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# *Analysis of Michigan's Options Under the EPA's Clean Power Plan*

Comparing Baseline, Cap-and-Trade, and Carbon Tax Scenarios

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# I. Executive Summary

## PURPOSE OF REPORT

On August 3, 2015, the U.S. Environmental Protection Agency (EPA) issued the Clean Power Plan (CPP) final rule.[1] The goal of the CPP is to reduce carbon dioxide ($CO_2$) emissions from existing coal- and natural gas-fired power plants across the country. Through the CPP final rule, the EPA allows states to develop their own plans for achieving their CPP emissions goals.

The Niskanen Center retained Anderson Economic Group (AEG) to evaluate potential regulatory scenarios that would allow Michigan to achieve compliance under the EPA's Clean Power Plan rule. In this report, we perform a multi-year analysis of the economy and electricity demand in Michigan under three scenarios:

1. A baseline scenario that accounts for ongoing changes in power generation and energy efficiency, as well as other economic trends, but does not assume any additional state measures to comply with the EPA's CPP final rule;
2. A cap-and-trade system in which permits to emit $CO_2$ to generate electric power are sold, increasing prices of electricity and generating revenue to the state government; and
3. A carbon tax implementation in which an excise tax on $CO_2$ is levied, increasing prices of electricity and generating revenue to the state government.

For both CPP compliance scenarios, we identify potential options for revenues, including a specific cut in Michigan state taxes, and estimate the net effects on Michigan's economy and electric power sector.

## OVERVIEW OF APPROACH

We reviewed the EPA's Clean Power Plan final rule and supplementary documents that outlined the methodology for calculating the state goals. We also reviewed the EPA's proposed federal implementation plan (FIP), which would serve as a default plan if states fail to submit a plan that is approved by the EPA. For a brief summary of the CPP, see "Overview of the EPA's Clean Power Plan Requirements for States" on page 11.

We developed a multi-year simulation model of the state economy, which we refer to as the Sectoral Business Decision model (SBD model). This model relies on an extensive empirical analysis that accounts for Michigan's industrial structure; changes in taxes and regulations in the electric power sector that are specific to Michigan; and taxes on the broader economy. The SBD model uses

1. U.S. Environmental Protection Agency, "Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule," *Federal Register* 80, no. 205, (October 23, 2015), pp. 64661–64964.

these Michigan-specific parameters to relate economic growth to electricity demand over time. The model relies on response functions that describe the response of the segments of the economy to changes in electricity prices. We developed recursive decision models to inform these response functions, which vary for different sectors of the economy depending on their sensitivity to energy prices. These sophisticated models predict levels of firm investment in response to uncertainty, prices, and other factors, and capture the discrete nature of business decisions.

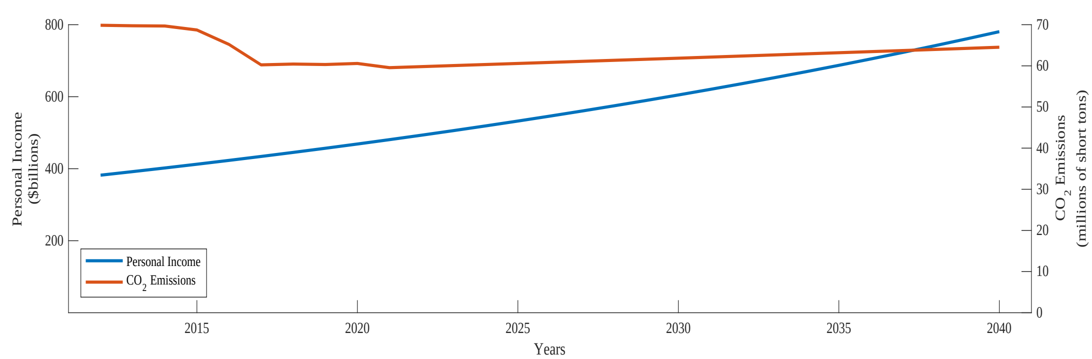
For a general discussion of our modeling efforts, see “Modeling the Effects of Regulatory Scenarios on State Economies” on page 28. For a more detailed discussion, see “Appendix C. Methodology” on page C-1. For supporting exhibits and data, see “Appendix D. Summary of Results from the Three Scenarios” on page D-1.

## OVERVIEW OF FINDINGS

1. *Under a baseline scenario, Michigan's economy continues to grow, with nominal personal income increasing to $605 billion by 2030. In this scenario, the electric power sector is likely to generate 62 million short tons of $CO_2$ emissions by 2030.*

We first estimated a baseline path for Michigan’s economy and electric power sector. This “no new policy” baseline scenario accounts for economic growth in Michigan, Michigan’s current Renewable Portfolio Standard (RPS), efficiency gains in electricity generation, and current plans from utilities to retire coal plants regardless of whether the CPP is imposed. It does not include any additional state measures to achieve compliance with the EPA’s CPP final rule, nor does it incorporate any costs from such measures.

**FIGURE 1. No New Policy: Personal Income and $CO_2$ Emissions in Michigan (2012-2040)**




*Source: AEG analysis using the Sectoral Business Decision Model*

Figure 1 on page 2 presented a comparison of personal income and $CO_2$ emissions under the baseline. We estimate that personal income in Michigan would increase to $469 billion in 2020 and $605 billion in 2030. We estimate that $CO_2$ emissions from Michigan's electric power sector would reach 61 million short tons in 2020 and increase slightly to 62 million short tons in 2030.[2]

See "1. "No New Policy" Scenario" on page 38 for details on this scenario, and "Outcomes of "No New Policy" Scenario" on page 41 for further discussion.

2. *The EPA final rule requires covered power generators to emit no more than 48.1 million short tons of $CO_2$ in 2030. This implies reductions in emissions that are far too large for Michigan's power generators to comply with the EPA's final rule under the "no new policy" baseline.*

The EPA's Clean Power Plan final rule requires states to meet either rate or mass $CO_2$ emissions goals. In particular, Michigan's power plants must either achieve an emissions rate of 0.59 short tons of $CO_2$ per megawatt-hour (MWh) or reduce their aggregate emissions to 48.1 million short tons by 2030. Under the "no new policy" baseline scenario, we estimate that Michigan's power plants' emissions rate would fall to 0.78 short tons of $CO_2$ per MWh and total emissions would fall to 62 million short tons. These estimates exceed the $CO_2$ emissions limits outlined in the CPP final rule.

In order to meet the EPA's CPP final rule, Michigan would need to adopt a new policy that would affect the behavior of firms in the electric power sector to reduce their $CO_2$ emissions. We have modeled two options that are available to states to comply with the CPP final rule: a cap-and-trade system and a carbon tax. We have modeled these scenarios for Michigan in a manner consistent with the "no new policy" baseline.

We are aware that our "no new policy" baseline results differ from the preliminary and partial baseline modeling results released by the Michigan Agency for Energy (MAE) on December 22, 2015.[3] Our baseline results indicate that Michigan likely would be out of compliance with the EPA's CPP final rule during all compliance periods without additional action. The MAE's results indicate that Michigan would not fall out of compliance until the 2025-2028 timeframe.

2. "Short ton" is a measure of mass that is equivalent to 2,000 pounds.
3. Michigan Agency for Energy, "Michigan announces baseline modeling results and stakeholder process for EPA carbon rule compliance," Michigan Agency for Energy, December 22, 2015, http://www.michigan.gov/documents/energy/12_22_Media_Release_509194_7.pdf, accessed December 2015.

While the MAE did not disclose the full methodology and set of assumptions, our analysis likely differs from the MAE's analysis due to differences in the assumptions used and the structures of our respective models.

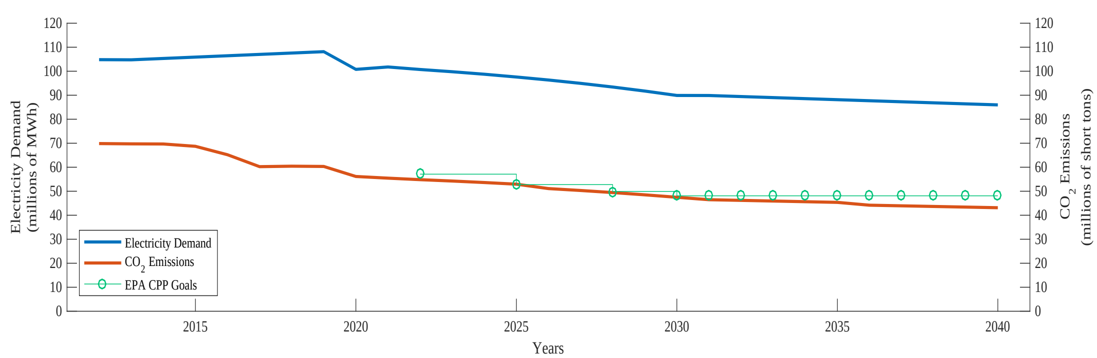
See "Overview of the EPA's Clean Power Plan Requirements for States" on page 11 for further discussion of the EPA's CPP final rule, and "EPA's Clean Power Plan Goals for Michigan" on page 37 for a discussion of the specific goals for Michigan. See "Michigan Agency for Energy Baseline Modeling" on page 50 for further comparison of the MAE's modeling results.

*3. Under the modeled cap-and-trade scenario, Michigan's power plants would incur an additional $2.2 billion in annual regulatory emissions costs by 2030. The resulting increase in electrical prices and reductions in electricity demand would reduce emissions from the electric power sector to 47.5 million short tons in 2030.*

We modeled a cap-and-trade scenario in Michigan that could be implemented under a state implementation plan (SIP) in order to meet the state's mass goals. We construct a scenario in which the State of Michigan would allocate allowances by auction and receive the revenue from the proceeds, although other policy designs are possible. See "2. Cap-and-Trade Scenario" on page 38 for a more detailed description of this scenario.

As shown in Figure 2 below, starting in 2020, we estimate that Michigan's electricity demand under the modeled cap-and-trade scenario would reach 101 million MWh of power and that $CO_2$ emissions from the electric power sector would reach 56 million short tons. We estimate that power plants would incur nearly $750 million in regulatory emissions costs. The average cost would amount to $14.85 per short ton of $CO_2$.

**FIGURE 2. Cap-and-Trade: Electricity Demand and $CO_2$ Emissions (2012-2040)**




*Source: AEG analysis using the Sectoral Business Decision Model*

In 2030, electricity demand would reach nearly 90 million MWh of power and $CO_2$ emissions would fall to 47.5 million short tons. Emissions would meet the allowed limit for final compliance under the EPA's CPP final rule. The regulatory costs of $CO_2$ emissions are likely to increase to $2.2 billion at a cost of about $53 per short ton.

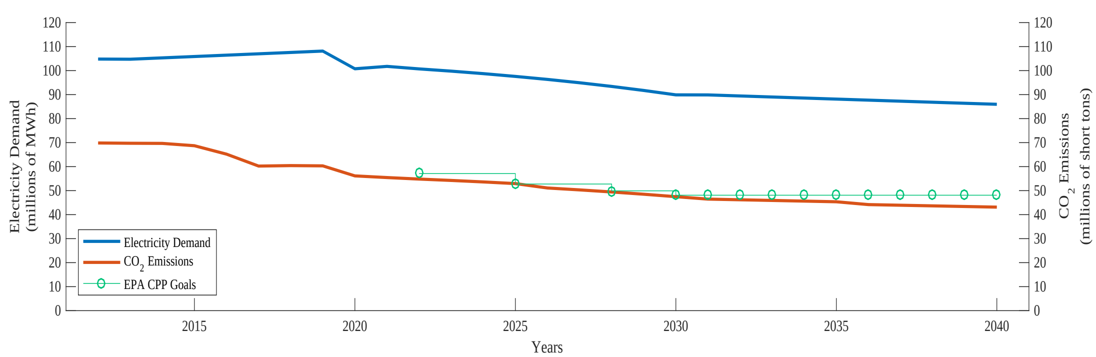
For further discussion, see "Outcomes of Cap-and-Trade Scenario" on page 43.

*4. Under the modeled carbon tax scenario, Michigan's power plants would incur an additional $2.2 billion in annual regulatory emissions costs by 2030. The resulting increase in electrical prices and reductions in electricity demand would reduce emissions from the electric power sector to 48.5 million short tons in 2030.*

We modeled a carbon tax scenario in Michigan that could be implemented in order to meet the state's mass goals. The State of Michigan would administer the tax and receive the tax revenues. See "3. Carbon Tax Scenario" on page 39 for a more detailed description of this scenario.

As shown in Figure 3 below, starting in 2020, we estimate that Michigan's electricity demand under the modeled carbon tax scenario would reach 102 million MWh of power and that $CO_2$ emissions from the electric power sector would reach 57 million short tons. Carbon tax revenues would total nearly $740 million at a tax rate of $13 per short ton of $CO_2$.

**FIGURE 3. Carbon Tax: Electricity Demand and $CO_2$ Emissions (2012-2040)**




*Source: AEG analysis using the Sectoral Business Decision Model*

In 2030, electricity demand would reach 92 million MWh of power and $CO_2$ emissions would fall to 48.5 million short tons. Emissions would meet the limits for the final compliance period under the EPA's CPP final rule. We estimate that carbon tax revenues would increase to $2.2 billion at a tax rate of $46 per short ton in 2030. For further discussion, see "Outcomes of Carbon Tax Scenario" on page 44.

5. *Both the cap-and-trade and the carbon tax regulatory scenarios generate significant income for the State of Michigan. This revenue could be used to reduce the state sales tax rate by 0.5 percentage points, as well as generate additional revenue that could be used to reduce other taxes or fund an income tax rebate.*

Under both the cap-and-trade and the carbon tax scenarios, the State of Michigan would receive revenue from utilities that generate power using carbon sources within the State of Michigan. Although the precise amount of revenue available in any given year would be uncertain, we presumed that the legislature would adopt a companion tax policy regime that—together with the regulatory revenue—was approximately revenue-neutral over time.[4]

In particular, we assumed that the State of Michigan would first allocate these revenues to a 0.5 percentage-point reduction in the state general sales tax rate, and to their costs of administering the regulatory program. After that, we presumed the remaining revenues would be returned to the taxpayers in the form of an unspecified reduction in other taxes or a tax rebate.

As shown in Table 1 on page 7, the revenue that the state would receive for emissions regulatory costs would be $2.1 billion under cap-and-trade and $2.2 billion under the carbon tax in 2030. The amount available to offset the sales tax reduction would be nearly $1 billion under both scenarios, though it is slightly higher under the carbon tax since the economy is larger under this scenario. As noted above, we presumed that the remaining revenue would be returned to taxpayers through an unspecified tax reduction or tax rebate.

Under both scenarios, the sales tax cut would have incentive effects on the economy that would partially offset the disincentive effects of increased electricity prices. We did not attribute positive incentive effects to any unspecified tax reductions or tax rebates. However, if the legislature enacted laws that reduced taxes in a specific and predictable manner, the economy would benefit from additional incentive effects. See "Regulatory Revenues and Offsetting Tax Reductions" on page 48 for further discussion.

4. We made this presumption in order to focus the analysis on the effects of the EPA's CPP rule, rather than the effects of the EPA's CPP rule combined with a tax policy that could change the size of government.

**TABLE 1. Summary of State Revenues from $CO_2$ Emissions Costs (Select Years)**

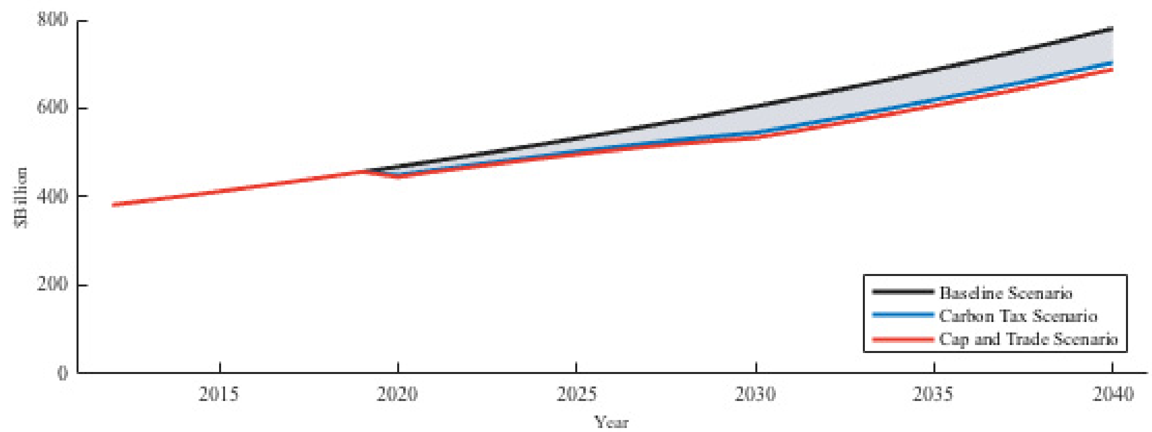
| | Price per ton of $CO_2$ | Allowance or Tax Revenue to the State | Offsets to Sales Tax |
|---|---|---|---|
| **2020 Baseline** | $0.00 | $0.0 million | $0.0 million |
| Carbon Tax | *$13.00* | *$735.3 million* | *$823.4 million* |
| Cap and Trade | *$14.85* | *$684.5 million* | *$816.5 million* |
| **2025 Baseline** | $0.00 | $0.0 million | $0.0 million |
| Carbon Tax | *$22.81* | *$1219.6 million* | *$921.2 million* |
| Cap and Trade | *$26.05* | *$1132.6 million* | *$909.8 million* |
| **2030 Baseline** | $0.00 | $0.0 million | $0.0 million |
| Carbon Tax | *$46.08* | *$2229.9 million* | *$999.1 million* |
| Cap and Trade | *$52.62* | *$2051.8 million* | *$977.9 million* |
| **2040 Baseline** | $0.00 | $0.0 million | $0.0 million |
| Carbon Tax | *$46.08* | *$2024.4 million* | *$1289.6 million* |
| Cap and Trade | *$52.62* | *$1863.7 million* | *$1262.2 million* |

*Source: AEG analysis using the Sectoral Business Decision Model*

*6. Both of the modeled regulatory scenarios would slow the economy and reduce personal income. In 2030, we estimate that Michigan's personal income would be over 12% lower under the cap-and-trade scenario than under the baseline and over 10% lower under the carbon tax scenario.*

Starting in 2020, we estimate that Michigan's personal income would be 5% lower under the modeled cap-and-trade scenario than under the baseline and 4% lower under the modeled carbon tax scenario than under the baseline. In 2030, we estimate that the relative difference in personal income compared to baseline would increase to 12% under cap-and-trade and 10% under carbon tax. This represents a difference of about $11 billion in personal income between the two scenarios. See Figure 4 on page 8 for a comparison of Michigan's personal income under the "no new policy" baseline, the cap-and-trade scenario, and the carbon tax scenario.

**FIGURE 4. All Regulatory Scenarios: Personal Income in Michigan (2012-2040)**




*Source: AEG analysis using the Sectoral Business Decision Model*

The difference in personal income between the cap-and-trade and carbon tax scenarios is primarily driven by two differences related to the regulatory costs of $CO_2$ emissions under these two scenarios.

First, administrative costs and the hedging costs are higher under the cap-and-trade scenario relative to the carbon tax scenario. These higher costs lead to electricity prices that are higher under cap-and-trade relative to carbon tax, which result in lower relative economic growth. In 2030, we project that electricity prices would be 20% higher under the cap-and-trade scenario than under baseline compared to 18% higher under the carbon tax scenario.

Second, the regulatory costs allocated to offset reductions to the state sales tax are slightly lower under the cap-and-trade scenario than under the carbon tax ($978 million compared to $999 million in 2030). The sales tax reductions (funded by the allowance fee or carbon tax revenue) have positive incentive effects on the economy. This would also lead to lower economic growth under the cap-and-trade compared to the carbon tax. However, the administrative costs, risk-hedging costs, and the allocation to unspecified tax cuts or rebates do not have incentive effects on the economy. These costs are nearly 3% higher under cap-and-trade than under the carbon tax.

**TABLE 2. Summary of Economic and Electric Power Indicators (Select Years)**

| | | Average Electriciy Price per KWh | Personal Income | Power Demand | Carbon Emissions |
|---|---|---|---|---|---|
| **2020 Baseline** | | 12.5 cents | $468.6 billion | 108.7 million MWh | 60.6 million short tons |
| Change from Baseline | Carbon Tax | *+5.6%* | *-4.1%* | *-6.4%* | *-6.4%* |
| | Cap and Trade | *+6.4%* | *-5%* | *-7.3%* | *-7.3%* |
| **2025 Baseline** | | 13.6 cents | $532.4 billion | 111.7 million MWh | 60.6 million short tons |
| Change from Baseline | Carbon Tax | *+9.5%* | *-5.6%* | *-11.5%* | *-11.5%* |
| | Cap and Trade | *+10.8%* | *-6.8%* | *-12.6%* | *-12.6%* |
| **2030 Baseline** | | 14.8 cents | $604.8 billion | 114.7 million MWh | 61.9 million short tons |
| Change from Baseline | Carbon Tax | *+17.8%* | *-9.9%* | *-19.8%* | *-21.5%* |
| | Cap and Trade | *+20.3%* | *-11.8%* | *-21.6%* | *-23.2%* |
| **2040 Baseline** | | 17.6 cents | $780.7 billion | 120.9 million MWh | 64.5 million short tons |
| Change from Baseline | Carbon Tax | *+17.7%* | *-9.9%* | *-27.4%* | *-31.7%* |
| | Cap and Trade | *+20.2%* | *-11.8%* | *-28.9%* | *-33.2%* |

*Source: AEG analysis using the Sectoral Business Decision Model*

## ABOUT ANDERSON ECONOMIC GROUP

Anderson Economic Group, LLC is a boutique research and consulting firm, with offices in Chicago, Illinois; East Lansing, Michigan; and Istanbul, Turkey. The experts at AEG specialize in economics, public policy, business valuation, and industry analyses. They have conducted nationally-recognized economic and fiscal impact studies for private, public, and non-profit clients across the United States.

The team at Anderson Economic Group has a deep understanding of advanced economic modeling techniques and extensive experience in a variety of industries in multiple states and countries. Work by AEG has been utilized in legislative hearings, legal proceedings, and public debates, as well as major planning exercises and executive strategy discussions. For more information, please see “Appendix A: About Anderson Economic Group” on page A-1 or visit www.AndersonEconomicGroup.com.

## ABOUT THE NISKANEN CENTER

Established in 2014, the Niskanen Center is a libertarian 501(c)(3) think tank that works to change public policy through direct engagement in the policymaking process: developing and promoting proposals to legislative and executive branch policymakers, building coalitions to facilitate joint action, and marshaling the most convincing arguments in support of their agenda. The Center's main audience is Washington insiders—policy-oriented legislators, presidential appointees, career civil servants in planning, evaluation and budget offices, congressional committee staff, engaged academics, and interest group analysts—who together decide the pace and direction of policy change. For more information, visit their website at www.niskanencenter.org.

# II. Overview of the EPA's Clean Power Plan Requirements for States

The EPA's Clean Power Plan is a complex rule that is intended to reduce carbon pollution from the U.S. electric power industry. The rule was issued on August 3, 2015 after the EPA considered public comments and stakeholder meetings in response to the proposed rule that was issued in June 2014. In this chapter, we provide an overview of the EPA's CPP final rule and briefly describe the options available to states to achieve compliance with this rule. We also acknowledge three controversial topics surrounding the EPA's CPP final rule.

## WHAT IS THE EPA'S CLEAN POWER PLAN?

The EPA's Clean Power Plan is a rule that intends to reduce $CO_2$ emissions from fossil fuel-fired power plants in the U.S.[5] Under the CPP final rule, the EPA sets emissions goals that start in 2022 and become progressively more stringent until 2030. States are required to develop and submit plans that describe how power plants in their state will meet their emissions goals.

### *State Emissions Goals*

For nearly every state, the EPA developed a set of rate and mass emissions goals based on the fleet of existing fossil fuel-fired steam generators and natural gas combined cycle generators.[6] States have the option of complying with either standard.

The rate goals set an aggregate emissions rate standard for all affected power plants in the state.[7] The EPA converted the rate standard into mass limits (i.e. a limit on the number of tons of $CO_2$ emitted per year) to produce the mass goals.[8] Both standards take into account the existing mixture of coal and natural

5.U.S. Environmental Protection Agency, "Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule," *Federal Register* 80, no. 205, (October 23, 2015), pp. 64661–64964.

See "Authority of the EPA" on page 17 for a brief discussion of the EPA's authority to issue the Clean Power Plan final rule.

6. Alaska, Hawaii, and Vermont are excluded from $CO_2$ emissions requirements under the EPA's CPP final rule.

   In this report, we refer to "fossil fuel-fired steam generators" as "coal plants" and the "natural gas combined cycle generators" as "natural gas plants" for brevity. The fossil fuel-fired steam category includes a minority of oil and natural-gas fired steam generators, but generally refers to coal-fired plants.

7. We refer to the amount of emissions per unit of power produced as the emissions rate. We express this in terms of either pounds or short tons of $CO_2$ emissions per MWh. We may also refer to this concept as either "carbon intensity" or "carbon rate."

gas plants in each state. For further discussion of how the EPA arrived at these goals, see "How the EPA Formed the State Emissions Goals" on page 12.

### *Emissions Goals and the Compliance Timeline*

As noted earlier, compliance with the EPA's CPP final rule starts in 2022. The EPA established an interim compliance period from 2022 through 2029. Final compliance begins in 2030. The EPA established rate and mass goals for the 2022-2029 interim period, as well as interim step goals for 2022-2024, 2025-2027, and 2028-2029 periods.[9] These interim step periods correspond with the periods for which states are to demonstrate compliance to the EPA. In 2030 and beyond, the compliance period is every two calendar years.

### *How the EPA Formed the State Emissions Goals*

The EPA identified three methods, or "building blocks," for reducing $CO_2$ emissions from existing power plants:

1. Improving the efficiency at existing coal plants so they burn less fuel and produce lower emissions per unit of power;
2. Substituting generation from coal to existing natural gas plants, which have lower emissions rates; and
3. Shifting generation from both coal and natural gas plants to new renewable sources.

Based on these three approaches, the EPA set performance standards for coal and natural gas power plants. A performance standard is the target $CO_2$ emissions rate for a plant category. The standard for coal plants is 1,305 pounds of $CO_2$ per MWh, while the standard for natural gas plants is 771 pounds of $CO_2$ per MWh.

## COMPLIANCE OPTIONS FOR STATES

The Clean Power Plan outlines several types of options that states can consider as they develop their plans, which the EPA refers to as state implementation plans. States also have the option to develop multi-state plans with other states.[10] If a state does not submit a plan that is approved by the EPA, then the EPA will impose the federal implementation plan on the state. The details

8. The mass goals are less stringent than the rate goals due to the EPA's methodology for calculating the mass goals.
   See U.S. Environmental Protection Agency, "$CO_2$ Emissions Performance Rate and Goal Computation Technical Support Document for CPP Final Rule," August 2015.
9. States are permitted to establish their own interim step goals (i.e., goals for 2022-2024, 2025-2027, and 2028-2029) as long as the annual average meets the EPA's interim period goal for 2022-2029.
10. See "Multi-state plans and multi-state coordination" on page 16 for a brief discussion.

regarding the structure of a federal implementation plan have not been finalized. The EPA has released a proposed federal plan and accepted comments on this proposed rule until January 2016.

While the EPA's CPP final rule allows states to choose among several possible compliance pathways, we describe them broadly in terms of three regulatory scenarios: cap-and-trade, carbon tax, and command-and-control.

Many knowledgable observers interpret the EPA's actions as encouraging states to adopt some sort of cap-and-trade system in order to achieve CPP compliance.[11] For this reason, a cap-and-trade system is the first option that we consider for implementing the CPP final rule in Michigan. We also consider a carbon tax scenario. However, we did not model a command-and-control regulatory scenario. See "Regulatory Scenarios in Michigan" on page 38 for more detailed descriptions of the scenarios that we consider for Michigan.

### *Cap-and-Trade*

Broadly, under a cap-and-trade scenario, the administrator sets a limit on the $CO_2$ emissions rate or total emissions from affected power plants. The EPA's CPP final rule allows for a cap-and-trade system through either a state plan or a FIP. The cap-and-trade system could be administered by either the state, a group of states, or the EPA, depending on whether it is implemented under a state plan, a multi-state plan, or a FIP, respectively.

**Mass-based or rate-based approach.** The emissions limits could correspond to either the rate or mass goals since the EPA's CPP final rule allows for market-based trading to meet either goal.[12] The EPA has yet to determine whether the federal plan would be implemented to meet the rate or the mass goals. The

11. Mark Drajen and Lynn Doan, "Don't Like Obama's Carbon Plan? Fine, Here's Cap and Trade," *Bloomberg Business*, August 4, 2015, http://www.bloomberg.com/news/articles/2015-08-04/don-t-like-obama-s-clean-power-plan-fine-here-s-cap-and-trade, accessed November 2015.

    Will Oremus, "Obama's Climate Plan is Basically Cap and Trade," *Slate*, August 4, 2015, http://www.slate.com/blogs/moneybox/2015/08/04/clean_power_plan_obama_s_climate_plan_is_cap_and_trade_after_all.html, accessed November 2015.

    Emily Holden, Elizabeth, Harball, and ClimateWire, "EPA Clean Power Plan: Start Trading Carbon, Please," *Scientific American*, August 5, 2015, http://www.scientificamerican.com/article/epa-clean-power-plan-start-trading-carbon-please/,accessed November 2015.

12. U.S. Environmental Protection Agency, "Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule," pp. 64887, 64896-64899; and U.S. Environmental Protection Agency, "Federal Plan Requirements for Greenhouse Gas Emissions from Electric Utility Generating Units Constructed on or Before January 8, 2014; Model Trading Rules; Amendments to Framework Regulations, Proposed Rule," August 3, 2015, *Federal Register* 80, no. 205, (October 23, 2015), pp. 64989, 65011.

EPA's proposed federal plan discusses provisions for both types of implementation.

Under a mass-based approach, the administrator allocates $CO_2$ emissions allowances to power plants, which sets the respective limit for each individual plant. If a plant were to exceed the emissions level for which it has allowances, it may purchase allowances on the open market from other plants.

Under a rate-based approach, the power plants may use emissions rate credits (ERCs) to adjust their reported $CO_2$ emissions rate. ERCs can be earned for substituting fossil-fuel fired generation with generation from renewable sources or for reducing generation due to demand-side energy efficiency. One ERC is equivalent to one MWh of either substitute generation or demand reduction. ERCs are added to the denominator of the reported $CO_2$ emissions rate, which results in an adjusted emissions rate that is lower than without the ERCs.

**Initial distribution of allowances.** Under a mass-based cap-and-trade system, there must be some sort of process to initially distribute allowances to power plants. The EPA's CPP final rule allows for power plants to initially acquire allowances through an auction or through direct allocation. Under an auction, power plants must pay for their initial allowances through an auction process. The State of California and the Regional Greenhouse Gas Initiative (RGGI) use this method for their respective cap-and-trade systems. The RGGI implements a cap-and-trade program for nine states in the northeast and mid-Atlantic region of the U.S. The auction allocation method generates revenue for the administrator, which can be used for a variety of purposes, such as investments in demand-side energy efficiency (EE) programs, targeted investments in low-income communities, or other priorities.

Under direct allocation, the administrator would grant allowances to power plants for free. The European Union (EU) uses this method for their cap-and-trade system. This method does not generate revenue for the administrator. While the EPA's CPP final rule does not go into such details, the EPA's proposed federal plan suggests several methods for direct allocation, such as allocation based on historical generation, emissions, or heat input.[13] The EPA also suggests an allocation method to load-serving entities (LSEs) that could be based on historical electricity demand, population served, or emissions.

13. U.S. Environmental Protection Agency, "Federal Plan Requirements for Greenhouse Gas Emissions from Electric Utility Generating Units Constructed on or Before January 8, 2014; Model Trading Rules; Amendments to Framework Regulations, Proposed Rule," pp. 65016-65018.

*Carbon Tax*

Under a carbon tax, the state would levy an excise tax on each unit of $CO_2$ emissions from affected power plants. The state would collect the revenues from the tax and distribute this revenue as allowed by state laws.

The EPA's CPP final rule allows for a carbon tax through a "state measures plan." A state measures plan allows states to rely upon state-enforceable measures on entities other than the power plants affected by the CPP in conjunction with the CPP goals on affected power plants.[14] The state measures plan is available only for meeting the mass goals. This type of plan must also include a backstop of federally enforceable emissions standards that would be triggered if the plan fails to meet the required emission reductions on schedule.

In addition to the carbon tax and the CPP mass goals, a "state measures plan" allows for other features, such as:

- Cap-and-trade program that includes emissions sources that are not affected by the CPP;
- Renewable energy requirements and demand-side energy efficiency programs, such as Renewable Portfolio Standards, energy efficiency resource standards (EERS), and utility- and state-administered incentive programs.

*Command-and-Control*

Under a command-and-control regulatory scenario, the state sets emissions standards directly on affected power plants. Uniform limits could be imposed on all plants or separate limits could be imposed on categories of plants or individual plants.[15] The EPA's CPP final rule offers these examples:

- Apply separate rate standards for coal and natural gas plants that are equal to or less than the respective emissions performance rates (i.e., 1,305 lbs of $CO_2$ per MWh for coal plans and 771 lbs of $CO_2$ per MWh for gas plants);
- Apply a uniform rate standard for all affected power plants that is equal to or less than the state rate goal;
- Apply rate standards to individual plants or to categories of plants at a rate that differs from either the emissions performance rate or the state rate goal;
- Apply mass standards to affected plants; or
- Establish a mass standard based on operational or other standards.

14. U.S. Environmental Protection Agency, "Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule," pp. 64835-68437.
15. U.S. Environmental Protection Agency, "Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule," pp. 64833-68435.

As indicated above, command-and-control policies can be implemented to meet either the rate or the mass goals.

*Additional Options Available to States*

**"Leakage" to new sources.** The EPA's CPP final rule is intended to limit emissions from existing generation sources; however, the EPA has designed the policy to limit electricity generators from building new fossil fuel-fired generating capacity in order to avoid these constraints. The EPA's CPP final rule allows states the following options to prevent "leakage" to new sources:[16]

1. Extend their mass-based limits to new power plants, which allows them to add a "new source complement" to their mass goals;
2. Either update output-based allocations or set aside allowances for RE generation and demand-side EE; or
3. Demonstrate that leakage to new sources is unlikely to occur in the absence of either of the two strategies above.

**Clean Energy Incentive Program.** The Clean Energy Incentive Program (CEIP) awards allowances for investments in RE generation and EE measures that take place in 2020 and 2021, before the CPP compliance period begins.[17] Through this optional program, states may award emissions allowances for eligible RE and EE projects. The EPA may match up to 300 million tons of extra allowances.

**Multi-state plans and multi-state coordination.** The EPA's CPP final rule proposed two approaches that allow for states to coordinate implementation of their CPP plans.[18] The first approach is for states to submit a multi-state plan that applies to the affected power plants in a group of states. Under a multi-state plan, states would aggregate either their rate or mass emissions goals. The second approach is for states to submit individual state plans, but to coordinate plan implementation through interstate transfer of emissions allowances. Under multi-state coordination, states would retain their individual emissions goals.

**Reliability "safety valve."** In the event of an emergency, such as a threat of a brownout or blackout, the EPA's CPP final rule gives states a 90-day period to exceed their emissions limits.[19] Emissions from affected power plants during this period would not be counted against the state's goal and would not be

16. U.S. Environmental Protection Agency, "Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule," pp. 64888-64890.
17. U.S. Environmental Protection Agency, "Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule," pp. 64675-64676.
18. U.S. Environmental Protection Agency, "Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule," pp. 64838-64840.

counted as an exceedance that requires corrective measures. However, any emissions in excess of the states goals must be later accounted for and offset.

## ISSUES OUTSIDE OF THE SCOPE OF THIS REPORT

There are a number of serious debates surrounding the EPA's Clean Power Plan final rule. An evaluation of these controversial topics is outside of the scope of this report. However, we acknowledge three such topics in this section: (1) the authority of the EPA to issue the Clean Power Plan final rule, (2) actions by the U.S. Supreme Court, and (3) the causes and the extent of climate change.

### *Authority of the EPA*

In the final rule for the Clean Power Plan, the EPA asserts that the rule is promulgated under section 111 of the Clean Air Act (CAA). The Clean Air Act is a U.S. federal law intended to control air pollution at the national level. Section 111 of the CAA lays out approaches for developing carbon pollution standards for new sources of emissions through a federal program and standards for existing sources through a state program. In particular, Section 111(d) states:

> (1) The Administrator [EPA] shall prescribe regulations which shall establish a procedure similar to that provided by section 7410 of this title under which each State shall submit to the Administrator a plan which
>
> > (A) establishes standards of performance for any existing source for any air pollutant (i) for which air quality criteria have not been issued or which is not included on a list published under section 7408(a) of this title or emitted from a source category which is regulated under section 7412 of this title but (ii) to which a standard of performance under this section would apply if such existing source were a new source, and
> >
> > (B) provides for the implementation and enforcement of such standards of performance.
>
> Regulations of the Administrator under this paragraph shall permit the State in applying a standard of performance to any particular source under a plan submitted under this paragraph to take into consideration, among other factors, the remaining useful life of the existing source to which such standard applies.
>
> (2) The Administrator shall have the same authority-
>
> > (A) to prescribe a plan for a State in cases where the State fails to submit a satisfactory plan as he would have under section 7410(c) of this title in the case of failure to submit an implementation plan, and
> >
> > (B) to enforce the provisions of such plan in cases where the State fails to enforce them as he would have under sections 7413 and 7414 of this title with respect to an implementation plan.
>
> In promulgating a standard of performance under a plan prescribed under this paragraph, the Administrator shall take into consideration, among other factors,

19. U.S. Environmental Protection Agency, "Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule," pp. 64877-648579.

> remaining useful lives of the sources in the category of sources to which such standard applies.[20]

However, whether the EPA actually has the statutory authority to issue the CPP final rule has been subject to considerable debate. In October 2015, a coalition of 24 states challenged the CPP final rule in the U.S. Court of Appeals, claiming that it is in excess of the agency's statutory authority under the CAA.[21] Michigan Attorney General Bill Schuette joined this coalition in his individual capacity. Meanwhile, Michigan Governor Rick Snyder announced that his administration would develop a state plan to comply with the CPP final rule. In response to the suit against the EPA, another coalition of 18 states, the District of Columbia, and four municipalities filed a motion to intervene.[22]

### *Actions by the U.S. Supreme Court*

On January 21, 2016, the U.S. Court of Appeals denied the requests to stay the EPA's CPP final rule during litigation. Later on February 9, 2016, U.S. Supreme Court overturned this decision and temporarily blocked the regulation until the appeals court issues its ruling. A week later, the State of Michigan announced that it would suspend its efforts to comply with the EPA's CPP final rule and its timeline for plan submission.

Our modeling results are based on the EPA's CPP final rule as issued in August 2015 and on the state economy and generation sector as known in late 2015. We have not taken into account any delay or modifications to the EPA's CPP final rule that may take place as a result of the U.S. Supreme Court's action.

### *Cause and Extent of Climate Change*

More broadly, there is debate over the extent to which greenhouse gas emissions contribute to anthropogenic (human-caused) climate change. For example, in 2007, the Intergovernmental Panel on Climate Change (IPCC) concluded that climate change is occurring, very likely due to greenhouse gases generated from human activity.[23] In contrast, the Nongovernmental International Panel on Climate Change (NIPCC) issued a rebuttal, concluding that the human effect on climate change is minimal relative to natural variability.[24]

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20. 42 U.S.C. §7411(d).
21. *West Virginia, et al. v. EPA*, D.C. Cir., No. 15-1363, October 23, 2015.
22. *West Virginia, et al. v. EPA*, D.C. Cir., No. 15-1363, Document #1581816, November 4, 2015.
23. Intergovernmental Panel on Climate Change, "Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change," IPCC, Geneva, Switzerland, 2007.
24. Craig Idso and S. Fred Singer, "Climate Change Reconsidered," Nongovernmental International Panel on Climate Change, The Heartland Institute, Chicago, IL, 2009.

We do not analyze the effects that CPP compliance would have on climate change. Thus, the validity of the assertions by proponents of either side of this debate has no bearing on our analysis. Evaluating whether the target reductions under the CPP final rule will slow down or reverse current trends in climate change is outside of the scope of this report.

As noted above, we recognize there are serious issues related to the EPA's authority to issue the Clean Power Plan final rule and to the general debate over climate change. However, we do not attempt to document or evaluate these topics in this report.

# III. Michigan's Economy and Electric Power Sector

In this chapter, we describe Michigan's economy and electric power sector. We first discuss the relationship between economic growth and electricity demand. We then describe Michigan's industrial structure and personal income growth. We follow this with a discussion of trends in electricity generation, electricity sales, and electricity prices. We conclude with a discussion of $CO_2$ emissions in Michigan.

## RELATIONSHIP BETWEEN ECONOMIC GROWTH AND ELECTRICITY USAGE

The relationship between energy demand and economic activity is one of the most well-documented relationships in macroeconomics. Under periods of economic growth, businesses expand and, as a result, consume more electricity to keep the lights on in their buildings and operate their industrial processes. During these times, households have a higher propensity to consume and take fewer measures to conserve electricity in their homes.

While the electricity intensity of the economy has gradually reduced over the past several decades, a recent study published by the U.S. Energy Information Administration (EIA) examines this question and demonstrates that this relationship still exists.[25] The authors show that electricity use is highly correlated with real GDP, and they show that electricity usage has tracked economic growth during the last five recessions. While there is some variation, electricity sales also generally coincides with other indicators such as real personal income, household and non-farm employment, industrial production, and manufacturing and trade sales.

This relationship between the economy and electricity demand informs the economic growth model that we develop to evaluate scenarios for achieving compliance with the Clean Power Plan. We discuss this model further in "Modeling the Effects of Regulatory Scenarios on State Economies" on page 28.

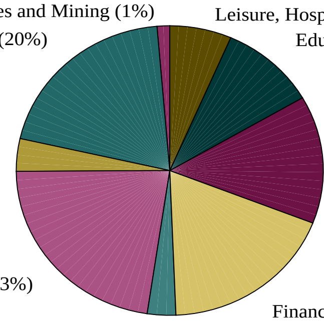
## MICHIGAN'S ECONOMY

State gross domestic product (GDP), the market value of all goods and services produced, is the most comprehensive measure of a state's economic health and performance. In 2014, Michigan's GDP was nearly $452 billion, the 13th highest in the country. Of that, $402 billion is due to the private sector.

25. Vipin Arora and Jozef Lieskovsky, "Electricity Use as an Indicator of U.S. Economic Activity," U.S. Energy Information Administration, November 2014, https://www.eia.gov/workingpapers/pdf/electricity_indicator.pdf, accessed October 2015.

As shown in Figure 5 below, "trade, transportation, and utilities," "manufacturing," and "financial activities" form the three largest sectors of Michigan's economy. Together, these sectors represent over 60% of Michigan's GDP.

**FIGURE 5. Gross Domestic Product in Michigan, by Sector (2014)**



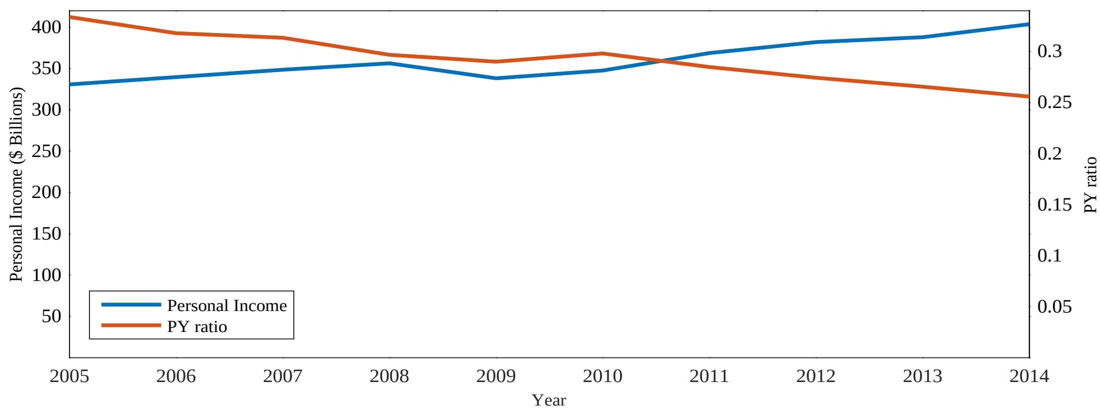

*Source: AEG analysis based on data sourced from the U.S. Bureau of Economic Analysis*

Personal income is another measure of a state's economic health. This measure includes salaries, wages, and bonuses from employment; dividends and interest from investments; rental income; and pension income. In 2014, Michigan's personal income exceeded $400 billion, ranking 10th in the country. Since 2005, nominal personal income has grown by 22%, or about 2.2% annually.

The ratio of electric power demand to nominal personal income (PY ratio) represents the relationship between electricity usage and economic activity. Since 2005, this measure has declined at a rate of 2.9% annually. This trend is due to inflation and to improvements in electricity efficiency.

Figure 6 on page 22 presents nominal personal income and PY ratio in Michigan over time.

**FIGURE 6. Nominal Personal Income and PY ratio in Michigan (2005-2014)**




*Source: AEG analysis based on data sourced from the U.S. Bureau of Economic Analysis and the U.S. Energy Information Administration*

## MICHIGAN'S ELECTRIC POWER SECTOR

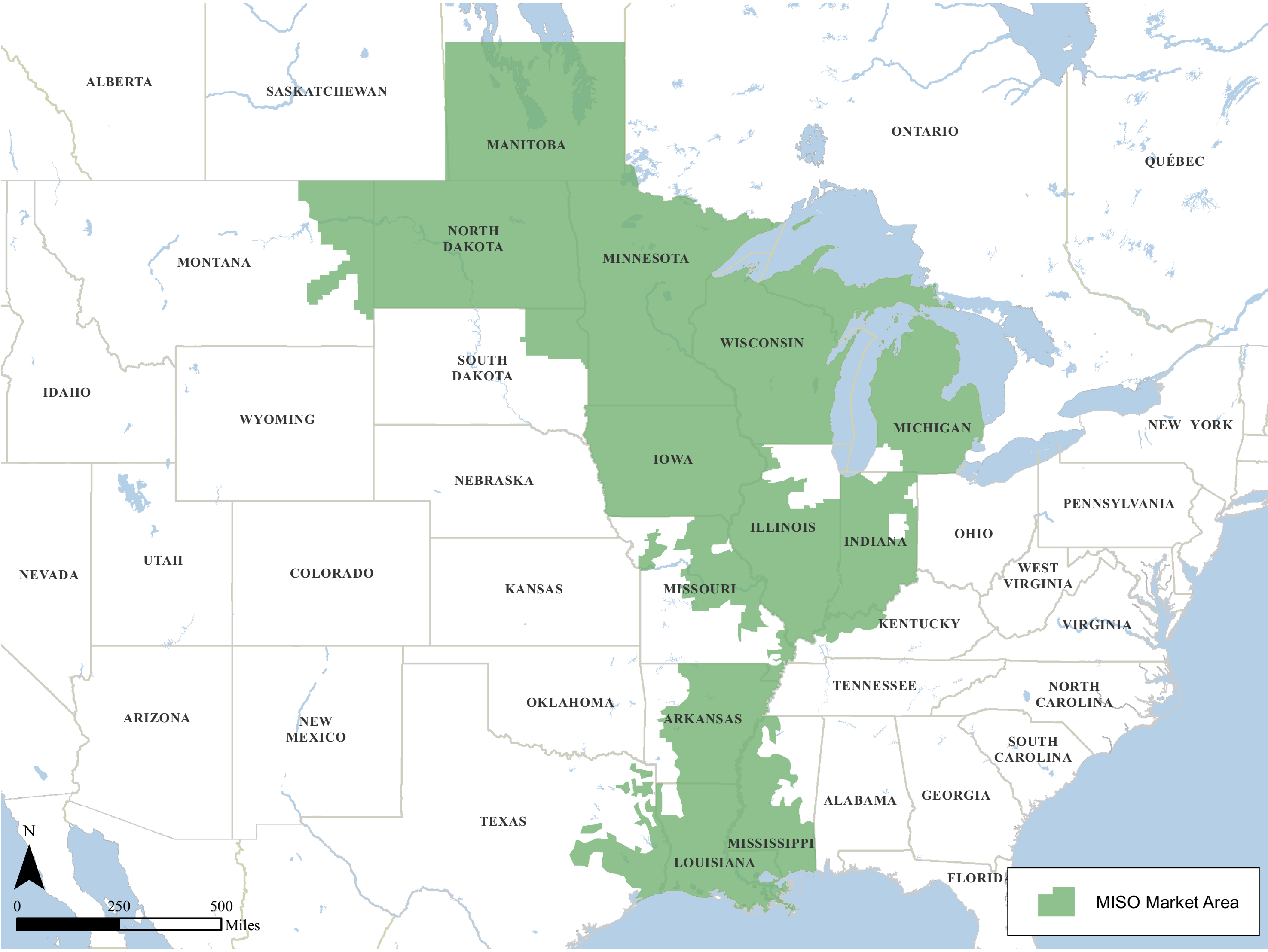
The electric power supply chain is divided into three segments: generation, high-voltage transmission, and local distribution to end-use consumers. Electricity generation facilities (i.e. power plants) fueled by coal, natural gas, nuclear power, and other sources generate electricity that is transmitted across what is called the "electric grid." Transmission occurs over high-voltage lines across long distances between generation sources and population centers. Local distribution to consumers occurs after high-voltage power is reduced to a lower voltage that is suitable for delivery to end-use facilities.

The Midcontinent Independent System Operator, Inc. (MISO) is an independent, non-profit corporation of grid stakeholders that is responsible for managing and planning the electrical grid across the Midwest and in portions of the South. As shown in Figure 7 on page 23, MISO's market area includes the majority of the state of Michigan.

While electricity demand is influenced by many factors, it typically peaks during the summer months. Consumption rises during this time due to increased usage of air conditioners, which rely on electricity. Figure 8 on page 24 presents the number of population-weighted cooling degree days (CDD) by state. Cooling degree days is an indicator of air conditioning energy requirements.[26] According to the figure, Michigan requires less air conditioning usage relative to the rest of the country.

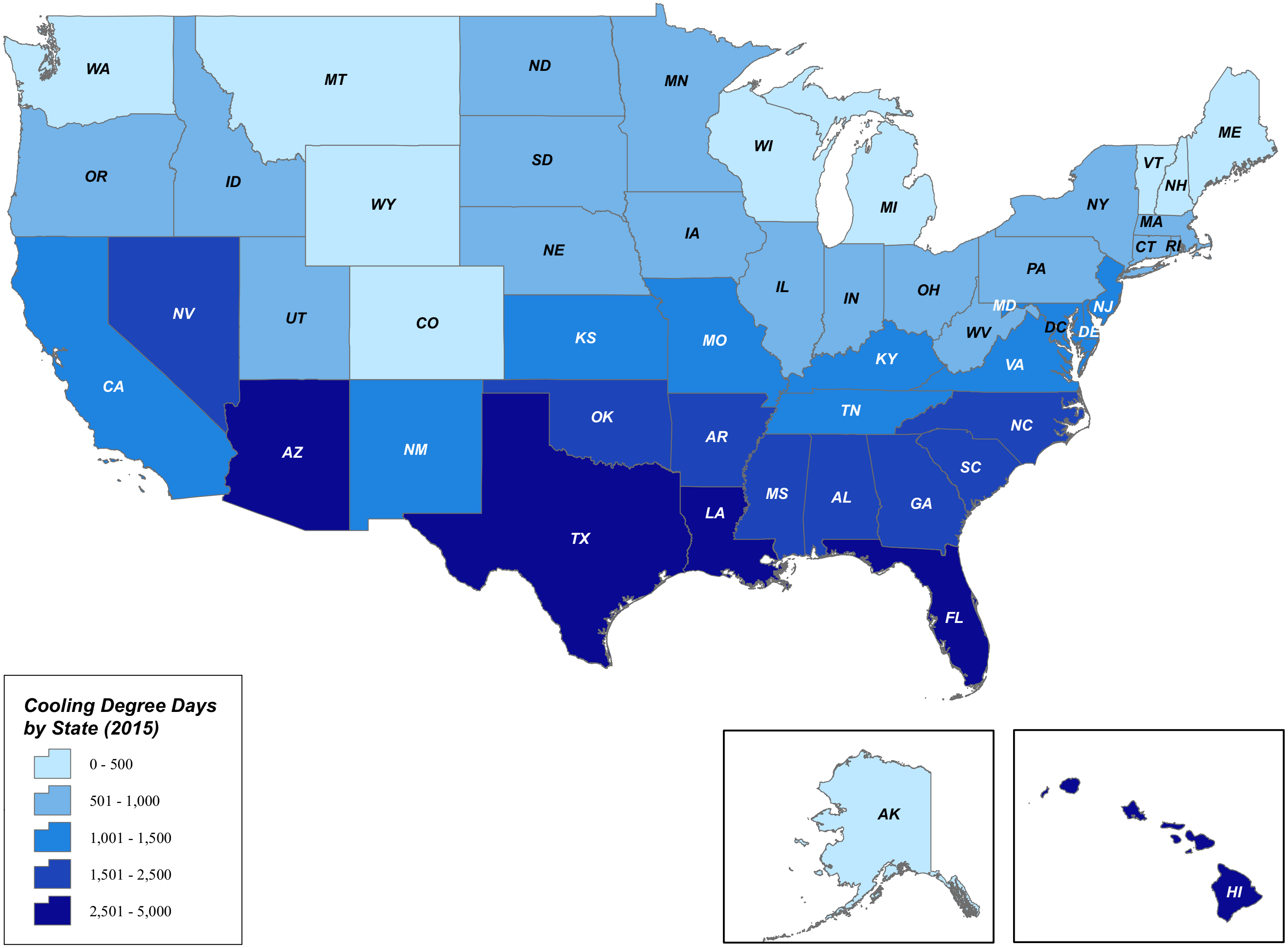
26. Cooling degree days is a measure of how warm a location is over a period of time relative to a base temperature.

FIGURE 7. **Midcontinent Independent System Operator Market Area**




*Source: Anderson Economic Group, LLC based on data sourced from the Midcontinent Independnet System Operator; and Esri, Inc.*

FIGURE 8. **Population-Weighted Cooling Degree Days by State (2015)**



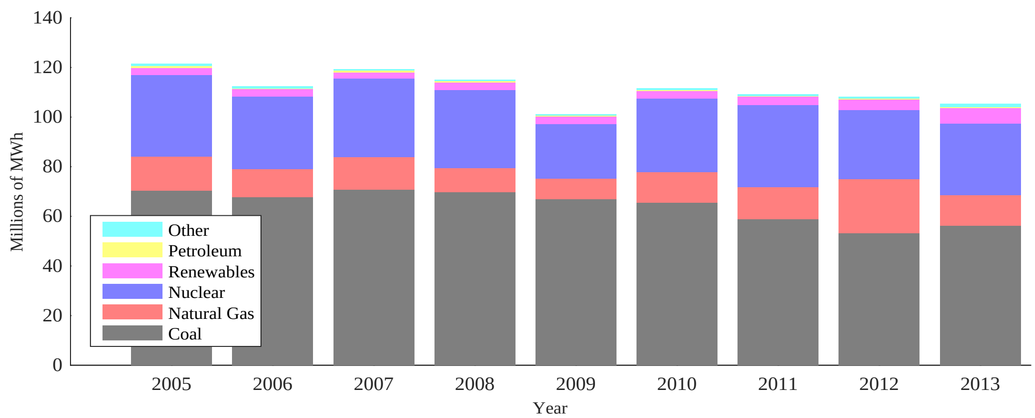

*Source: Anderson Economic Group, LLC analysis based on data sourced from the U.S. National Oceanic and Atmospheric Administration.*

### *Electricity Generation and Demand in Michigan*

In 2013, net generation from Michigan's power plants totaled 105 million MWh of electricity. Net generation in Michigan ranked 14th in the country.

Figure 9 below presents the composition of electricity generation in Michigan by fuel source. The majority of net electricity generation in Michigan has been sourced from coal. However, this has gradually declined since 2005. Generation from natural gas has remained about 11% of total generation, with the exception of 2012 when it represented 20% of total generation. Generation from nuclear power has made up roughly about 26% of total generation. From 2005 through 2012, generation from renewable sources has been about 3% of total generation, but increased to 5.8% in 2013.

**FIGURE 9. Net Electricity Generation in Michigan by Source (2005-2013)**

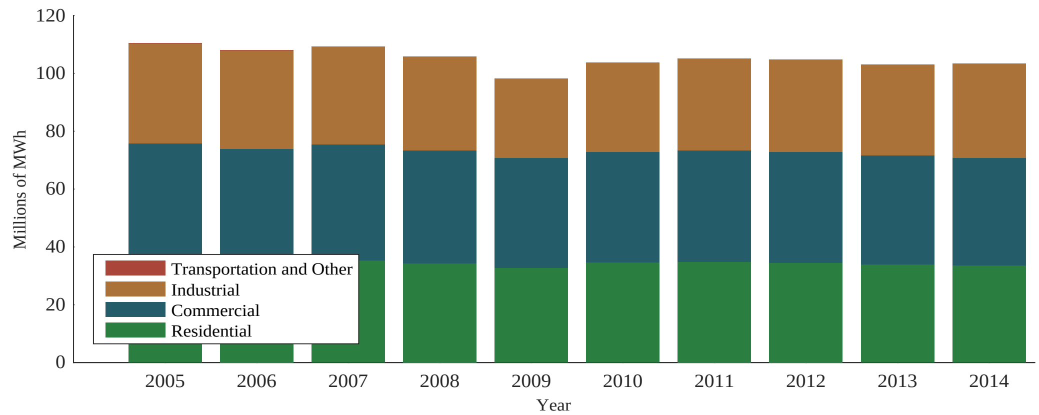



*Source: AEG analysis based on data sourced from the U.S. Energy Information Administration*

Electricity demand in Michigan totaled 103 million MWh of power in 2014, ranking 12th in the country. While there has been a modest decline in electricity demand over the last several years, the composition of electricity sales in Michigan has been fairly consistent. In 2013, residential sales represented about 32% of total, commercial sales represented about 36%, and industrial sales represented about 31%. These shares are fairly representative of those in previous years.

See Figure 10 on page 26 for more details.

**FIGURE 10. Electric Sales in Michigan by Sector (2005-2014)**

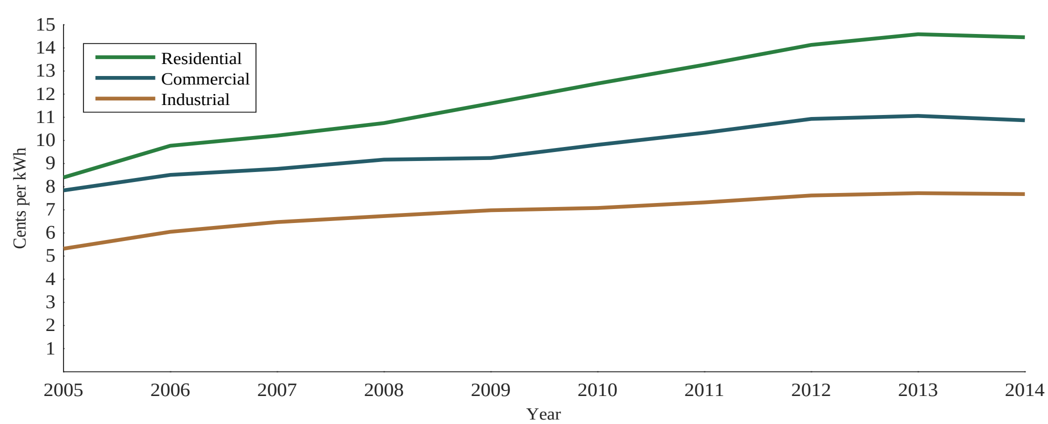



*Source: AEG analysis based on data sourced from the U.S. Energy Information Administration*

Figure 11 below presents average nominal electricity prices in Michigan by sector from 2005 through 2014. In 2014, the average retail prices for residential consumers was about 14.5 cents per kilowatt-hour (kwh), for commercial consumers was about 10.9 cents per kwh, and for industrial consumers was about 7.7 cents were kwh.

Since 2005, residential prices increased about 6% annually, while commercial and industrial prices increased about 4% annually.

**FIGURE 11. Electricity Prices in Michigan by Sector (2005-2014)**

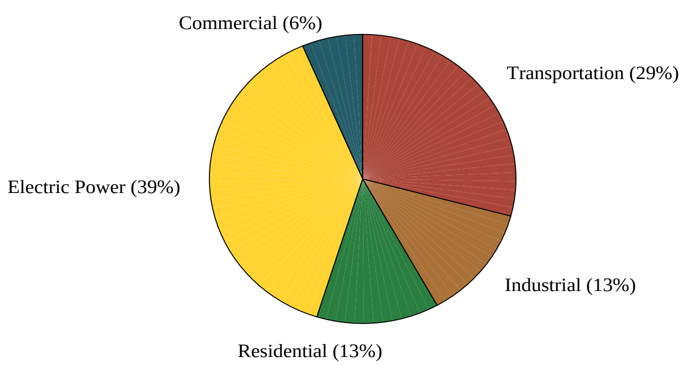



*Source: AEG analysis based on data sourced from the U.S. Energy Information Administration*

### *Michigan's $CO_2$ Emissions*

As shown in Figure 12 below, the electric power sector represents the largest source of $CO_2$ emissions in Michigan. Nearly 39% of such emissions are from this sector, followed by 29% from the transportation sector. The residential and industrial sectors represent about 13%, while the commercial sector only represents about 6% of $CO_2$ emissions.

**FIGURE 12. $CO_2$ Emissions in Michigan by Sector (2013)**




*Source: AEG analysis based on data sourced from the U.S. Energy Information Administration*

Figure 13 below presents $CO_2$ emissions from Michigan's electric power sector over time. Between 2005 and 2013, emissions have decreased by nearly 16%. Emissions from coal generation have been between 81 and 91 percent of the total over this period, while natural gas has been between 6 and 16 percent.

**FIGURE 13. Michigan's Electric Power $CO_2$ Emissions by Source (2005-2013)**


*Source: AEG analysis based on data sourced from the U.S. Energy Information Administration*

# *IV. Modeling the Effects of Regulatory Scenarios on State Economies*

In this chapter, we describe our approach to modeling the effects of various regulatory scenarios on a state's economy.

## BASELINE AND COMPARISON

As noted, we consider three regulatory scenarios in this analysis:

1. A "no new policy" baseline scenario that assumes the continuation of existing state policies, existing trends toward efficiency, and planned changes in generation capacity and technology;
2. A cap-and-trade scenario based on a state implementation plan to comply with the EPA's CPP final rule with offsetting tax reductions; and
3. A carbon tax scenario based on a state implementation plan to comply with the EPA's CPP final rule with offsetting tax reductions.

The baseline for our analyses is the "no new policy" scenario.

### *Importance of a Relevant Baseline*

The baseline scenario takes into account significant economic and policy effects already in motion. The utility industry, electric power consumers, and other consumers and producers in the broader U.S. economy already face incentives to improve energy efficiency over time. These incentives start with the fundamental consideration of the cost of energy; improving efficiency reduces that cost.

On top of this fundamental incentive, the utility industry already faces incentives from various policies, including the Renewable Portfolio Standard mandate in many states, including Michigan, to reduce their use of carbon-intensive generating technologies. Furthermore, other technological changes, such as the availability of LED lighting and improving efficiency of heating and cooling systems, will result in improving efficiency over time with or without additional policies.

The appropriate comparison for any proposed new policy is a baseline that takes into account what consumers and producers are already likely to experience, including the effects of fundamental incentives, technology changes, and existing policies. Ignoring these effects would mislead readers by implying that all changes in the economy we project, including any related costs and benefits, were caused by the policy we consider. To ensure we accurately present the results of our analyses of potential new policies, we compare them with a relevant baseline that incorporates existing trends, incentives, and technology shifts.

## GENERAL MODELING APPROACH

### *Growth Model Approach*

In this report, we model a state's economy over multiple decades. Because state economies grow and change over time, and because such changes and growth are cumulative, the focus of our modeling is on the path over time. In particular, we focus on how decisions made in each individual year affect the growth path over time. We believe this approach is the best one for analyzing multi-year effects of policies that affect the behavior of individuals and organizations, and where those changes in behavior have immediate and cumulative effects.

These long-term cumulative effects tend to dominate short-term changes in an economy, when the relevant time period extends past a decade. Such long-term effects are particularly important to model properly when the policies under consideration are intended to affect behavior. For the Clean Power Plan (as well as many related current and proposed policies involving energy), the focus of the policy is to reduce aggregate emissions across the entire country, meaning the collective effects of decisions of nearly every resident of the country over a period extending well beyond a decade.

As noted further below, this growth model approach is different from other modeling approaches that focus on short-term changes, or on mechanistic relationships between inputs and outputs. We discuss these approaches further under "Comparison to Other Approaches" on page 32.

### *Components of Growth Model*

The essence of an economic growth model is the projection of year-to-year changes in the economy, beginning with a base year.[27] These projections are done using difference equations, meaning equations that focus on the period-to-period changes (differences) in key variables.

The most important variable representing the economy of a state is the personal income of its residents. Conceptually, income to residents is equivalent to output, because the residents receive income collectively that must match their collective output, measured in the same units.[28]

We use equations to represent the relationship between the demand for electric power and economic output (and income). This relationship has been exten-

27. The intellectual origins of economic growth models are very deep, and arguably extend back at least as far as Adam Smith's 1776 classic *Wealth of Nations.* The modern neoclassical growth model originated with Robert Solow in the 1950's, and has been extended by Robert Lucas, Jr. and others to take into account expectations, technology, human capital, and other factors. See "Neoclassical growth theory" in *The New Palgrave: A Dictionary of Economics,* MacMillan, 1991; "Robert Merton Solow: The Concise Encyclopedia of Economics | Library of Economics and Liberty," 2008, http://www.econlib.org/library/Enc/bios/Solow.html, accessed November 2015.

sively studied and is one of the most important for predicting the other variables of interest. We also use equations to represent the relationship between electricity generation and carbon emissions.

Key components of the model that are used in these equations are:

- The ratio of electricity demand to personal income and projected improvement;
- Projected carbon emissions rate of power plants per unit of power produced, which incorporates assumptions regarding the type of generation used in these plants (such as coal, natural gas, or nuclear) as well as the use of "renewable" sources of power such as wind and solar;
- Projected growth in electricity prices, which we break down by major sector (residential, commercial, and industrial); and
- Projected heat rate (generation efficiency) improvement of power plants.

To effect the year-to-year changes in the key variables of income and energy usage, we use a set of response functions. These functions represent the decisions that consumers and producers in the economy make when they are presented with changes in prices, taxes, and expectations about their future income and job prospects. We discuss these functions in the next section under "Response Functions" on page 30.

For a detailed presentation of the growth model and the related assumptions, see "Economic Growth Model" on page C-2 in the Appendix.

### *Response Functions*

As noted above, the essence of a growth model is the incorporation of year-by-year decisions of millions of consumers and producers in the economy into the growth path of that same economy. Thus, a focus of a growth model is representing the effect of these decisions on income and other variables in the succeeding time periods.

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28. The National Income and Product Accounts (NIPA) is the accounting framework for this identity. Under NIPA, the gross domestic income (national income) of the country must equal the gross domestic product of the country. Of course, differences in reporting and aggregation, and vagaries of categorizing such concepts as depreciation and net exports, lead to some discrepancies, even in the U.S. Furthermore, economies of states and regions within the country cannot be measured as precisely given the very large cross-state border flows of goods, services, payments, and workers.

    The national accounts for the U.S. are maintained by the BEA at the Commerce Department. An excellent summary of the history of national income accounts is Ott, Mack (2008). "National Income Accounts," in David R. Henderson (ed.) *Concise Encyclopedia of Economics* (2nd ed.). Indianapolis: Library of Economics and Liberty. An online version is available from the Library of Economics & Liberty, at: http://www.econlib.org/library/Enc/NationalIncomeAccounts.html.

In our model, we take into account the information presented to consumers, workers, and investors each year regarding prices, taxes, and expectations about their future income and job prospects. This information includes variations in current prices and quantities; information on policy changes; and information related to the uncertainty and risks that accompany future time periods.

To represent the decisions firms and individuals make in response to this information, we develop a set of response functions characterizing likely industry responses to changes in key economic variables. These response functions account for the impact of changes in behavior by certain industries in response to changes in energy prices, uncertainty, tax burdens, and other regulatory costs. Through these functions, we are able to accurately model the impacts on economic growth of proposed methods for complying with the CPP. In each year modeled, we combine our general growth projections and likely industry responses to estimate personal income and other variables of interest in Michigan.

For a more detailed discussion of our methodology, see "Electricity Price and Risk Response Functions" on page C-5 in the Appendix.

### *Use of Recursive Decision Models*

Anderson Economic Group has pioneered the use of recursive models for analyzing firm decisions.[29] We use this breakthrough modeling method to capture the discrete nature of investment decisions, which more accurately reflects the nature of firm decisions. We first construct a model of firm investment in light of uncertain energy prices and other economic conditions. We then parameterize this model for a number of representative firms in key industries. Solving these models, we obtain valuable information about likely responses of key players to the changes brought about by a specific scenario. We then aggregate these results, and combine them with the projections from our growth model for each year.

For a more detailed discussion of our methodology, see "Recursive Model of Business Decisions" on page C-7.

## EFFECTS CONSIDERED

### *Effects on Investment*

Using the response functions and recursive methods discussed previously, we model the effects on investment by taking into account that firms make both continuous and discrete decisions in response to market conditions. While firms

29. Patrick L. Anderson, *The Economics of Business Valuation*, Stanford University Press, 2013 and Patrick L. Anderson, "Policy Uncertainty and Persistent Unemployment," *Business Economics*, January 2014.

can scale back production or adjust inputs and capital, they can also decide to relocate operations elsewhere in response to rising electricity costs.

We consider that there is variation in the sensitivity of firms to electricity prices across industries. We identify the commercial and industrial sectors of the economy, quantify the relative size of these sectors, and estimate the response of these sectors to changes in electricity prices.

### *Effects on Prices*

We consider that extra costs imposed on $CO_2$ emissions would be passed along to consumers. We assume that any incremental increase in the price of electricity due to such costs would be applied equally for each sector (i.e. residential, commercial, and industrial electric rates would increase by the same price per MWh).[30] We acknowledge that the actual effects may differ due to political pressure to shift costs to one sector over another.

### *Effects of Taxes*

In both modeled CPP regulatory scenarios, it is possible to offset the costs of the carbon emissions by reducing taxes or distributing the revenues back to taxpayers in the form of a rebate. We consider that offsetting tax cuts would have positive incentive effects on the state economy.

## COMPARISON TO OTHER APPROACHES

**Other Growth Models.** The fundamental growth model is the basis for many models. It is arguably the basis for *all* multi-year models, since input-output and computable general equilibrium models are based on one-time adjustments in a market economy, and therefore their use to model multi-year effects requires stringing together these effects over time.

30. The Michigan Public Service Commission (MPSC) has demonstrated that it would approve increases in rates associated with more expensive generation facilities. The MPSC recently approved rate increases for DTE Electric and Consumers Energy. The utilities filed these rate cases in part to cover costs associated with purchasing natural gas plants (both DTE Electric and Consumers Energy) and retiring seven coal plants (Consumers Energy only). The amounts approved represent increases of 5.3% (DTE Electric) and 4.5% (Consumers Energy) above the respective utilities' previous rate cases. For Consumers Energy, the amount would represent 3.2% over the previous rates when the seven coal plants retire in April 2016.

    See Michigan Public Service Commission, "MPSC authorizes DTE Electric Company to increase its electric rates, approves settlement agreement increasing Michigan Gas Utilities rates," December 11, 2015, http://www.michigan.gov/mpsc/0,4639,7-159-16400_17280-371177--,00.html, accessed February 2016 and
    Michigan Public Service Commission, "MPSC authorizes Consumers Energy Company to increase its electric rates," November 19, 2015, http://www.michigan.gov/mpsc/0,4639,7-159-16400_17280-369707--,00.html, accessed November 2015.

One growth model that has been used regularly is called a Capital, Labor, Energy, and Materials (CLEM) model. These may be the most reliable of the approaches used since the 1970s. As noted by recent University of Kentucky authors:

> Many researchers have used CLEM type models to estimate the economic effects of oil price shocks in the 1970's (see, e.g., Hamilton, 1983; Hooker, 1996; Davis and Haltiwanger, 2001). Davis and Haltiwanger (2001) examine the effects of oil and monetary shocks in the U.S. on job creation and destruction in the manufacturing sector from 1972 to 1988.[31]

CLEM models often employ disaggregated sectors to allow responses to price changes to vary across the economy, as would be expected for responses to energy prices.

**Input-output model.** Input-output models depict inter-industry relationships in an economy with a well-defined region. These models link the outputs from one industry to the inputs for another industry. Typically, the inter-industry relationships are linear in nature. Because these models are useful for conducting "economic impact" analyses, they are sometimes called economic impact models. These models can be very useful for analyzing short-term effects of events that do not change the underlying structure of the economy or result in major technological change. They are not useful for analyses of economies over time, when structural and technological change are important factors.

The following are some input-output models that are commercially available:

- Regional Economic Models, Inc.'s (REMI) PI+ model employs input-output techniques.[32] A number of reports on energy policy use variations of the PI+ model.
- MIG. Inc.'s IMPLAN (IMpact analysis for Planning) data and software is a popular

In addition, the U.S. Department of Commerce Bureau of Economic Analysis (BEA) produces input-output model factors, commonly known as "multipliers,"

31. John Garen, Christopher Jepsen, and James Saunoris, "The Relationship between Electricity Prices and Electricity Demand, Economic Growth, and Employment," University of Kentucky CBER, October 2011.

    Referenced works in the excerpt include: Steven J. Davis and John Haltiwanger, "Sectoral Job Creation and Destruction Responses to Oil Price Changes," *Journal of Monetary Economics*, 2001, 48(3), pp. 465-512; and James D. Hamilton, "Oil and the macroeconomy since World War II," *Journal of Political Economy* 1983, 91, pp. 228–248.

32. Regional Economic Models, Inc., "Economic Policy Analysis | Economic Software | REMI," 2015, http://www.remi.com/products/pi, accessed November 2015.

on a periodic basis. These are produced under their RIMS program, which dates from the 1970s.

The RIMS "multipliers" are not models. Unfortunately, it is common to read claims from analysts that they "used" the RIMS model to estimate impacts, that the RIMS program is a method, or that the RIMS program is a method approved by the U.S. government. RIMS factors are widely available for a nominal cost, and they can be used—or misused—easily by anyone with access to them.

**Utility or dispatch model.** Utility models are detailed, mechanical models that account for the numerous inputs and outputs of utility facilities. They account for the differences across production technologies in converting fuel and other inputs to useful outputs, by-products, and pollutants. They also might account for production and load constraints. These models are particularly useful for analyzing short-term planning, and effective use of utility models (like effective use of inventory and production models in any industry) can improve efficiencies. However, they are not intended to analyze economic growth over time, nor assess the effects of changes in prices and reliability on the economy as a whole.

There are a set of commonly used utility models:

- ABB Group's Promod incorporates extensive details regarding generating unit operating characteristics, transmission grid topology and constraints, and market system operations.[33]
- ICF International's Integrated Planning Model (IPM), which was used by the EPA to evaluate the CPP, is another detailed model of the electric power sector.[34] This model relies on linear programming techniques to identify the least-cost method of meeting energy and peak-demand requirements subject to operating and regulatory constraints.

**"CGE," "DSGE," and "DSE" Models.** Computable general equilibrium (CGE), dynamic stochastic equilibrium (DSGE), and dynamic stochastic equilibrium (DSE) models have been developed recently, and are intended to capture more of the microeconomic adjustments than have been practical or possible to incorporate in traditional input-output models.

These models attempt to incorporate the microeconomic decisions of households, firms, and governments, and to take into account the interactions among them. They rely on a mechanism that aggregates modeled decisions of sectors of the economy, and adjusts prices and quantities until markets clear. These mechanisms can be quite complex or relatively simple. It is important to recognize

33. ABB Group, "Promod IV," 2015, http://new.abb.com/enterprise-software/energy-portfolio-management/market-analysis/promod-iv, accessed November 2015.

34. ICF International, "Integrated Planning Model," 2015, http://www.icfi.com/insights/products-and-tools/ipm, accessed November 2015.

that standard models also have such mechanisms, although they are generally much more blunt.

These models are relatively new, and their complexity has led to criticism that they are similar to "black boxes."[35] Furthermore, the boundaries between CGE and standard econometric and growth models are not always clear, and the differentiation among CGE, DSGE, and DSE are similarly vague.

Some of the models that could be considered CGE models and have been used in energy policy are:

- NERA's NewEra model, which was used to model a proposed CPP rule.[36]
- The Heritage Foundation's HEMS model, which is based on two other models, and was used to model a proposed CPP rule.[37]

35. Ian Sue Wing, "Computable General Equilibrium Models for the Analysis of Energy and Climate Policies," in Joanne Evans & Lester C. Hunt (eds.), *International Handbook on the Economics of Energy*, Edward Elgar, 2009 notes this criticism:

> Unearthing the features of CGE models [...] is often a time-consuming exercise. This is because their sheer size, facilitated by recent advances in computer technology, makes it difficult to pinpoint the precise source of a particular result. They often remain a black box. Indeed, frequently, authors are themselves unable to explain their results intuitively and, when pressed, resort to uninformative answers...

Garen, Jepsen, and Saunoris cite these authors as well in their critiques of CGE models.

Antoine Bouet, "The Expected Benefits of Trade Liberalization: Opening the Black Box of Global Trade Modeling," *Food Policy Review*, Vol. 8, 2008, notes, "Moreover, as a sophisticated and complex tool of analysis, CGEMs are often treated as 'black boxes,' results of which are difficult to understand."

36. David Harrison Jr. and Anne E. Smith, "Potential Energy Impacts of the EPA Proposed Clean Power Plan," NERA Economic Consulting, October 2014, http://www.nera.com/content/dam/nera/publications/2014/NERA_ACCCE_CPP_Final_10.17.2014.pdf.

37. Kevin D. Dayaratna, Nicolas Loris, and David W. Kreutzer, "The Obama Administration's Climate Agenda Will Hit Manufacturing Hard: A State-by-State Analysis," Heritage Foundation Backgrounder No. 2990, February 17, 2015, http://www.heritage.org/research/reports/2015/02/the-obama-administrations-climate-agenda-will-hit-manufacturing-hard-a-state-by-state-analysis.

Heritage authors also cite: U.S. Energy Information Administration, "The National Energy Modeling System: An Overview," October 2009, http://www.eia.gov/oiaf/aeo/overview/pdf/0581(2009).pdf; and Steven A. Gabriel, Andy S. Kydes, and Peter Whitman, "The National Energy Modeling System: A Large-Scale Energy-Economic Equilibrium Model," *Operations Research*, Vol. 49, No. 1, January–February 2001, pp. 14–25, http://pubsonline.informs.org/doi/pdf/10.1287/opre.49.1.14.11195.

## LIMITATIONS

We acknowledge the following limitations to our modeling efforts.

1. We use trend personal income as our fundamental indicator of economic activity, and rely on a trend assumption regarding electricity price inflation. We do not attempt to estimate cyclical variations in the economy, nor changes in price inflation trends.
2. We also do not use the extensive catalogue of generation data that are available in other models—in particular, utility models. These data include technology, inputs, input prices, by products, emissions other than $CO_2$, and constraints on other types of emissions; and
3. We do not account for how stakeholders might respond to the residual risk of federal regulation due to non-compliance under the CPP scenarios.

We further describe the limitations to our model in "Limitations" on page C-21.

# *V. Outcomes of Regulatory Scenarios in Michigan*

In this section, we summarize our analysis of the effects of Clean Power Plan compliance in Michigan. We first present the emissions goals for Michigan under the EPA's CPP final rule and describe the regulatory scenarios we considered. We then present our findings from each of these scenarios and compare the results to other studies.

## EPA'S CLEAN POWER PLAN GOALS FOR MICHIGAN

As discussed previously, the EPA developed three types of emissions goals for each state:

1. Rate goals set an aggregate emissions rate for the existing coal- and natural gas-fired power plants in the state;
2. Mass goals are limits on the total $CO_2$ emissions from the fleet of existing power plants; and
3. Mass goals plus new source complements are limits on total $CO_2$ emissions from both existing and new power plants in order to prevent leakage.

We present the goals for Michigan in Table 3 below.

**TABLE 3. $CO_2$ Emissions Baseline and Clean Power Plan Goals for Michigan**

| | 2012 Baseline | Interim Goal 2022-2024 | Interim Goal 2025-2027 | Interim Goal 2028-2029 | Final Goal 2030 & After |
|---|---|---|---|---|---|
| Rate goal (short tons $CO_2$ per MWh) | 0.964 | 0.734 | 0.633 | 0.614 | 0.584 |
| Mass goal (million short tons $CO_2$) | 69.9 | 56.85 | 51.89 | 49.11 | 47.54 |
| Mass goal and new source complement (million short tons $CO_2$) | n/a | 57.11 | 52.76 | 49.92 | 48.09 |

*Note: Interim goals indicate the annual average for the years in the respective interim period.*
*n/a: not applicable*

*Source: AEG analysis based on data sourced from the U.S. Environmental Protection Agency, Clean Power Plan*

According to the 2012 baseline data used to develop the CPP goals, the emissions rate in Michigan was 1,928 lbs $CO_2$ per MWh and the total $CO_2$ emissions amount was 69.9 million short tons. This implies that CPP compliance requires a 39% reduction in the emissions rate and 32% reduction in emissions from 2012 to 2030.[38]

38. The total emissions reduction is based on the mass goals, as opposed to the mass goals plus new source complement.

## REGULATORY SCENARIOS IN MICHIGAN

As noted elsewhere in the report, we consider three regulatory scenarios:

1. A "no new policy" baseline in which there is no new state or federal plan to comply with the EPA's CPP final rule;
2. A cap-and-trade system as an option for achieving the requirements of the CPP final rule; and
3. A carbon tax as an alternate compliance option for the CPP final rule.

We modeled the two CPP compliance options as if they are implemented in year 2020. We discuss these regulatory scenarios in further detail in this section.

For a more detailed discussion of our methodology and assumptions, see "Appendix C. Methodology" on page C-1.

### *1. "No New Policy" Scenario*

Our "no new policy" scenario presumes the absence of either a state or federal plan to comply with the EPA's CPP final rule. This scenario provides a baseline for economic and electric industry performance. We consider that there are existing actions and policies unrelated to implementation of the CPP final rule that would reduce $CO_2$ emissions. For example, Michigan's existing Renewable Portfolio Standards require Michigan's electric providers to generate at least 10% of electricity from renewable sources by 2015.[39] In addition, there are several planned coal plant retirements that were announced prior to when the CPP final rule was issued.[40]

### *2. Cap-and-Trade Scenario*

The first Clean Power Plan compliance option that we consider is a cap-and-trade system. As discussed previously, it is likely that this is the EPA's preferred option that states adopt. Our cap-and-trade scenario presumes that the state would adopt a mass-based state plan.[41] The State of Michigan would set a cap on the total $CO_2$ emissions from affected power plants and would also administer the initial allocation of emissions allowances.[42]

39. MCL 460.1021 through 460.1053.

40. For further discussion of our assumptions regarding the future mix of electricity generation sources, see "Electric Power Sector CO2 Emissions" on page C-15.

41. Mass-based implementation is more likely than a rate-based implementation since the mass goals are less stringent than the rate goals. Further, the EPA estimates that the rate-based implementation is more costly; the annual incremental compliance cost for the rate-based implementation would be $8.4 billion in 2030, while cost for the mass-based implementation would be $5.1 billion.
See U.S. Environmental Protection Agency, "Regulatory Impact Analysis for the Clean Power Plan Final Rule," August 2015, p. 3-22.

This scenario also presumes that the total $CO_2$ emissions limit for the entire state is consistent with the mass emissions goals plus the new source complement. Emissions allowances would be allocated by auction and auction revenues would be collected by the Michigan Department of Treasury. We also presume that electricity generators would take precautionary actions to ensure that they acquire enough allowances to achieve compliance during each compliance period.

See “Tax Changes” on page 39 for further discussion regarding our consideration for these actions and for how the auction revenues would be allocated.

### *3. Carbon Tax Scenario*

We then consider a carbon tax that would be implemented as an alternative option to comply with the Clean Power Plan. Our carbon tax scenario presumes the State of Michigan would levy an excise tax on each ton of $CO_2$ emitted by affected power plants that starts at $15 per short ton of $CO_2$. The carbon tax rises at an annual rate of about 15.8% per year and is capped at $60 per short ton. This type of tax policy is consistent with the Michigan Constitution, which imposes revenue limits on the legislature and requires that taxes be subject to such limits.[43] In addition, this is a tax path that the State of Michigan would need to impose such that power generators remain in compliance during each interim and compliance period. The revenues from the carbon tax would be used to offset cuts to other taxes, which we describe in “Tax Changes” on page 39.

This scenario also presumes that the MPSC would allow for 100% of the carbon tax to be passed through to consumers in their electric rates. See “Tax Changes” on page 39 for further discussion regarding our consideration for how the carbon tax revenues would be allocated.

### *Tax Changes*

As noted previously, we presume that the State of Michigan would receive:

1. Carbon allowance auction revenues under the cap-and-trade scenario; and
2. Carbon tax revenues under the carbon tax scenario.

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42. We presume that the State of Michigan would adopt a SIP rather than be subject to a FIP, based on public statements from the Snyder administration.
See Michigan Agency for Energy, “Michigan to Develop Its Own State Carbon Implementation Plan to Ensure it Retains Control of Its Energy Future,” September 2015.
In addition to relinquishing autonomy over its electricity policy, under a FIP, a state faces the risk of the EPA collecting potential revenues from carbon allowance allocations that could otherwise be collected by the State of Michigan.

43. Mich. Const. Article IV, §32 and Article IX, §§3, 6, 7, 8, 25, 26.

See “Electric Power Sector CO2 Emissions” on page 15, for further discussion of the parameters identified in this section.

**Cap-and-trade scenario.** We assume that the emissions allowance price would be equivalent to the carbon tax rate for the same year from the carbon tax scenario (see “Carbon tax scenario” on page 40). We then add an additional premium of 14.2% to arrive at the gross per-unit regulatory emissions cost.

The first 10% of this incremental increase is due to hedging costs that generators would incur to mitigate the risk of not acquiring sufficient allowances such that they would meet electricity demand and maintain reliability. The next 4.2% of the incremental increase would cover costs for the State of Michigan to administer allowance auctions. The remaining regulatory emissions costs represent net allowance auction revenues that are available for offsets to tax reductions or rebates.

We presume that the State of Michigan would adopt a companion tax policy in order to a establish an approximately revenue-neutral carbon emissions policy. Under this scenario, we first allocated the net allowance revenues to offset a 0.5 percentage-point cut in the state general sales tax rate, which is currently 6%. Any remaining auction revenues would be allocated to unspecified tax reductions or rebates. See “Regulatory Revenues and Offsetting Tax Reductions” on page 48 for a discussion of options for allocating the unspecified tax reductions or rebates.

**Carbon tax scenario.** First, we assume that power plants would receive a 0.3% collection allowance and that 1% of carbon tax revenues would be allocated for state administrative expenses for collecting the tax.[44]

Similar to the cap-and-trade scenario, we presume that the State of Michigan would adopt a companion tax policy in order to implement a revenue-neutral carbon tax. Under this scenario, we allocated the net carbon tax revenues to offset a 0.5 percentage-point cut in the general state sales tax rate. Any remaining carbon tax revenues after that would be allocated to unspecified tax reductions or rebates.

## OUTCOMES OF REGULATORY SCENARIOS IN MICHIGAN

For each of the three regulatory scenarios, we project the path of Michigan’s economy, power plant emissions, and electricity prices. Our projections are based on our modeling approach that we described in the previous chapter. We use the economic and electric power industry conditions in 2012 as a baseline, which is consistent with the EPA’s use of historic data from 2012 to develop the

44. The collection allowance is consistent with Michigan state law that provides for a collection allowance on the general state sales tax.

Clean Power Plan goals. We discuss the outcomes of each of the regulatory scenarios in this section.

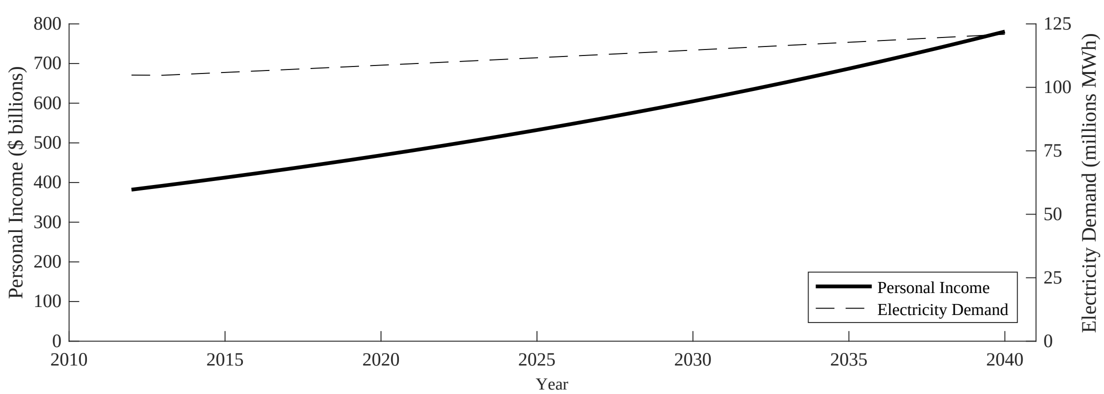
### *Outcomes of "No New Policy" Scenario*

We summarize the main results of our modeling of the "no new policy" baseline. See Figure D-3 on page D-6 for additional exhibits and Table D-6 on page D-3 for supporting data.

In Figure 14 below, we present our projections for Michigan's nominal personal income and electricity demand under the "no new policy" baseline. We estimate that Michigan's economy would continue to grow and that personal income would reach $469 billion in 2020 and increase to $605 billion in 2030.

Based on our projections for the path of Michigan's economic growth, we estimate that electricity demand will reach 109 million MWh of power in 2020 and 115 million MWh of power in 2030.

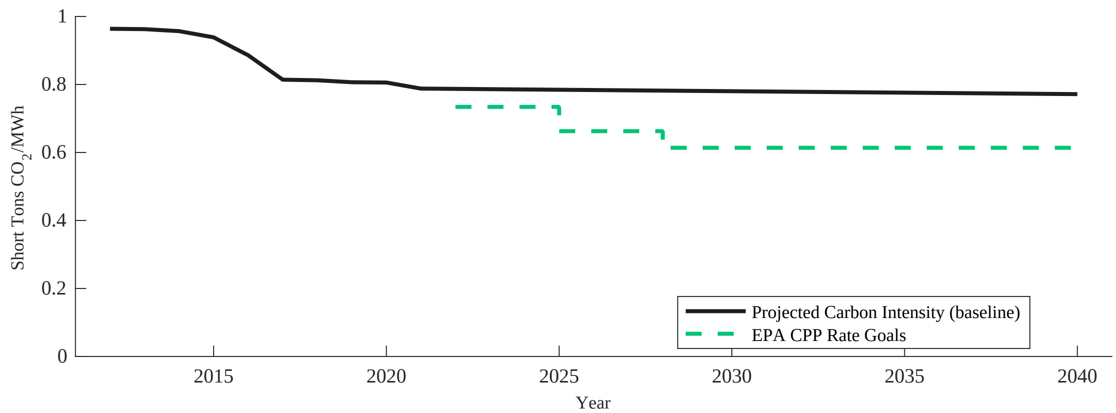
**FIGURE 14. No New Policy: Personal Income and Electricity Demand in Michigan (2012-2040)**




*Source: AEG analysis using the Sectoral Business Decision Model*

We estimate that the emissions rate for fossil-fuel electricity generation would reach 0.81 short tons of $CO_2$ per MWh in 2020 and fall to 0.78 short tons per MWh 2030. We present our emissions rate projections in Figure 15 on page 42 and compare them against the rate goals for Michigan under the EPA's CPP final rule.

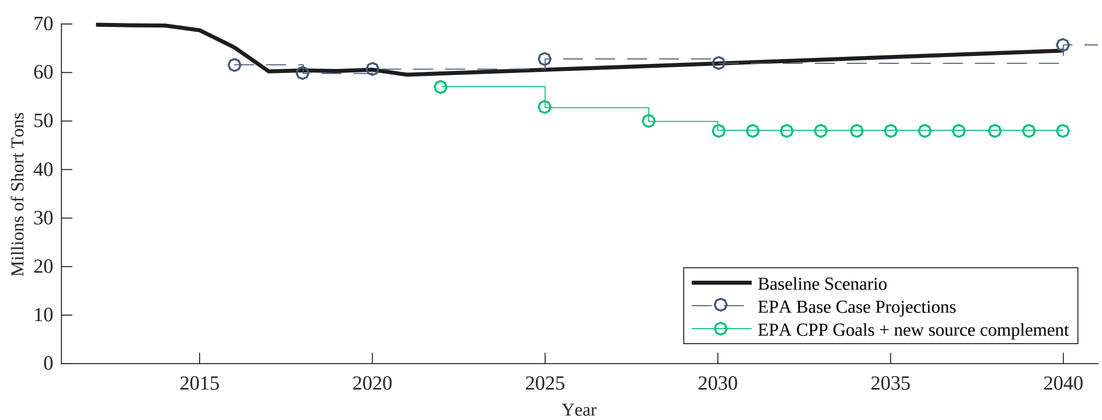
**FIGURE 15. No New Policy: $CO_2$ Emissions Rate for Michigan's Electricity Generation Subject to CPP (2012-2040)**




*Source: AEG analysis using the Sectoral Business Decision Model*

From our projections for electricity demand and the emissions rate, we estimate that $CO_2$ emissions from the electric power sector would fall to 60.6 million short tons by 2020 and increase to nearly 62 million short tons in 2030. Based on these estimates, power plants in Michigan would not achieve the 2030 goal of 48.1 million short tons of $CO_2$ required by the CPP final rule under "no new policy." See our projections in Figure 16 below.

**FIGURE 16. No New Policy: $CO_2$ Emissions from Michigan's Electric Power Sector (2012-2040)**



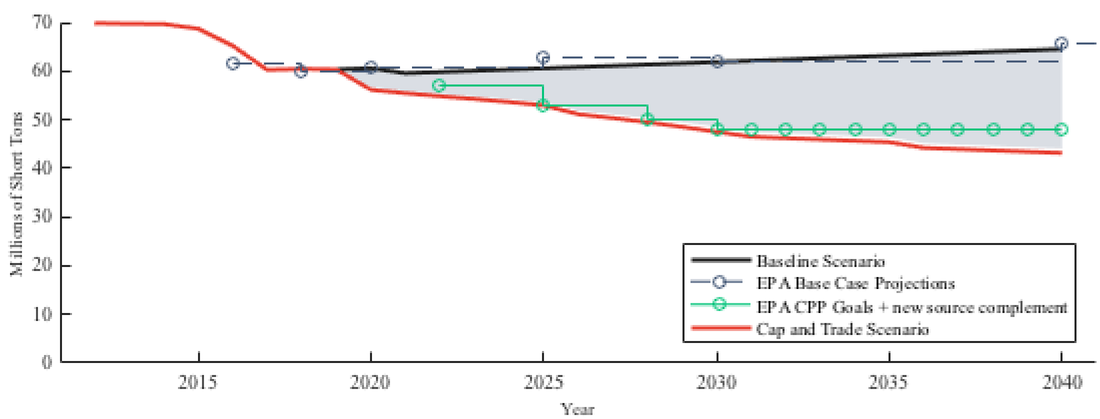

*Source: AEG analysis using the Sectoral Business Decision Model*

*Outcomes of Cap-and-Trade Scenario*

We summarize the main results of our modeling of the cap-and-trade scenario. See Figure D-2 on page D-4 for additional exhibits and Table D-7 on page D-5 for supporting data.

Under the modeled cap-and-trade scenario, Michigan's power plants would meet the limits based on the CPP $CO_2$ emissions mass goals plus new source complement during all interim and final compliance periods. We present our emissions projections in Figure 17 below.

**FIGURE 17. Cap-and-Trade: $CO_2$ Emissions from Michigan's Electricity Generation Subject to the CPP (2012-2040)**

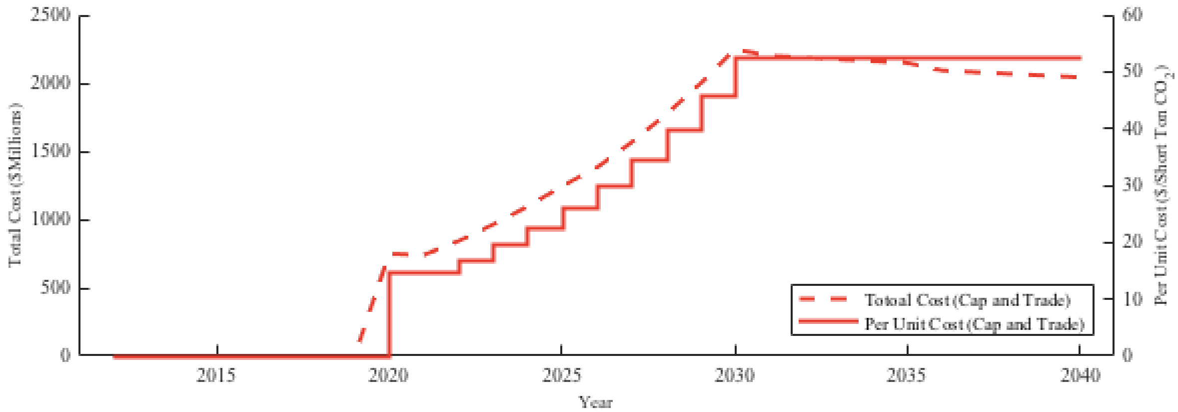



*Source: AEG analysis using the Sectoral Business Decision Model*

Figure 18 on page 44 presents the projected costs of $CO_2$ emissions that electricity generators would incur in order to achieve the projected emissions path. These costs include not only the price of emissions allowances, but also hedging costs and administrative costs. Starting in 2020, we estimate that emissions under the cap-and-trade system would cost nearly $15 per short ton in Michigan for a total of $750 million. At final compliance in 2030, these costs would likely increase to over $52 per short ton for a total of $2.2 billion.

After accounting for $280 million in administrative costs and hedging costs, we estimate that nearly $2 billion would be available to offset cuts to taxes or fund rebates in 2030. We estimate that $980 million of the net carbon allowance revenues would be available for a 0.5 percentage-point cut in the sales tax rate and the remaining $990 million would be available for unspecified tax cuts or rebates.

**FIGURE 18. Cap-and-Trade: $CO_2$ Emissions Allowance Costs (2012-2040)**



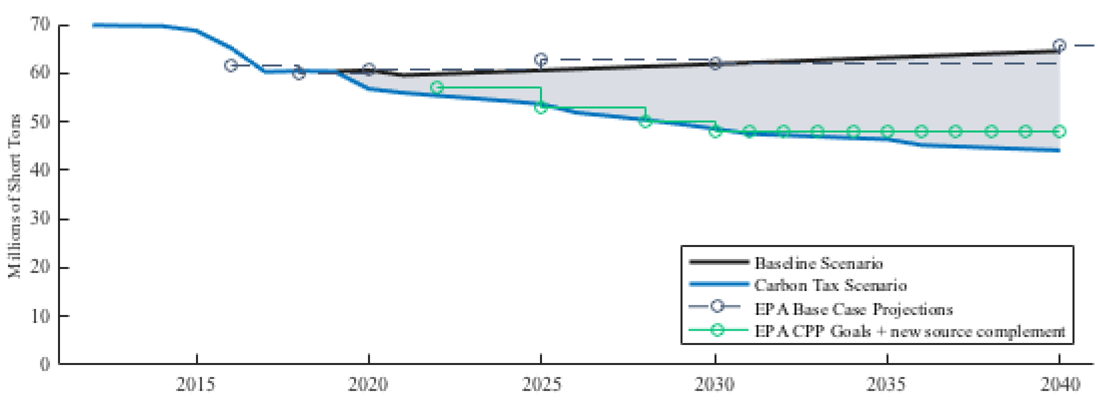

*Source: AEG analysis using the Sectoral Business Decision Model*

## *Outcomes of Carbon Tax Scenario*

We summarize the main results of our modeling of the carbon tax scenario. See Figure D-3 on page D-6 for additional exhibits and Table D-8 on page D-7 for supporting data.

Under the modeled carbon tax scenario, emissions from Michigan's power plants would meet limits based on the CPP $CO_2$ emissions mass goals plus new source complement during all interim and final compliance periods. We present our emissions projections in Figure 19 below.

**FIGURE 19. Carbon Tax: $CO_2$ Emissions from Michigan's Electricity Generation Subject to the CPP (2012-2040)**

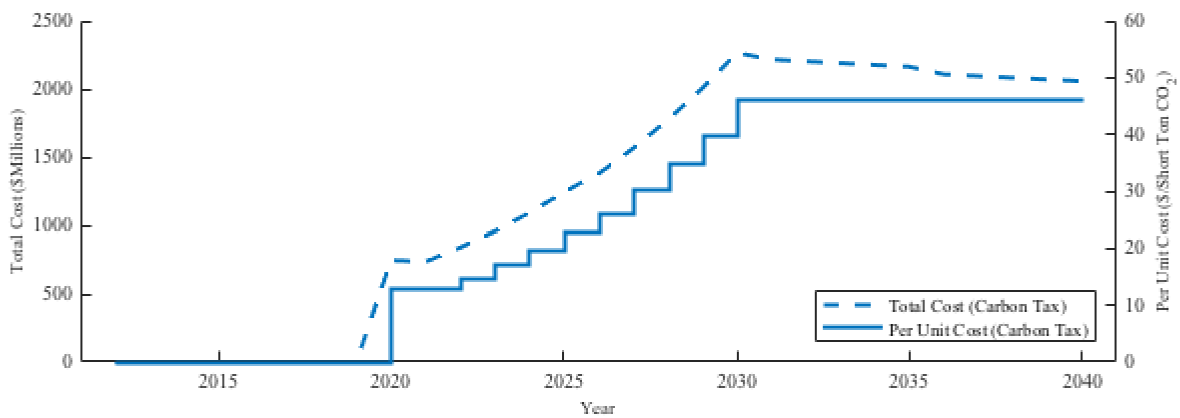



*Source: AEG analysis using the Sectoral Business Decision Model*

Figure 20 below presents the projected carbon tax rates and revenues that would be associated with achieving the emissions path reported in Figure 19 on page 44. Starting in 2020, we estimate that the carbon tax rate would start at $13 per short ton for a total of $738 million in carbon tax costs. At final compliance in 2030, the carbon tax rate would increase to $46 per short ton for a total of $2.2 billion in carbon tax costs.

After accounting for $29 million in administrative costs and collection allowances, we estimate that $2.2 billion would be available to offset cuts to taxes or fund rebates in 2030. We estimate that $999 million of the net carbon tax revenues would be available for a 0.5 percentage-point cut in the sales tax rate and the remaining $1.2 billion would be available for unspecified tax cuts or rebates.

**FIGURE 20. Carbon Tax: Carbon Tax Revenues and Rates (2012-2040)**



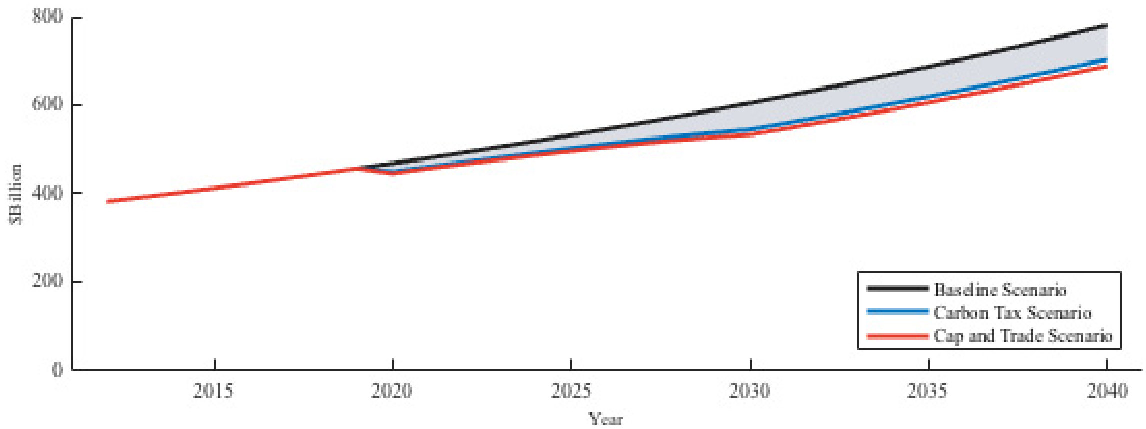

*Source: AEG analysis using the Sectoral Business Decision Model*

### *Effects Compared to Baseline*

Growth in electricity prices and the offsets to tax cuts both affect year-to-year changes in economic growth. After taking these effects into account, we estimate that personal income in Michigan would be 12% lower under the cap-and-trade scenario than under the baseline in 2030. We estimate the personal income under the carbon tax scenario would be 10% lower than under the baseline.

See Figure 21 on page 46 for our projections for the path of personal income growth under the modeled regulatory scenarios.

**FIGURE 21. All Regulatory Scenarios: Personal Income in Michigan (2012-2040)**




*Source: AEG analysis using the Sectoral Business Decision Model*

The difference in personal income under cap-and-trade compared to carbon tax is primarily attributed to two issues related to the regulatory costs of $CO_2$ emissions.

First, administrative costs and the hedging costs are higher under the cap-and-trade scenario relative to the carbon tax scenario. These increased costs lead to higher electricity prices under cap-and-trade relative to carbon tax, which result in lower relative economic growth. In 2030, we project that electricity prices would be 20% higher under the cap-and-trade scenario than under baseline compared to 18% higher under the carbon tax scenario.

Second, we project that the regulatory costs allocated to offset reductions to the state sales tax in 2030 are $999 million under the carbon tax scenario compared to $978 million under the cap-and-trade scenario. This is a 2% difference that would result in lower positive incentive effects on the economy under the cap-and-trade scenario compared to the carbon tax scenario.

The remaining costs do not have any positive incentive effects on the economy. These costs include:

- Administrative costs;
- Collection allowance (carbon tax only);
- Hedging costs (cap-and-trade only); and
- Other unspecified tax reductions or rebates.

In 2030, the components that do not have any incentive effects would total about $1.3 billion under the cap-and-trade system. In comparison, under the carbon tax, the components that do not have any incentive effects would total $1.2 billion, about 3% less than under cap-and-trade.

See Table 4 below for additional comparisons of selected measures under the cap-and-trade and carbon tax scenarios to the "no new policy" baseline.

**TABLE 4. Summary of Economic and Electric Power Indicators (Select Years)**

| | | Average Electriciy Price per KWh | Personal Income | Power Demand | Carbon Emissions |
|---|---|---|---|---|---|
| **2020 Baseline** | | 12.5 cents | $468.6 billion | 108.7 million MWh | 60.6 million short tons |
| Change from Baseline | Carbon Tax | *+5.6%* | *-4.1%* | *-6.4%* | *-6.4%* |
| | Cap and Trade | *+6.4%* | *-5%* | *-7.3%* | *-7.3%* |
| **2025 Baseline** | | 13.6 cents | $532.4 billion | 111.7 million MWh | 60.6 million short tons |
| Change from Baseline | Carbon Tax | *+9.5%* | *-5.6%* | *-11.5%* | *-11.5%* |
| | Cap and Trade | *+10.8%* | *-6.8%* | *-12.6%* | *-12.6%* |
| **2030 Baseline** | | 14.8 cents | $604.8 billion | 114.7 million MWh | 61.9 million short tons |
| Change from Baseline | Carbon Tax | *+17.8%* | *-9.9%* | *-19.8%* | *-21.5%* |
| | Cap and Trade | *+20.3%* | *-11.8%* | *-21.6%* | *-23.2%* |
| **2040 Baseline** | | 17.6 cents | $780.7 billion | 120.9 million MWh | 64.5 million short tons |
| Change from Baseline | Carbon Tax | *+17.7%* | *-9.9%* | *-27.4%* | *-31.7%* |
| | Cap and Trade | *+20.2%* | *-11.8%* | *-28.9%* | *-33.2%* |

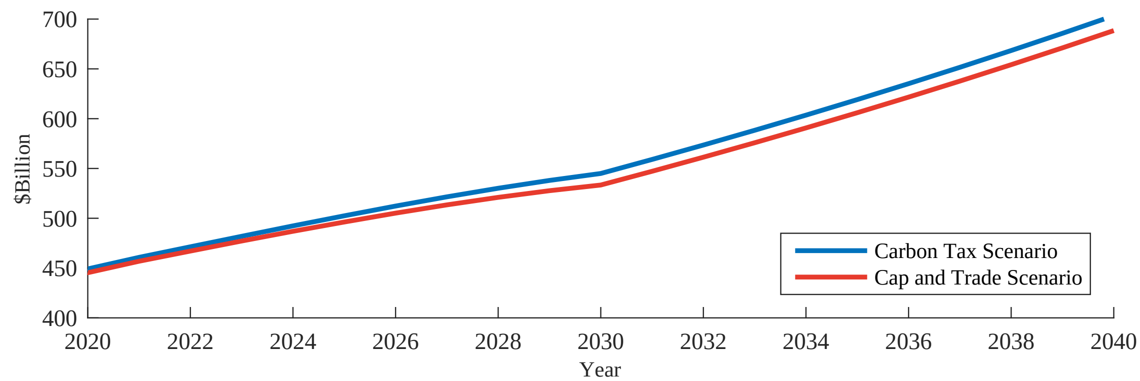
*Source: AEG analysis using the Sectoral Business Decision Model*

### *Cap-and-trade vs. Carbon Tax*

As a result of the differences between the cap-and-trade and carbon tax, personal income under the cap-and-trade scenario would be 1% lower than under the carbon tax scenario in 2020. We estimate that this difference would increase to 2% in 2030. This difference is equivalent to $11 billion dollars. We compare personal income under these two scenarios in Figure 22 on page 48. For additional exhibits that present the differences between the cap-and-trade and carbon tax scenarios, see Figure D-4 on page D-8.

Under the modeled cap-and-trade scenario, we presumed that the State of Michigan would allocate emissions allowances by auction. If allowances were initially distributed via free allocation, then the State would not receive any revenues.[45] There would be no offsetting tax cuts, and therefore, there would be no positive incentive effects on the economy from lower taxes. Thus, the economy would likely be even smaller under this allocation scheme compared to under the modeled cap-and-trade scenario.

**FIGURE 22. Cap-and-Trade vs. Carbon Tax: Personal Income in Michigan (2020-2040)**




*Source: AEG analysis using the Sectoral Business Decision Model*

## REGULATORY REVENUES AND OFFSETTING TAX REDUCTIONS

Under both the cap-and-trade and the carbon tax scenarios, the State of Michigan would receive revenue from utilities that generate power using carbon sources within the State of Michigan. Although the precise amount of revenue available in any given year would be uncertain, we assumed that the legislature would adopt a companion tax policy regime that—together with the regulatory revenue—is approximately revenue-neutral over time.

### *Companion Tax Policy for Revenue-Neutral Carbon Policy*

In particular, we assumed that the State of Michigan would first allocate these revenues to a 0.5 percentage-point reduction in the state general sales tax rate, and to their costs of administering the regulatory program. We assumed the revenues offsetting the assumed reduction in the general state sales tax rate would be dedicated to purposes that are consistent with current sales tax allocations.[46]

We project that the sales tax reduction alone would not be sufficient to offset all of the regulatory revenue under the two scenarios presented here. Acknowledging that it would not be possible to know the exact amount of revenue each year until after the year was completed, we presumed the remaining revenues would

45. We discussed the possible schemes in which generators could receive allowances in "Initial distribution of allowances" on page 14.

be returned to the taxpayers in the form of a reduction in other taxes or an income tax rebate. The following list of tax policy options provides a number of examples for how this could be accomplished:

- A 0.2 percentage-point cut in the state personal income tax rate;
- A cut in the state corporate income tax that would be equivalent to roughly $1 billion in 2030;[47] or
- A lump-sum rebate to households, which would be equivalent to $100 to $300 per household after final compliance, depending on the scenario and the year.[48]

### *Incentive and Disincentive Effects*

The reduction in the state sales tax rate would have positive incentive effects on the economy. This would partially offset the disincentive effects of increased electricity prices on the economy. We took into account both the incentive and the disincentive effects in the economic growth we forecast in the regulatory scenarios.

If the legislature offset the remaining revenues by adopting a tax policy that provided a predictable reduction in a major taxes, there would likely be additional incentive effects on the economy. We did not attribute positive incentive effects to these remaining revenues under the modeled scenarios since their use was unspecified. It is important to note that these incentives to economic growth affect the size of the economy, and therefore also demand for electricity, in the future.

46. Article IX, section 8 of the Constitution requires that the State levy at least a 2% sales tax, on top of a sales tax that can be levied up to 4%. The state has levied the maximum 4% plus the required 2% since the adoption of Proposal A in 1994.

    Other sections of Article IX allocate a large share of the sales tax revenue (including to local governments and the school aid fund). We presumed that any regulatory revenues offsetting a sales tax reduction would be allocated in exactly the manner currently applied to the existing sales tax revenue.

47. In general, S corporations, partnerships, and sole proprietorships, which make up the majority of businesses in the state, are taxed via the personal income tax on passed-through income of their shareholders (who may be known as “partners” or “members”). The Michigan corporate income tax (CIT) is levied on C corporations, which include many of the largest companies in the state and are often publicly-traded entities.

    We do not specify an equivalent percentage-point cut due to a policy transition from the Michigan Business Tax (MBT), which was repealed effective in 2012, to the CIT. Some taxpayers currently elect to pay the MBT in order to receive certificated credits that were offered against this tax. When the MBT credits expire, these taxpayers may then be subject to the CIT, which would expand the tax base during the period of analysis. Policymakers would need to consider this if they propose to offset a portion of revenues from carbon emissions with a CIT tax cut. For reference, annual CIT revenues over the past couple of years have been on the order of $1 billion.

48. This is based on a trend annual growth in Michigan’s residential electric customers of 0.1%.

## COMPARISON WITH OTHER STUDIES

Over the last several years, there have been numerous reports that evaluate the effects of carbon taxes and cap-and-trade scenarios. Since the EPA Clean Power Plan proposed rule and final rule have been issued, additional studies have emerged.[49] This will likely continue as states and electricity generators evaluate how they might be affected by CPP compliance.

### *Michigan Agency for Energy Baseline Modeling*

The Michigan Agency for Energy released preliminary and partial baseline modeling results for Michigan's $CO_2$ emissions on December 22, 2015. Based on their modeling efforts, the executive director of the MAE concluded that:

> Our early actions mean that the state can comply with the EPA's carbon rule emission requirements for at least the next 10 years just by continuing a no regrets energy strategy.[50]

This statement contrasts with our "no new policy" baseline modeling results, which indicate that Michigan would be out of compliance with the EPA's CPP final rule during all compliance periods without additional actions. We have identified four areas in which our approach differs from MAE's that would likely explain the difference between our results:

1. We relied on an economic growth model, while MAE used a utility dispatch model.
2. Our assumptions result in positive growth throughout the model run, while MAE assumed initial negative net load growth due to electricity demand and efficiency assumptions.
3. We included a set of announced coal plant retirements, while MAE assumed more aggressive retirements.
4. MAE's model may have produced different results for the generation technology used for capacity replacement.

However, we cannot directly compare our results with MAE's since several aspects of their modeling assumptions and outputs were not disclosed. First, the economic growth scenario that underlies their electric load growth assumptions were not included in their list of modeling assumptions. Second, their model outputs for new capacity of renewable and natural gas sources were not disclosed. Lastly, their model outputs for electric generation by source and technology were not disclosed.

49. While a detailed comparison is outside of the scope of this report, see "Clean Power Plan Studies" on page B-2 for additional reports.

50. Michigan Agency for Energy, "Michigan announces baseline modeling results and stakeholder process for EPA carbon rule compliance," Michigan Agency for Energy, December 22, 2015, http://www.michigan.gov/documents/energy/12_22_Media_Release_509194_7.pdf, accessed December 2015.

### *University of Kentucky Study*

Economists from the University of Kentucky Center for Business and Economic Research (CBER) used a growth model calibrated on the basis of empirical research on energy-intensive state economies, including over 20 different states. Their empirical research on these states' uses of electricity, as well as demand for energy fuels, was extensive and resulted in both short-run and long-run estimates of responses to energy price changes. Using these data, they used a variant of an economic growth model called a Capital, Labor, Energy and Materials model, citing the recurring use of such models in applied research.[51]

Their report is explicit about the structure of the model and explicit about the response functions and equations used. We found it to be one of the most well-documented and credible analyses available. We quote select results from their report below:

- We illustrate our findings through a set of policy scenarios of assumed 10% and 25% increases in electricity prices for energy-intensive states such as Kentucky. We consider both short-run and long-run effects of these price increases. For each scenario, we assume that the price increase is permanent but is not accompanied by any other notable changes such as technological advancement or the discovery of new energy supplies. We assume that, in the absence of the price shock, economic growth consists of 3% annual growth in GSP and 1% annual growth in employment, the historical averages for each.
- A 25% electricity price increase is estimated to reduce the GSP growth rate from 3% to 2.30% in the long run. The price increase is estimated to reduce employment growth from 1% to 0.61% in the long run.[52]

We refer to additional studies that we consulted in "Appendix C. Methodology" on page C-1.

### *Comparison of Results with the University of Kentucky Study*

The results from the UK CBER study indicate that a permanent, exogenous 10% increase in electricity prices reduces the state GDP annual growth rate from 3% to 2.7% in the long run for energy-intensive states, while a permanent 25% increase in electricity prices reduces the growth rate to 2.3%. After 10 years, this implies a 2.6% reduction in state GDP under 10% increase scenario compared to baseline, and a 7% reduction under the 25% increase scenario.

Our modeled scenarios are not exactly the same as those modeled in the UK CBER study. In particular, our CPP compliance scenarios include offsets to tax

51. John Garen, Christopher Jepsen, and James Saunoris, "The Relationship between Electricity Prices and Electricity Demand, Economic Growth, and Employment," University of Kentucky CBER, October 2011.

52. Ibid.

cuts that would have incentive effects, which are not applicable to the UK CBER's scenarios. However, they model similar changes to electricity prices, so we compare the results. As shown in Table 4 on page 47, electricity prices under both the cap-and-trade and carbon tax scenarios gradually increase to be roughly 18 to 20 percent higher than under the "no new policy" baseline after 10 years. Our estimates suggest that personal income is roughly 10 to 12 percent lower under these CPP compliance scenarios than under the baseline after the same time period. Thus, the estimated effects in our study are on the same order of magnitude as those reported in the UK CBER study.

# *Appendix A: About Anderson Economic Group*

Anderson Economic Group, LLC is a boutique consulting firm founded in 1996, with offices in East Lansing, Chicago, and Istanbul. Our team has a deep understanding of advanced economic modeling techniques and extensive experience in multiple industries in multiple states and countries. We are experts across a variety of fields in tax policy, strategy and business valuation, public policy and economic analysis, and market and industry analysis.

The consultants at Anderson Economic Group are often published on topics within their respective fields of expertise. Publications from our team include:

- *Annual State Business Tax Burden Rankings,* published since 2007.
- *The State Economic Handbook,* published by Palgrave Macmillan, 2008, 2009, and 2010.
- *Applied Game Theory and Strategic Behavior,* published by CRC Press in 2009.
- *The Economics of Business Valuation: Toward a Value Functional Approach,* published by Stanford University Press in 2013.
- *Business Economics and Finance with MATLAB®, GIS, and Simulation Models,* published by CRC Press in 2000.

Past clients of Anderson Economic Group include:

- *Governments:* The government of Canada; the states of Michigan, North Carolina, and Wisconsin; the cities of Detroit, Cincinnati, and Sandusky; counties such as Oakland County, and Collier County; and authorities such as the Detroit-Wayne County Port Authority.
- *Businesses:* Ford Motor Company, First Merit Bank, Lithia Motors, Spartan Stores, Nestle, and InBev USA; automobile dealers and dealership groups representing Toyota, Honda, Chrysler, Mercedes-Benz, General Motors, Kia, and other brands.
- *Trade associations, colleges, and nonprofit organizations:* Convention and visitor bureaus of Lansing, Ann Arbor, Traverse City, and Detroit, and Experience Grand Rapids; higher education institutions including Michigan State University, Wayne State University, and University of Michigan; trade associations such as the Michigan Manufacturers Association, Service Employees International Union, Automation Alley, the Michigan Chamber of Commerce, and Business Leaders for Michigan.

Please visit www.AndersonEconomicGroup.com for more information.

The team at Supported Intelligence, LLC also contributed to this report. Their services include modern data analytics applications and powerful modeling of decision solutions including uncertainty over time, using Rapid Recursive® technology. Please visit www.SupportedIntelligence.com for more information.

## AUTHORS

*Patrick L. Anderson*

Mr. Anderson founded Anderson Economic Group in 1996, and serves as a Principal and Chief Executive Officer in the company.

Mr. Anderson has written over 100 published works, including *Economics of Business Valuation* from Stanford University Press. Three of his journal articles, "Pocketbook Issues and the Presidency," "The Value of Private Businesses in the United States," and "Policy Uncertainty and Persistent Unemployment," have each been awarded for outstanding writing from the National Association of Business Economics.

Mr. Anderson has taken a leading role in several major public policy initiatives in his home state. He was the author of the 1992 Term Limit Amendment to the Michigan Constitution, and also the author of the 2006 initiated law that repealed the state's 4-decade-old Single Business Tax. His firm's work resulted in a wage increase for Home Help workers in 2006, the creation of a Michigan earned income tax credit in 2008, and the repeal of the item pricing law in 2011. Before founding Anderson Economic Group, Mr. Anderson was the deputy budget director for the State of Michigan, and Chief of Staff for the Michigan Department of State.

Mr. Anderson is a graduate of the University of Michigan, where he earned a Master of Public Policy degree and a Bachelor of Arts degree in political science. He is a member of the National Association for Business Economics and the National Association of Forensic Economists. The Michigan Chamber of Commerce awarded Mr. Anderson its 2006 Leadership Michigan Distinguished Alumni award for his civic and professional accomplishments. The University of Michigan Ford School of Public Policy awarded him its Neil Staebler Award for civic participation in 2014.

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Ms. Taylor is a Senior Analyst with Anderson Economic Group, working in the Public Policy and Economic Analysis practice area. Her recent work includes research and data analysis for economic and fiscal impact studies, benchmarking studies, and tax reform proposals.

Prior to joining AEG, Ms. Taylor was a graduate assistant at Michigan State University, where her research focused on local governments facing fiscal stress. She also interned at the Citizens Research Council, a non-profit research organization that focuses on public policy issues in Michigan. Prior to attending graduate school, she worked as an engineer in the petrochemicals industry in Louisiana and as an AmeriCorps VISTA at a non-profit organization in New Orleans.

Ms. Taylor holds a Master of Science in Agricultural, Food, and Resource Economics and a Bachelor of Science in Chemical Engineering, both from Michigan State University.

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# Appendix C. Methodology

This appendix supplements the discussion in the body of the report on the approach taken by the authors, which is contained in “Modeling the Effects of Regulatory Scenarios on State Economies” on page 28.

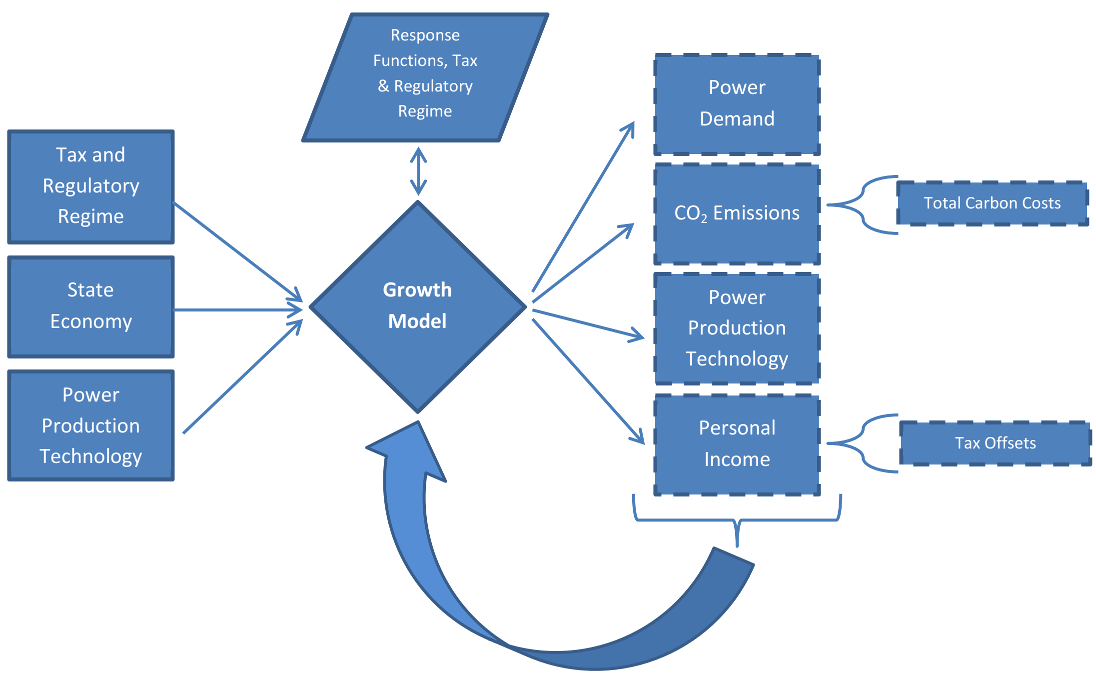
In this appendix, we present the following information in some detail:

1. The general structure used for estimating effects;
2. The economic growth model within that general structure;
3. The response functions we use for electricity prices and risk, including a discussion on the traditional constant-elasticity, risk-agnostic method, and the innovative recursive model of business decisions we employ here; and
4. A summary of parameters and numerical assumptions.

## GENERAL STRUCTURE

The general structure of our model, which we call the “Sector Business Decision model” is depicted in Figure C-1 below.

**FIGURE C-1. Structure of the Sector Business Decision Model**




*Source: AEG analysis using the Sectoral Business Decision Model*

We begin with a number of inputs describing the state economy, power production technology in the state, and the regulatory and tax regimes we wish to consider. These inputs, along with values for a base year, are passed to our economic growth model (see "Economic Growth Model" on page C-2), where we project values for the next year. These outputs are fed back into the growth model to project values for the following year and so on until we reach the final year of interest. For each year, we record a number of output variables, including personal income, electricity generation, $CO_2$ emissions, tax, and other government revenue.

## ECONOMIC GROWTH MODEL

Our economic growth model captures the relationships between a number of key economic and energy-specific variables in Michigan. We begin by estimating year-to-year changes in personal income, the primary economic variable for a state. To do so, we assume an underlying growth trend, which we adjust to account for producer responses to changes in other variables, including electricity prices and sales tax rate. This relationship is described by the following equation:

**Personal Income** **(EQ 1)**

$$Y_t = (1 + g + R_{tax} + R_{price}) \cdot Y_{t-1}$$

where:
$g$ = trend growth,
$R_{tax}$ = industry responses to non-carbon tax changes,
$R_{price}$ = industry responses to electricity price changes,
$Y_t$ = personal income in time $t$

For a discussion of the parameters in Equation 1, see "Parameters" on page C-10. Note that our model allows for different price changes and different personal income responses in different sectors of the state economy. To match conventions in electricity data, we bifurcate the economy into a commercial and an industrial sector. We then weight the responses from each sector by the share of personal income historically generated by that sector. We provide a detailed discussion of our industry response functions in "Electricity Price and Risk Response Functions" on page C-5. We assume exogenous changes in the sales tax rate in the carbon tax and cap-and-trade scenarios. More information on these changes can be found in "Electric Power Sector CO2 Emissions" on page 15.

As indicated in Equation 1, projecting changes in personal income requires estimates of changes in the prices of electricity for end consumers. In a manner similar to that used to project changes in personal income, we assume trend growth in electricity prices, which we adjust when necessary to account for additional costs imposed by any regulations impacting electricity generators. When such regulatory costs exist, we assume that electricity generators are able to pass the entirety of these costs through to consumers. See "Calculating Carbon Tax Rates and Allowance Prices" on page C-4 for a discussion of how we determine the carbon tax rate or allowance price each year. We use Equation 2 to project year-to-year changes in electricity price changes for residential, commercial, and industrial consumers.

**Electricity Prices by Sector** **(EQ 2)**

$$P_{i,t} = P_{i,t-1} \cdot (1 + g_{i,p}) + \tau_t \cdot G_{affected}$$

where:
$P_{i,t}$ = price per KWh in sector $i$ at time $t$,
$g_{i,p}$ = trend growth in prices for sector $i$,
$\tau_t$ = cost, per KWh, of carbon tax or cap and trade policies,
$G_{affected}$ = share of electricity generation subject to CPP

Parameters for Equation 2 are discussed in "Electricity prices" on page C-14. Note that not all electricity generators would be subject to the requirements of the CPP. Thus, we calculate the average change in price, weighted by the share of electricity generated by affected and non-affected generators. This provides a conservative estimate of the price impact of CPP compliance plans implemented by the state.

To obtain an estimate for energy demand in a given year, we apply a ratio of energy demand to personal income to our personal income estimate for that year. We then split this total into residential, commercial, and industrial demand according to the historic share of demand coming from each of these sectors. Price responses in the commercial and industrial sectors are captured by the response functions included in our personal income projections, but we still need to account for responses of residential electricity consumers to changes in the price of their electricity. We do so by applying a price elasticity adjustment to our estimated quantity of residential electricity demand. This process is described in the equations below. Total electricity consumption is represented by the sum of consumption across all sectors.

**Electricity Consumption** **(EQ 3)**

$$E_{i,t} = Y_t \cdot PY_t \cdot e_i$$

where:
$E_{i,t}$ = electricity consumption in sector $i$ at time $t$,
$Y_t$ = personal income in time $t$,
$PY_t$ = ratio of power consumption to personal income at time $t$,
$e_i$ = share of total consumption from sector $i$

**Residential Price Adjustment** **(EQ 3a)**

$$E_{\text{residential},t} = Y_t \cdot PY_t \cdot e_{\text{residential}} \cdot (1 + \Delta P_{\text{residential},t} \cdot \eta_{\text{residential}})$$

where:
$\Delta P_{\text{residential,t}}$ = percent change in residential price at time $t$,
$\eta_{\text{residential}}$ = residential price elasticity of electricity demand

To estimate total generation, we apply a ratio of generation to consumption to our estimate of electricity demand. We then apply an exogenous estimate of the emissions rate for affected generators to the share of generation attributed to affected generators. This yields our estimate for carbon dioxide emissions by affected electricity generators for a given year. In scenarios with state-imposed costs of emissions (either a carbon tax, levied per short ton of $CO_2$ emitted, or a cap-and-trade system with allowances for a certain number of short tons of $CO_2$ emitted), we multiply total emissions by the "price of emissions" to obtain our estimate of gross revenue. We then subtract appropriate administrative and other costs to determine net revenue available to the state for offsets to taxes.

Results of our economic growth model are presented in "Appendix D. Summary of Results from the Three Scenarios" on page D-1.

### *Calculating Carbon Tax Rates and Allowance Prices*

We set out to provide a carbon price policy that could conceivably be adopted by the legislature. This requires a stable, predictable tax path rather than a tax rate determined each year by an exercise in mathematical optimization. In addition, we set out to provide a policy such that the emissions goals would be met during each compliance period. We did this in the following manner.

To determine the carbon tax rate path (in dollars per short ton of $CO_2$ emitted) that achieves compliance with the EPA's CPP final rule, we adopt an iterative approach. We set an initial rate for the carbon tax and solve our model using that rate. Before moving to the next year, however, we compare estimated $CO_2$ emissions to the CPP goal emissions for that year, if such goals exist. If projected emissions are equal to or below goal emissions, we move to the next year. If projected emissions exceed goal emissions, we increase the tax rate by $0.50 and solve the model again. We repeat this process until projected emissions fall below goal emissions, or until the tax rate reaches $60, our exogenously-imposed tax ceiling. Once we obtain the required path, we note the starting year of the tax and the year in which it reaches the ceiling or its value in the final year. From this information, we calculate the compounded annual growth rate (CAGR). We then run the model again, assuming the tax starts in 2020 at its starting value and increases each year by the CAGR obtained from the optimization exercise. If the projected emissions did not meet the goal emissions during every compliance period, then we increased the starting tax rate until this condition was met.

We assume that the allowance price under the cap-and-trade scenario is equivalent to the carbon tax rate for the same year from the carbon tax scenario. We then add an adjustment for higher administrative costs and a hedging cost borne by the generators to mitigate a portion of the price risk unique to the cap-and-trade scenario. Carbon tax and cap-and-trade parameters are discussed in "Electric Power Sector CO2 Emissions" on page C-15.

## ELECTRICITY PRICE AND RISK RESPONSE FUNCTIONS

As should be clear from Equation 1, industry responses to changes in the price of electricity play a central role in our economic growth model. These responses impact nearly every output variable in the model through their effects on personal income projections. In the sections below, we discuss traditional methods for modeling firm response, concerns with the traditional method, and our chosen approach to this important task.

### *Traditional Constant-Elasticity, Risk-Agnostic Response Functions*

It is common, and indeed nearly universal in applied economics, to characterize responses to changes in prices in terms of elasticities. The "elasticity" is the proportional change in quantity resulting from a proportional change in price. If the "quantity" is the quantity demanded by consumers and the "price" is the price paid by those same consumers, economists for generations have used "the price elasticity of demand" to characterize the effect on quantity purchased due to a change in price. This measure carries with it an implication that the "proportional" change is identical when the direction of change is positive and negative.

Constant elasticity models provide a simple framework for estimating the effect on demand of a positive or negative change in the price of that good. Such models tend to do a pretty good job of estimating responses to small fluctuations in price, but become less effective as the magnitude of the price change increases. Constant elasticity models also ignore changes in price and other risks, making the implicit assumption that such risks remain constant over time.

Since industry responses to price changes play such a large role in our model, and because we seek to understand the likely impacts of policies that will directly increase both price levels and price risk, we turned to a better method for modeling firm behavior.

### *Evidence of Non-Constant Elasticities for Energy Prices*

Given the existence of non-constant elasticity behavior among consumers, and the predominance of it among business investment decisions, one should expect that decisions regarding energy prices would also display asymmetries. In fact, the differences in behavior regarding price reductions and price increases for energy prices have been observed for some time. In particular:

- During the early 1990s in the United States and many other developed countries, energy prices in real terms declined. However, demand did not increase in the manner suggested by constant-elasticity models.[53]
- During the oil price shocks of the 1970s, when fuel prices skyrocketed, demand was strongly affected—but structural changes that might be expected from the magnitude of the price change alone did not occur.[54]

Evidence from multiple empirical analyses confirm the existence and pervasiveness of asymmetric responses to energy price changes. One seminal analysis, from Steven Davis and John Haltiwanger in 2001, summarized the evidence as follows:

> Employment growth declines sharply following a large oil price increase but changes little following a large oil price decrease. A unit standard deviation positive oil shock leads to a cumulative two-year employment decline of about 2 percent, ten times bigger than the estimated response to the same size negative oil shock.
>
> Several other studies, most based on different econometric specifications and identifying assumptions, also conclude that oil price increases have larger effects on aggregate or regional activity than oil price decreases. See Mork (1989), Mory (1993), Lee et al. (1995), Hamilton (1996b), Hooker (1996b) and Davis et al. (1997). In light of this work, we view the evidence for asymmetric

53. See Michele Grubb, “Asymmetric price elasticities of energy demand,” in *Global Warming and Energy Demand*, Routledge, 2005. Grubb cites multiple empirical studies demonstrating asymmetry in demand, many from the early 1990s, and observes the asymmetry in US consumer responses to energy price changes in the 1970s through the 1990s.

54. As noted in the Michael Grubb article cited above, there are many factors related to government policies regarding inflation and monetary policy, perceptions of permanence, and other conditions that were involved. Also worth noting is that asymmetry means that changes are not symmetric, so evidence from the 1970s should be different from that of the 1990s.

responses to oil price ups and downs as well established (for the United States).[55]

Based on this evidence from the economic literature, we account for the asymmetric response of industries to energy price changes in our economic growth model.

### *Recursive Model of Business Decisions*

Recursive models capture the discrete nature of firm decisions by identifying various configurations of conditions in which the firm may face a decision and determining the optimal action for the firm in each situation.[56] These models do not assume that firm behavior can be accurately approximated by a smooth curve, nor do they assume that firm responses are constantly proportional to changes in key variables.

For the purposes of this report, we constructed a set of recursive models for representative firm decisions in light of changing electricity costs.[57] These models evaluate the tension between immediate profit incentives and exposure to the risk of increasing prices and returns the firm's best decision for each possible set of current prices and future beliefs. In these models, we create sample firms that observe the current electricity price and combine this observation with beliefs about future prices and knowledge of the amount of electricity required by the firm's production process to decide how much capital to purchase during the current year. We assume that firms can always increase their output by purchasing more capital. Doing so, however, gives the firm greater exposure to the risk of increasing electricity prices in the future, particularly in industries where the production process is relatively electricity-intensive (such as precious metals or wood products manufacturing). Furthermore, we assume that firms face a higher risk of large price changes under the carbon tax and cap-and-trade scenarios than in the no new policy

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55. Steven J. Davis and John Haltiwanger; "Sectoral Job Creation and Destruction Responses to Oil Price Changes," *Journal of Monetary Economics*, 2001, 48(3), pp. 465-51.

    Referenced works in the excerpt include: Knut Anton Mork, "Oil and the macroeconomy when prices go up and down: an extension of Hamilton's results," *Journal of Political Economy*, 1989, 97, pp. 740–744; Javier F. Mory, "Oil prices and economic activity: is the relationship asymmetric?" *The Energy Journal, 1993,* 14, pp. 151–161; and James D. Hamilton, "Oil and the macroeconomy since World War II," *Journal of Political Economy*, 1983, 91, pp. 228–248.

56. For a theoretical motivation and a complete description of the application of recursive model to firm decision-making, see Patrick L. Anderson, *The Economics of Business Valuation*, Stanford University Press, 2013.

57. For a detailed discussion of a similar model of firm decisions in light of changing employment costs, see Patrick L. Anderson, "Policy Uncertainty and Persistent Unemployment," *Business Economics*, January 2014.

scenario, due to the increased regulatory burdens placed on the electricity providers in these scenarios.

We used these recursive decision models to evaluate whether the responses of firms to electricity prices are asymmetric. We simulated the decisions of the sample firms when electricity prices change, as described in the previous paragraph. We then aggregated the individual firm responses to the industry level.

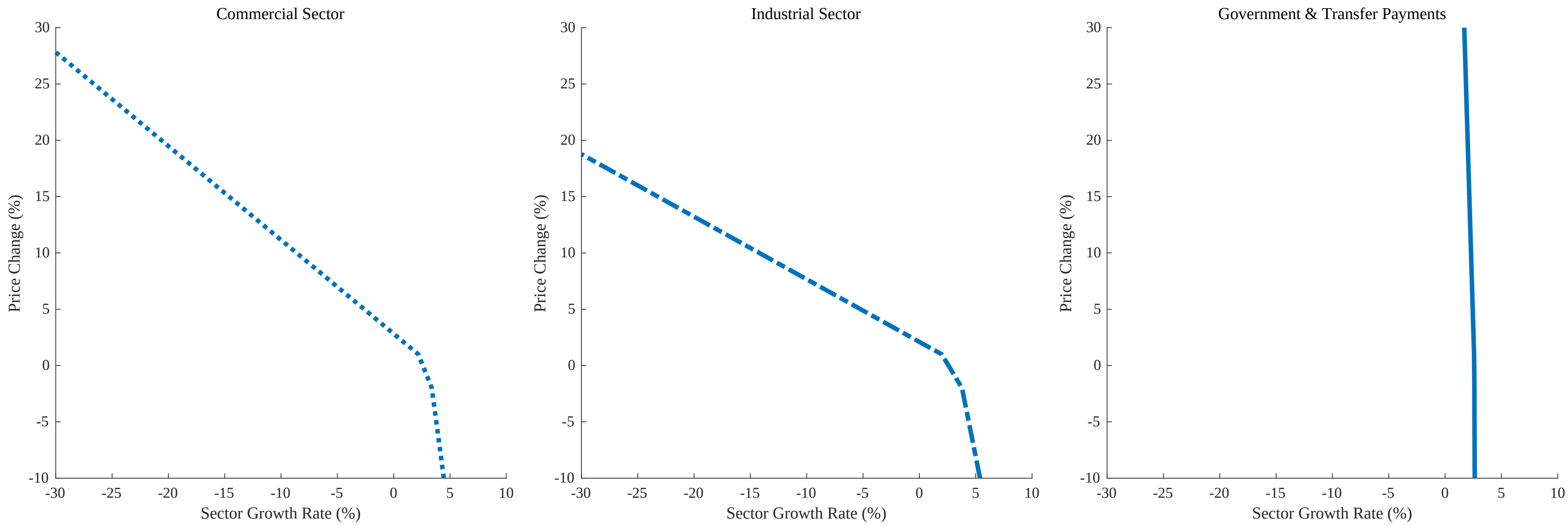
We observed that these aggregate responses are consistent with the asymmetric motivation, as described in "Evidence of Non-Constant Elasticities for Energy Prices" on page C-6. Our results indicate that firms tend to respond more sharply to large deviations in price than they do to smaller deviations. In particular, firm responses become more elastic (leading to larger changes in the quantity invested) in light of large increases in price, and less elastic (leading to smaller changes in the quantity invested) in light of large decreases in price.

### *Piecewise Industry Response Functions*

To better capture likely responses to electricity price changes, we use the results from our recursive models to inform a piecewise industry response function. Under this function, responses are consistent with traditional elasticity estimates in a small range around the current price (which we refer to as the "central range"), and become more elastic above the range and less elastic below that range.

Figure C-2 on page C-9 presents a comparison of the response functions between the commercial, industrial, and government sectors.

**FIGURE C-2.** **Response Function Comparisons**




*Source: AEG analysis using the Sectoral Business Decision Model*

## PARAMETERS

In this section, we provide the parameters that we used in our economic growth model. As noted elsewhere, we projected changes in Michigan's economy and electric power sector from a 2012 baseline, which is consistent with the 2012 baseline used in EPA's CPP final rule. Where indicated, we used trend annual growth rates, which do not capture business cycle fluctuations. Therefore, for the years 2013 through 2015, our projections do not reflect deviations from trends during those years.

Please see "Appendix B. Sources" on page B-1 for detailed citations of our sources.

### *Economic Growth and Industrial Structure*

**TABLE C-1. Growth and Industrial Structure Parameters**

| Parameter | Value |
|---|---|
| 2012 Michigan personal income (thousands) | $382,064,571 |
| Annual trend growth, nominal personal income | 2.58% |
| Share of personal income from commercial sector | 41.1% |
| Share of personal income from industrial sector | 19.0% |
| Share of personal income from government sector | 16.6% |
| Share of personal income from transfer payments | 21.0% |
| Growth elasticity, sales tax (commercial and industrial sectors) | -0.2 |
| Growth elasticity, sales tax (government and transfer payments) | 0 |
| Growth elasticity, electricity price (commercial sector, central range) | -0.4 |
| Growth elasticity, electricity price (industrial sector, central range) | -0.6 |
| Growth elasticity, electricity price (government sector, central range) | -0.01 |
| Growth elasticity, electricity price (transfer payments, all price changes) | 0 |

*Source: AEG analysis of data sourced from U.S. Bureau of Economic Analysis; sources cited in "Modeling the Effects of Regulatory Scenarios on State Economies" and "Appendix C. Methodology"; and AEG professional judgment. See "Appendix B: Sources" on page B-1 for a complete list of sources.*

**Industrial structure.** It is well-known that different sectors of the economy are sensitive to electricity prices. In order to segment Michigan's economy into separate sectors, we first relied on the EIA's definitions for the commercial, industrial, and transportation sectors for energy consumption.[58] We then identified which industry codes under the BEA's personal income tables belong to each respective sector. We disaggregated the commercial sector even further into industries that are less sensitive to electricity prices. We refer to the segment as the "government sector," which includes the public sector and hospitals.

58. U.S. Energy Information Administration, "Glossary," http://www.eia.gov/tools/glossary/, accessed November 2015.

**Personal income.** We relied on historical estimates for Michigan's personal income from the BEA, and projected a future nominal income growth based on historical growth. We then used personal income data for Michigan to determine the share of personal income that is due to income from each of sector, as defined previously.

We assumed that the elasticity of personal income with respect to the sales tax rate is greater for the commercial and industrial sectors than for government sector and transfer payment sectors.

We assumed that the elasticity of personal income with respect to electricity prices would be negative and inelastic. We also assumed that the commercial sector is less sensitive to changes in electricity prices than the industrial sector. There is overwhelming evidence, across numerous countries, numerous U.S. states, and multiple decades, that higher energy prices decrease energy usage. The numerous analyses cited "Electricity Price and Risk Response Functions" on page C-5 demonstrate this. Thus, it is clear that higher energy prices will discourage consumption of goods and services that include energy as a component. As nearly all goods and services include energy as a component, the unavoidable implication is that demand for nearly all goods and services would decline in response to a significant increase in energy prices.[59]

This reduction in demand is strongly related to a reduction in economic activity overall, as would be expected. For example, a team of U.S. and British economists writing in the *Review of Economics and Statistics* in 1998 demonstrated that oil prices and interest rates alone explain much of the fluctuation in U.S. unemployment in the prior years.[60] A very recent analysis in the September 2015 edition of *Energy* examined emerging economies (including Russia, Korea, and India), with the following summary of results:

> Results of the causal linkage between the variables point that energy consumption (i.e., oil or nuclear) has either a predictive power for economic growth, or a feedback impact between with real Gross Domestic Product (GDP) growth in all countries. Hence, energy conservation policies might harmful negative consequences on the growth of economic for this group of countries.[61]

59. Furthermore, since this is a federal rule, some such effect is likely in all states.

60. Alan Caruth, Mark Hooker, and Andrew Oswald, "Unemployment Equilibria and Input Prices: Theory and Evidence from the United States," *Review of Economics and Statistics,* November 1998, Vol. 80, No. 4, pp. 621-628.

61. Hanan Nasar, "Analysing the long-run relationship among oil market, nuclear energy consumption, and economic growth: An evidence from emerging economies," *Energy,* September 2015, Volume 89, pp. 421–434.

*Electricity Demand and Prices*

**TABLE C-2. Electricity Demand and Price Parameters**

| Parameter | Value |
|---|---|
| Michigan electricity consumption, 2012 (MWh) | 104,818,191 |
| PY ratio, 2012 (MWh/$Million Personal Income) | 274.3 |
| Annual trend improvement, PY ratio, No New Policy | -2.0% |
| Annual trend improvement, PY ratio, CPP | -3.0% |
| Residential price elasticity of demand | -0.9 |

| Parameter | Residential | Commercial | Industrial |
|---|---|---|---|
| Price per kwh | $0.141 | $0.109 | $0.076 |
| Share of electricity consumption | 32.9% | 36.7% | 30.4% |
| Annual trend growth, price | 2.0% | 1.5% | 1.5% |

*Source: AEG analysis of data sourced from U.S. Bureau of Economic Analysis, U.S. Energy Information Administration, and AEG professional judgment. See "Appendix B: Sources" on page B-1 for a complete list of sources.*

**Electricity demand.** From EIA data for electricity sales and the BEA data for personal income, we estimated the ratio of electricity demand to personal income in Michigan. We projected that the PY ratio would continue to improve under the "no new policy" baseline scenario at a rate of 2.0%. This value was informed by annual historical improvement, which was about 2.5%. This parameter accounts for general improvements in energy efficiency over time, including any reductions electricity demand due to the State of Michigan's energy efficiency standards.[62]

Since this is a key parameter in our model, we compared the results for electricity demand against Michigan electricity demand forecasts reported in:

- EPA's Base Case projections;[63]
- EIA's Annual Energy Outlook (AEO) 2015;[64] and
- Purdue University State Utility Forecasting Group's (SUFG) 2015 MISO Independent Load Forecast.[65]

62. MCL 460.1071 through 460.1097.

63. U.S. Environmental Protection Agency, Base Case v.5.15 Using Integrated Planning Model (IPM), Electricity generation and $CO_2$ emissions data, August 2015.

64. U.S. Energy Information Administration, Annual Energy Outlook (AEO) 2015, Electricity generation, sales, $CO_2$ emissions, and price data, http://www.eia.gov/forecasts/aeo/, retrieved October 2015.

65. Douglas J. Gotham, Liwei Lu, Fang Wu, Timothy A. Phillips, Paul V. Preckel, and Marco A. Velastegui, "2015 MISO Independent Load Forecast," Purdue University State Utility Forecasting Group, November 2015.

In Table C-3 below, we compare our projections for electricity sales in Michigan with those from other sources. Both the EPA and the EIA did not provide electricity sales estimates for the state of Michigan. The modeling regions that most closely represented the state of Michigan for both sources excluded Michigan's Upper Peninsula and a portion of southwest Michigan.

**TABLE C-3. Comparison of Baseline Electricity Sales Projections (Select Years)**

| | | Electricity Sales in Michigan (million MWh) | | | |
|---|---|---|---|---|---|
| **Source** | **Trend Economic Growth** | **2016** | **2020** | **2025** | **2030** |
| AEG Sector Business Decision Model | 2.58% (nominal MI personal income) | 106.4 | 108.7 | 111.7 | 114.7 |
| U.S. EPA Base Case v.5.15 | not provided[a] | not provided[b] | | | |
| U.S. EIA AEO 2015 Reference Case | 2.4% (real U.S. GDP) | not provided[c] | | | |
| 2015 MISO Independent Load Forecast | 1.67% (real MI GDP) | 107.3 | 111.6 | 116.2 | no estimate |

*Source: AEG aggregation of data from the AEG Sector Business Decisions Model, U.S. Environmental Protection Agency, U.S. Energy Information Administration, Purdue University State Utility Forecasting Group*

a. According to the supplemental documentation for the EPA Base Case v.5.15, the EPA's electric load assumptions are based on the EIA AEO 2015. This implies that the EPA's base case relies on the same economic growth assumptions as the EIA AEO 2015. However, such assumptions are not explicitly stated in the modeling documentation.

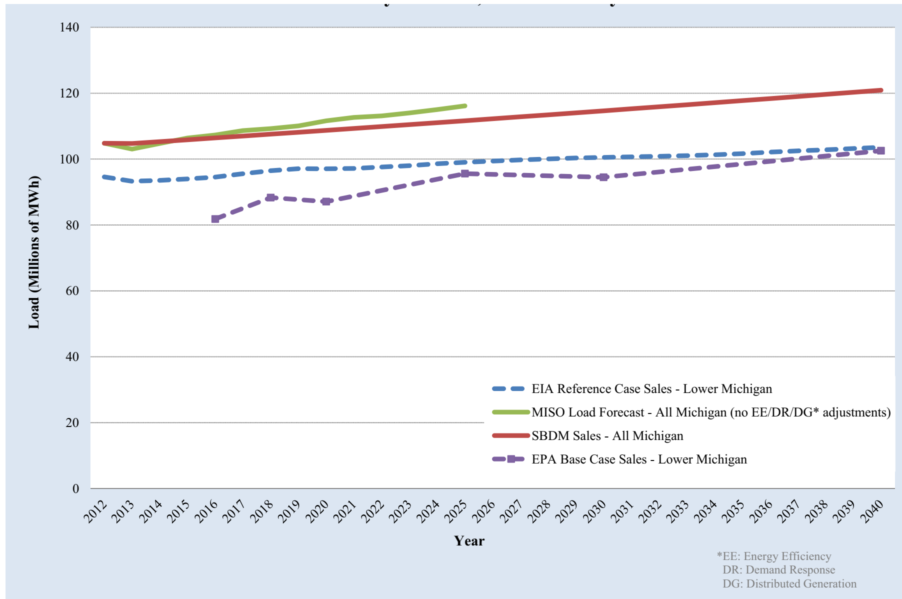
b. Source did not report projected electricity sales for the state of Michigan. The modeling region that most closely represents the state of Michigan (MIS_LMI) excludes Michigan's Upper Peninsula and a portion of southwest Michigan.

c. Source did not report projected electricity sales for the state of Michigan. The modeling region that most closely represents the state of Michigan (Reliability First Corporation—Michigan) excludes Michigan's Upper Peninsula and a portion of southwest Michigan.

We can extrapolate the EIA's estimates based on the historic generation in the modeling region as share of total generation in Michigan. We found that our results were within the range of the extrapolated EIA estimates and the MISO independent load forecast estimates.

In Figure C-3 on page C-14, we provide a comparison of our electricity demand projections for the entire state of Michigan with estimates directly from the EIA, the EPA, and the SUFG. Note that the EIA and the EPA projections covers a portion of Michigan's Lower Peninsula. This region excludes Michigan's Upper Peninsula and a portion of the southwest Michigan. In addition, the SUFG projections for the 2015 MISO load forecasts do not account for energy efficiency, demand response, and distributed generation.

**FIGURE C-3. Comparison of Projections: Electricity Demand Under "No New Policy"**




*Source: AEG analysis using the Sectoral Business Decision Model; U.S. Energy Information Administration; U.S. Environmental Protection Agency; and State Utility Forecasting Group*

Under the two CPP compliance scenarios, we assumed that there would be a slight improvement in the annual growth rate of the PY ratio due to increased cost of electricity under these scenarios. These increased costs would induce firms to become more efficient in their reliance on electricity and result in less electricity demanded at a given level of the economy.

Using EIA data for electricity sales in Michigan by sector, we estimated that the share of electricity sales due to the residential, commercial, and industrial sectors. We assumed that this share would remain the same throughout the period of analysis.

**Electricity prices.** We relied on EIA data for average electricity prices in Michigan by sector. Based on historical performance as well as the EIA AEO 2015 projections, we assumed that residential electricity prices in Michigan would grow at a faster rate than commercial and industrial prices.

Under the two CPP compliance scenarios, we assumed that electricity generators would pass along 100% of either the gross carbon allowance price (under cap-and-trade) or the gross carbon tax costs (under carbon tax) to consumers. As noted in "Economic Growth Model" on page C-2, we took into account that not all electricity sold is subject to the costs of carbon.

### *Electric Power Sector $CO_2$ Emissions*

**TABLE C-4. Power Sector $CO_2$ Emissions Parameters**

| Parameter | Value |
|---|---|
| Ratio of electricity generation to consumption in Michigan | 1.03 |
| Share of generation subject to CPP | 67.0% |
| Annual trend growth, heat rate improvement | -0.1% |
| Carbon tax collection allowance (share of carbon tax revenue) | 0.3% |
| Carbon tax administrative cost (share of revenue) | 1.0% |
| Cap-and-trade hedging cost (share of emissions costs) | 8.8% |
| Cap-and-trade administrative cost (share of emissions costs) | 3.7% |

*Source: AEG analysis of data sourced from U.S. Energy Information Administration and AEG professional judgment. See "Appendix B: Sources" on page B-1 for a complete list of sources.*

**Electricity generation.** We assumed that the relative size of electricity demand in Michigan to electricity generated in Michigan is constant throughout the period of analysis. This holds an implicit assumption that electricity prices in Michigan would not change considerably relative to prices in other states. This is a reasonable assumption since nearly all states would be subject to the CPP's emissions reduction requirements. Thus, electricity prices in most states will face similar upward pressure. Our assumption also implies that the State of Michigan would maintain its current cap on sales purchased from generators other than incumbent utilities, which is 10%.

We also estimated that about 67% of electricity generation in Michigan is from existing sources that would be affected by the EPA's CPP final rule. Sources in Michigan that are not affected by the CPP final rule include existing nuclear power plants, renewable sources such as wind and hydroelectric, and simple cycle combustion turbines.[66] We relied on Appendix 1 of the EPA's supporting documentation for the CPP final rule to identify the affected sources. Using this appendix, we estimated the 2012 baseline electricity generation from these power plants as a share of generation from all power plants. We assumed that this share is constant during the modeling period.

**Emissions rate.** We relied on Appendix 1 of the EPA's supporting documentation for the CPP final rule to identify the power plants in Michigan that are subject to the CPP emissions reduction requirements. From this appendix, we estimated the 2012 baseline electricity generation and emissions

66. For further discussion of affected sources and examples of sources exempted from the EPA's CPP final rule, see U.S. Environmental Protection Agency, "Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule," pp. 64715-64717.

from these power plants by source categories and estimated the 2012 emissions rate. We verified that the 2012 baseline emissions rate and total emissions estimates match those published in the EPA's CPP fact sheet for Michigan.

From this, we forecasted changes to the baseline emissions rate due to the following reasons:

1. Michigan's current Renewable Portfolio Standards, which required that 10% of electricity sold by providers in Michigan be generated from renewable sources by 2015;
2. Coal plant retirements that have been announced to take place during the period of analysis; and
3. Incremental shifts in generation from coal to generation from either natural gas or renewable sources due to increased costs of emissions under the CPP.

Items 1 and 2 above take place under all three regulatory scenarios, while item 3 takes place only under the two CPP compliance scenarios.

For item 1, we relied on the MPSC's report on implementing Michigan's RPS for data on electricity generation from renewable sources in Michigan.[67] The MPSC projected that electricity generators are on target to meet the RPS requirements in 2015. We then estimated that change in emissions rate if fossil fuel generation shifted to renewable generation to meet the RPS targets in 2015.

For item 2, several coal plants in Michigan are planned to retire, culminating in 2020.[68] We present the schedule of coal plant retirements that we included in our model in Table C-5 on page C-17. We presumed that generation from these sources would shift to either new or existing natural gas sources. We estimated the change emission rate from 2016 through 2020 based on the timing of these retirements and generation from these units.

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67. John D. Quackenbush, Greg R. White, and Sally A. Talberg, “Report on the Implementation of P.A. 295 Renewable Energy Standard and the Cost-Effectiveness of the Energy Standards,” Michigan Public Service Commission, February 13, 2015, http://www.michigan.gov/documents/mpsc/PA_295_Renewable_Energy_481423_7.pdf, retrieved November 2015.

68. See JC Reindl, “25 Michigan coal plants are set to retire by 2020,” *Detroit Free Press*, October 10, 2015, http://www.freep.com/story/money/business/michigan/2015/10/10/25-michigan-coal-plants-set-retire-2020/73335550/, accessed October 2015;

    Jessica Remer, “Michigan Retiring 25 Coal-Fired Power Plants by 2020; Utilities Turning to NatGas for Lost Capacity,” *Power Engineering*, October 12, 2015, http://www.power-eng.com/articles/2015/10/michigan-retiring-25-coal-fired-power-plants-by-2020-utilities-turning-to-natgas-for-lost-capacity.html, accessed October 2015; and

    Lindsay Vanhulle, “DTE, Consumers Energy want to shut off Michigan's renewable energy mandates,” Crain’s Detroit Business, October 11, 2015, http://www.crainsdetroit.com/article/20151011/NEWS/310119977/dte-consumers-energy-want-to-shut-off-michigans-renewable-energy, accessed October 2015.

**TABLE C-5. Schedule of Planned Coal Plant Retirements in Michigan**

| Year | Utility | Plant | Nameplate Capacity (MW) | Number of Units |
|---|---|---|---|---|
| 2015 | DTE Electric[a] | Trenton Channel | 120 | 1 |
| 2016 | DTE Electric | Trenton Channel | 120 | 1 |
| | Consumers Energy[b] | B C Cobb | 312 | 2 |
| | | J C Weadock | 312 | 2 |
| | | J R Whiting | 345 | 3 |
| | Michigan South Central Power Agency[c] | Endicott | 55 | 1 |
| 2017 | Holland Board of Public Works[d] | James De Young | 63 | 3 |
| 2020 | Lansing Board of Water and Light[e] | Eckert | 335 | 6 |
| | Wisconsin Electric[f] | Presque Isle | 450 | 5 |

*Source: AEG aggregation of data from multiple sources*

a. DTE Electric, “Planned Long Range Generation Changes Years 2015 through 2025,” Michigan Public Service Commission, Case No. U-18014, Document No. 0009, February 1, 2016, https://efile.mpsc.state.mi.us/efile/viewcase.php?casenum=18014, accessed February 2016.

b. Michigan Public Service Commission, “Order”, Michigan Public Service Commission, Case No. U-17735, Document No. 0381, November 19, 2015, https://efile.mpsc.state.mi.us/efile/viewcase.php?casenum=17735, accessed February 2016.

c. East Technical Study Task Force, “SSR Alternatives Review Endicott Unit 1,” Midcontinent Independent System Operator, January 6, 2016, https://www.misoenergy.org/_layouts/MISO/ECM/Redirect.aspx?ID=210420, accessed February 2016.

d. Andrea Goodell, “Holland Energy Park taking shape, more to come,” Holland Sentinel, January 27, 2016, http://www.hollandsentinel.com/article/20160127/NEWS/160129238, accessed February 2016.

Annette Manwell, “James De Young power plant will shut down,” Holland Sentinel, December 6, 2012, http://www.hollandsentinel.com/article/20121206/NEWS/312069881, accessed November 2015.

e. Eric Lacy, “Lansing 'workhorse' will retire despite uncertainty,” Lansing State Journal, February 15, 2016, http://www.lansingstatejournal.com/story/news/local/2016/02/15/lansing-bwl-eckert-plant/80408722/, accessed February 2016.

6 News Staff, “BWL May Shut Down Eckert Plant,” WLNS, October 1, 2015, http://wlns.com/2015/10/01/bwl-may-shuit-down-eckert-place/, accessed October 2015.

f. Midcontinent Independent System Operator, “Chapter 4.4 Generation Retirements and Suspensions | MISO MTEP,” http://www.misomtep.org/generation-retirements-suspensions-mtep15/, accessed January 2016.

For only the two CPP scenarios, starting in 2025, we assumed that about 5% of coal generation would shift to natural gas generation every five years as a response to regulatory costs. This assumption reflects a shift in electric generation from coal that is in line with the trend that resulted from the announced coal plant retirements through 2020. We estimated the change in emissions rates based on these exogenously-imposed shifts in the generation mix.

For item 3, we presume that the shifts in emission rate under the CPP compliance scenarios would be modest, despite that the cost of emissions provides incentive to shift to cleaner generation sources. First, there are supply constraints due to restrictions and resistance to siting new generation facilities, such as natural gas plants and wind turbines.[69] Second, the cost of new or purchased generation facilities would also likely be incorporated into electric rates, which would offset savings from avoided emissions.[70] Third, the ability of existing generation sources to shift from coal to natural gas is fairly limited.[71]

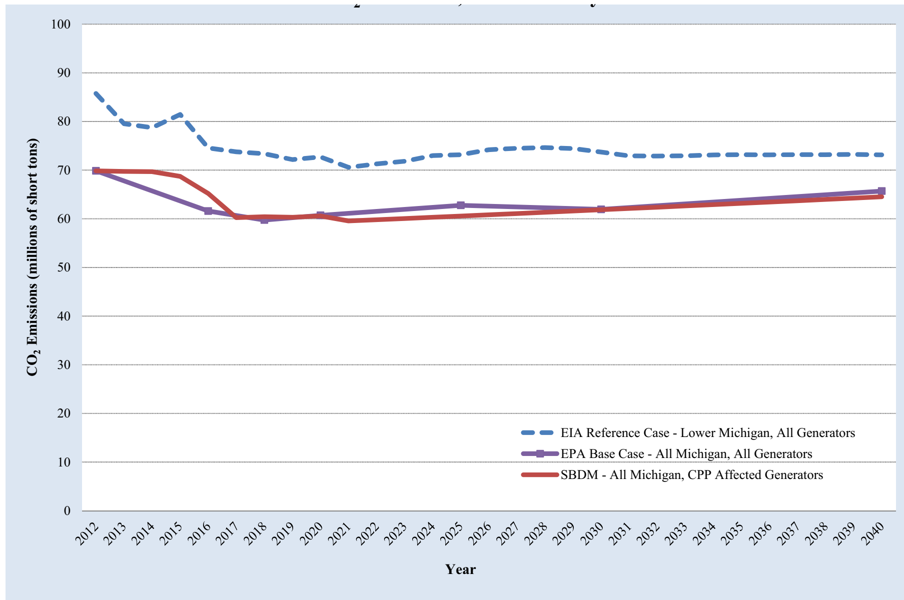
In Figure C-3 on page C-14, we provide a comparison of our $CO_2$ emissions projections for the entire state of Michigan with estimates directly from the EIA, the EPA, and the SUFG. Note that the EIA and the EPA projections covers a portion of Michigan's Lower Peninsula. This region excludes Michigan's Upper Peninsula and a portion of the southwest Michigan.

69. A recent report from the MPSC and Michigan Agency for Energy provides a brief discussion of siting restrictions as a potential factor that limits feasibility of new renewable sources in Michigan:
See John D. Quackenbush and Steve Bakkal, "Readying Michigan to Make Good Energy Decisions," Michigan Public Service Commission and Michigan Energy Agency, November 13, 2013, http://www.michigan.gov/documents/energy/renewable_final_438952_7.pdf, retrieved November 2015.

70. The MPSC recently approved rate increases for Consumers Energy and DTE Electric newly acquired natural gas plants, as we noted in "Effects on Prices" on page 32.

71. A recent EIA report evaluated the ability of electricity generation facilities to displace fuel for other sources in the short term in response to prices by various regions in the U.S. The reported cross-price elasticity for substitutability between gas and coal was inelastic for the Reliability-First Corporation (RFC), the region in which the majority of Michigan belongs. This suggests that fuel displacement between coal and natural gas is limited; however, there is some flexibility compared to other regions.
See U.S. Energy Information Administration, "Fuel Competition in Power Generation and Elasticities of Substitution," June 2012.

**FIGURE C-4. Comparison of Projections: $CO_2$ Emissions Under "No New Policy"**




*Source: AEG analysis using the Sectoral Business Decision Model; U.S. Energy Information Administration; and U.S. Environmental Protection Agency*

**Emissions goals.** For both the cap-and-trade and the carbon tax scenario, we set the emissions goals to be equal to the mass goals plus the new source complement. We relied on the annual goals for Michigan in Appendix 5 of the EPA's technical support document for estimating the emissions goals. We also relied on the annual new source complements for Michigan in the appendix of the EPA's technical support document for estimating the new source complements.

As discussed in the body of the report, the EPA's CPP final rule allows for states to use an approach that limits total $CO_2$ emissions from both existing and new sources to an amount equal to or less than the state's mass goal plus new source complement. The EPA calculated the new source complements on the basis of meeting projected incremental electricity demand from the 2012 baseline. This approach is permissible for types of plans in which the cap-and-trade and carbon tax scenarios would be authorized.

We have interpreted the CPP's discussion of the new source complement to allow for the emissions from both existing and new sources, in aggregate, to be equivalent or less than the mass goals plus new source complement. This contrasts with an alternate interpretation in which the emissions from existing sources are limited to the mass goals and emissions from new sources are separately limited to the new source complement.

We chose this interpretation for practical purposes. The latter interpretation unrealistically limits new generation sources. Planned coal plant retirements may require generation from new sources in order to address potential shortfalls in electricity generation. These new sources might not necessarily be used to meet incremental increase in electricity demand (the basis for the new source complement calculations), but rather replace the generating capacity that meets existing demand that would be lost due to the retirements.

**Carbon tax costs.** Of the gross carbon tax revenues, we assumed that power plants would keep 0.3% of revenue collected as a collection allowance and 1% of revenue would be used to cover the State of Michigan's administrative costs.

**Cap-and-trade costs.** We assumed that the gross per-unit costs of carbon emissions under cap-and-trade would be 14.2% higher than the carbon tax rate under the carbon tax scenario. Of this, 10% is due to an uncertainty premium, which is makes up about 8.8% of the gross cap-and-trade costs. The remaining 4.2% is due to higher administrative and transaction costs, which makes up about 3.7% of the gross cap-and-trade costs.

The uncertainty premium accounts for the electric power sector's responses to risk. In particular, this refers to the risk of failing to acquire the number of allowances required to achieve compliance while still meeting electricity demand. This risk may be due to insufficient volume (i.e. emissions may exceed allowances available) and, to some degree, due to price volatility (i.e. allowances are more expensive than expected). This uncertainty premium may present itself in a couple of ways. For example, it may represent the cost of hedging. If a generator decides not to hedge, then it represents the potential costs to shareholders, as they would bear the risk of emissions non-compliance.

The State of Michigan would not receive any revenue for this portion of the carbon costs. Our estimate for the uncertainty premium was based on intuition and analogous insurance costs in other markets. For example, many commercial airlines hedge against electricity prices,[72] which suggests that these firms would rather incur small, expected losses rather than large losses under adverse events (i.e. price shocks). In addition, generators in the EU's cap-and-trade system often hedge a portion of their generation to protect against price volatility.[73]

72. Mercatus Energy Advisors, "The State of Airline Fuel Hedging and Risk Management in 2013," Mercatus Center.

We also examined income statements from publicly-traded airline companies, such as Delta and Southwest. This confirmed that existing firms commit large sums of money to hedging programs when their on-going operations depend on predictable prices of fuel.

73. A. Denny Ellerman and Paul L. Joskow, "The European Union's Emissions Trading System in Perspective," Massachusetts Institute of Technology, May 2008.

Eurelectric, "EU ETS Phase 3 Auctioning – Timing and Futures versus Spot", October 2009.

We have assumed that any interstate trading would not strongly affect the price and availability of allowances. We assume that the main drivers of electricity demand (and thus $CO_2$ emissions), such as weather and economic conditions, would affect all states.

While both cap-and-trade and carbon taxes would require emissions monitoring mechanisms, we anticipate that administrative costs are higher under cap-and-trade due to the trading system. The additional administrative responsibility may involve establishing a registry for allowances, tracking allowance trades, and tracking changes in ownership of allowances.

## LIMITATIONS

In this section, we note the following limitations in our approach and assumptions:

**Trend growth rates.** As noted elsewhere, we used annual growth rates to project the trend path of the economy, electricity prices, and other parameters. Thus, our results do not capture cyclical fluctuations in the economy (i.e. periods of recession or recovery) or short-term deviations from trend for electricity prices.

**Response of electricity generators.** As discussed previously, we exogenously imposed the electricity generation mix in order to estimate the $CO_2$ emissions rate based on announced coal plant retirements and existing RPS standards. We do not attempt to estimate additional response to the EPA's CPP final rule that could occur, such as a significant additional coal plant retirements, replacement with large amounts of wind, or dramatic improvements in solar technology. Generation technology scenarios other than those we modeled are possible, but the costs of such scenarios should also be considered. Further, we do not attempt to estimate electric generation for individual generators, which would rely on their respective generating technologies, inputs, input prices, and other parameters.

**Residual federal regulation risk.** We modeled two regulatory scenarios under which we forecast that the state approximately complies with the EPA's CPP final rule. Actual legislative implementation as well as the economy, business cycle, weather, and other factors may cause variation from the forecasted path, which extends beyond a decade past the current period. We do not explicitly account for residual risks that the state is not in compliance with the final rule.

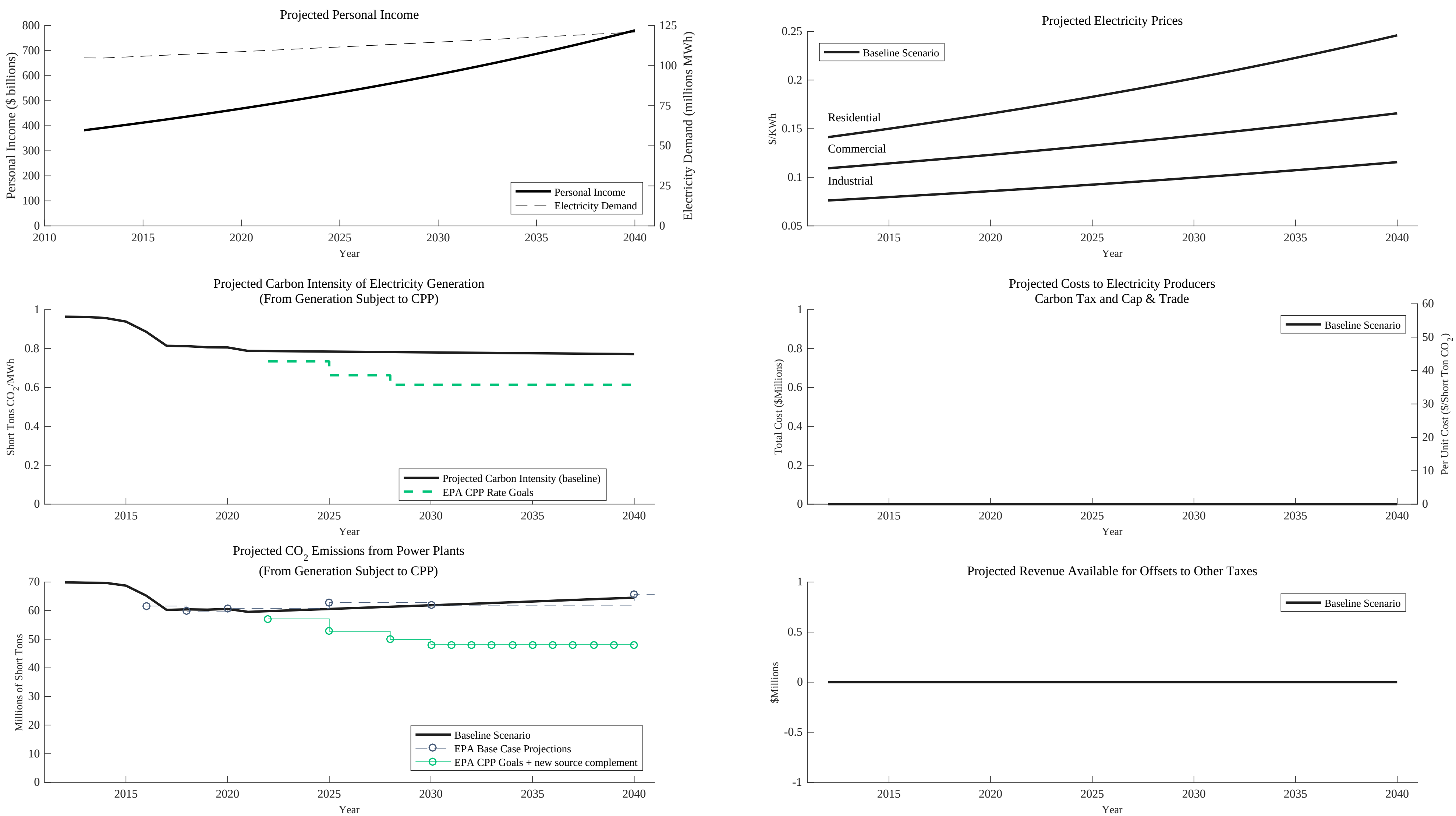
## *Appendix D. Summary of Results from the Three Scenarios*

This appendix includes summary exhibits and data tables for each of the three regulatory scenarios that we modeled:


- Figure D-1, ""No New Policy" Baseline: Summary Exhibits (2012-2040)," on page D-2
- Table D-6, ""No New Policy" Baseline: Summary Data (2012-2040)," on page D-3
- Figure D-2, "Cap-and-Trade Scenario: Summary Exhibits (2012-2040)," on page D-4
- Table D-7, "Cap-and-Trade Scenario: Summary Data (2012-2040)," on page D-5
- Figure D-3, "Carbon Tax Scenario: Summary Exhibits (2012-2040)," on page D-6
- Table D-8, "Carbon Tax Scenario: Summary Data (2012-2040)," on page D-7
- Figure D-4, "Cap-and-Trade vs. Carbon Tax Scenarios: Summary Exhibits (2020-2040)," on page 8

## *"No New Policy" Scenario*

**FIGURE D-1. "No New Policy" Baseline: Summary Exhibits (2012-2040)**




*Source: AEG analysis using the Sectoral Business Decision Model*

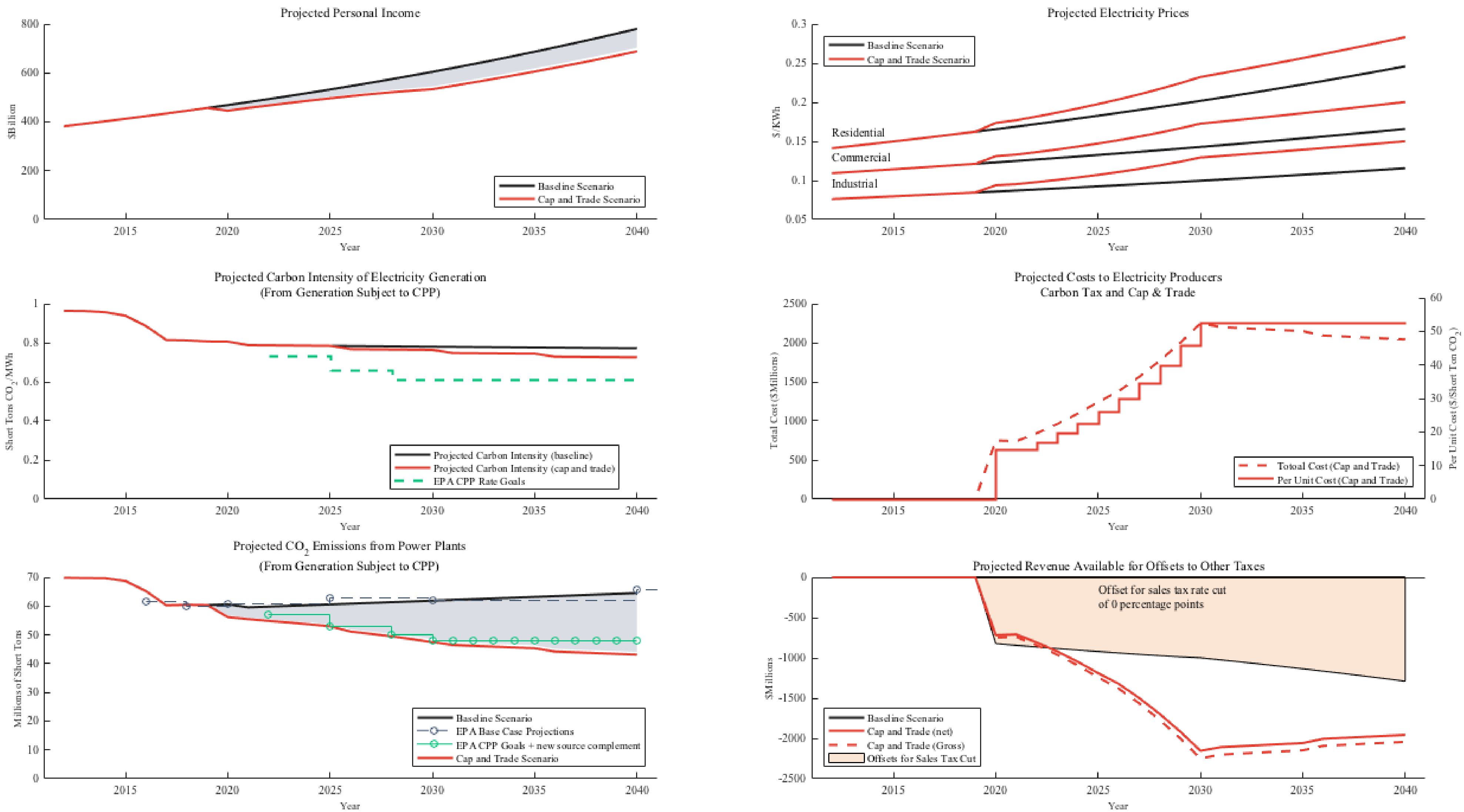
**TABLE D-6. "No New Policy" Baseline: Summary Data (2012-2040)**

| | Personal Income (billions) | PY Ratio | Electricity Consumption (million MWh) | Carbon Intensity (short tons/MWh) | Emissions (million short tons) | Residential Price | Commercial Price | Industrial Price | Carbon Price | Carbon Cost (millions) |
|---|---|---|---|---|---|---|---|---|---|---|
| **2012** | $382.1 | 274.3 | 104.8 | 0.9638 | 69.9 | $0.141 | $0.109 | $0.076 | $0.00 | $0.0 |
| **2013** | $391.9 | 268.9 | 104.8 | 0.9627 | 69.7 | $0.144 | $0.111 | $0.077 | $0.00 | $0.0 |
| **2014** | $402.1 | 263.5 | 105.3 | 0.9569 | 69.7 | $0.147 | $0.113 | $0.079 | $0.00 | $0.0 |
| **2015** | $412.5 | 258.2 | 105.9 | 0.9386 | 68.7 | $0.150 | $0.114 | $0.080 | $0.00 | $0.0 |
| **2016** | $423.1 | 253.0 | 106.4 | 0.8859 | 65.2 | $0.153 | $0.116 | $0.081 | $0.00 | $0.0 |
| **2017** | $434.1 | 248.0 | 107.0 | 0.8141 | 60.2 | $0.156 | $0.118 | $0.082 | $0.00 | $0.0 |
| **2018** | $445.3 | 243.0 | 107.6 | 0.8124 | 60.4 | $0.159 | $0.120 | $0.083 | $0.00 | $0.0 |
| **2019** | $456.8 | 238.2 | 108.1 | 0.8066 | 60.3 | $0.162 | $0.121 | $0.085 | $0.00 | $0.0 |
| **2020** | $468.6 | 233.4 | 108.7 | 0.8057 | 60.6 | $0.166 | $0.123 | $0.086 | $0.00 | $0.0 |
| **2021** | $480.7 | 228.7 | 109.3 | 0.7879 | 59.6 | $0.169 | $0.125 | $0.087 | $0.00 | $0.0 |
| **2022** | $493.1 | 224.2 | 109.9 | 0.7870 | 59.8 | $0.172 | $0.127 | $0.088 | $0.00 | $0.0 |
| **2023** | $505.9 | 219.7 | 110.5 | 0.7862 | 60.1 | $0.176 | $0.129 | $0.090 | $0.00 | $0.0 |
| **2024** | $519.0 | 215.3 | 111.1 | 0.7853 | 60.3 | $0.179 | $0.131 | $0.091 | $0.00 | $0.0 |
| **2025** | $532.4 | 211.0 | 111.7 | 0.7844 | 60.6 | $0.183 | $0.133 | $0.092 | $0.00 | $0.0 |
| **2026** | $546.1 | 206.8 | 112.2 | 0.7836 | 60.8 | $0.186 | $0.135 | $0.094 | $0.00 | $0.0 |
| **2027** | $560.2 | 202.6 | 112.8 | 0.7827 | 61.1 | $0.190 | $0.137 | $0.095 | $0.00 | $0.0 |
| **2028** | $574.7 | 198.6 | 113.4 | 0.7819 | 61.3 | $0.194 | $0.139 | $0.097 | $0.00 | $0.0 |
| **2029** | $589.6 | 194.6 | 114.1 | 0.7810 | 61.6 | $0.198 | $0.141 | $0.098 | $0.00 | $0.0 |
| **2030** | $604.8 | 190.7 | 114.7 | 0.7801 | 61.9 | $0.202 | $0.143 | $0.100 | $0.00 | $0.0 |
| **2031** | $620.5 | 186.9 | 115.3 | 0.7793 | 62.1 | $0.206 | $0.145 | $0.101 | $0.00 | $0.0 |
| **2032** | $636.5 | 183.2 | 115.9 | 0.7784 | 62.4 | $0.210 | $0.147 | $0.103 | $0.00 | $0.0 |
| **2033** | $652.9 | 179.5 | 116.5 | 0.7776 | 62.6 | $0.214 | $0.149 | $0.104 | $0.00 | $0.0 |
| **2034** | $669.8 | 175.9 | 117.1 | 0.7767 | 62.9 | $0.218 | $0.152 | $0.106 | $0.00 | $0.0 |
| **2035** | $687.1 | 172.4 | 117.8 | 0.7759 | 63.2 | $0.223 | $0.154 | $0.107 | $0.00 | $0.0 |
| **2036** | $704.9 | 168.9 | 118.4 | 0.7750 | 63.4 | $0.227 | $0.156 | $0.109 | $0.00 | $0.0 |
| **2037** | $723.1 | 165.6 | 119.0 | 0.7741 | 63.7 | $0.232 | $0.159 | $0.111 | $0.00 | $0.0 |
| **2038** | $741.8 | 162.2 | 119.6 | 0.7733 | 64.0 | $0.236 | $0.161 | $0.112 | $0.00 | $0.0 |
| **2039** | $761.0 | 159.0 | 120.3 | 0.7724 | 64.3 | $0.241 | $0.163 | $0.114 | $0.00 | $0.0 |
| **2040** | $780.7 | 155.8 | 120.9 | 0.7716 | 64.5 | $0.246 | $0.166 | $0.116 | $0.00 | $0.0 |

*Source: AEG analysis using the Sectoral Business Decision Model*

## *Cap-and-Trade Scenario*

**FIGURE D-2. Cap-and-Trade Scenario: Summary Exhibits (2012-2040)**




*Source: AEG analysis using the Sectoral Business Decision Model*

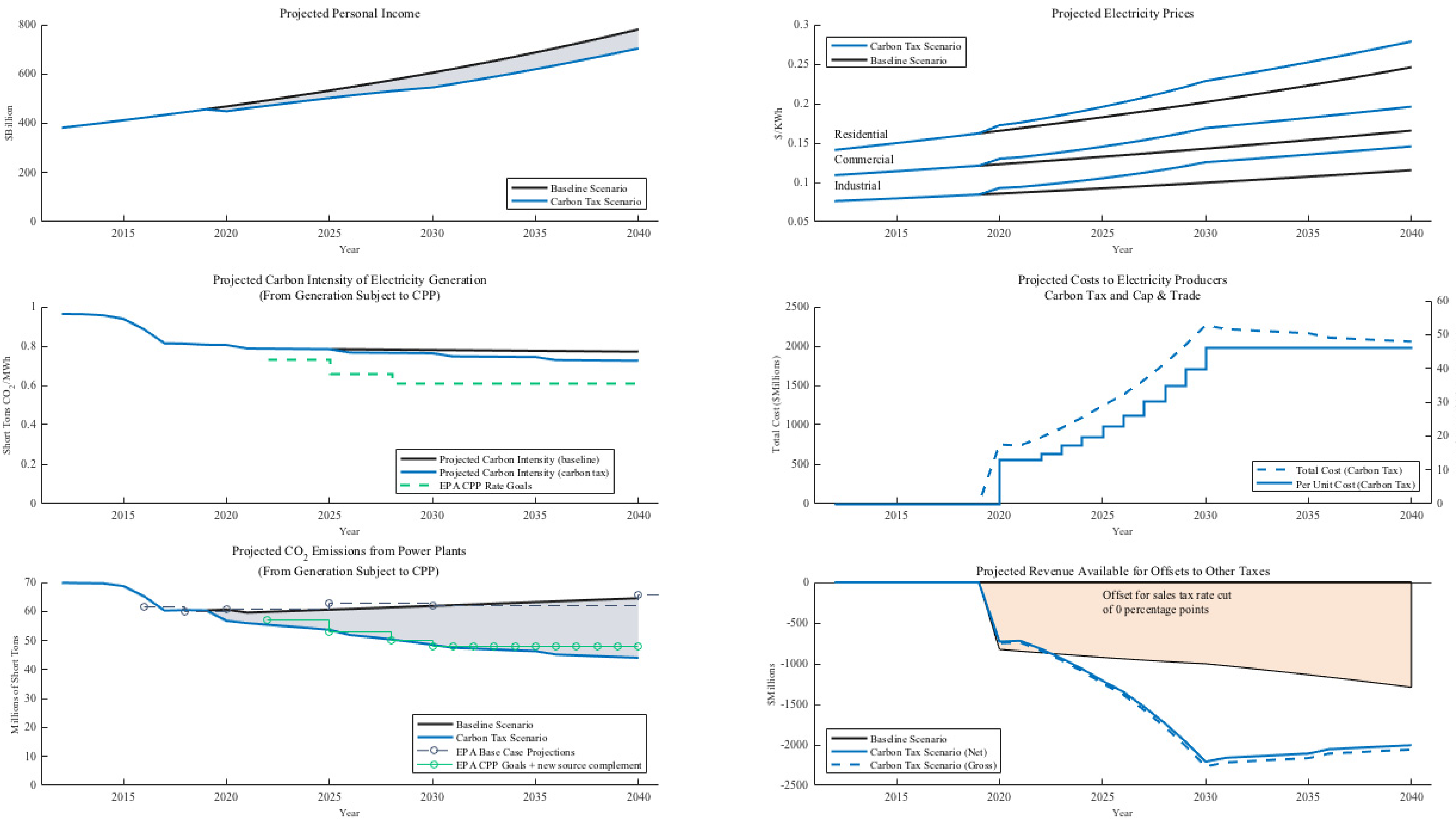
TABLE D-7. Cap-and-Trade Scenario: Summary Data (2012-2040)

| | Personal Income (billions) | PY Ratio | Electricity Consumption (million MWh) | Carbon Intensity (short tons/MWh) | Emissions (million short tons) | Residential Price | Commercial Price | Industrial Price | Carbon Price | Carbon Cost (millions) | Sales Tax Offset (millions) | Other Legislative Priorities (millions) | Hedging and Compliance Costs (millions) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2012** | $382.1 | 274.3 | 104.8 | 0.9638 | 69.9 | $0.141 | $0.109 | $0.076 | $0.00 | $0.0 | $0.0 | $0.0 | $0.0 |
| **2013** | $391.9 | 268.9 | 104.8 | 0.9627 | 69.7 | $0.144 | $0.111 | $0.077 | $0.00 | $0.0 | $0.0 | $0.0 | $0.0 |
| **2014** | $402.1 | 263.5 | 105.3 | 0.9569 | 69.7 | $0.147 | $0.113 | $0.079 | $0.00 | $0.0 | $0.0 | $0.0 | $0.0 |
| **2015** | $412.5 | 258.2 | 105.9 | 0.9386 | 68.7 | $0.150 | $0.114 | $0.080 | $0.00 | $0.0 | $0.0 | $0.0 | $0.0 |
| **2016** | $423.1 | 253.0 | 106.4 | 0.8859 | 65.2 | $0.153 | $0.116 | $0.081 | $0.00 | $0.0 | $0.0 | $0.0 | $0.0 |
| **2017** | $434.1 | 248.0 | 107.0 | 0.8141 | 60.2 | $0.156 | $0.118 | $0.082 | $0.00 | $0.0 | $0.0 | $0.0 | $0.0 |
| **2018** | $445.3 | 243.0 | 107.6 | 0.8124 | 60.4 | $0.159 | $0.120 | $0.083 | $0.00 | $0.0 | $0.0 | $0.0 | $0.0 |
| **2019** | $456.8 | 238.2 | 108.1 | 0.8066 | 60.3 | $0.162 | $0.121 | $0.085 | $0.00 | $0.0 | $0.0 | $0.0 | $0.0 |
| **2020** | $445.4 | 231.0 | 100.8 | 0.8057 | 56.1 | $0.174 | $0.131 | $0.094 | $14.85 | $750.2 | $816.5 | -$159.5 | $93.3 |
| **2021** | $456.9 | 224.1 | 101.8 | 0.7879 | 55.5 | $0.177 | $0.133 | $0.095 | $14.85 | $740.9 | $837.6 | -$188.8 | $92.1 |
| **2022** | $467.1 | 217.4 | 100.7 | 0.7870 | 54.8 | $0.182 | $0.136 | $0.098 | $17.09 | $843.0 | $856.3 | -$118.1 | $104.8 |
| **2023** | $477.2 | 210.8 | 99.8 | 0.7862 | 54.3 | $0.187 | $0.140 | $0.101 | $19.67 | $960.3 | $874.8 | -$33.9 | $119.4 |
| **2024** | $486.9 | 204.5 | 98.8 | 0.7853 | 53.6 | $0.192 | $0.143 | $0.104 | $22.64 | $1,092.5 | $892.7 | $64.0 | $135.8 |
| **2025** | $496.2 | 198.4 | 97.6 | 0.7844 | 52.9 | $0.198 | $0.147 | $0.107 | $26.05 | $1,241.3 | $909.8 | $177.2 | $154.3 |
| **2026** | $505.2 | 192.4 | 96.3 | 0.7671 | 51.1 | $0.204 | $0.152 | $0.111 | $29.99 | $1,379.2 | $926.1 | $281.6 | $171.5 |
| **2027** | $513.5 | 186.7 | 95.0 | 0.7663 | 50.3 | $0.210 | $0.156 | $0.115 | $34.51 | $1,562.8 | $941.3 | $427.1 | $194.3 |
| **2028** | $521.0 | 181.1 | 93.4 | 0.7654 | 49.4 | $0.217 | $0.161 | $0.119 | $39.72 | $1,767.7 | $955.2 | $592.8 | $219.8 |
| **2029** | $527.7 | 175.6 | 91.7 | 0.7646 | 48.5 | $0.224 | $0.167 | $0.124 | $45.72 | $1,995.8 | $967.4 | $780.2 | $248.2 |
| **2030** | $533.4 | 170.4 | 89.9 | 0.7637 | 47.5 | $0.232 | $0.173 | $0.129 | $52.62 | $2,248.7 | $977.9 | $991.2 | $279.6 |
| **2031** | $547.2 | 165.3 | 89.9 | 0.7476 | 46.5 | $0.237 | $0.175 | $0.131 | $52.62 | $2,200.7 | $1,003.1 | $923.9 | $273.6 |
| **2032** | $561.3 | 160.3 | 89.4 | 0.7468 | 46.2 | $0.242 | $0.178 | $0.133 | $52.62 | $2,187.5 | $1,029.1 | $886.4 | $272.0 |
| **2033** | $575.8 | 155.5 | 89.0 | 0.7460 | 45.9 | $0.247 | $0.181 | $0.135 | $52.62 | $2,174.3 | $1,055.7 | $848.3 | $270.4 |
| **2034** | $590.7 | 150.8 | 88.6 | 0.7452 | 45.6 | $0.252 | $0.183 | $0.137 | $52.62 | $2,161.2 | $1,083.0 | $809.5 | $268.7 |
| **2035** | $606.0 | 146.3 | 88.1 | 0.7443 | 45.4 | $0.257 | $0.186 | $0.139 | $52.62 | $2,148.2 | $1,111.0 | $770.1 | $267.1 |
| **2036** | $621.6 | 141.9 | 87.7 | 0.7286 | 44.2 | $0.262 | $0.189 | $0.141 | $52.62 | $2,092.5 | $1,139.7 | $692.6 | $260.2 |
| **2037** | $637.7 | 137.6 | 87.3 | 0.7278 | 43.9 | $0.267 | $0.192 | $0.144 | $52.62 | $2,079.9 | $1,169.1 | $652.2 | $258.6 |
| **2038** | $654.2 | 133.5 | 86.8 | 0.7270 | 43.7 | $0.272 | $0.194 | $0.146 | $52.62 | $2,067.4 | $1,199.3 | $611.0 | $257.1 |
| **2039** | $671.1 | 129.5 | 86.4 | 0.7262 | 43.4 | $0.278 | $0.197 | $0.148 | $52.62 | $2,054.9 | $1,230.3 | $569.1 | $255.5 |
| **2040** | $688.4 | 125.6 | 86.0 | 0.7254 | 43.1 | $0.283 | $0.200 | $0.150 | $52.62 | $2,042.6 | $1,262.2 | $526.4 | $254.0 |

*Source: AEG analysis using the Sectoral Business Decision Model*

*Carbon Tax Scenario*

**FIGURE D-3. Carbon Tax Scenario: Summary Exhibits (2012-2040)**



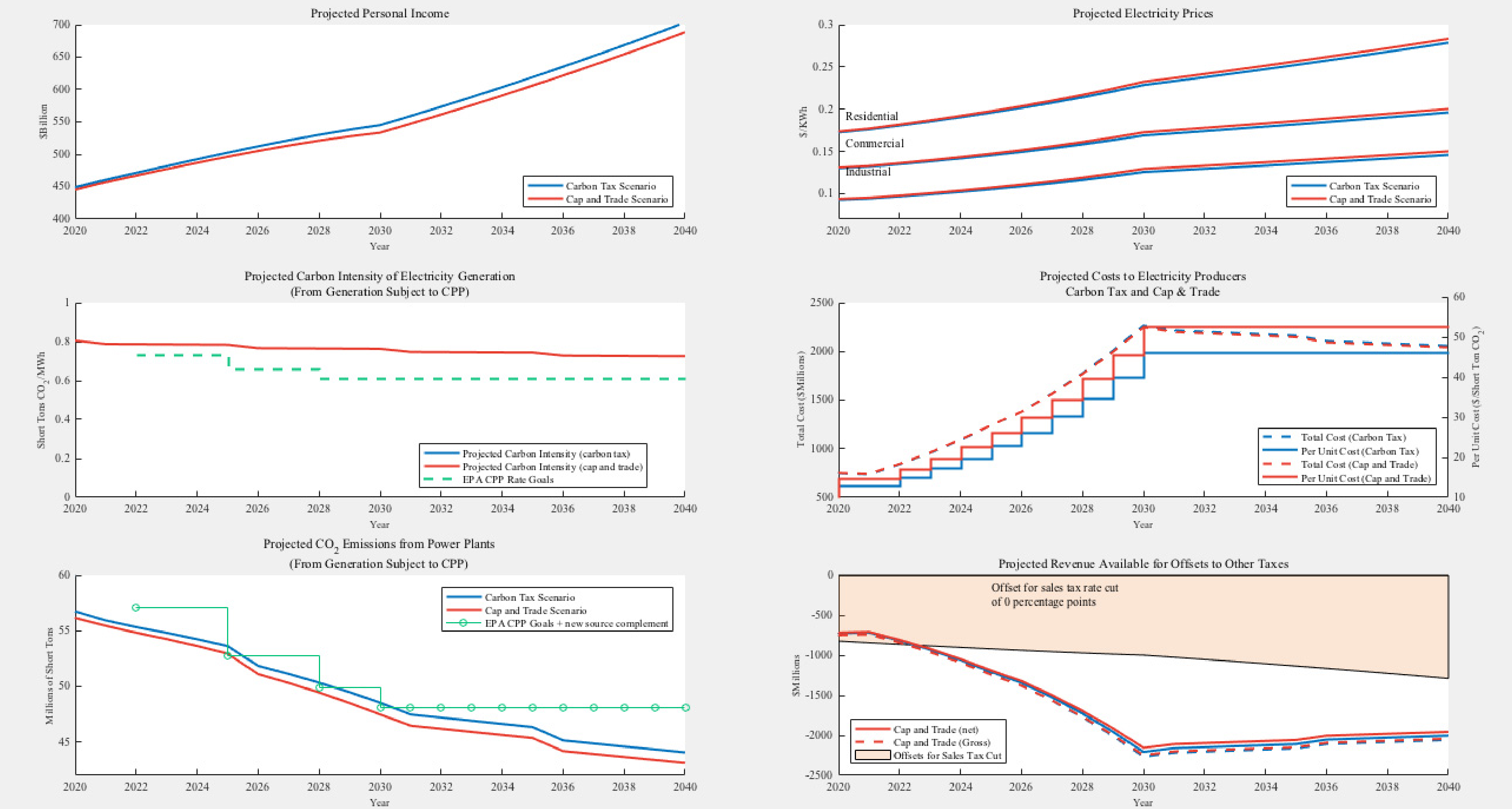

*Source: AEG analysis using the Sectoral Business Decision Model*

**TABLE D-8.** **Carbon Tax Scenario: Summary Data (2012-2040)**

| | Personal Income (billions) | PY Ratio | Electricity Consumption (million MWh) | Carbon Intensity (short tons/MWh) | Emissions (million short tons) | Residential Price | Commercial Price | Industrial Price | Carbon Price | Carbon Cost (millions) | Sales Tax Offset (millions) | Other Legislative Priorities (millions) | Administrative Costs, Collection Allowance (millions) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2012** | $382.1 | 274.3 | 104.8 | 0.9638 | 69.9 | $0.141 | $0.109 | $0.076 | $0.00 | $0.0 | $0.0 | $0.0 | $0.0 |
| **2013** | $391.9 | 268.9 | 104.8 | 0.9627 | 69.7 | $0.144 | $0.111 | $0.077 | $0.00 | $0.0 | $0.0 | $0.0 | $0.0 |
| **2014** | $402.1 | 263.5 | 105.3 | 0.9569 | 69.7 | $0.147 | $0.113 | $0.079 | $0.00 | $0.0 | $0.0 | $0.0 | $0.0 |
| **2015** | $412.5 | 258.2 | 105.9 | 0.9386 | 68.7 | $0.150 | $0.114 | $0.080 | $0.00 | $0.0 | $0.0 | $0.0 | $0.0 |
| **2016** | $423.1 | 253.0 | 106.4 | 0.8859 | 65.2 | $0.153 | $0.116 | $0.081 | $0.00 | $0.0 | $0.0 | $0.0 | $0.0 |
| **2017** | $434.1 | 248.0 | 107.0 | 0.8141 | 60.2 | $0.156 | $0.118 | $0.082 | $0.00 | $0.0 | $0.0 | $0.0 | $0.0 |
| **2018** | $445.3 | 243.0 | 107.6 | 0.8124 | 60.4 | $0.159 | $0.120 | $0.083 | $0.00 | $0.0 | $0.0 | $0.0 | $0.0 |
| **2019** | $456.8 | 238.2 | 108.1 | 0.8066 | 60.3 | $0.162 | $0.121 | $0.085 | $0.00 | $0.0 | $0.0 | $0.0 | $0.0 |
| **2020** | $449.2 | 231.0 | 101.8 | 0.8057 | 56.7 | $0.173 | $0.130 | $0.093 | $13.00 | $737.5 | $823.4 | -$95.5 | $9.6 |
| **2021** | $460.8 | 224.1 | 102.6 | 0.7879 | 55.9 | $0.176 | $0.132 | $0.094 | $13.00 | $727.0 | $844.7 | -$127.1 | $9.5 |
| **2022** | $471.4 | 217.4 | 101.7 | 0.7870 | 55.3 | $0.181 | $0.135 | $0.097 | $14.96 | $828.0 | $864.2 | -$46.9 | $10.8 |
| **2023** | $481.9 | 210.8 | 100.8 | 0.7862 | 54.8 | $0.185 | $0.138 | $0.099 | $17.22 | $943.8 | $883.5 | $48.1 | $12.3 |
| **2024** | $492.4 | 204.5 | 99.9 | 0.7853 | 54.2 | $0.190 | $0.142 | $0.102 | $19.82 | $1,075.1 | $902.7 | $158.5 | $14.0 |
| **2025** | $502.5 | 198.4 | 98.8 | 0.7844 | 53.6 | $0.196 | $0.145 | $0.105 | $22.81 | $1,223.3 | $921.2 | $286.2 | $15.9 |
| **2026** | $512.3 | 192.4 | 97.7 | 0.7671 | 51.8 | $0.202 | $0.149 | $0.109 | $26.26 | $1,361.2 | $939.1 | $404.4 | $17.7 |
| **2027** | $521.5 | 186.7 | 96.5 | 0.7663 | 51.1 | $0.208 | $0.154 | $0.112 | $30.22 | $1,545.0 | $956.1 | $568.8 | $20.1 |
| **2028** | $530.1 | 181.1 | 95.1 | 0.7654 | 50.3 | $0.214 | $0.158 | $0.116 | $34.78 | $1,750.9 | $971.9 | $756.2 | $22.8 |
| **2029** | $538.0 | 175.6 | 93.6 | 0.7646 | 49.5 | $0.221 | $0.163 | $0.121 | $40.03 | $1,980.7 | $986.3 | $968.6 | $25.7 |
| **2030** | $545.0 | 170.4 | 91.9 | 0.7637 | 48.5 | $0.229 | $0.169 | $0.126 | $46.08 | $2,236.6 | $999.1 | $1,208.4 | $29.1 |
| **2031** | $559.1 | 165.3 | 91.8 | 0.7476 | 47.5 | $0.233 | $0.171 | $0.128 | $46.08 | $2,187.7 | $1,024.9 | $1,134.3 | $28.4 |
| **2032** | $573.5 | 160.3 | 91.4 | 0.7468 | 47.2 | $0.238 | $0.174 | $0.129 | $46.08 | $2,174.6 | $1,051.4 | $1,094.9 | $28.3 |
| **2033** | $588.3 | 155.5 | 90.9 | 0.7460 | 46.9 | $0.243 | $0.177 | $0.131 | $46.08 | $2,161.5 | $1,078.6 | $1,054.8 | $28.1 |
| **2034** | $603.5 | 150.8 | 90.5 | 0.7452 | 46.6 | $0.247 | $0.179 | $0.133 | $46.08 | $2,148.4 | $1,106.5 | $1,014.0 | $27.9 |
| **2035** | $619.1 | 146.3 | 90.0 | 0.7443 | 46.3 | $0.252 | $0.182 | $0.135 | $46.08 | $2,135.5 | $1,135.1 | $972.7 | $27.8 |
| **2036** | $635.1 | 141.9 | 89.6 | 0.7286 | 45.1 | $0.257 | $0.185 | $0.137 | $46.08 | $2,080.2 | $1,164.4 | $888.7 | $27.0 |
| **2037** | $651.6 | 137.6 | 89.2 | 0.7278 | 44.9 | $0.263 | $0.188 | $0.139 | $46.08 | $2,067.6 | $1,194.5 | $846.2 | $26.9 |
| **2038** | $668.4 | 133.5 | 88.7 | 0.7270 | 44.6 | $0.268 | $0.190 | $0.142 | $46.08 | $2,055.2 | $1,225.4 | $803.0 | $26.7 |
| **2039** | $685.7 | 129.5 | 88.3 | 0.7262 | 44.3 | $0.273 | $0.193 | $0.144 | $46.08 | $2,042.8 | $1,257.1 | $759.2 | $26.6 |
| **2040** | $703.4 | 125.6 | 87.8 | 0.7254 | 44.1 | $0.279 | $0.196 | $0.146 | $46.08 | $2,030.5 | $1,289.6 | $714.5 | $26.4 |

*Source: AEG analysis using the Sectoral Business Decision Model*

**FIGURE D-4. Cap-and-Trade vs. Carbon Tax Scenarios: Summary Exhibits (2020-2040)**




Note: Time and value scales have been adjusted to highlight the policy differences for these comparison charts.

*Source: AEG analysis using the Sectoral Business Decision Model*