wider economy and markets react to changes in public policy:
  - **Economy** – employment, business sales, gross product, household income, government tax revenues, demographics, and cost of living
  - **Markets** – impacts to supply, demand, prices, profitability, and rates of growth
- Our deliverables formulate clients' strategic plans and educate stakeholders, including policymakers, regulators, the media, and the public

MARKET AND ECONOMIC IMPACT MODELS

IMPLAN MAKE AN IMPACT.

- Input-output model showing linkages across 550+ sectors including households and governments down to the zip code level.

REMI

- Long-term computable general equilibrium (CGE) model of demand and supply for labor and commodities as well as demographics.

GTAP

- Commodity and sectoral CGE model of production, consumption, and international trade and financial transactions.

ISSUE AND SECTORAL COVERAGE

Agriculture and Resources	Energy and the Environment	International Trade
Banking and Finance	Fiscal Policy	Manufacturing
Construction	Healthcare	Retail and Wholesale
Demographics	Insurance and Pensions	Transportation and Infrastructure

Energy Markets Advisory Team | Overview

The Energy Market Advisory team is part of FTI's Energy, Power & Products group, providing the analytical insights required to make the right strategic decisions in business planning, disputes, policy design, and transactions.

OVERVIEW

- Team with extensive biofuels, electricity, coal, oil & gas, renewables, and emissions expertise
- Clients range from law firms, trade associations and think tanks to merchants, utilities, shippers, and renewables offtakers
- Deliverables often are data intensive and include an expert report, market report, or presentation
- Recent projects include:
  - Economic harm if a pipeline were to cease operation
  - U.S. market landscape study for biomass with carbon capture
  - White paper on the closure of two coal-fired plants in NJ
  - Independent market report for a wind farm sale in SPP

ENERGY MARKET MODELS

PLEXOS – Electricity & Coal

- Unit generation, emissions, additions, and retirements
- Zonal energy, REC, and capacity prices
- Zonal transmission/ interchange flows
- Coal basin production, transport, and prices

PLEXOS – Global Gas & LNG

- Represents more than 20 supply countries
- Includes more than 20 demand regions / countries
- Accounts for long-term contracts
- Simulates monthly LNG trade and prices

ENELYTIX

- Cloud-based, nodal security-constrained economic dispatch model
- Simulates day-ahead and real-time nodal, hub, and zonal prices and transmission flows

SERVICES PROVIDED

Business Strategy	**Market Landscape Studies**	**Revenue Due Diligence**
Emissions Forecasting	**Monte Carlo Modeling**	**Scope 1, 2, and 3 Accounting / Strategy**
Energy Policy Studies	**Price Forecasting**	**Stochastic Modeling**
Expert Testimony	**Resource Planning**	**Supply and Demand Forecasting**

Deep Decarbonization

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Technological Pathway

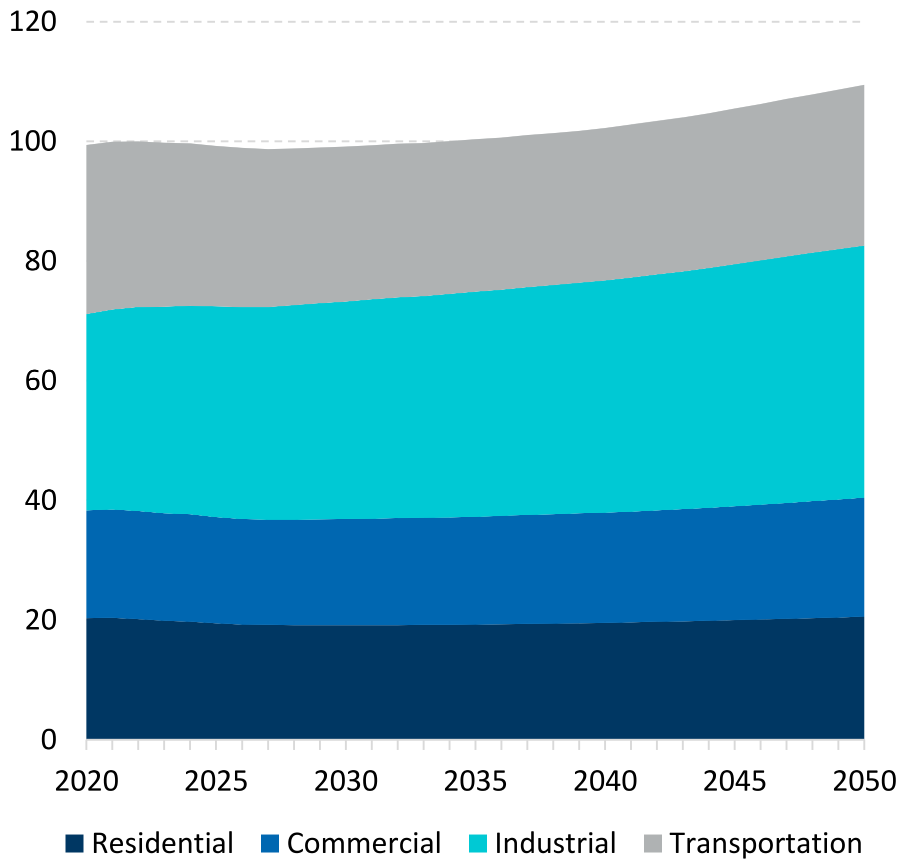
The goal of this research was to identify a technological pathway to the U.S. economy achieving net-zero emissions by 2050 and what this would entail for the U.S. and regional economies.

- **Federal policy**
  - $40 per metric ton of CO_2 starting in 2025 and escalating (real dollars) at 8% per year
  - Revenues recycled through administration of the program (1%), infrastructure investments, worker retraining and relocation, and the leftover balance paid to households as a dividend
  - Border adjustment for heavy manufacturing
  - Aggressive state/federal RPS/CES policies
- **Energy demand**
  - 25% reduction in energy service demand from all sources by 2050 compared to the AEO Reference Scenario forecast of energy demand
- **Energy supply**
  - 5% of residential and commercial heating load for natural gas or petroleum products converted to electricity from 2031 through 2050
  - Same pattern for industrial heating, though only 2% would be converted each year
  - For light-duty vehicles ("LDVs") by 2030, 80% of new sales would be electric and 100% of new sales would be electric by 2035
  - For heavy-duty vehicles ("HDVs") by 2030, 60% of new sales would be electric, though there would be no further increase from there
- **Power sector**
  - Substantially lower capital costs:
    - 80% decrease by 2050 for wind and solar
    - 50% decrease by 2050 for battery storage, nuclear, and carbon capture
  - Relaxed annual build limits for wind and solar to symbolize larger interconnection queues
  - New technologies (e.g., direct air capture of CO_2 and modular nuclear reactors, etc.)

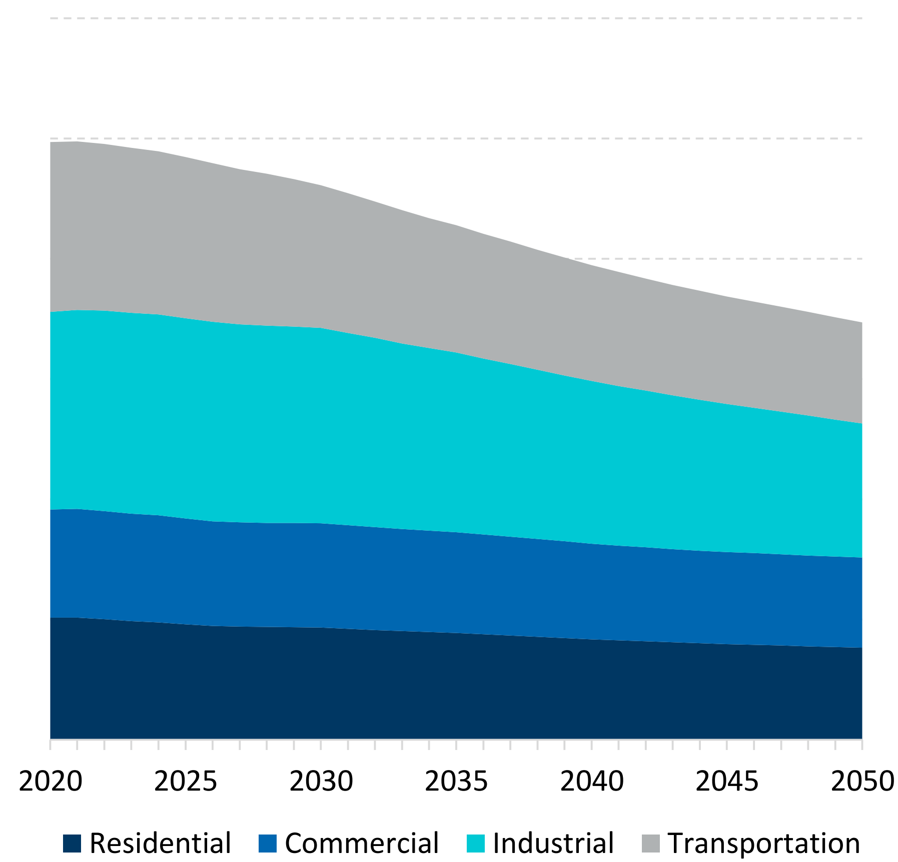
Energy Demand by “Supersector”

In the AEO Reference Scenario, U.S. energy demand (measured in quadrillions of BTUs, or “quads”) would increase between 2020 and 2050 (+10.1%). MIT presumes a steep drop (-30.2%).

AEO Reference Scenario

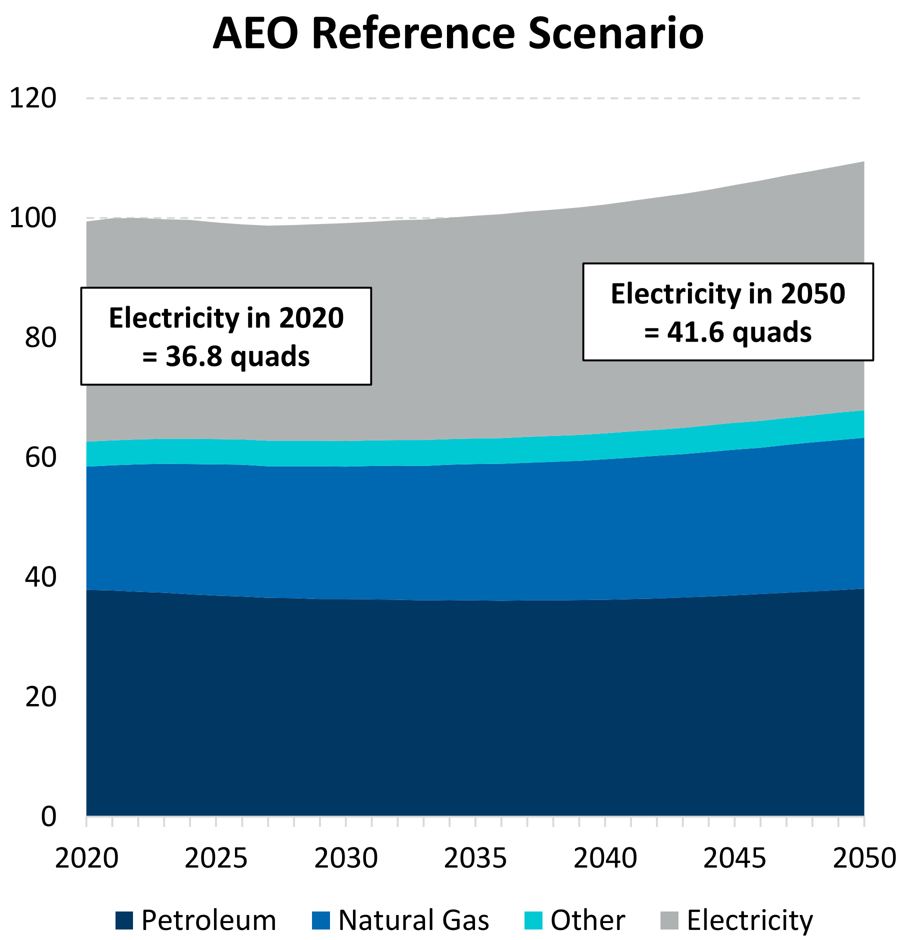


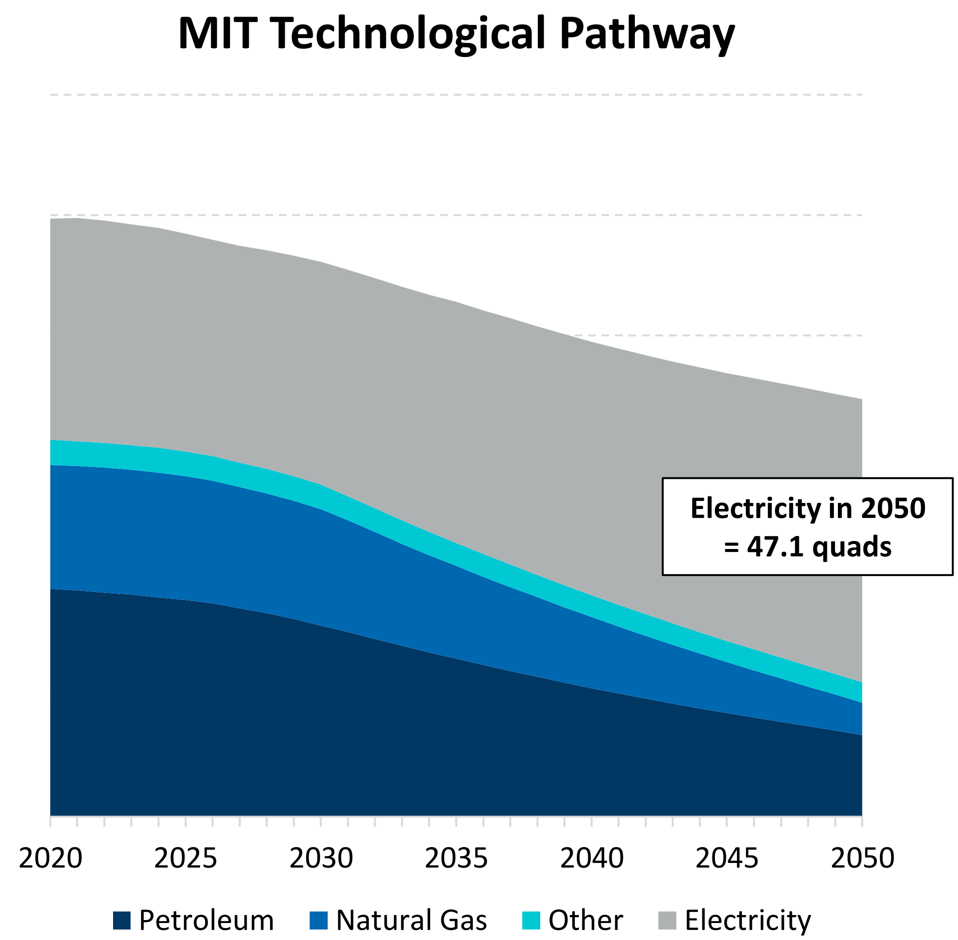
MIT Technological Pathway



Energy Demand by Fuel Type

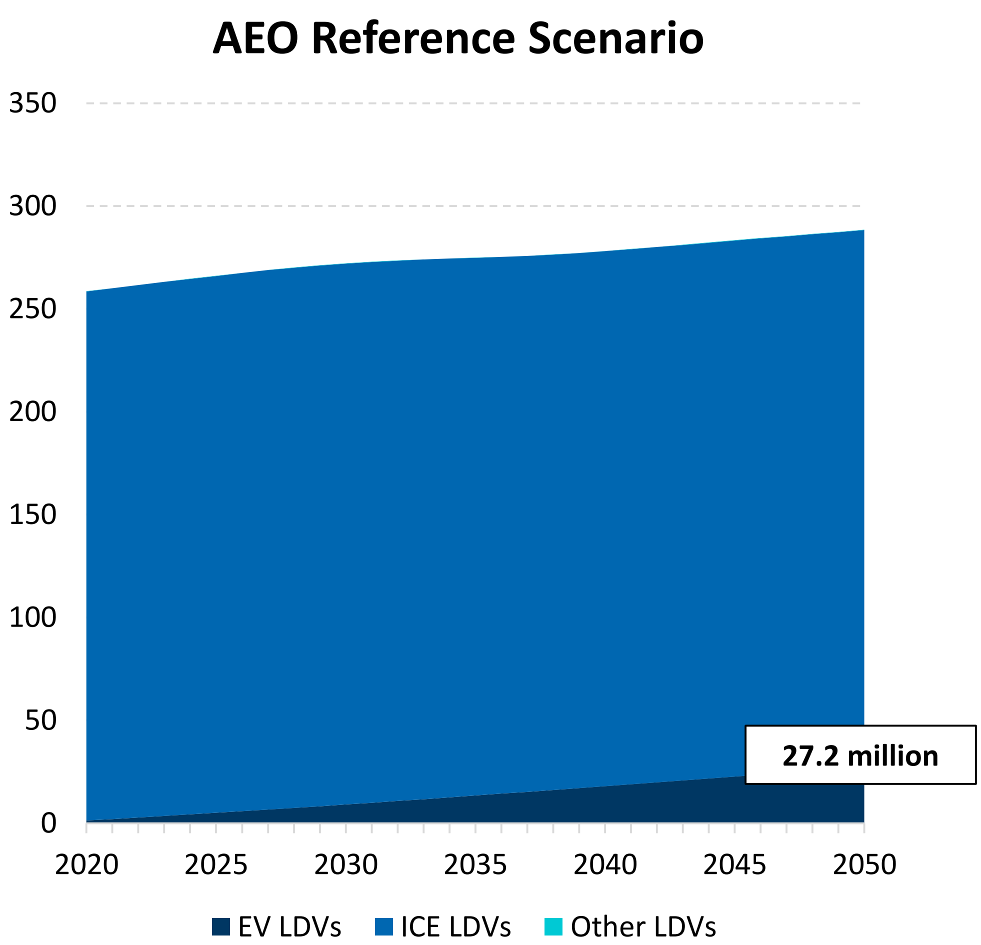
While MIT projects decreasing energy demand, more demand would concentrate in the power sector. Reference demand would increase +13.1% and MIT demand would increase +28.0%.

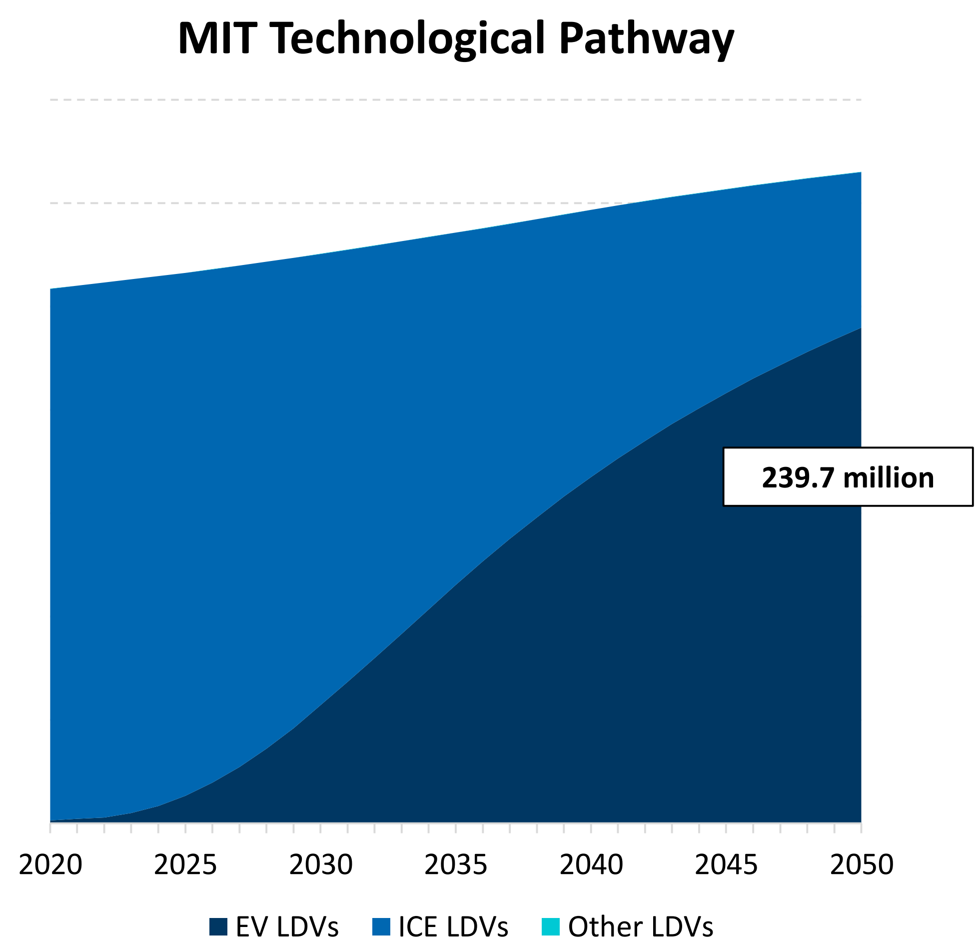




U.S. Light-Duty Vehicle Fleet

The AEO Reference Scenario projects 27.2 million electric LDVs by 2050. The MIT Technological Pathway would require 239.7 million (or 8.8x more) to meet the stated net-zero goal.





Regional Power Demand

Characteristics of Electrified Energy Demand

Electricity markets have dynamic interactions between supply and demand on a regional, seasonal, and hourly basis. Different regions/markets would experience MIT's scenario differently.

Residential and Commercial Heating

- **Regionality** – Highly regional (strong impact in NE and MW, little impact in S and W)
- **Seasonality** – Highly seasonal (strong impact in winter, little impact in summer)
- **Hourly shape** – Highly shaped (strongest at night, smaller impact during daytime)

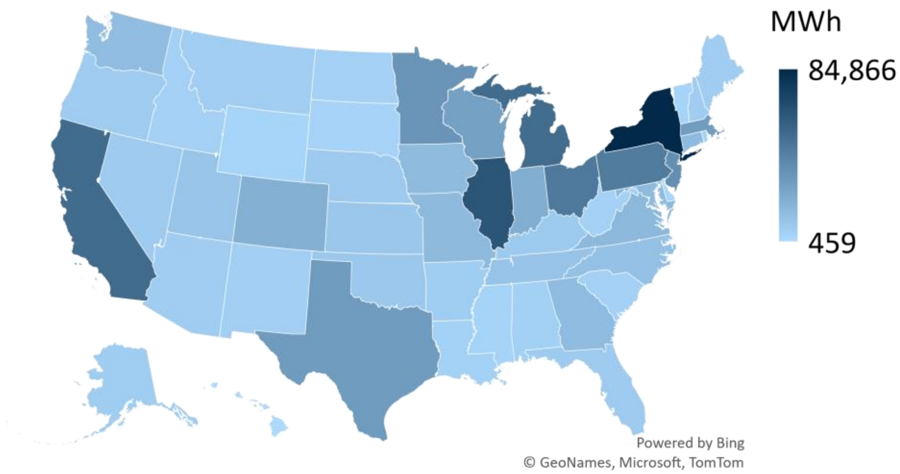
Industrial Processes

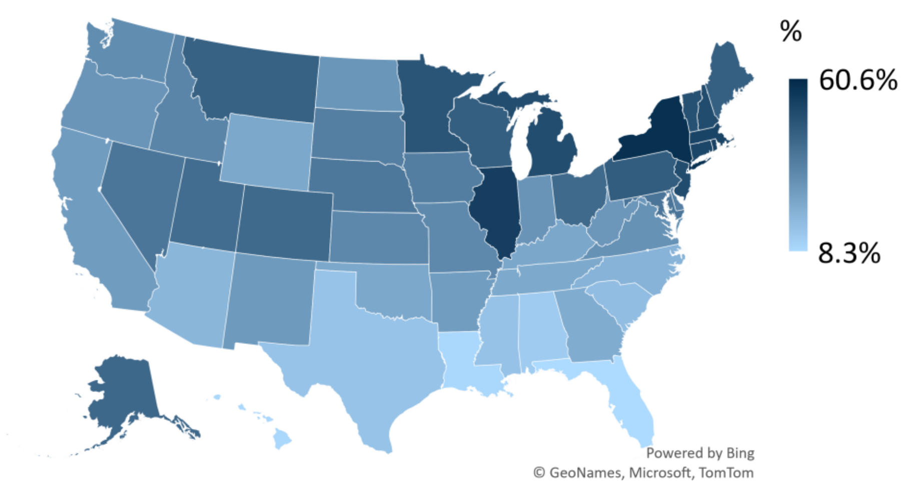
- **Regionality** – Bespoke regionality (e.g., strongest in states like TX, OH, MI, etc.)
- **Seasonality** – Very slight seasonality (industrial production occurs in all months)
- **Hourly shape** – Moderately shaped (strongest during working hours on workdays)

Electric Vehicles

- **Regionality** – Affects all states, but less efficient in NE/MW compared to S/W regions
- **Seasonality** – NE/MW have highly-seasonal VMT patterns compared to S/W, extreme temperatures affect efficiency of EVs during cold and hot weather
- **Hourly shape** – Highly shaped (strongest at night, smaller impact during daytime)

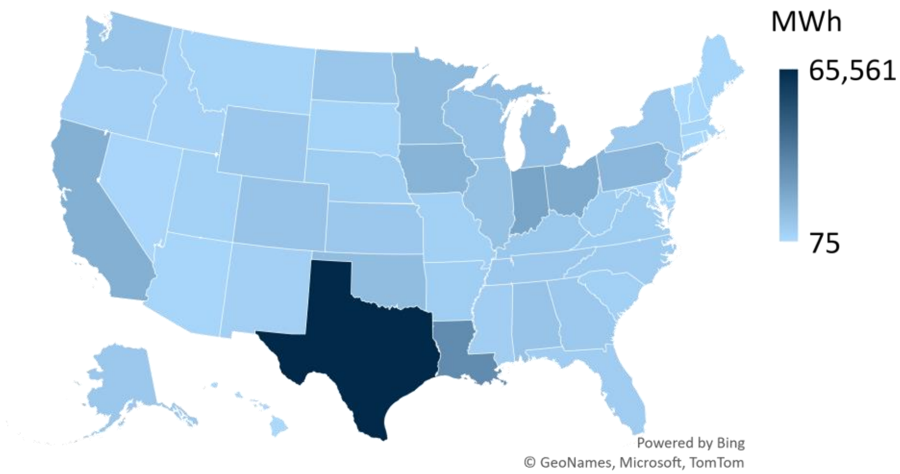
Residential and Commercial Heating

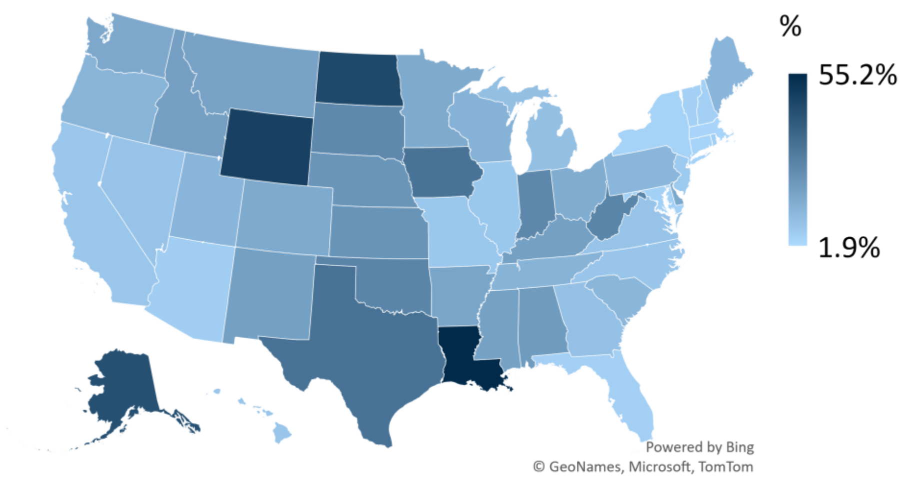




- These two maps illustrate the impact on power demand from the electrification of residential and commercial heating by state in 2050
  - The top map shows the gross impact on load by state (measured in MWh)
  - The bottom map shows the share of the gross impact on load caused by residential and commercial heating (as opposed to industrial processes or electric vehicles)
- The Northeast and Midwest states with large populations (e.g., NY, IL, MI, etc.) would have the largest impact because they have numerous structures needing heat and because of the cold temperatures of their longer winters
- States in the Southeast and Southwest would have relatively little impact from this change
- California and Texas have mild climates but very large populations needing (some) heat

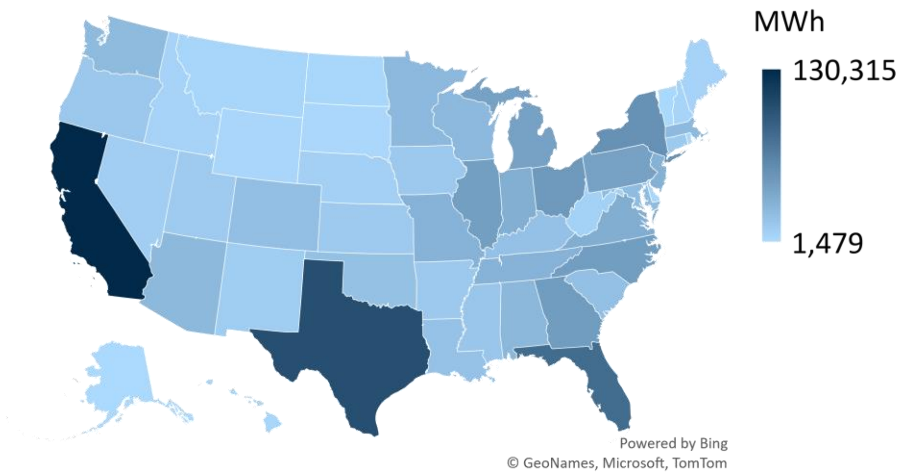
Industrial Processes

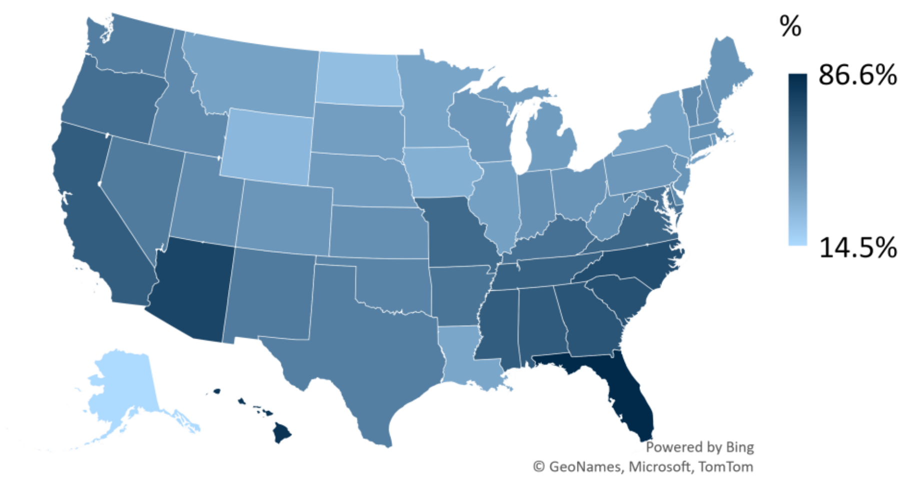




- Like the previous two maps for residential and commercial heating in 2050, these maps show impacts of electrifying industrial processes in 2050 by state and in gross impact (on top) and in terms of which states would have the most intense impacts on demand (on bottom)
- The states with large industrial sectors (and especially electricity-intensive manufacturing sectors, such as petroleum refineries or chemical manufacturers) would have the most significant impacts from this electrification
  - The states with the most MWh added would include TX, LA, IN, OH, CA, and IA
  - States with the most intense impacts would be those with large industrial sectors relative to their share of GDP or population, such as WY, ND, IA, AK, TX, LA, IN, and WV
- Electrifying industrial processes would have much less impact on seasonality of demand

Electric Vehicles

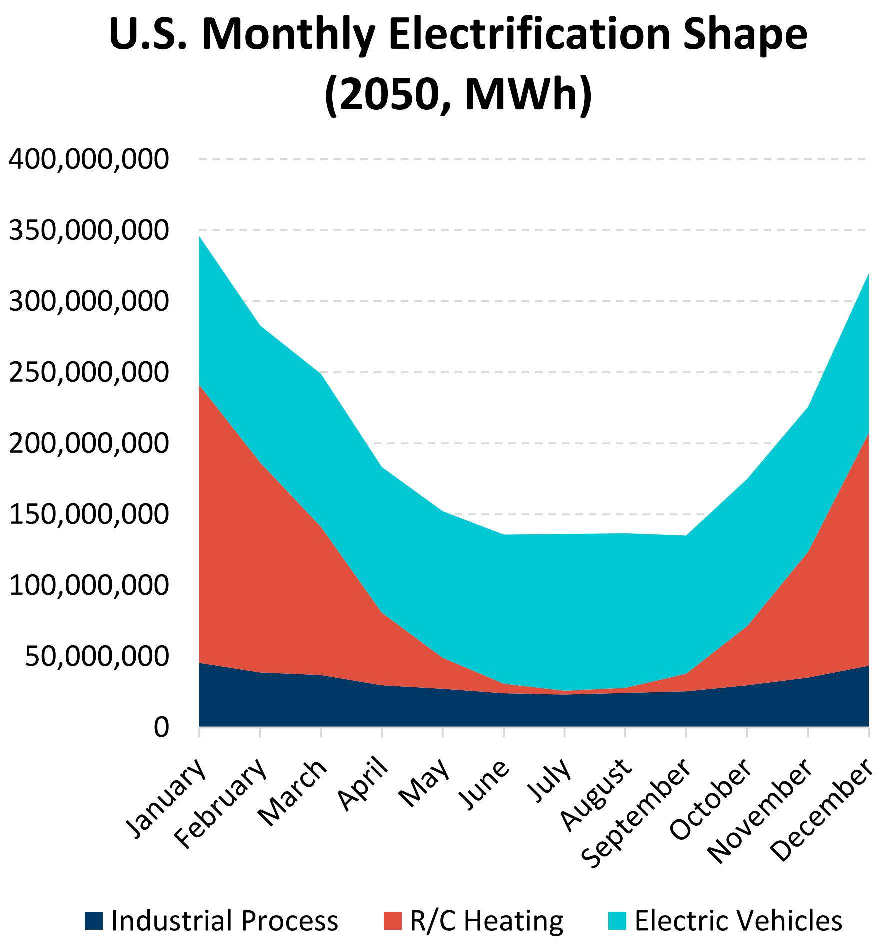


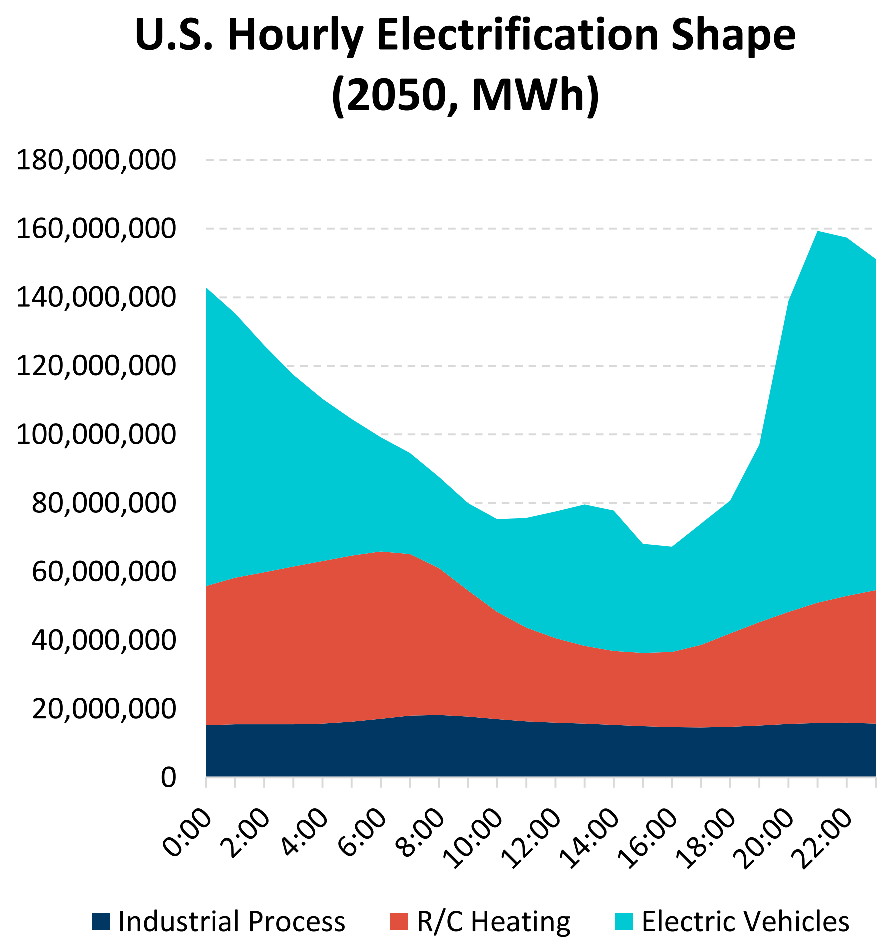


- The maps show the states that would have the largest gross impact from electrifying vehicles in 2050 (on top) and the states most affected by vehicular electrification compared to electric heating and industry (on bottom)
- States with the largest MWh impacts would include ones with these characteristics:
  - Larger populations/economies
  - Longer than average commutes
  - Poor access to public transportation
  - Extreme temperatures
  - Examples include CA, TX, FL, and NY
- States where vehicle electrification would be the most important issue are the ones without a significant impact to demand from the other types of electrification considered here
  - Atlantic Coast, Southeast, and Southwest

U.S. Monthly and Hourly Shapes

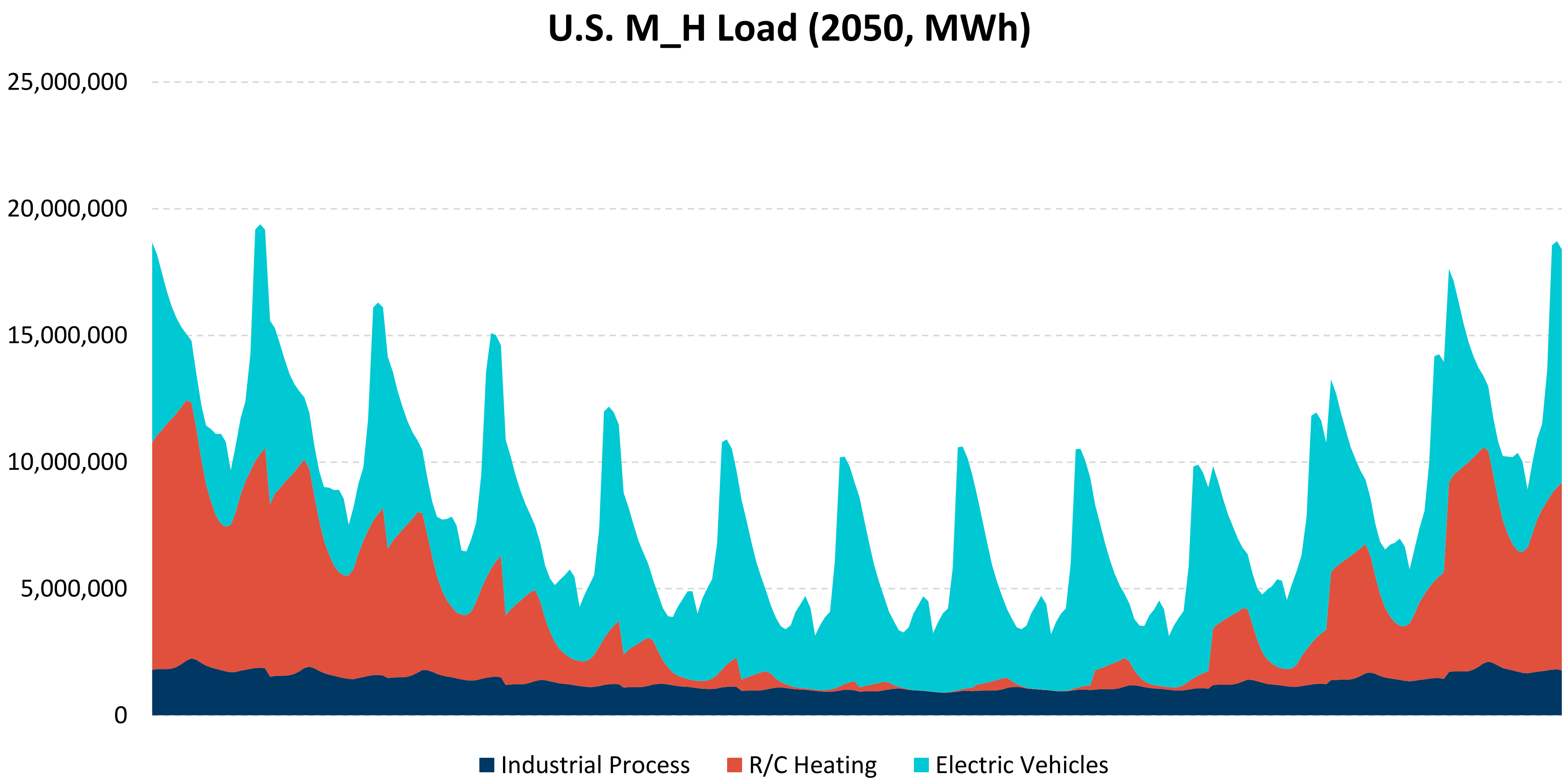
Residential and commercial heating would have the strongest seasonal pattern while charging electric vehicles would have the strongest oscillation between day/night and during the midday.





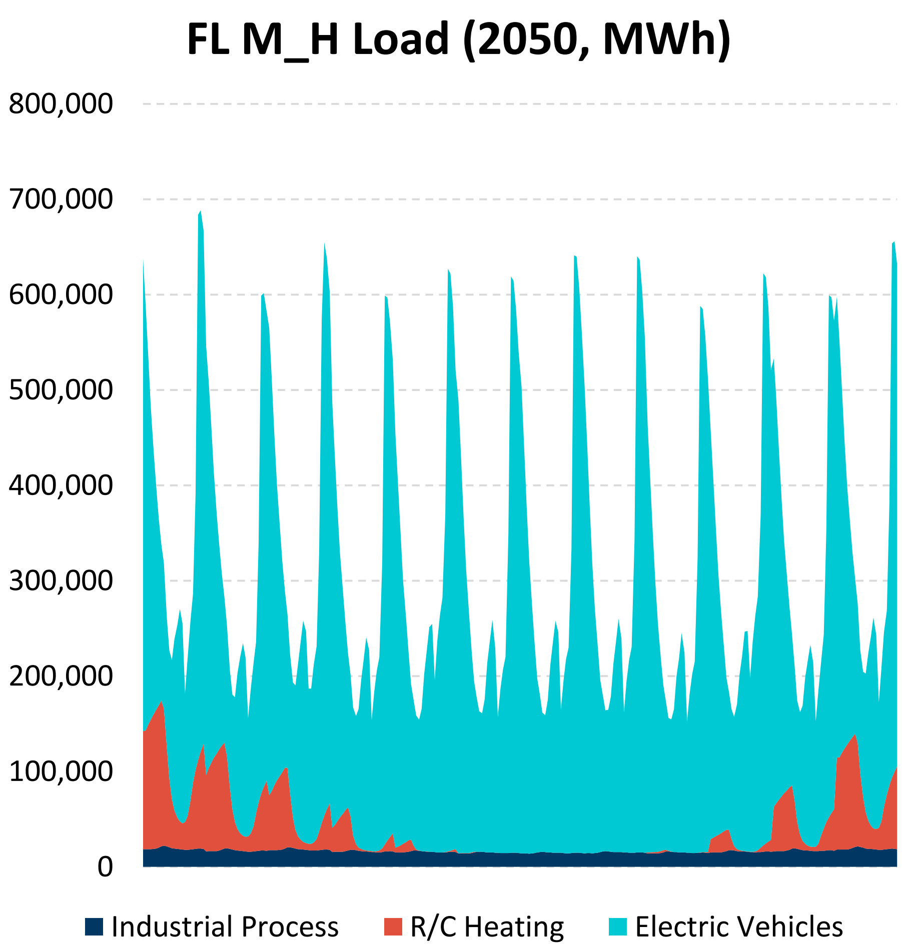
U.S. M_H Shape

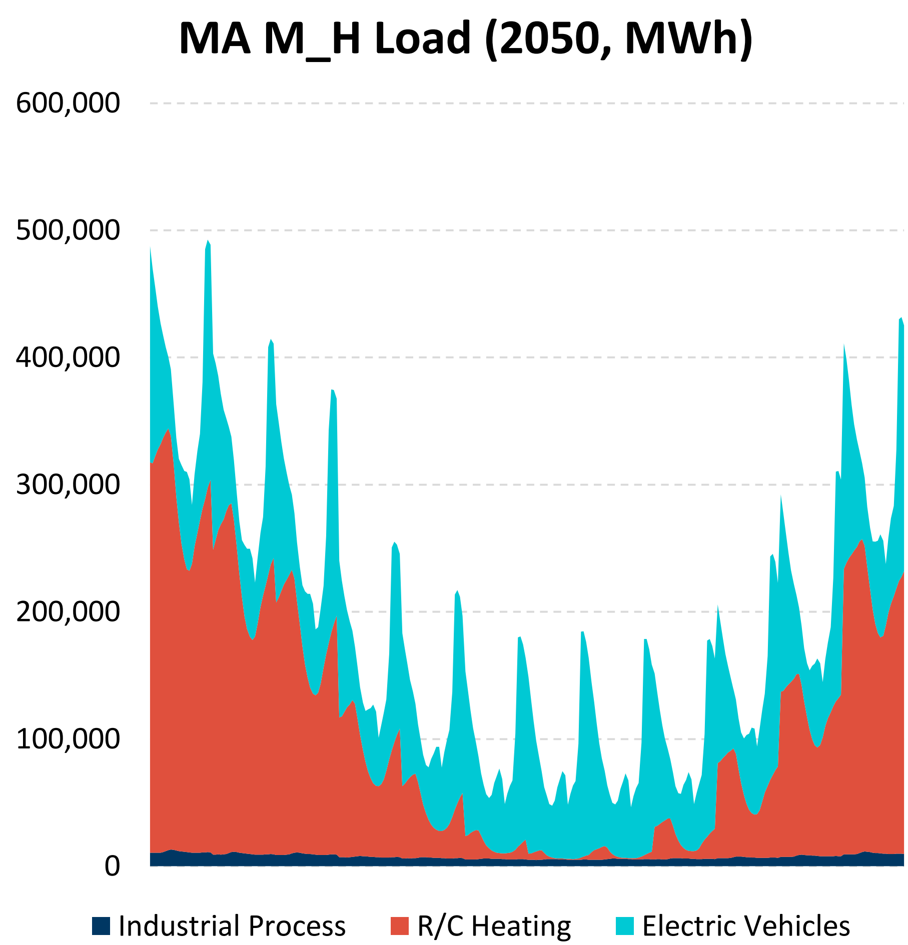
The "M_H Shape" summarizes electricity demand throughout the year by representing each month as its average day (e.g., January becomes 24 hours, and the year becomes 12*24 = 288 hours).



Florida v. Massachusetts

The impact in Florida would mostly come from vehicle charging because of its warm climate and relative lack of heavy industry. Massachusetts would be dominated by its heating demand.

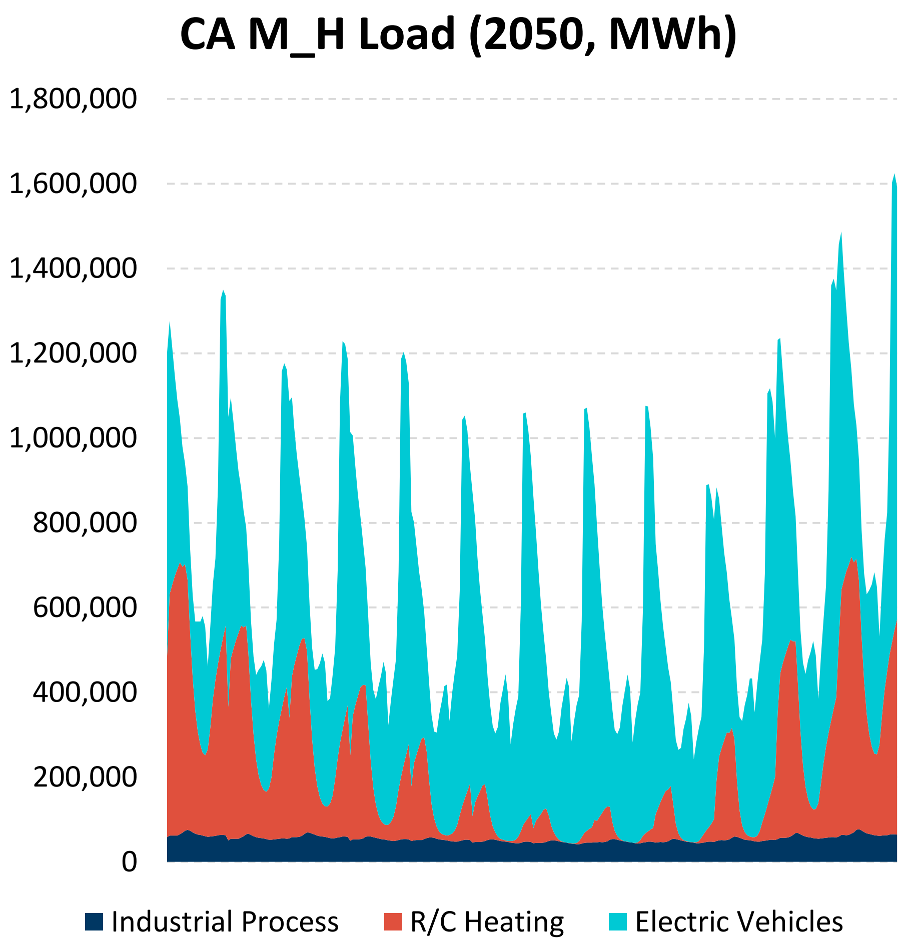


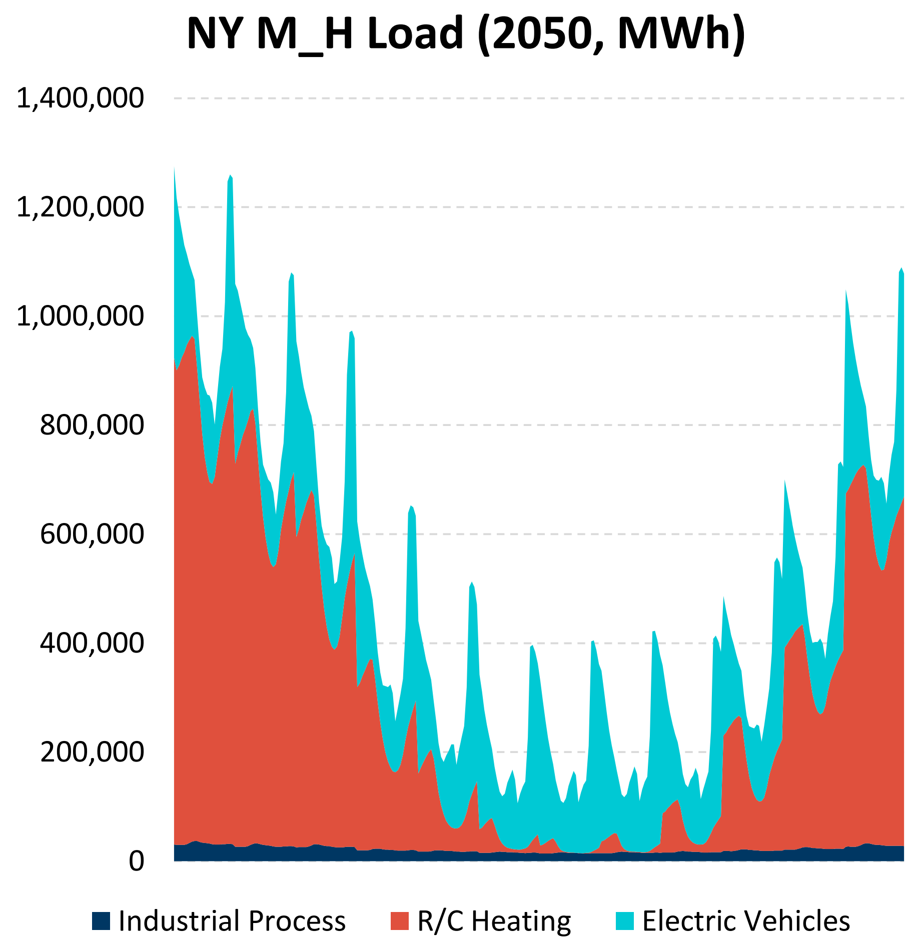


FL population = 21.2 million
MA population = 06.9 million

California v. New York

California would have some impact from residential and commercial heating demand (especially in its northern counties) while New York would need to grapple with high heating demand.

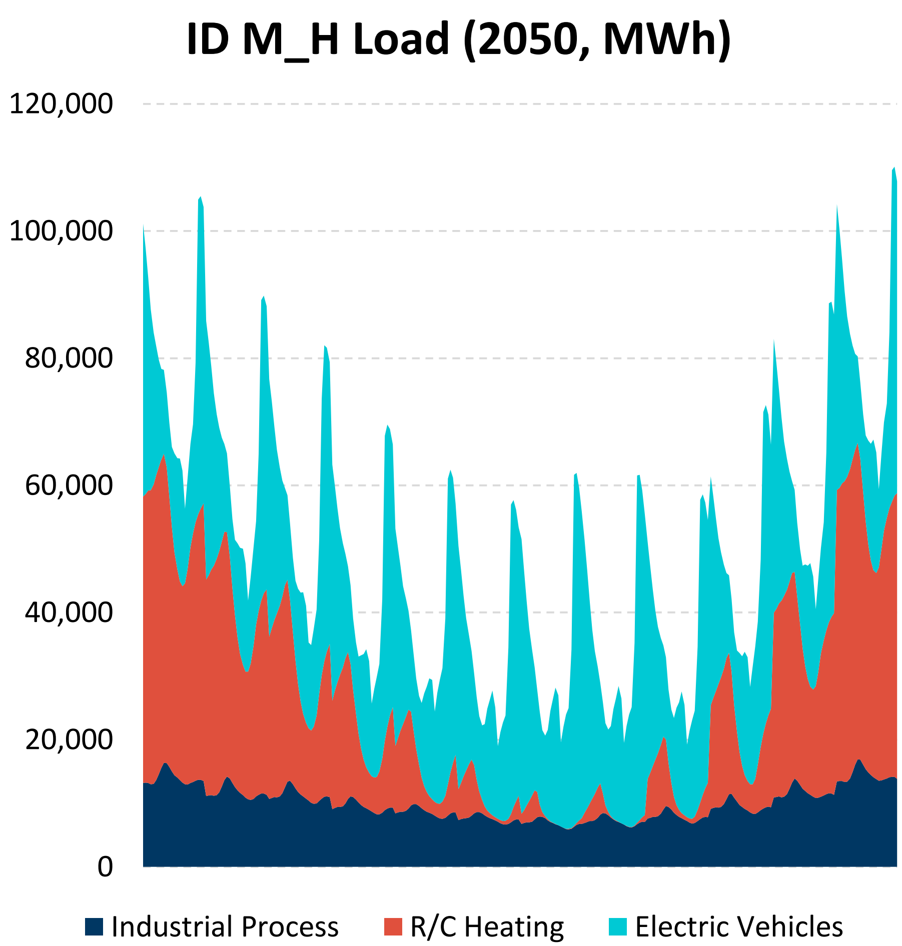


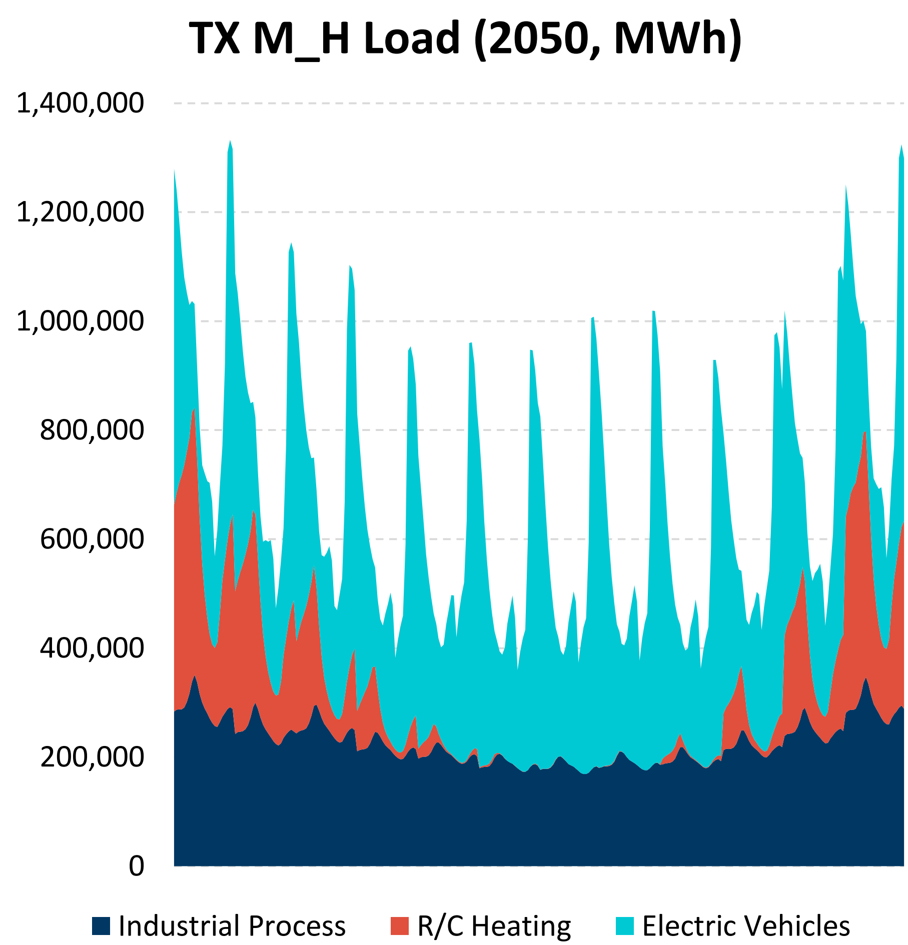


CA population = 39.4 million
NY population = 19.5 million

Idaho v. Texas

Idaho and Texas are two of the states where electrifying industrial processes would be more important. Idaho, being further north, would have more of an impact from structural heating.



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ID population = 01.8 million
TX population = 28.6 million
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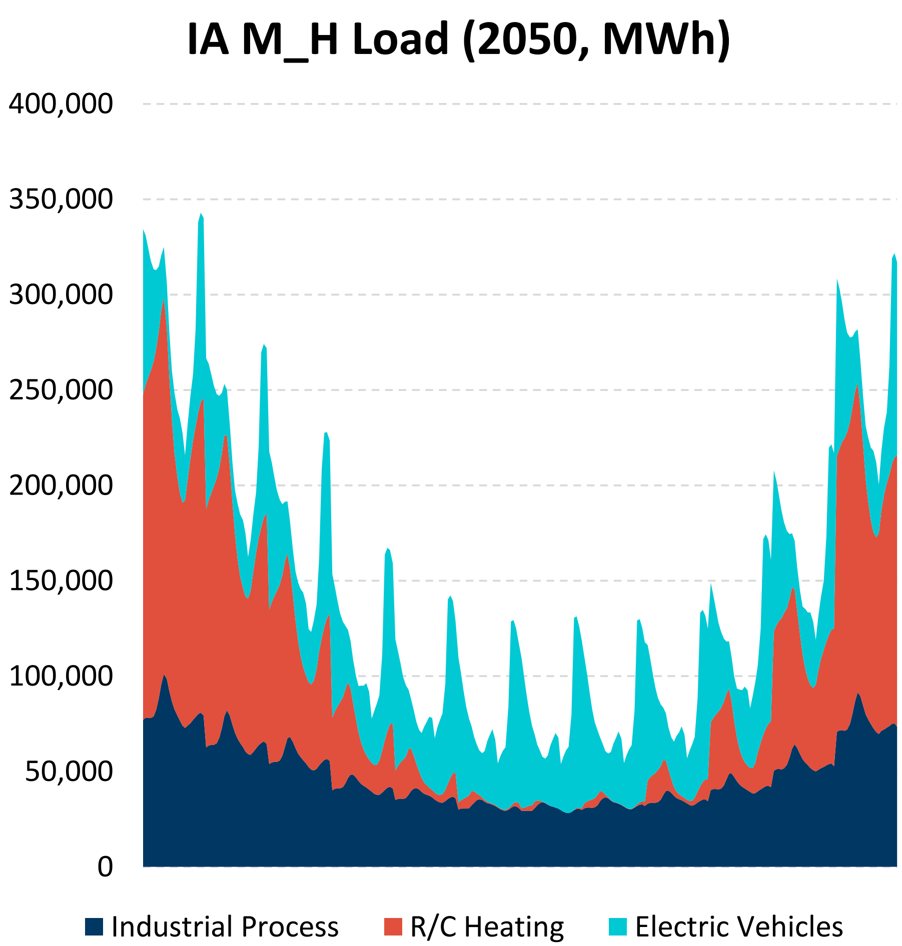
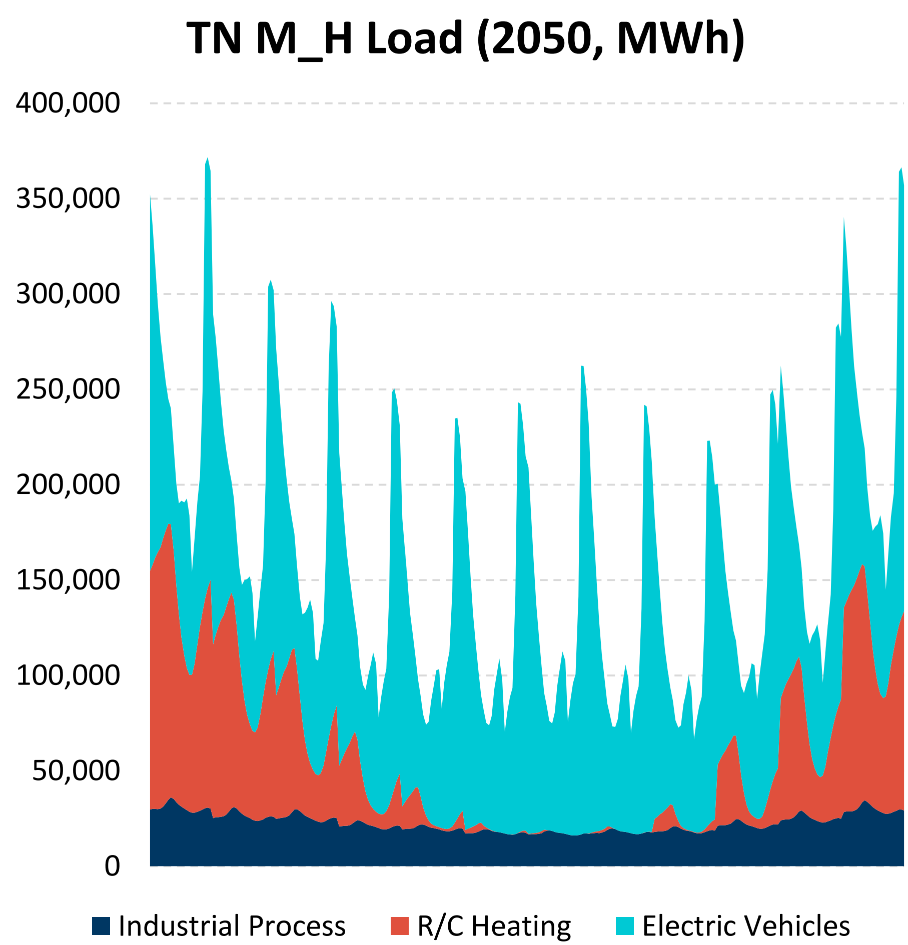
Iowa v. Tennessee

Iowa and Tennessee would have similar impacts in terms of their seasonal and hourly shapes, but Iowa (with more heavy industry and a northerly climate) would have a larger gross impact.





IA population = 03.1 million
TN population = 06.8 million

Power Sector Modeling

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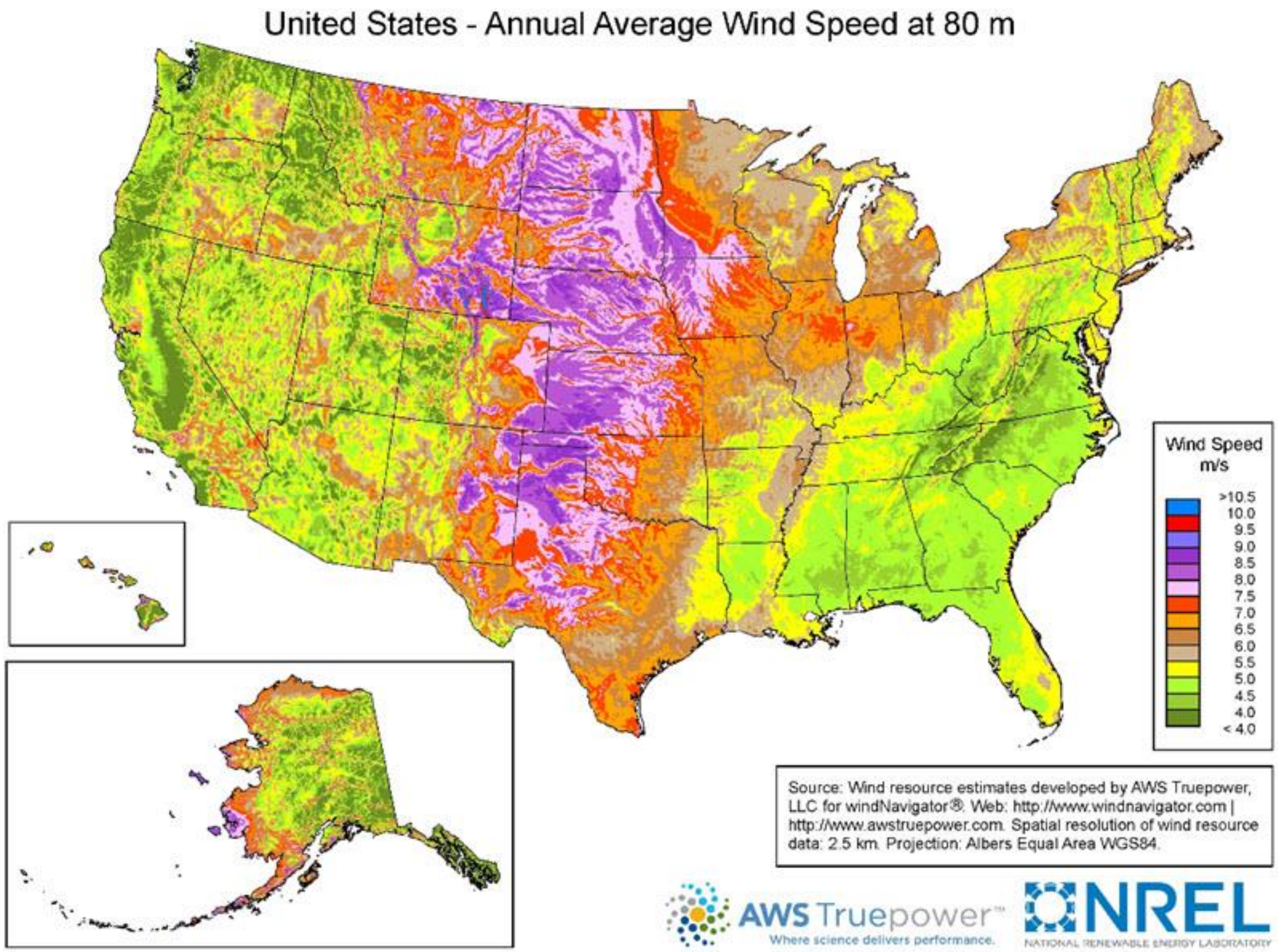
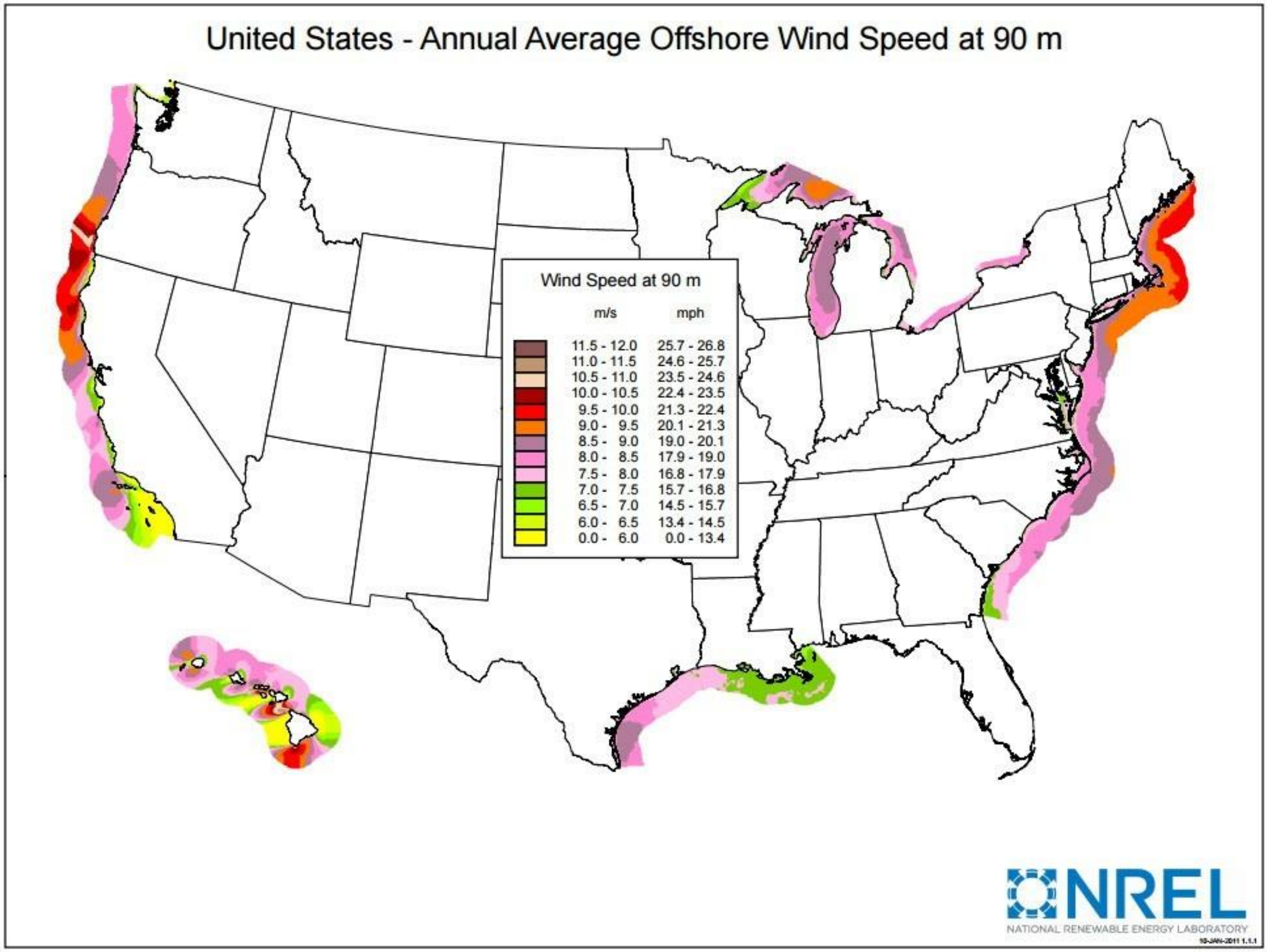
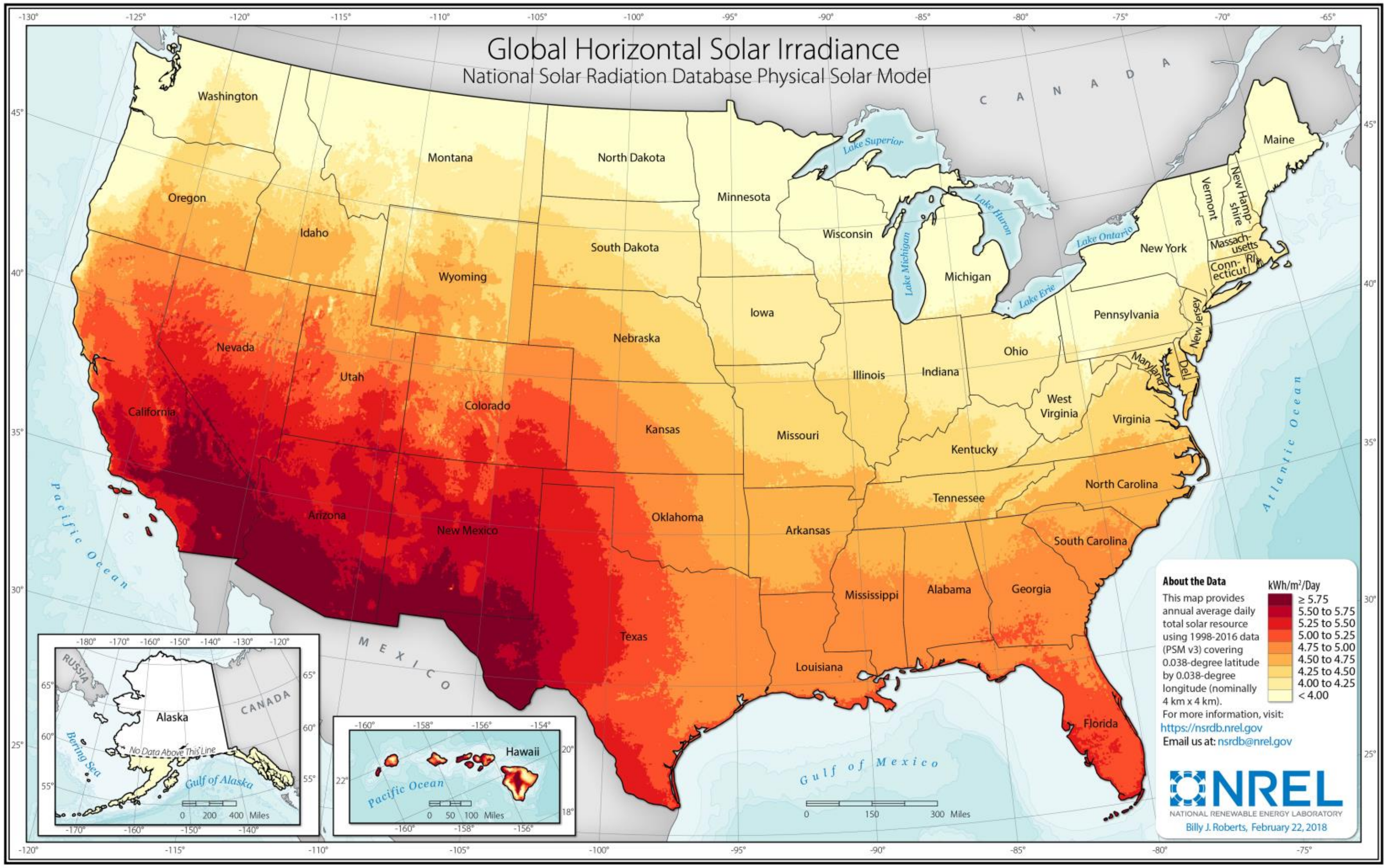
Onshore Wind Potential



Offshore Wind Potential

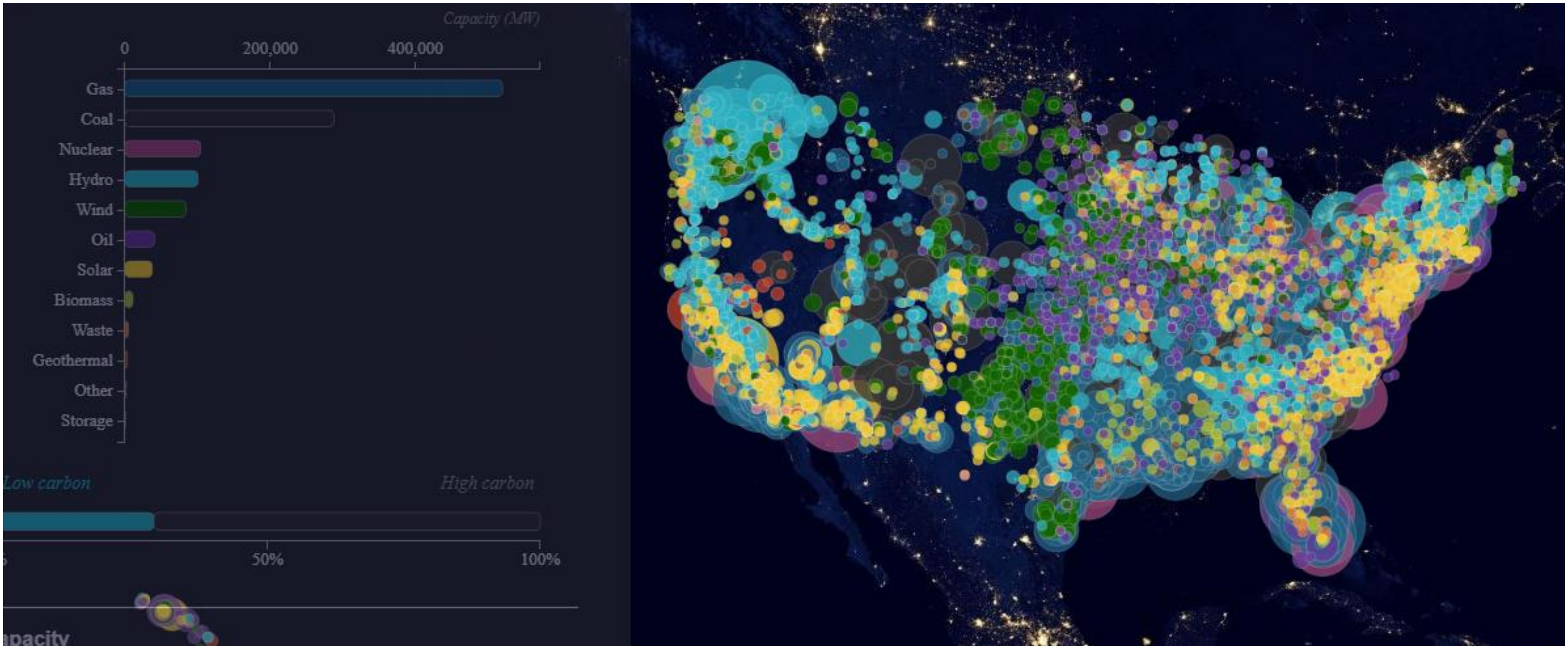


Solar Potential Map



Existing Generation Assets

The existing assets for power generation are predominantly gas- or coal-fired ones followed in capacity by nuclear power and hydroelectricity. Wind and solar are smaller but growing rapidly.



Electricity Markets Map

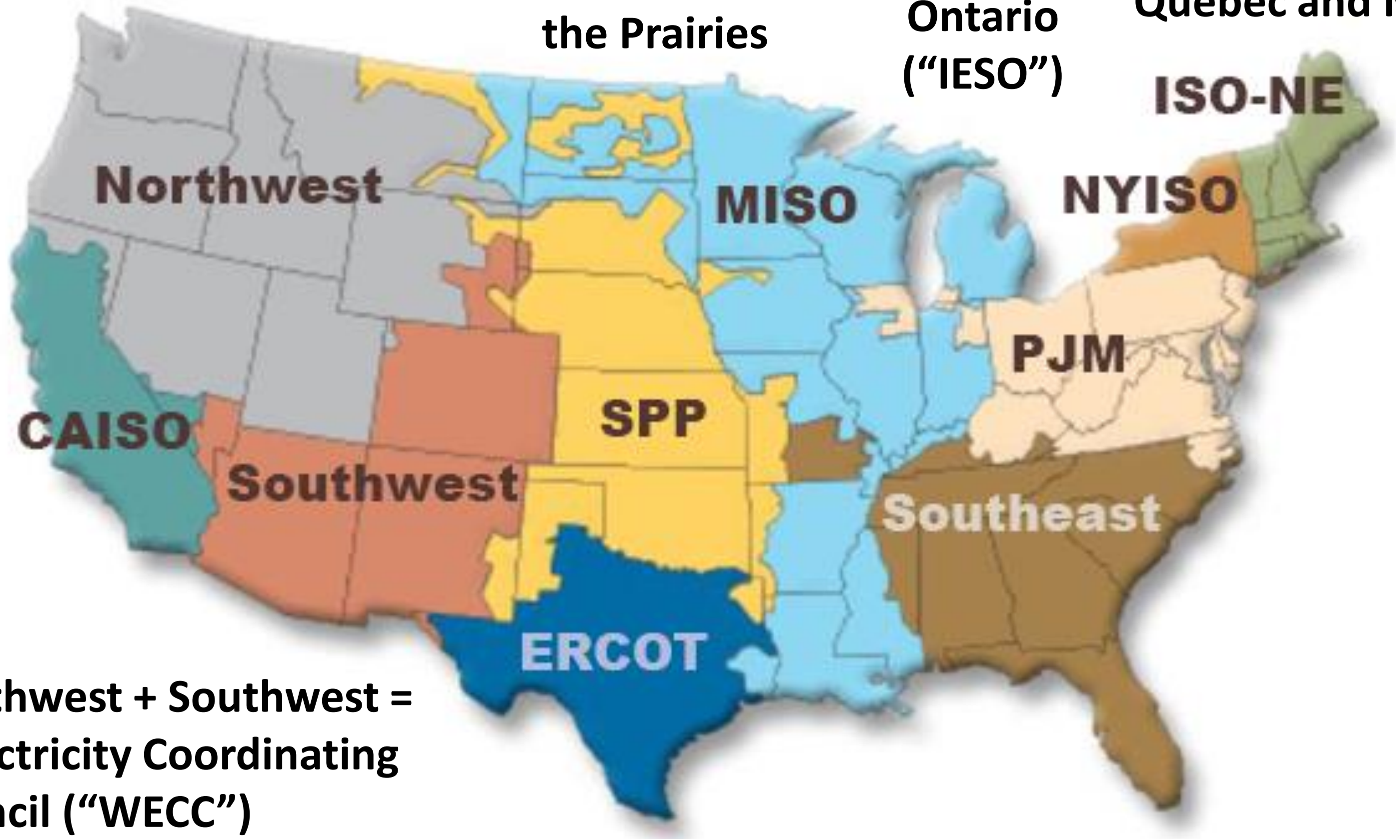
The North American power grid is operated by a series of regional markets. The geography of these markets has only modest regard for political boundaries (e.g., Texas divided between four systems).

Northwest up into British Columbia

MISO up into the Prairies

Ontario ("IESO")

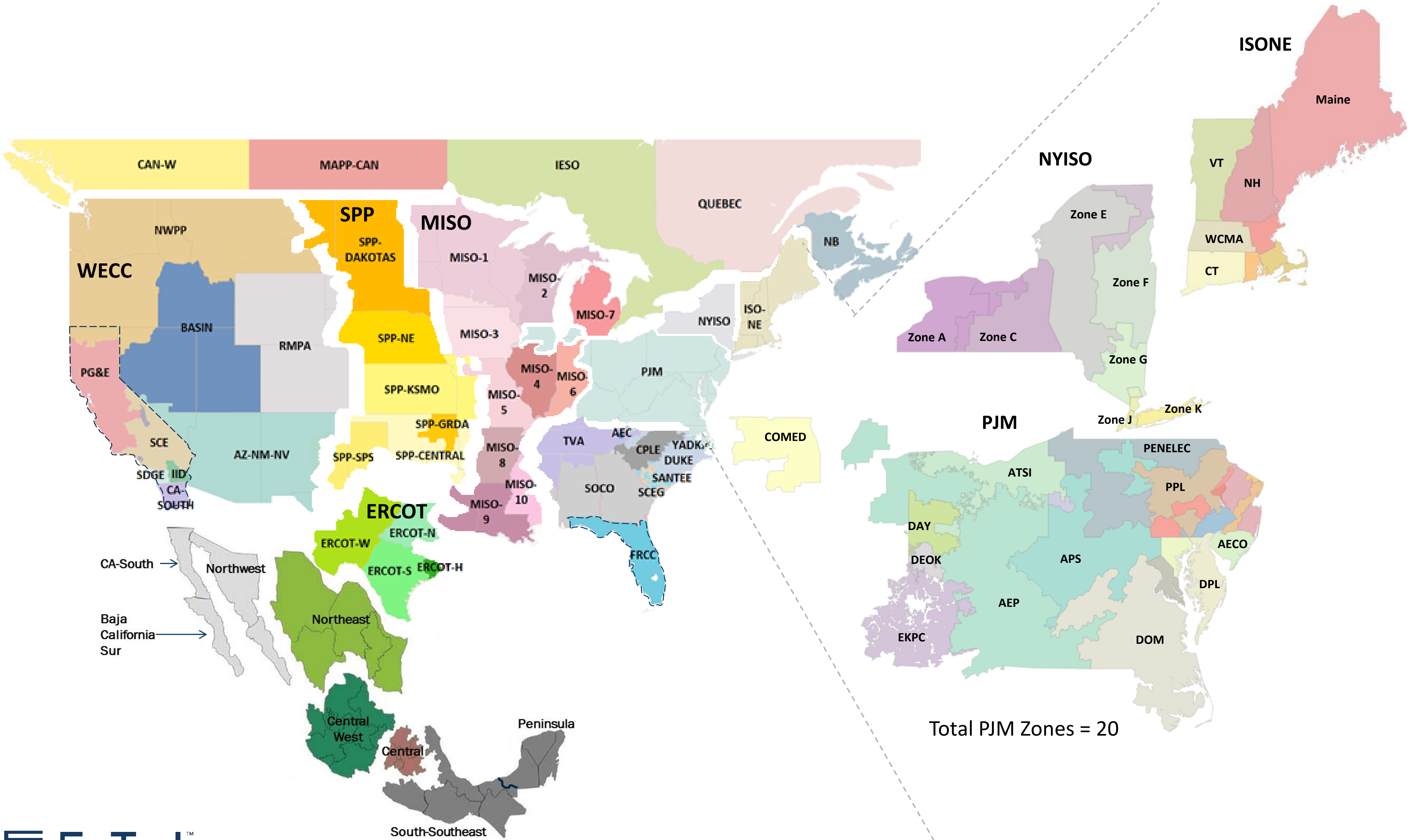
Quebec and Maritimes



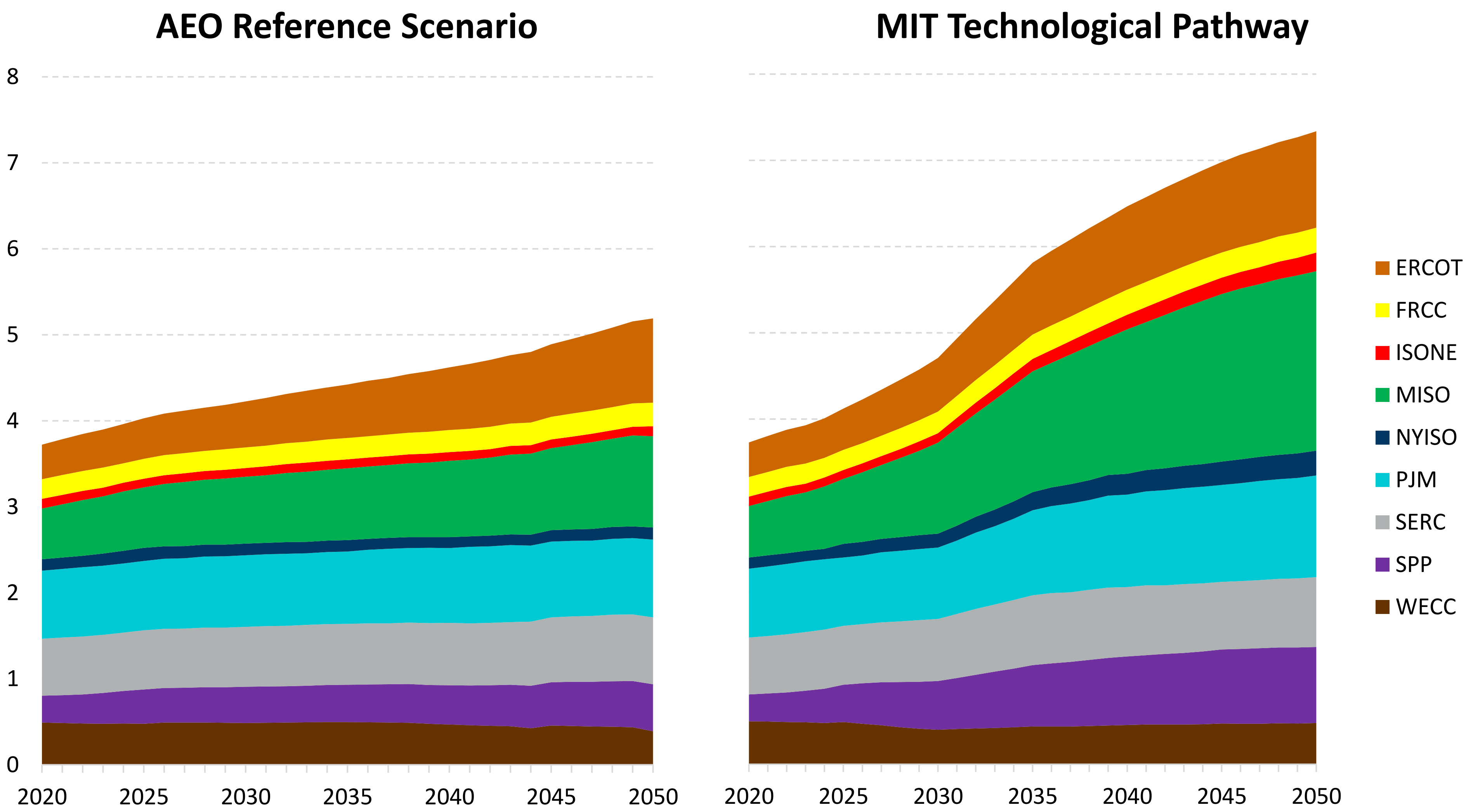
CAISO + Northwest + Southwest = Western Electricity Coordinating Council ("WECC")

Southeast has a series of utilities that operate relatively independently (e.g., TVA in Tennessee, Southern Company in Alabama, Georgia, and west Florida)

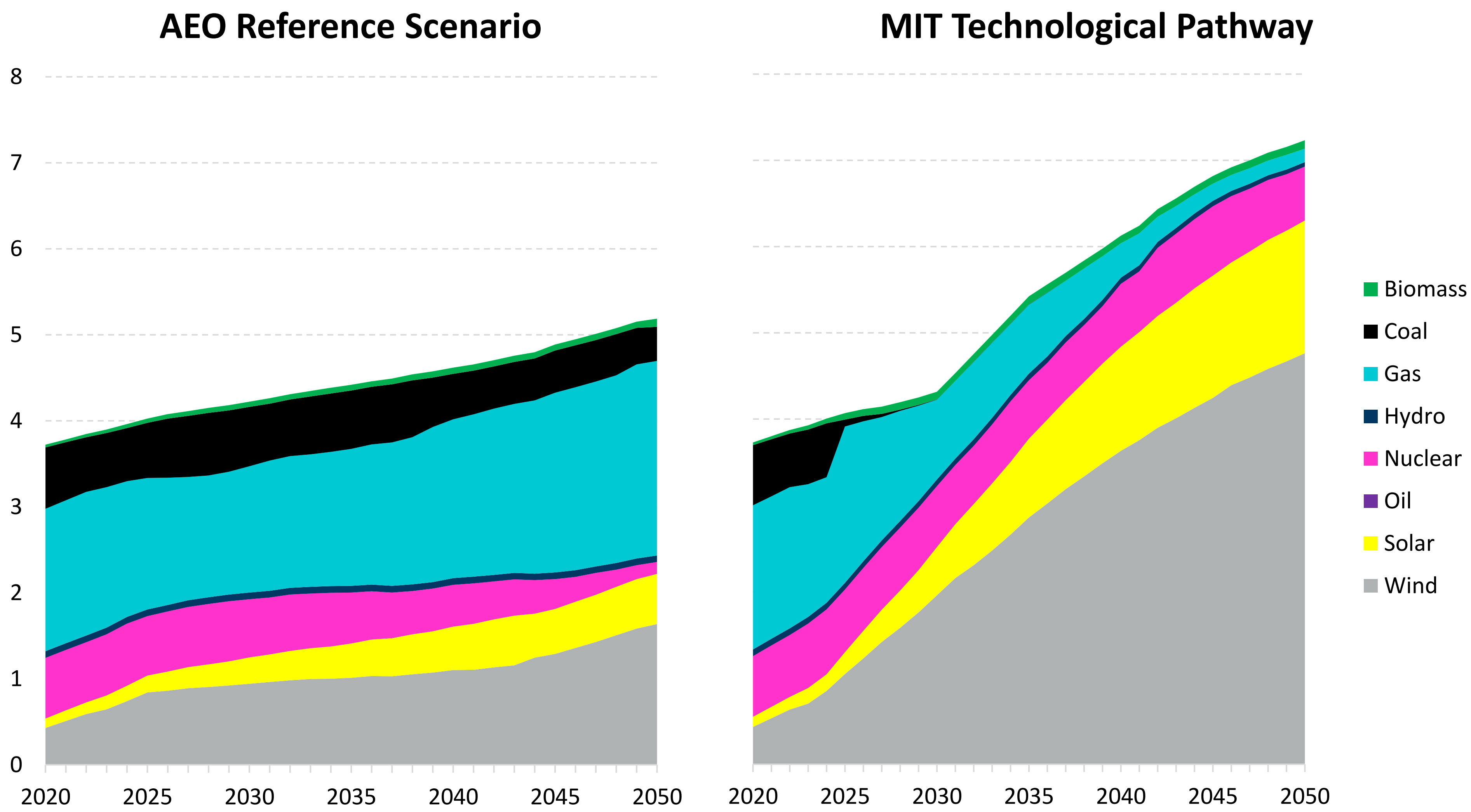
PLEXOS® Model Zonal Map



Power Generation by Region (PWh)

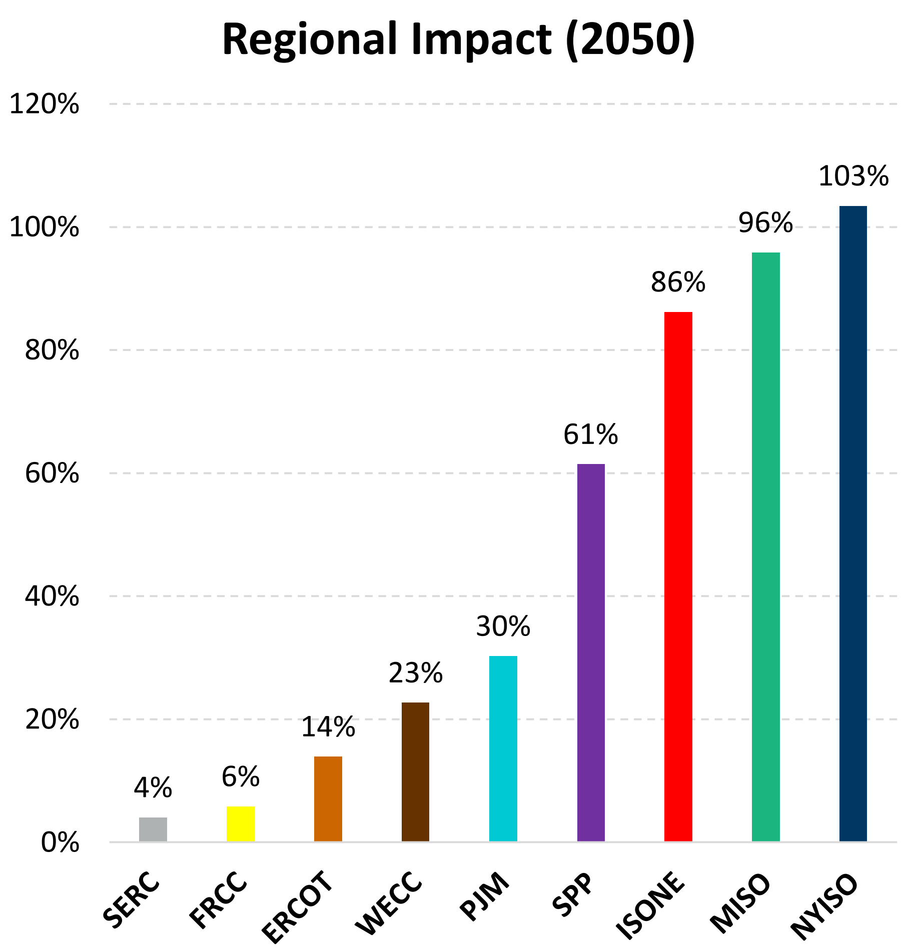


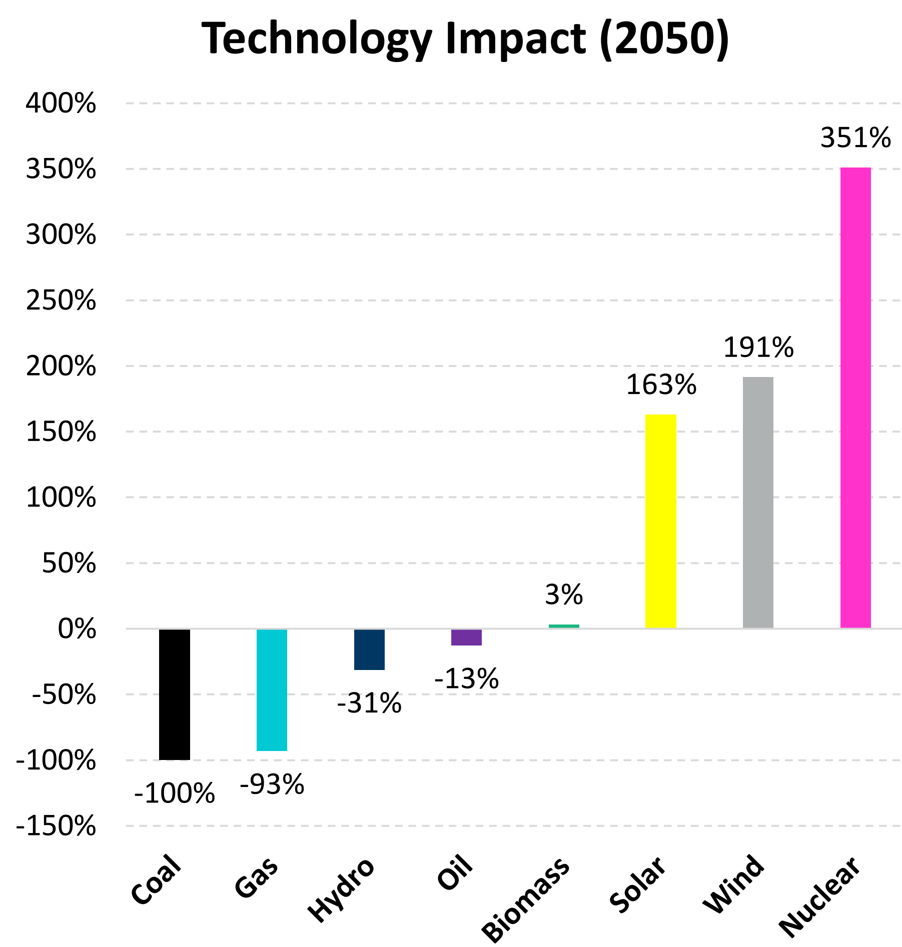
Power Generation by Technology (PWh)



Impact to Generation in 2050

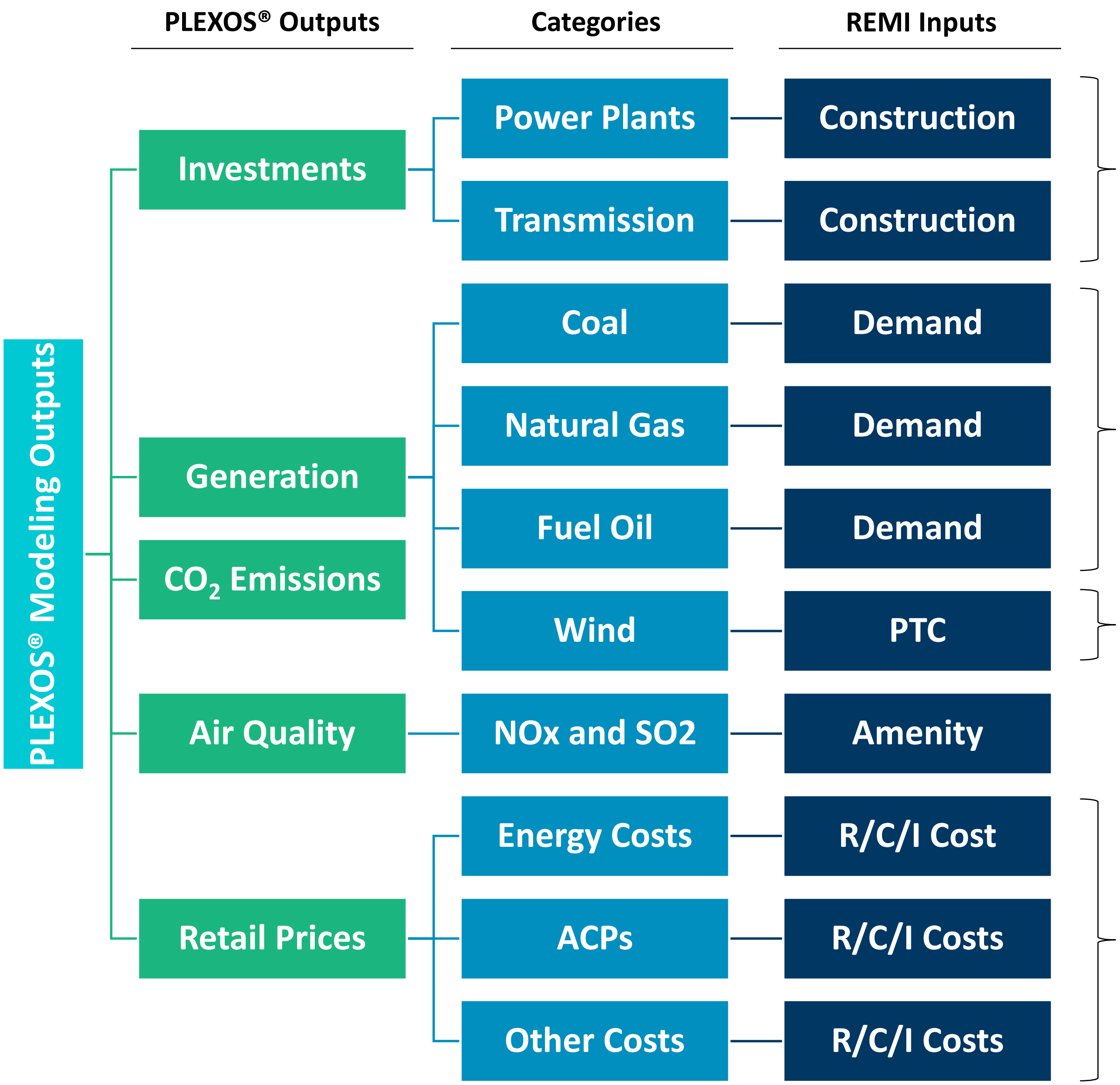
Northeastern and Midwest markets (e.g., NYISO, MISO, ISONE, and SPP) would have the largest impacts to generation by 2050. Solar, wind, and nuclear generation would increase the most.





REMI Integration

Integrating PLEXOS® Outputs into REMI



Economic benefits for regions with additional renewable investments, such as wind-heavy midwestern or solar-heavy southwestern states

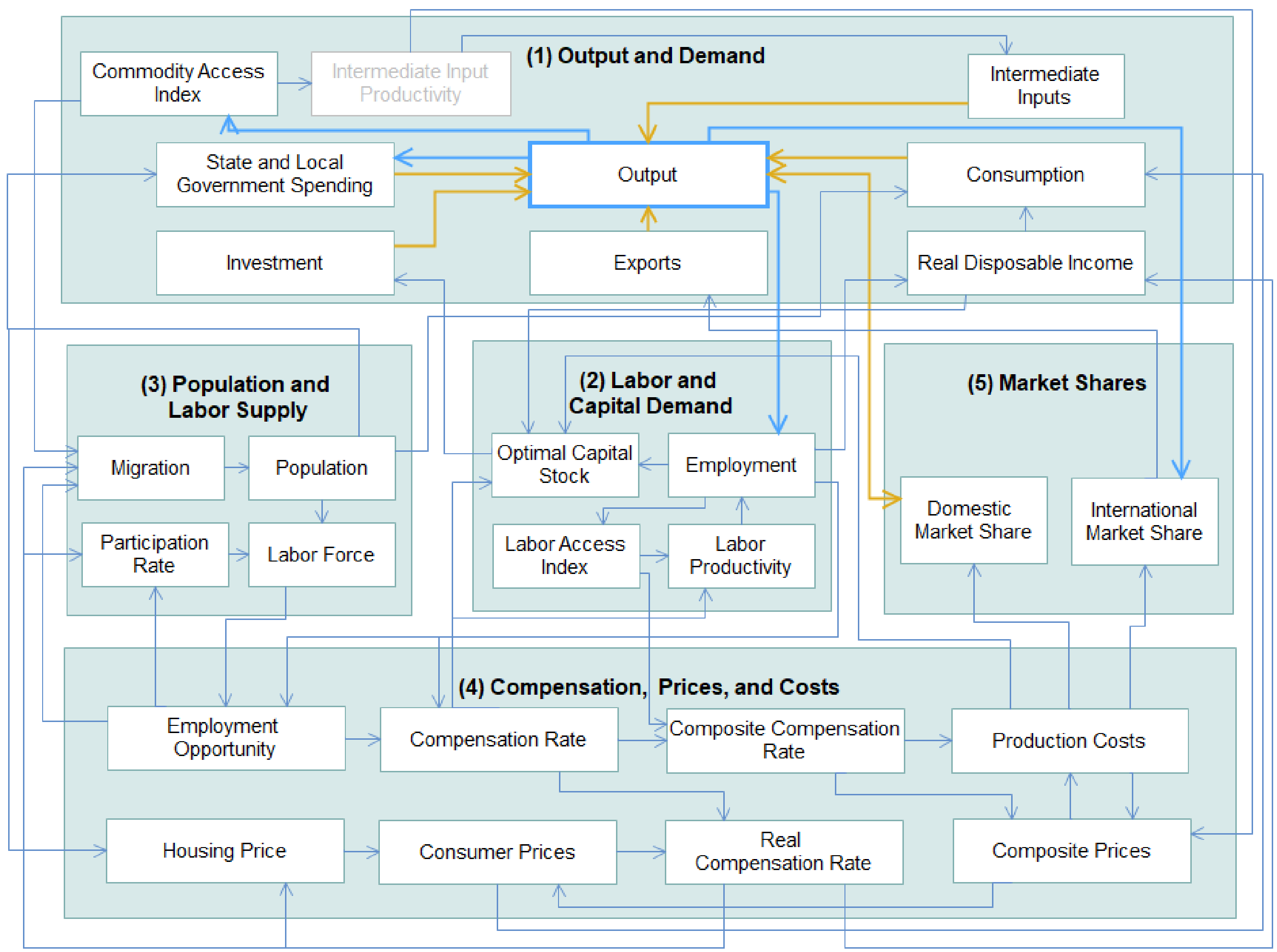
RPS would change generation by technology type, influencing demand for fossil fuel extraction activities

The federal government pays roughly $18 per MWh for wind generation, which would likely increase under a RPS and increase these costs

The increase in low- and zero-cost dispatch technology (e.g., wind and solar) would reduce energy costs, though ACPs and other costs would offset this (or more) in some regions of the country in most years

REMI Model Structure

REMI is a dynamic, computable general equilibrium ("CGE") model of regional economies. The outputs of the PLEXOS® modeling became input variables for the REMI model simulations.



Policy Variables Most Relevant to Energy

- **Block 1 – Output and Demand**
  - Exogenous final demand
  - Detailed industry sales
  - Detailed farm output
- **Block 2 – Labor and Capital Demand**
  - Industry employment
- **Block 3 – Population and Labor Supply**
  - Nonpecuniary amenity aspects
- **Block 4 – Compensation, Prices, and Costs**
  - Responding to price changes
    - Consumer prices
    - Fuel costs
  - Responding to preference changes
    - Consumer spending
    - Consumption reallocation

Economic Sectors Most Relevant to Energy

- **Mining**
  - — Coal mining
  - — Oil and natural gas extraction
  - — Metals mining
  - — Nonmetallic minerals mining
- **Utilities**
  - — Electric power
  - — Natural gas
  - — Water and wastewater
- **Construction**
- **Manufacturing**
- **Transportation and Warehousing**
- **Farm**

Q&A

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