
**Michigan Nuclear Power Plants'
Contribution to the State Economy**

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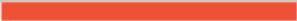
NUCLEAR MATTERS 

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September 2015



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The authors would like to acknowledge the invaluable assistance of Stephen Lagos, Wade Davis, and Paul Organ in preparing this analysis.

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Table of Contents

I.	Executive Summary.....	1
II.	Background.....	2
III.	Nuclear Plants Make a Considerable Contribution to the Michigan Economy.....	4
	A. Impact on Electric Generation Mix.....	6
	B. Impact on Electricity Prices.....	7
	C. Impact on Economic Output.....	8
	D. Impact on Employment.....	9
	E. Impact on Federal and State Tax Revenues.....	10
	F. Michigan Nuclear Plants Prevent Substantial Carbon Dioxide and Criteria Pollutant Emissions.....	11

I. Executive Summary

At the request of Nuclear Matters, The Brattle Group has estimated the value of the nuclear plants in Michigan to the state's economy.

Our analysis has determined that nuclear plants operating in Michigan:

- **contribute approximately \$596 million to state gross domestic product (GDP)** (\$842 million in gross output).
- **account for 3,200 in-state full time jobs** (direct and secondary).
- **help keep electricity prices low.** Michigan consumers would pay \$37 million more annually (2015\$) and over \$300 million more over the next ten years (on a present value basis) without these plants
- **are responsible for \$23 million in net state tax revenues** annually.

These values reflect the incremental contribution of Michigan's nuclear plants to the economy, measured by comparing the performance of the Michigan economy with and without these nuclear plants. This approach nets off the contribution of the alternative generation that would be necessary if the nuclear industry did not exist, to determine its incremental contribution. Absent nuclear energy, the Michigan economy would rely more heavily on existing natural gas and coal-fired generating plants, many of which are outside Michigan, leading to greater reliance overall on out-of-state generation. The greater use of fossil generation would mean higher electricity prices – wholesale prices would be higher on average in Michigan. It is this effect on electricity prices that accounts for the majority of nuclear's overall incremental economic impact. Note that these measures do not reflect the impacts outside Michigan, although the absence of in-state nuclear plants will have significant additional consequences beyond the state's borders.

The absence of Michigan's nuclear plants would also result in much higher carbon dioxide (CO₂) emissions and greater emissions of criteria pollutants, such as nitrogen oxides (NO_x) and sulfur dioxide (SO₂). These impacts are not limited to Michigan, first because much of the alternative fossil-fired generation would occur outside Michigan, and second because air pollution impacts can cross state borders – they are often regional in the case of criteria pollutants, and global in the case of carbon. Large-scale renewable energy probably would not substitute significantly for nuclear; intermittent renewable generation is not a direct substitute for the baseload profile of nuclear.

Absent Michigan's nuclear plants, consumers would pay more for electricity, the economy would suffer both in terms of GDP and jobs, and we would face substantially higher emissions of CO₂ and other pollutants.

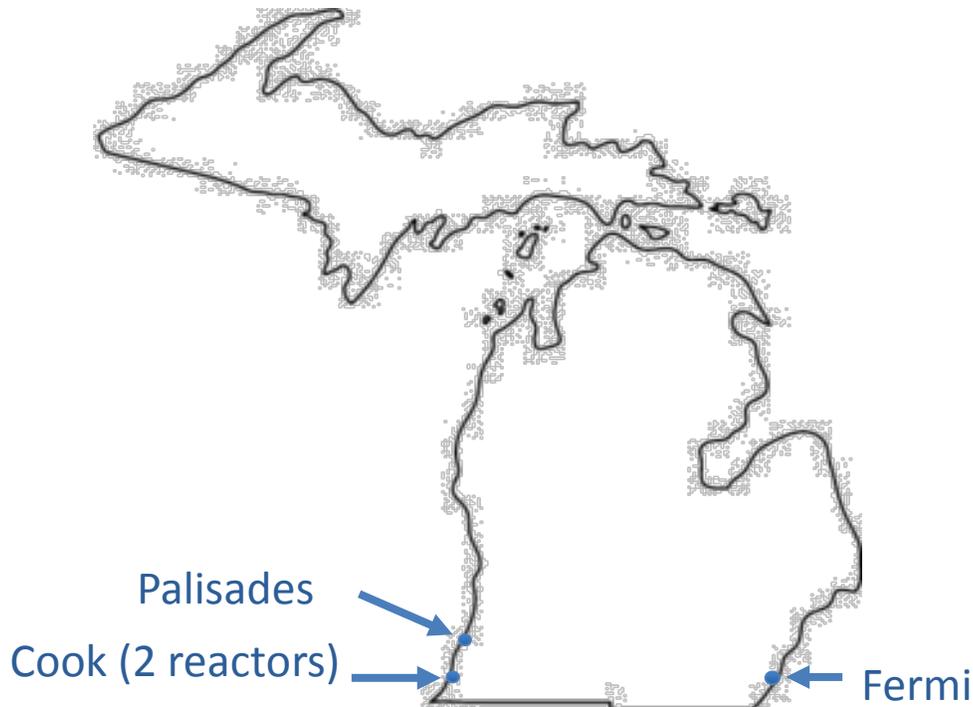
II. Background

Three nuclear plants, comprising four nuclear reactors, operate in Michigan, representing about 4,000 megawatts (MW) of capacity and nearly 32 million megawatt hours (MWh) of annual electricity generation, as shown in Table 1 and illustrated in Figure 1.¹ Michigan is served by two independent system operators, PJM and MISO.² Michigan nuclear generation makes up 1% of total capacity and 2% of generation in both PJM and MISO, as shown in Table 2. It should be noted that both PJM and MISO extend well beyond Michigan's borders, as illustrated in Figure 2. Within Michigan, however, nuclear power represents a considerably larger share of capacity and generation at 12% and 26%, respectively, as shown in Table 3.

Table 1: Summary of Nuclear Generation in Michigan

Variable	Value
[1] Number of nuclear plants	3
[2] Number of nuclear reactors	4
[3] Total capacity (MW)	4,030
[4] Estimated generation (MWh)	31,892,021

Figure 1: Locations of Michigan Nuclear Plants



¹ Data comes from Ventyx's Energy Velocity.

² Independent system operators (ISOs) establish and maintain electricity capacity and energy markets.

Figure 2: PJM and MISO Region Maps

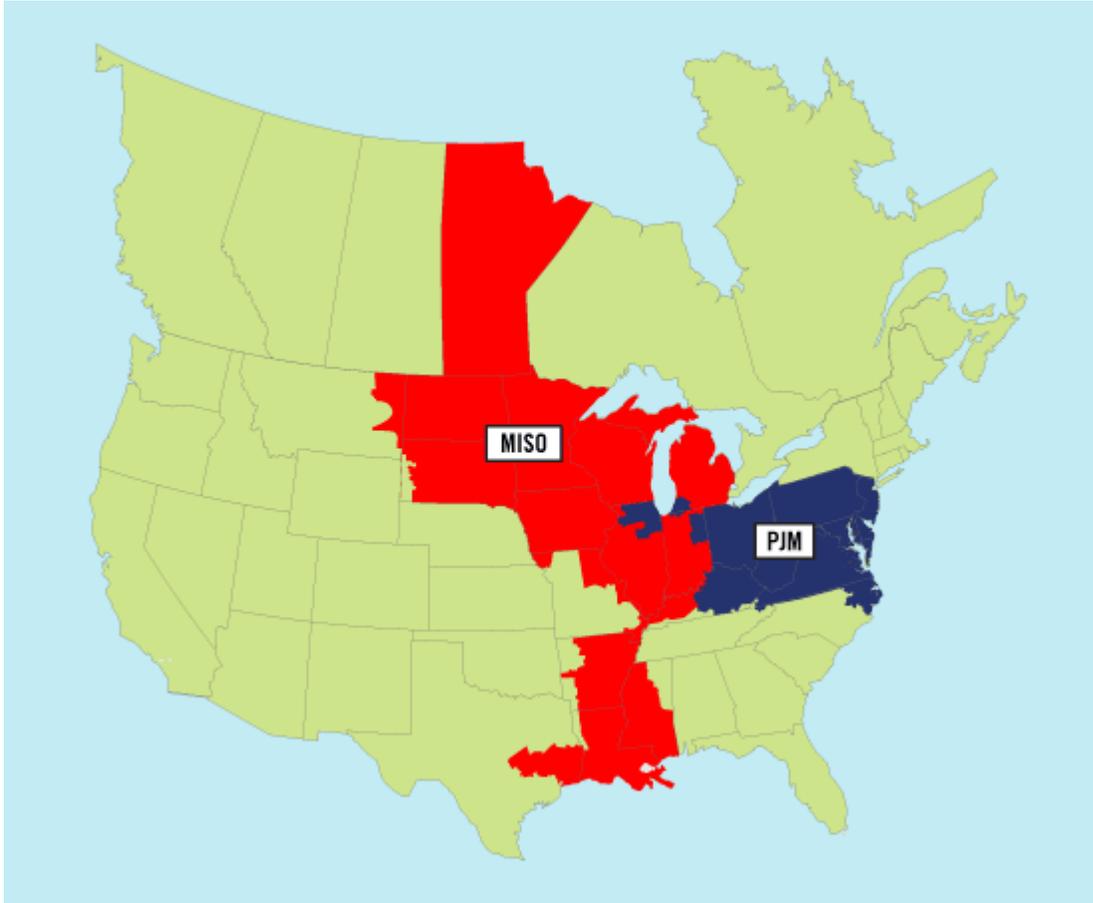


Table 2: Michigan Nuclear Power Share of Capacity and Generation by Reliability Region

Region	Michigan nuclear share of region's capacity	Michigan nuclear share of region's generation
[1] MISO	1%	2%
[2] PJM	1%	2%
[3] MISO and PJM	1%	2%

Table 3: Nuclear Power Provides a Large Share of Michigan Capacity and Generation

Category	Michigan nuclear share
[1] Michigan capacity	12%
[2] Michigan generation	33%

III. Nuclear Plants Make a Considerable Contribution to the Michigan Economy

We have estimated the economic value of Michigan’s nuclear plants to Michigan using REMI, a widely-used dynamic input output model of the U.S. economy, linked with a simplified Brattle model of the electricity sector to better capture the dynamics of power markets and prices.³ By linking these models, we are able to measure the economic output, employment, and tax revenue in Michigan with and without its nuclear plants, providing the most accurate picture of their incremental contribution to the economy. The economic impacts presented here are limited to Michigan, but the nuclear plants operating in Michigan have significant economic impacts well beyond the state’s borders. Economic markets, including electricity markets, do not generally coincide with state borders. As a result, estimating the overall economic impacts of the Michigan nuclear plants would require a regional model. Although we have not created such a regional model for Michigan, we have developed a national model that looks at the entire U.S. nuclear fleet, accounting for electricity and other market activities both within and across states.⁴

This analysis indicates that Michigan’s nuclear plants make a significant contribution to keeping regional electricity costs down, and this has a substantial effect on the state’s economy. Netting out the value of the alternative electric generation that would substitute if they did not exist, Michigan’s nuclear plants are responsible for substantial economic output and accompanying employment and tax revenues. Table 4 summarizes our findings for the impacts within Michigan (not including the impact outside the state).

³ For more details on the REMI model, see www.remi.com.

⁴ The Brattle Group, “The Nuclear Industry’s Contribution to the U.S. Economy,” July 7, 2015. Note that economic impacts presented for Michigan in the national study will differ substantially from those reported in this study. In the national report, we measure the contribution of all nuclear plants. Consequently, state impacts are influenced not only by plants located within a given state, but also by plants located in other states. The economic impacts presented in this report are limited to only the contributions of in-state nuclear plants.

Table 4: Net Contribution of Michigan Nuclear Plants to the Michigan Economy

	Average Annual (2015-2024)
Direct and Secondary Employment (jobs)	3,200
Direct and Secondary Output (2015 dollars)	\$842 million
Direct and Secondary GDP (2015 dollars)	\$596 million
Direct and Secondary State Tax Revenues (2015 dollars)	\$23.1 million
Direct and Secondary Federal Tax Revenues (2015 dollars)	\$89.4 million

Michigan’s nuclear plants contribute \$596 million to the state’s GDP, and account for about 3,200 direct and secondary jobs.⁵ The nuclear plants’ owners also pay substantial federal and state taxes, as do businesses providing good and services to the plants and their employees. In addition, the nuclear plants’ incremental contributions to state output account for additional tax revenues. Michigan plants’ effect on the economy leads to about \$23 million in additional state tax revenues and \$89 million in federal tax revenues, beyond what would be provided by the alternative electric supply that would be utilized in their absence.

Below, we provide further detail regarding the impact of Michigan nuclear plants on:

- The electricity generation mix
- The cost of electricity
- Economic output and GDP
- Employment (direct and secondary)
- Federal and state tax revenues

⁵ We report both GDP and gross output since both are useful economic statistics in Table 4. GDP is the most widely-used measure of national income. It reflects value added, which includes industry sales to other industries and to final users minus the value its purchases from other industries. Gross output is a measure of industry sales, which includes sales to final users and intermediate sales to other industries. This leads to a form of double counting, but does not prevent the measure from being a meaningful indicator of how individual industries perform relative to one another.

Further details regarding our data, assumptions, and modeling results can be found in “The Nuclear Industry’s Contribution to the U.S. Economy,” prepared for Nuclear Matters by The Brattle Group, July 7, 2015.

A. IMPACT ON ELECTRIC GENERATION MIX

As shown in Figure 3, without Michigan’s nuclear power plants, electricity demand would be met mostly by increased reliance on existing natural gas and coal-fired generation. The share of Michigan generation from natural gas-fired plants would increase from 22% to 32%, and the share from coal-fired plants would increase from 37% to 56%. Large-scale renewable energy probably would not be significantly different; intermittent renewable generation alone is not a direct substitute for the baseload profile of nuclear, and at current capital and fuel prices (absent other policy changes), natural gas generation is generally more cost-effective. (While wind represents a higher share of generation absent nuclear generation, this is the result of increased reliance on out-of-state capacity within PJM and MISO rather than an increase in wind generation.) PJM and MISO rely on non-Michigan power plants for 93% of their generation when Michigan’s nuclear plants are included. This share would increase to 95% absent these plants, as shown in Figure 4. Higher electricity prices, however, might somewhat reduce demand for grid-based electricity, by inducing efficiency, conservation, and switching to alternative fuels or electricity sources.

Figure 3: Electric Generation Mix in Michigan in 2015

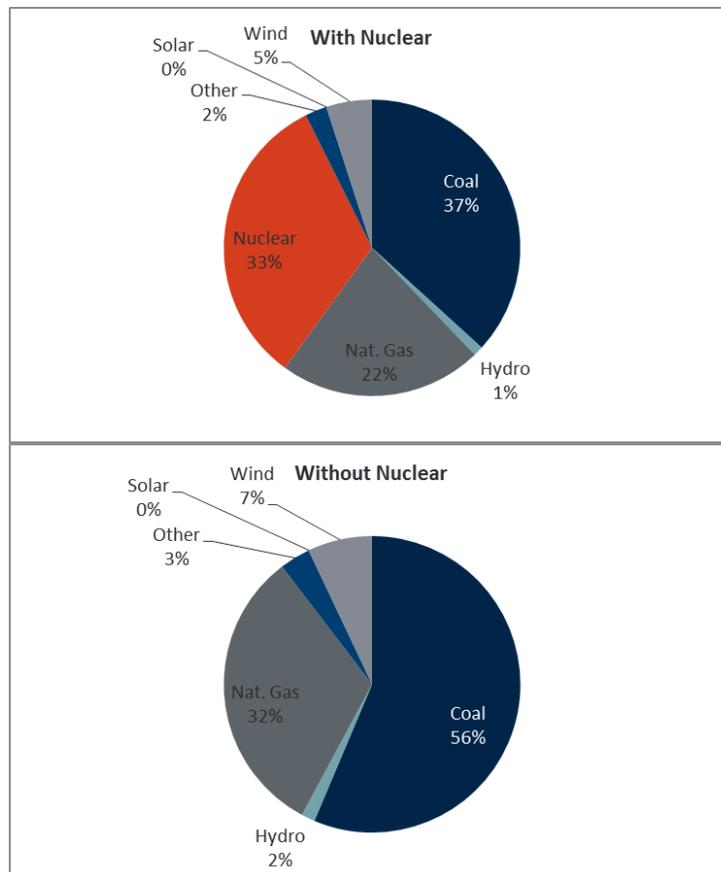
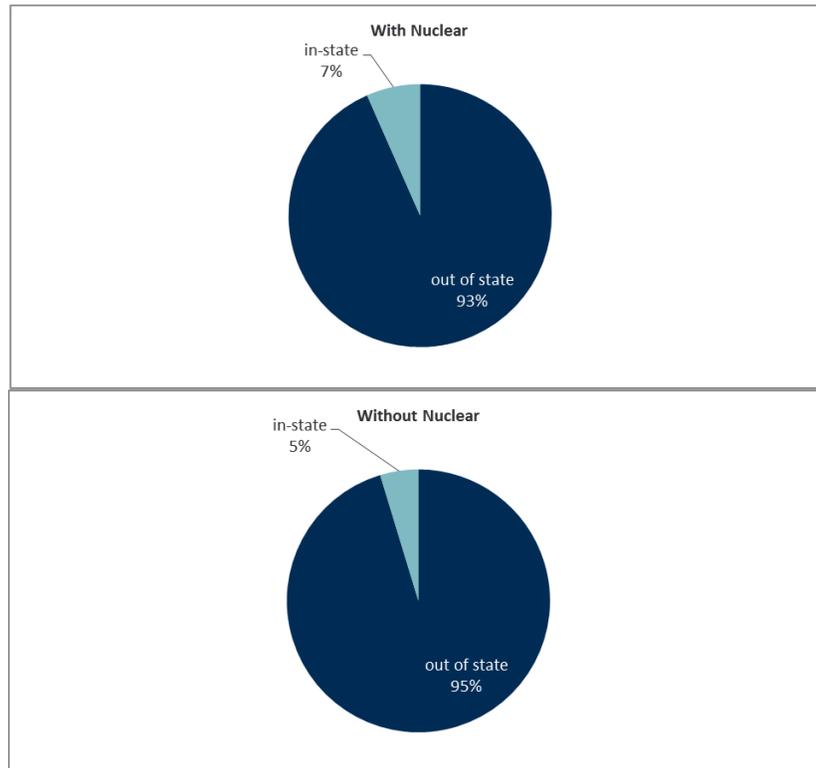


Figure 4: Michigan Share of PJM and MISO Electric Generation in 2015



B. IMPACT ON ELECTRICITY PRICES

Michigan nuclear power plants' impact on the Michigan economy is primarily the result of their influence on electricity prices. As noted above, absent Michigan's nuclear plants, electricity demand would be met by increased utilization of natural gas and coal-fired plants, some within Michigan, but much outside it. This alternative generation mix would mean higher electricity prices across PJM and MISO. As shown in Table 5, on average, electricity prices in Michigan, PJM and MISO would be higher on a wholesale basis.⁶ These increases mean substantial cost increases to consumers. Michigan consumers would pay \$37 million more per year on electricity absent nuclear plants in the state. Between 2015 and 2024 this increase totals \$319 million on a present value basis. Throughout all the PJM and MISO states, annual costs would increase by \$785 million and would total \$6.7 billion (on a present value basis) between 2015-2024. Higher

⁶ This analysis shows the average electricity price effect across PJM and MISO, without making locational distinctions within each ISO. In fact, because of transmission constraints that can occur within the ISO, the price effect would not necessarily be distributed uniformly. In some localized areas, the price effects may be larger (and they could be smaller in other areas), which might lead to greater local economic impacts closer to the plant at issue.

electricity prices hurt the economy primarily by reducing residential, commercial, and industrial spending on other goods and services.

**Table 5: Michigan Nuclear Plants Avoid Higher Electricity Prices
(All-in Wholesale Electricity Prices with and without Nuclear, Average Annual \$/MWh, 2015-2024)**

Region	Wholesale price with nuclear	Wholesale price without nuclear	Wholesale price change	Electricity consumption (millions of MWh)	Total annual electricity cost change (millions of 2015 dollars)	Total electricity cost increase 2015-2024 (millions of dollars) ¹
[1] MISO	\$33.25	\$33.58	\$0.33	701	\$234	\$1,998
[2] PJM	\$46.04	\$46.70	\$0.65	843	\$551	\$4,699
[3] Michigan	\$33.72	\$34.07	\$0.35	108	\$37	\$319

¹ Present value for the periods 2015-2024 at a 3% discount rate.

The magnitude of the power price effects, and ultimately the economic and jobs effects, could depend on movements in the price of natural gas, since it plays a primary role in setting power prices in most U.S. regions.⁷ In addition, although local and possibly regional transmission needs might differ, perhaps significantly, in the absence of nuclear plants, we do not consider changes in transmission investment levels as costs in this report.⁸

C. IMPACT ON ECONOMIC OUTPUT

Michigan’s nuclear plants contribute \$596 million to annual state GDP and \$842 million to gross output, largely through the electricity price effects shown above. These figures include both direct and secondary economic activity attributable to Michigan’s nuclear plants, net of the economic activity associated with alternative generating capacity that would be necessary in their absence. The economic sectors most affected are shown in Table 6. The largest effects are found in the utilities, manufacturing, and construction sectors.

⁷ For example, the economic and jobs effects could be up to twice the values shown here if gas prices were to return to levels seen just a couple years ago.

⁸ These transmission costs, are not captured here because the contribution of nuclear plants to the economy is measured by comparing scenarios with and without nuclear plants – the costs of transition to other generation sources do not enter this comparison. Transmission costs could, however, be substantial if a premature transition to natural gas occurred.

**Table 6: Net Economic Output Impacts by Sector in Michigan
(Average Annual Direct and Secondary Impacts, 2015-2024)**

Sector	Direct and Secondary Output <i>(millions of 2015 dollars)</i>
Utilities	361.2
Manufacturing	109.4
Construction	107.9
Professional, Scientific, and Technical Services	39.4
Retail Trade	35.9
Real Estate and Rental and Leasing	34.5
Health Care and Social Assistance	27.7
Finance and Insurance	24.3
Mining	23.4
Wholesale Trade	16.5
Other	62.0
Total	842

Note: Numbers may not sum due to rounding.

D. IMPACT ON EMPLOYMENT

Michigan’s nuclear plants account for about 3,200 direct and secondary jobs in the state’s economy, as shown in Table 4. The employment sectors most influenced are sales, construction, and business and financial occupations, as shown in Table 7. As with the economic impact, the jobs impact occurs mostly indirectly; not as employment within the nuclear sector itself, but as enhanced employment in other sectors primarily caused by the economic effect of lower power prices.

**Table 7: Net Employment Impacts by Sector in Michigan
(Average Direct and Secondary Impacts, 2015-2024)**

Sector	Direct and Secondary Employment <i>(jobs)</i>
Sales and related, office and administrative support occupations	810
Construction and extraction occupations	570
Management, business, and financial occupations	340
Installation, maintenance, and repair occupations	260
Production occupations	210
Healthcare occupations	170
Computer, mathematical, architecture, and engineering occupations	170
Transportation and material moving occupations	160
Food preparation and serving related occupations	150
Building and grounds cleaning and maintenance, personal care and service occupations	150
Other	210
Total	3,200

Note: Numbers may not sum due to rounding.

E. IMPACT ON FEDERAL AND STATE TAX REVENUES

Michigan’s nuclear plants and the businesses providing goods and services to these plants pay substantial federal and state taxes. In addition, since these plants avoid higher electricity prices, they create incremental economic output and associated tax revenues. Average incremental annual federal tax payments attributable to the plants total \$89 million, and average annual state tax payments total \$23 million.

Table 8: Net Annual Federal and State Tax Payments Attributable to Economic Activity Related to the Michigan Nuclear Plants

	Average Annual (2015-2024)
Direct and Secondary State Tax Revenues (2015 dollars)	\$23.1 million
Direct and Secondary Federal Tax Revenues (2015 dollars)	\$89.4 million
Total Federal and State Tax Revenues (2015 dollars)	\$112.5 million

Note: Numbers may not sum due to rounding.

F. MICHIGAN NUCLEAR PLANTS PREVENT SUBSTANTIAL CARBON DIOXIDE AND CRITERIA POLLUTANT EMISSIONS

Michigan’s nuclear power plants prevent substantial emissions of CO₂, SO₂, and NO_x compared to the alternative of natural gas and coal-fired generation. Average annual CO₂ emissions would be about 25 million tons greater absent the generation from Michigan nuclear plants. This represents a 2% increase over current power sector emissions in PJM and MISO. Similarly, power sector SO₂ emissions would be 53,000 tons higher, and NO_x emissions would be 32,000 tons higher – about a 1% and 2% increase in PJM and MISO, respectively. Particulate matter emissions (such as PM-2.5 and PM-10) would be approximately 2% higher in PJM and MISO. These reductions are summarized in Table 9. Note that the beneficiaries of these reductions are not necessarily located in Michigan. CO₂, for example, is a global pollutant. The higher fossil generation and associated criteria pollutant emissions would originate in the larger PJM and MISO region outside Michigan as well as within it, and can be transported beyond the point of emissions into still other states.

Table 9: Emissions Prevented by Michigan Nuclear Plants (Average Annual, 2015-2024)

Pollutant	Avoided emissions (tons)
CO ₂	25,050,887
SO ₂	53,701
NO _x	31,966
PM 2.5	2,724
PM 10	3,544

The social cost of these emissions can be estimated using the federal government’s social cost of CO₂ emissions (\$43.31/ton) and the National Academy of Science’s externality estimates for SO₂, NO_x, PM-2.5, and PM-10. Evaluated at these rates as shown in Table 10, the avoided social cost of CO₂ is \$1,085 million, and the avoided costs of SO₂ and NO_x are \$365 million and \$60 million, respectively. The avoided costs of particulate matter emissions are approximately \$30 million. These costs reflect environmental and human health damages and are independent of and in addition to the direct and secondary economic impacts addressed elsewhere in this report. They also reflect costs incurred by society, not directly by the economy; the subsequent economic implications of these social costs are not reflected in the economic results above.

**Table 10: Value of Emissions Prevented by Michigan Nuclear Power Plants
(Average Annual, 2015-2024)**

Pollutant	Avoided emissions (thousands of tons)	Emissions social cost per ton (\$/ton)	Avoided emissions value (millions of 2015 dollars)
CO ₂	25,051	\$43	\$1,085
SO ₂	54	\$6,789	\$365
NO _x	32	\$1,873	\$60
PM 2.5	3	\$11,119	\$30
PM 10	4	\$538	\$2

Sources:

Carbon costs come from the Interagency Working Group on Social Cost of Carbon, United States Government.

SO₂, NO_x, PM-2.5, and PM-10 costs come from "Hidden Cost of Energy: Unpriced Consequences of Energy Production and Use" by the National Research Council.

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