
Pennsylvania Nuclear Power Plants' Contribution to the State Economy

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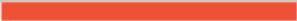
NUCLEAR MATTERS 

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I. Executive Summary

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

Our analysis has determined that nuclear plants operating in Pennsylvania:

- **contribute approximately \$2.36 billion to state gross domestic product (GDP)** (\$3.56 billion in gross output).
- **account for 15,600 in-state full time jobs** (direct and secondary).
- **help keep electricity prices low.** Pennsylvania consumers would pay almost \$600 million more annually (2015\$) and over \$5 billion more over the next ten years (on a present value basis) without these plants.
- **are responsible for \$81 million in net state tax revenues** annually.

These values reflect the incremental contribution of these nuclear plants to the economy, measured by comparing the performance of Pennsylvania's economy with and without its 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, Pennsylvania's economy would rely more heavily on existing natural gas and coal-fired generating plants, many of which are outside Pennsylvania, 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 Pennsylvania. 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 Pennsylvania, although the absence of in-state nuclear plants will have significant additional consequences beyond the state's borders.

The absence of Pennsylvania'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 Pennsylvania, first because much of the alternative fossil-fired generation would occur outside Pennsylvania, 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 Pennsylvania'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.

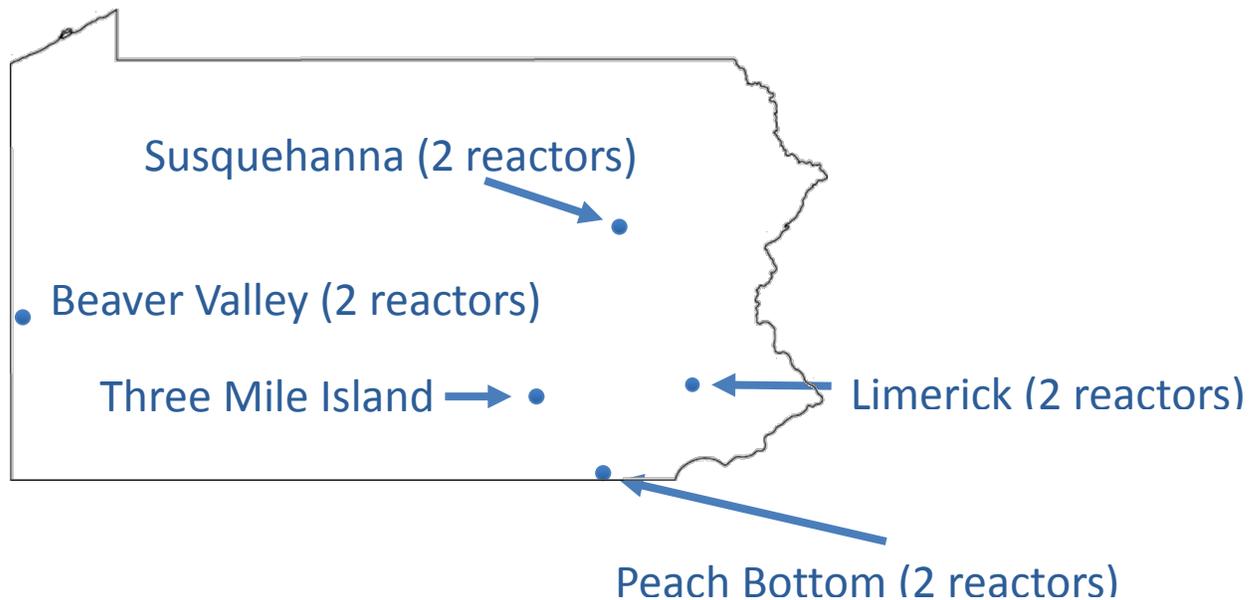
II. Background

Five nuclear plants, comprising nine nuclear reactors, operate in Pennsylvania, representing nearly 10,000 megawatts (MW) of capacity and over 78 million megawatt hours (MWh) of annual electricity generation, as shown in Table 1 and illustrated in Figure 1.¹ Pennsylvania is within the electric region operated by the PJM independent system operator.² Pennsylvania's nuclear generation makes up 6% of PJM's total capacity and 10% of its electricity generation, as shown in Table 2. It should be noted that PJM extends well beyond Pennsylvania's borders, as illustrated in Figure 2. Within Pennsylvania, nuclear power represents a considerably larger share of capacity and generation at 22% and 34% respectively, as shown in Table 3.

Table 1: Summary of Nuclear Generation in Pennsylvania

Variable	Value
[1] Number of nuclear plants	5
[2] Number of nuclear reactors	9
[3] Total capacity (MW)	9,826
[4] Estimated generation (MWh)	78,388,981

Figure 1: Locations of Pennsylvania 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 Region Map

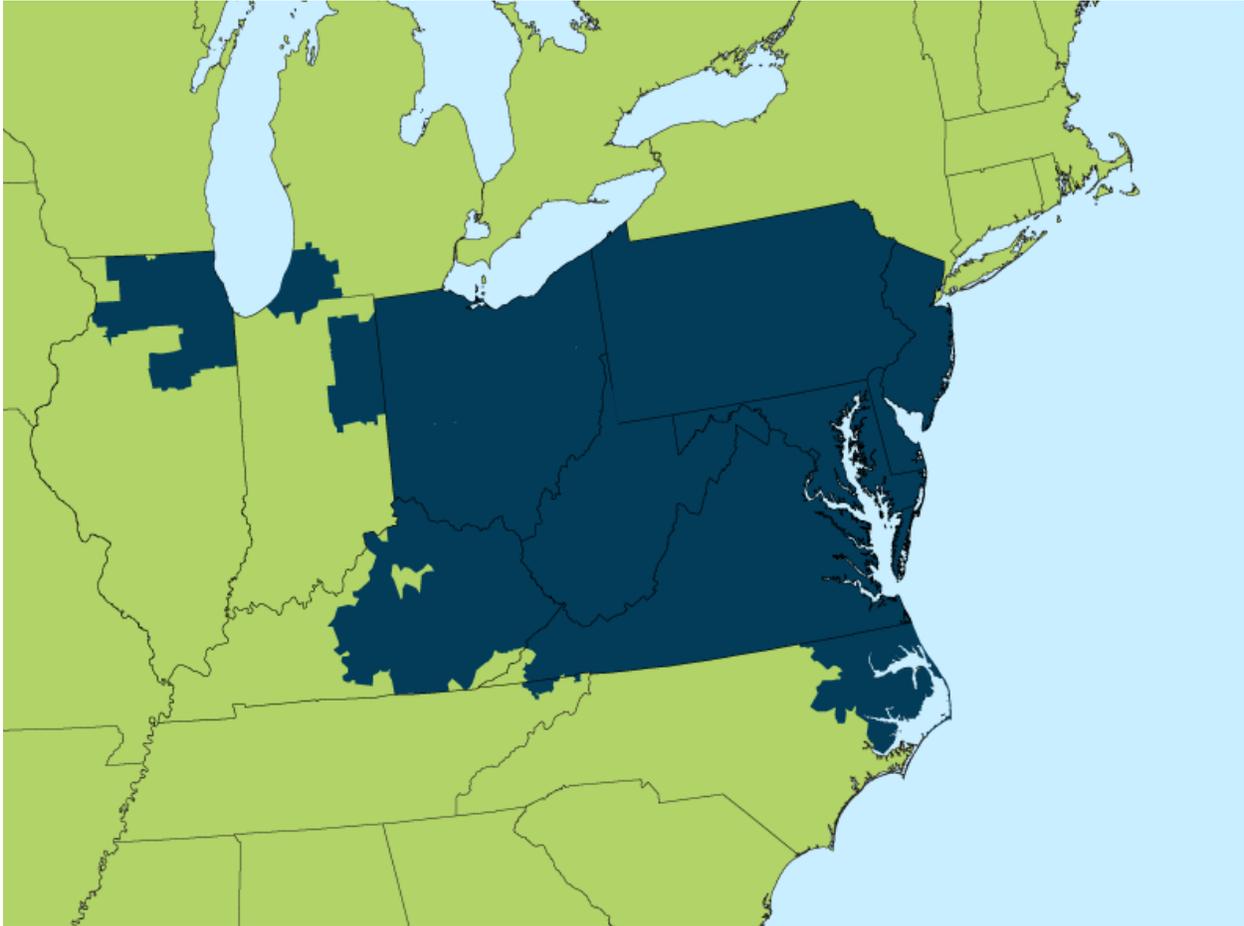


Table 2: Pennsylvania Nuclear Power Share of Capacity and Generation by Reliability Region

Region	Penn. nuclear share of region's capacity	Penn. nuclear share of region's generation
[1] PJM	6%	10%

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

Category	Penn. nuclear share
[1] Pennsylvania capacity	22%
[2] Pennsylvania generation	34%

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

We have estimated the economic value of Pennsylvania’s nuclear plants to Pennsylvania 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 Pennsylvania 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 Pennsylvania, but the nuclear plants operating in Pennsylvania 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 Pennsylvania’s nuclear plants would require a regional model. Although we have not created such a regional model for Pennsylvania, 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 Pennsylvania’s nuclear plants make a significant contribution to keeping regional electricity costs down, and this has a substantial effect on the Pennsylvania economy. Netting out the value of the alternative electric generation that would substitute if they did not exist, Pennsylvania’s nuclear plants are responsible for substantial economic output and accompanying employment and tax revenues. Table 4 summarizes our findings for the impacts within Pennsylvania (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 Pennsylvania 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 Pennsylvania Nuclear Plants to the Pennsylvania Economy

	Average Annual (2015-2024)
Direct and Secondary Employment (jobs)	15,600
Direct and Secondary Output (2015 dollars)	\$3.56 billion
Direct and Secondary GDP (2015 dollars)	\$2.36 billion
Direct and Secondary State Tax Revenues (2015 dollars)	\$81.1 million
Direct and Secondary Federal Tax Revenues (2015 dollars)	\$431.7 million

Pennsylvania’s nuclear plants contribute \$2.36 billion to the state’s GDP, and account for 15,600 direct and secondary jobs.⁵ Pennsylvania’s 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. Pennsylvania plants’ effect on the economy leads to about \$81 million in additional state tax revenues and \$432 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 Pennsylvania 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 Pennsylvania’s nuclear power plants, electricity demand would be met mostly by increased reliance on existing natural gas and coal-fired generation. The share of Pennsylvania generation from natural gas-fired plants would increase from 19% to 36%, and the share from coal-fired plants would increase from 38% to 52%. 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. PJM relies on non-Pennsylvania power plants for 76% of its generation when Pennsylvania’s nuclear plants are included. This share would increase to 82% 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 Pennsylvania in 2015

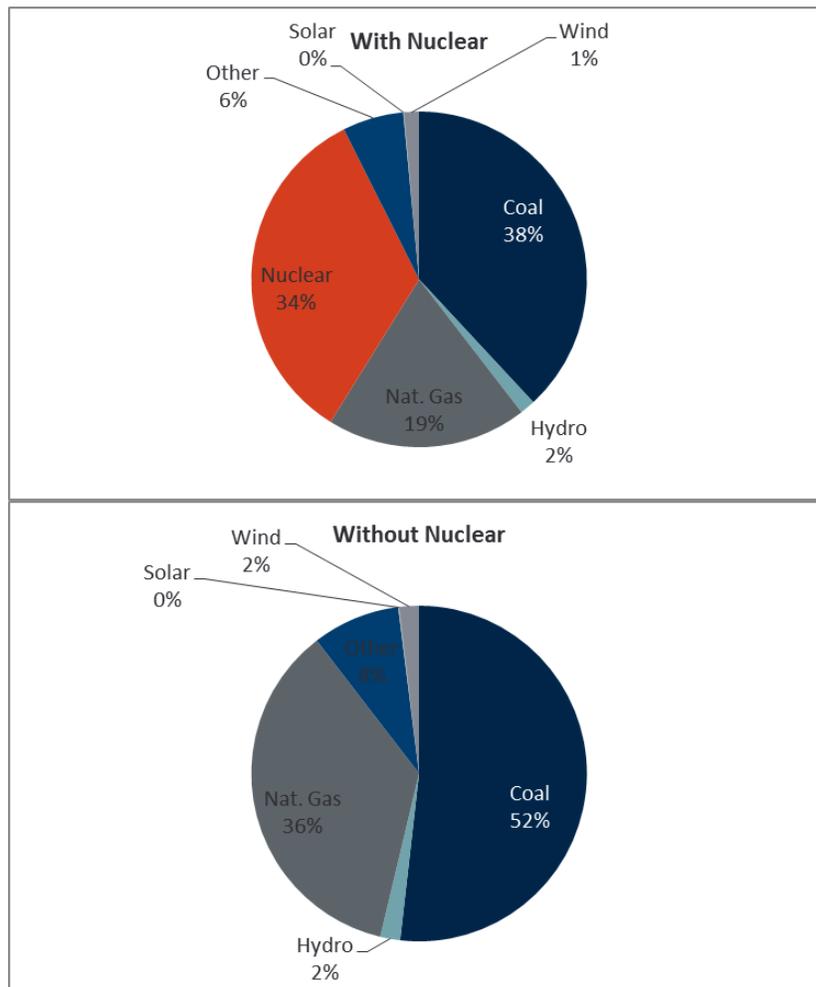
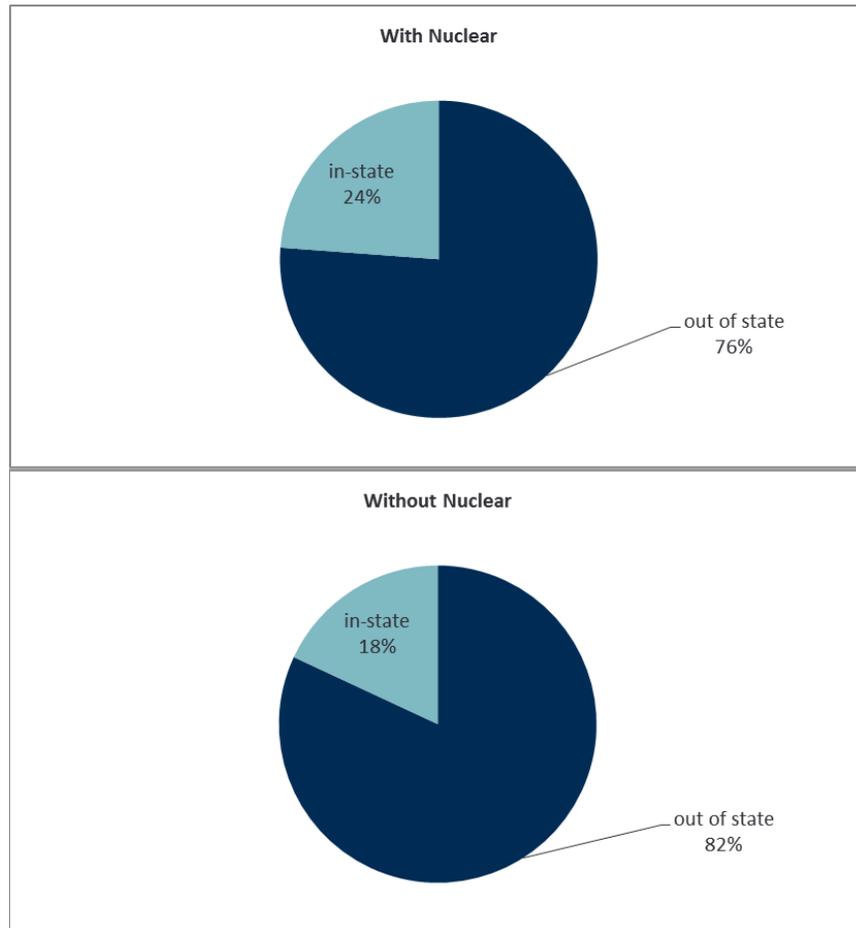


Figure 4: Pennsylvania Share of PJM Generation in 2015



B. IMPACT ON ELECTRICITY PRICES

The impact of Pennsylvania’s nuclear power plants on the state’s economy is primarily the result of their influence on electricity prices. As noted above, absent Pennsylvania’s nuclear plants, electricity demand would be met by increased utilization of natural gas and coal-fired plants, some within Pennsylvania but much outside it. This alternative generation mix would mean higher electricity prices across PJM. As shown in Table 5, on average electricity prices in Pennsylvania and PJM would be higher on a wholesale basis.⁶ These increases represent

⁶ This analysis shows the average electricity price effect across PJM, without making locational distinctions within the 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 plants in question. Many of Pennsylvania’s nuclear units are in the eastern portion of the state which can experience locally higher prices under current conditions, and

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substantial cost increases to consumers. Pennsylvania consumers would spend almost \$600 million per year more on electricity absent nuclear plants in the state. Between 2015 and 2024 this increase totals over \$5 billion on a present value basis. Throughout all the PJM states, that would translate to an annual increase of over \$2.6 billion which totals to more than \$22 billion between 2015 and 2024. Higher electricity prices hurt the economy primarily by reducing residential, commercial, and industrial spending on other goods and services.

**Table 5: Pennsylvania 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] PJM	\$46.14	\$49.31	\$3.17	843	\$2,673	\$22,799
[2] Pennsylvania	\$46.14	\$49.31	\$3.17	189	\$598	\$5,101

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

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could be further exaggerated by the loss of nuclear units. The analysis here captures effects at the ISO and state level, but does not make finer geographic distinctions.

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, as noted by a PJM study regarding the closure of nuclear plants in Illinois. See PJM Response to Illinois Commerce Commission (ICC) Request to Analyze the Impact of Various Illinois Nuclear Power Plant Retirements, 10/21/2014, <http://www.icc.illinois.gov/electricity/hr1146.aspx>. PJM found that premature retirement would require “substantial time to correct;” “would require substantial construction activity and could significantly inconvenience Illinois citizens;” and “[transmission] costs would be significant – in the hundreds of millions of dollars or more” (see pg. 7).

C. IMPACT ON ECONOMIC OUTPUT

Pennsylvania’s nuclear plants contribute \$2.36 billion to annual state GDP and \$3.56 billion to gross output, largely through the electricity price effects shown above. These figures include both direct and secondary economic activity attributable to Pennsylvania 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.

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

Sector	Direct and Secondary Output <i>(millions of 2015 dollars)</i>
Utilities	848.9
Manufacturing	602.4
Construction	521.9
Real Estate and Rental and Leasing	193.8
Retail Trade	192.5
Professional, Scientific, and Technical Services	173.3
Finance and Insurance	168.7
Health Care and Social Assistance	163.6
Mining	157.0
Wholesale Trade	102.7
Other	433.2
Total	3,558

Note: Numbers may not sum due to rounding.

D. IMPACT ON EMPLOYMENT

Pennsylvania’s nuclear plants account for 15,600 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 Pennsylvania
(Average Direct and Secondary Impacts, 2015-2024)**

Sector	Direct and Secondary Employment <i>(jobs)</i>
Sales and related, office and administrative support occupations	4,020
Construction and extraction occupations	2,470
Management, business, and financial occupations	1,600
Food preparation and serving related occupations	1,050
Installation, maintenance, and repair occupations	1,030
Production occupations	940
Healthcare occupations	910
Transportation and material moving occupations	880
Building and grounds cleaning and maintenance, personal care and service occupations	830
Computer, mathematical, architecture, and engineering occupations	710
Other	1,170
Total	15,600

Note: Numbers may not sum due to rounding.

E. IMPACT ON FEDERAL AND STATE TAX REVENUES

Pennsylvania’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 \$432 million, and average annual state tax payments total \$81 million.

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

	Average Annual (2015-2024)
Direct and Secondary State Tax Revenues (2015 dollars)	\$81.1 million
Direct and Secondary Federal Tax Revenues (2015 dollars)	\$431.7 million
Total Federal and State Tax Revenues (2015 dollars)	\$512.9 million

Note: Numbers may not sum due to rounding.

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

Pennsylvania’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 52 million tons greater absent the generation from Pennsylvania nuclear plants. This represents a 10% increase over current power sector emissions in PJM. Similarly, power sector SO₂ emissions would be 68,000 tons higher, and NO_x emissions would be 53,000 tons higher – about a 3% and 6% increase in PJM, respectively. Particulate matter emissions (such as PM-2.5 and PM-10) would be approximately 5% higher in PJM. These reductions are summarized in Table 9. Note that the beneficiaries of these reductions are not necessarily located in Pennsylvania. CO₂, for example, is a global pollutant. The higher fossil generation and associated criteria pollutant emissions would originate in the larger PJM region outside Pennsylvania as well as within it, and can be transported beyond the point of emissions into still other states.

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

Pollutant	Avoided emissions (tons)
CO ₂	51,607,412
SO ₂	68,041
NO _x	53,027
PM 2.5	5,160
PM 10	6,112

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 \$2,235 million, and the avoided costs of SO₂ and NO_x are \$462 million and \$99 million, respectively. The avoided costs of particulate matter emissions are approximately \$57 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 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 Pennsylvania Nuclear Power Plants
(Average Annual, 2015-2024)**

Pollutant	Avoided emissions (thousands of tons)	Emissions social cost per ton (\$/ton)	Avoided emissions value (<i>millions of 2015 dollars</i>)
CO ₂	51,607	\$43	\$2,235
SO ₂	68	\$6,789	\$462
NO _x	53	\$1,873	\$99
PM 2.5	5	\$11,119	\$57
PM 10	6	\$538	\$3

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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