Quantifying Socioeconomic Impacts of Electricity Generating Technologies

Nuclear Fuel Cycle and Supply Chain

Prepared for
U.S. Department of Energy
Systems Analysis & Integration Campaign
W. Jenson, L. Larsen (INL)
E. Davidson, M. Asgari (ORNL)
September 2024
INL/RPT-24-80621

EXECUTIVE SUMMARY

The energy planning process includes comparing different metrics depending on the stakeholders involved. Rate payers, utility companies, suppliers, communities, policy makers, and workers all have different interests that may require additional metrics beyond cost alone. Electricity analysts calculate levelized costs of energy (LCOE) as a tool to make cross-technology cost comparisons of various generating technologies. It is also important to consider the broader economic effects of energy choices. It is possible that two forms of electricity generating technology could have similar LCOE, but one of those choices may have additional benefits to the economy through job creation, increased supply chain activity, and local spending. While a decision-maker at the utility or asset owner level may compare multiple forms of electricity using LCOE, a decision-maker in energy policy may be interested in considering impacts beyond those that LCOE measures.

One way to evaluate economic effects is to quantify economic impacts such as job creation, wages, contributions to gross domestic product, and revenues using an input-output model. These results could then be normalized in a per unit of electricity produced format, like LCOE, for a cross-technology comparison of economic benefits. Traditional LCOE calculations include costs from categories that include electricity generation, upfront capital costs, fuel costs, and operating and maintenance expenses. These costs are important to owners of energy generation assets but may not address all interests of other decision-makers. This report solves that LCOE shortcoming by evaluating generating technology impacts for the same cost categories used in LCOE calculations and utilizing an approach that makes it possible to consider factors beyond cost when contemplating energy choices. To address additional workforce-related impacts, this report also compares the typical workforce education requirements and annual income levels for multiple types of electricity generating facilities. The grid scale electricity generating technologies analyzed in this report produce power using conventional hydroelectric dams, coal, natural gas, nuclear reactors, solar panels, land-based wind turbines, geothermal heat, and woody biomass combustion. Although battery storage does not generate electricity, the economic impacts associated with battery storage equipment manufacturing and installation were also analyzed.

The findings of this report indicate electricity generated using biomass and coal yield the highest level of combined economic impacts in per megawatt year units of production. Biomass and coal are estimated to create 11.5 and 6.9 jobs per MWe-yr of electricity production, respectively. Solar and wind both showed a total jobs impact of 3.6, the lowest of any technology. Because of its high capacity factor and long lifetime, nuclear energy is expected to create between 4.8 and 5.2 jobs per MWe-yr depending on construction and equipment costs. If measured against the net generating capacity of the facility, nuclear energy has the highest annual jobs impact potential, creating or sustaining 2.9 jobs per MWe. It can also be concluded that energy from solar and nuclear technologies requires the most education for generating facility operations workers while biomass, geothermal, and hydro require the lowest levels of education. Nuclear energy had the highest average annual pay compared to other electricity generating technologies.

Report findings show that high costs associated with construction, generating equipment, and labor can result in greater economic benefits per megawatt year of electricity being produced, especially if infrastructure lifespans and capacity factors are low. However, those same attributes that create the highest impacts can also make electricity generating technologies financially unsustainable without additional support.

ACKNOWLEDGEMENT

The authors would like to thank the following individuals for their reviews and strategic direction throughout the course of the research and writing of this technical report:

- U.S. Department of Energy – Bhupinder Singh and Andrew Foss
- National Energy Technology Laboratory – Erik Shuster
- Idaho National Laboratory – Brent Dixon, Dr. Jason Hansen, and Dr. Abdalla Abou Jaoude
- Argonne National Laboratory – Dr. Taek K. Kim

The authors would like to thank the following individuals for their modeling expertise and results of previous studies that contributed greatly to the success of this report:

- National Renewable Energy Laboratory – Tom Harris and David Keyser
- Idaho National Laboratory – Dr. Tim McJunkin and Dr. Pralhad Burli

The authors would also like to thank Rebecca Ritter from Idaho National Laboratory for the technical review of this report.

CONTENTS

FIGURES

TABLES

ACRONYMS

AEO	Annual Energy Outlook
ATB	Advanced Technology Baseline
BLS	Bureau of Labor Statistics
CON	Conservative
EIA	Energy Information Administration
GDP	Gross domestic product
INL	Idaho National Laboratory
IO	Input-output
JEDI	Jobs and Economic Development Impact
LCOE	Levelized cost of energy
MOD	Moderate
NREL	National Renewable Energy Laboratory
OCC	Overnight capital cost
SMR	Small modular reactors

QUANTIFYING SOCIOECONOMIC IMPACTS OF ELECTRICITY GENERATING TECHNOLOGIES

1. INTRODUCTION

The levelized cost of energy (LCOE) used in energy planning does not account for out-of-market impacts of the technology choice that may be important to other stakeholders. These LCOE calculations are usually displayed in terms of cost per megawatt hour (MWh) of electricity produced. Figure 1 shows the LCOE ranges reported in the Lazard LCOE annual analysis from 2023 (Lazard 2023). The Lazard report is broadly cited and commonly used by experts within the energy industry. While most of the generating technologies in the Lazard report have multiple recent construction projects as a cost basis, the only recent U.S. nuclear power plants constructed were Plant Vogtle Units 3 and 4. The Lazard report references the Vogtle AP1000 units and associated costs to develop the nuclear facility LCOE values.

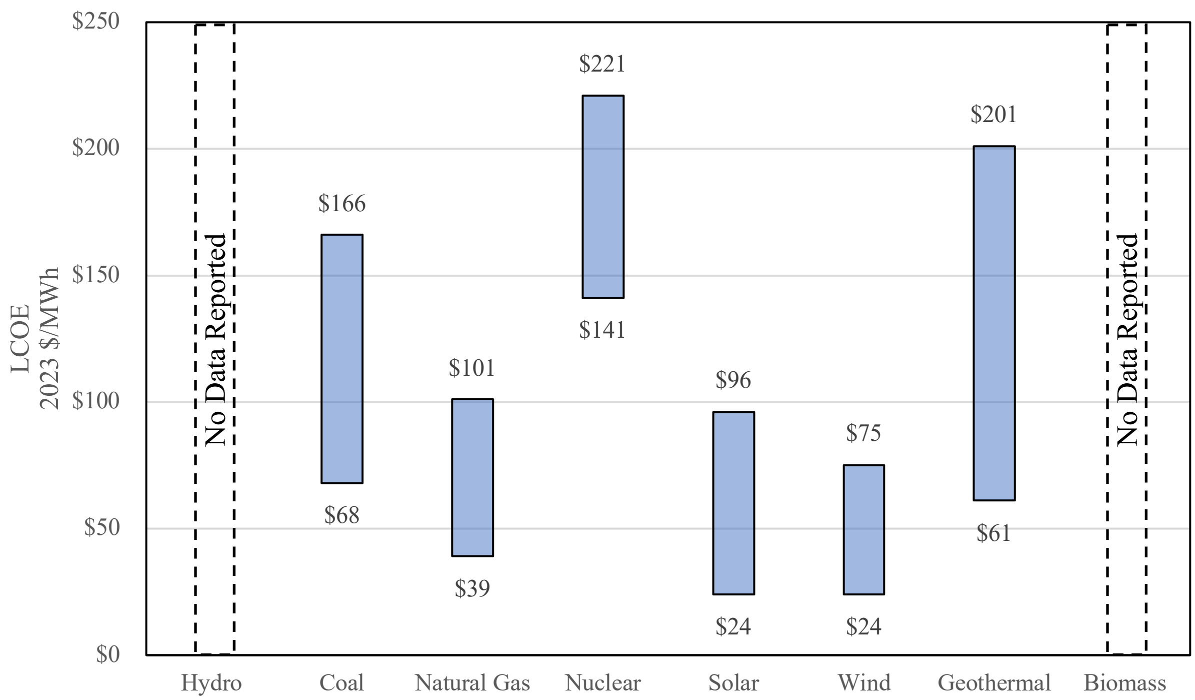

Figure 1. Lazard LCOE ranges by generation technology.

For background, LCOE was created because upfront capital costs alone do not paint a complete picture. It was necessary to consider the cost of building and operating the power plant while taking asset lifetime and total electricity production into consideration. Each electricity generating technology has a diverse life span, project size, electricity production capacity, and associated construction cost. Without LCOE, it would be difficult to compare one form of technology with another.

Using LCOE allows for a cross-technology comparison of generation costs across technologies. Although the cost of energy is important to rate payers and utility companies, it is vital for communities and other stakeholders to consider the boarder economic effects of energy choices. It is possible that two forms of electricity generating technology could have similar LCOE values, but one of those choices may have additional benefits to the economy through increased supply chain spending that creates additional economic activity which in turn benefits local communities and the economy overall. One way to evaluate these economic effects is to quantify economic impacts, such as job creation, wages, contributions to gross domestic product (GDP), and revenues, using an input-output (IO) model. This approach allows a systematic comparison of socioeconomic metrics like changes in workforce education levels, job creation, income, and changes to GDP across technology choices. These results are normalized in a per megawatt year unit of electricity produced format, like how LCOEs are presented, for comparing economic benefits across technologies.

Traditional LCOE calculations include costs from categories such as electricity generation, upfront capital costs, fuel costs, and operating and maintenance expenses. This report evaluates generating technology socioeconomic impacts for the same categories used in LCOE calculations. This approach will create an opportunity for further consideration beyond cost alone when considering energy choices.

The grid-scale electricity generating technologies analyzed in this report produce power using conventional hydroelectric dams, coal, natural gas, nuclear reactors, solar panels, land-based wind turbines, geothermal heat, and woody biomass combustion. For simplicity, these various types of technology will be referenced using shorter descriptions like hydro for conventional hydroelectric dams, nuclear for nuclear reactors, and so on. Although battery storage does not generate electricity, the economic impacts associated with battery storage equipment manufacturing and installation were also analyzed.

Electricity generating facilities will eventually require some form of decommissioning, disposal, or remediation effort. Costs associated with these activities are not explicitly included in LCOE calculations. Those activities would create economic impacts and are not included in this report but could be evaluated in future work.

There are many societal impacts that stem from energy choices. This report combines economic impacts like changes in jobs and GDP with information on workforce education and income levels to provide additional insight on potential socioeconomic impacts.

2. INPUT-OUTPUT MODELS EXPLAINED

IO economic impact models are analytical tools used to evaluate the interdependencies between different sectors of an economy. In this case, these models are applied to industries related to electricity production. They provide a framework for understanding how the output of one industry affects the inputs of another, creating a comprehensive picture of the economic ripple effects that occur within the U.S. economy. These models are used for various purposes, including analyzing public investments, understanding the effects of new policies, and planning for economic development. IO economic impact model results are valuable for policymakers and analysts because they provide a detailed picture of how different parts of the economy are interconnected. By understanding these connections, decision-makers concerned with the economy-wide impact can better assess the potential impacts of economic changes and formulate strategies to enhance economic performance. Economic impacts presented in this report were generated using the IMPLAN[a] application.

An IO model represents the economy as a matrix that depicts the flow of goods and services between sectors. Each sector is both a producer and a consumer of products and services. The core of the model is

[a] IMPLAN® model, 2022 data, using inputs provided by the user and IMPLAN Group LLC, IMPLAN System (data and software), 16905 Northcross Dr., Suite 120, Huntersville, NC 28078, www.IMPLAN.com.

a transactions table that records the sale and purchase relationships between different economic sectors. For instance, it details how much the turbine equipment manufacturing sector sells to the electric power generating sector and vice versa.

The model captures economic impacts from the point of extracting the energy feedstock (e.g., mining) through to the point of electricity generation. Direct effects show the initial economic activity, such as the spending by the mining company or the power plant on local goods and services. In this report, direct effects include electricity-generating-facility-related fuel production, annual operations, construction, and equipment manufacturing. Indirect effects show the subsequent chain of transactions required to produce the direct effects, like the additional inputs needed from suppliers. In this report, the indirect effects are referred to as "supply chain" impacts. Last, induced effects show the spending by employees from the direct and indirect effects, which further stimulates the economy. This report calls these induced effects the "community" impacts.

The accuracy of IO models depends on several assumptions, such as constant returns to scale and fixed production coefficients, which assume that the relationships between inputs and outputs are stable over time. Default values within the IMPLAN application were adjusted in cases where modifications were necessary to improve accuracy.

The results of the model are presented across four different measures. The first measure estimates the number of jobs created or sustained and is commonly referred to as the employment impact. The labor income impact estimates the total dollar value of worker income including wages, salaries, benefits, and both the employer and employee payroll taxes. The third measure estimates the dollar value of contributions toward the U.S. GDP, commonly referred to as the value-added impact. The last impact measure, total output, estimates the total dollar value of economic activity and will be referred to as the "business revenue" impact in this report.

3. MODELING METHODOLOGY

The socioeconomic impact analysis in this report was completed with the intention of creating results that would be usable by multiple audiences. The ability to model the different technology choices was limited by IO data availability. The IMPLAN application includes an industry sector for each electricity generating technology except for battery storage facility operation. The application also included the appropriate industry sectors for fuel production, mining, manufacturing, and construction of new power structures.

Within the application, 33 different economic models were created. These models consist of 24 pre-generation models. Four models were used for fuel-production-related impacts, 10 models were for equipment manufacturing, and 10 models were for construction. The remaining nine models were for electricity generation scenarios. All the scenarios were selected based on generation facility data collected by the Energy Information Administration (EIA). These EIA data on electricity generators provided enough information to determine the relevant size of facilities based on market trends for recently completed projects as well as projects currently under construction. Once the size of generating facility was established, it became possible to estimate other needed information about fuel requirements, construction, and manufacturing electricity generating equipment.

IO analysis requires defining a region of impact wherein to measure economic activity. The defined region for this study is at a national level rather than defining the region of analysis at a state or county level. This was done to prevent local supply chain availability from impacting the result comparability across the different types of technology. In application, an electricity generating facility may source goods and services locally or from outside the region. Modeling results would be different for every geography within the United States if completed at a county or state level.

The amount of goods or services brought in from outside the economy, commonly referred to as imports, would also be a contributing factor in determining the level of economic impacts resulting from electricity generation and pre-generation activities. Imports of electricity generating equipment do occur, and in those cases, spending on imports would be considered a loss or "leakage" to the U.S. economy which would ultimately reduce the overall economic impact of the generating technology. In some cases, the level of imports is significant. According to EIA, in 2022, roughly 88% of solar panels were imported from other countries to the United States (EIA 2023a). Unfortunately, import data specific enough to adjust all the economic impact models were not available for this report. So, for this report's purpose, the authors did not attempt to account for imports of major generating equipment from foreign producers, and all production of equipment is assumed to be done in the United States. Within each IO model, allowance for some importing does exist if an industry or resource is not available to meet domestic production needs.

3.1 Overview of Assumptions and Data Sources

To perform the modeling, a series of cases were made for each generation technology. These cases were developed with the objective to analyze scenarios that are reflective of typically sized generating facilities based on recent deployment trends. These cases required technology-specific capacity factors and nameplate capacity. Figure 2 shows nameplate capacity (top, blue) and capacity factor (bottom, green) for the modeling cases. As mentioned in Section 3, the size of generating facility modeled was chosen after analyzing EIA data on existing facilities that are currently operating and future electricity generators that are under construction.

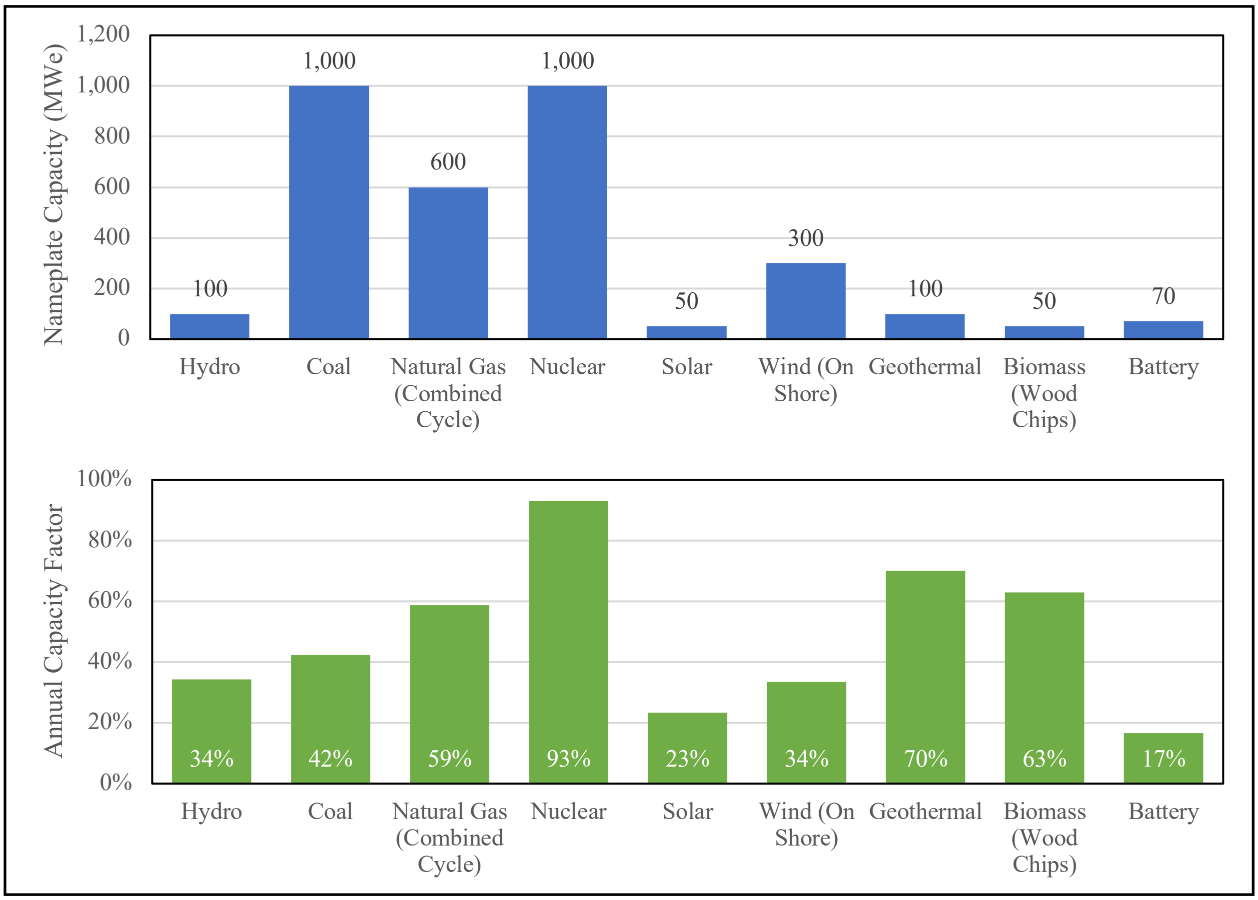

Figure 2. Nameplate capacity (top, blue) and annual capacity factor (bottom, green) by generation type.

The modeling cases used in this report are partially driven by the sale of electricity. As revenue is earned by industries involved with electricity generation, the IO model distributes dollars to other industries and to employee paychecks based on industry-specific spending patterns. This required estimating revenue for each type of generating facility. To calculate revenue from the sale of electricity, a flat wholesale price of $56.09 per MWh was used across all technologies. This price was developed from wholesale prices reported by EIA through the Intercontinental Exchange (EIA 2024a). This means every MWh of electricity sold was worth the same amount regardless of technology. The price per MWh is dependent on a myriad of factors such as regulatory environment (deregulated vs. regulated markets), regional energy mix, weather patterns, and supply and demand changes. This work aims to measure the socioeconomic impacts of different generation types when deployed in a similar region. Subsequently, the assumption of identical power prices should be considered reasonable for this report's purpose. Note that fixing power prices means that cost differences between technologies drive modeling results.

The data used to feed the IO models came from a variety of sources. One source of particular importance was the National Renewable Energy Laboratory (NREL) Jobs and Economic Development Impact (JEDI) model (National Renewable Energy Laboratory 2024b). NREL JEDI models were developed to estimate the economic impacts of constructing and operating power generation plants. JEDI models exist for biofuels, coal, hydropower, solar power, geothermal, natural gas, wind, and several others. Default data is provided within each JEDI model that is based on interviews with industry experts and project developers. The categories of data span construction costs, equipment costs, annual operating and maintenance costs, financing parameters, and other costs.

Another key source of data was the EIA report titled, *Capital Cost and Performance Characteristics for Utility-Scale Electric Power Generating Technologies* (Sargent & Lundy 2024). This report, produced as part of the Annual Energy Outlook 2025 (AEO2025), provides the current overnight capital cost[b] (OCC) estimates for 19 electric generator cases as well as their key performance characteristics. Table 1 provides a summary of the eight cases that were evaluated in this report using cost information provided by the EIA Sargent & Lundy report.

Table 1. Summary of EIA modeled generator types.

Technology	Description	Net Capacity (MWe)	Capital Cost ($/kW)	Nitrogen Oxide (NOx) (lb/MMBtu)	Sulfur Dioxide (SO_2) (lb/MM Btu)	Carbon Dioxide (CO_2) (lb/MM Btu)
USC[1] Coal without Carbon Capture – Greenfield	1 x 735 MW Gross	650	$4,103	0.06	0.09	206
Combined-Cycle 2x2x1	2 x 1 H Class	1,227	$868	0.0075	0	117
Biomass Plant with 95% Carbon Capture	1 x BFB[2]	50	$12,631	0.08	<0.03	10.3

[b] Overnight capital costs (i.e., OCC) according to Sargent & Lundy include the total cost a developer would expect to incur during construction of a project, excluding financing costs. These costs include all materials, labor, mechanical equipment, electrical, instrumentation, switchgear, control systems, wiring, raceways, and installation. Project indirect costs for engineering, construction management, as well as startup and commissioning are included. The fees include contractor overhead costs, fees, and profits.

Technology	Description	Net Capacity (MWe)	Capital Cost ($/kW)	Nitrogen Oxide (NOx) (lb/MMBtu)	Sulfur Dioxide (SO_2) (lb/MM Btu)	Carbon Dioxide (CO_2) (lb/MM Btu)
Geothermal	Binary Cycle	50	$3,963	0	0	0
Hydroelectric Power Plant	New Stream Reach Development	100	$7,073	0	0	0
Onshore Wind – Large Plant Footprint:	200 MW Total | 2.8 MW WTG[3]	200	$1,489	0	0	0
Solar PV with Single-Axis Tracking	150 MW_{AC}[4]	150	$1,502	0	0	0
Battery Energy Storage System	4-Hour Lithium Ion, 150 MW | 600 MWh	150	$1,744, ($436/kWh)	0	0	0

[1]USC = Ultra-supercritical
[2]BFB = Bubbling fluidized bed
[3]WTG = Wind turbine generators
[4]AC = Alternating current

Because the EIA report had a limited amount of data granularity for nuclear-powered electricity, alternative sources were used where the methodology for cost estimation was provided in greater detail. Nuclear data were collected from the NREL-Advanced Technology Baseline (ATB) database (National Renewable Energy Laboratory 2024a). Additionally, it was decided to only model large gigawatt-scale reactors for three main reasons. First, small modular reactors (SMRs) are yet to be built, and therefore, any data that does exist is not yet based on actual outcomes. Second, SMRs use a variety of fuel types that would require substantial modeling variations for fuel production. Third, some information about the cost of recently built gigawatt scale nuclear reactor construction was available from Plant Vogtle Units 3 and 4. The following sections provide additional detail on where data was sourced for annual operations, generating facility construction, electricity generating equipment manufacturing, and fuel production.

3.1.1 Pre-Generation Models

Construction, generating equipment manufacturing, and fuel production are categorized in this report as pre-generation activities. The following sections provide insight on the methodologies related to how data for these activities were collected and prepared for further analysis in the IO model.

3.1.1.1 Fuel Production

Fuel production work was relevant to four generating technologies: coal, natural gas, nuclear, and biomass. In each case, modeling these activities required a thorough understanding of industries involved in the fuel production supply chain and matching them with the relevant IMPLAN sectors. Each generating facility requiring fuel was evaluated to determine the typical amount of fuel required for 1 year of operation.

Coal and natural gas fuel requirements were based on EIA information for electricity-production-related fuel utilization (EIA 2023b). Coal and gas prices were also sourced from EIA and are also specific to fuel for electricity production. The plant-specific fuel requirement for nuclear is based on estimates for existing fleet nuclear reactors with domestic-sourced fuel (Jenson, Hoffman and Williams 2023). Biomass fuel requirements were based on actual plant cases utilizing woody fuel sources (We Energies 2024) (Moran 2024).

Employment and wage estimates for coal and natural gas fuel production utilized U.S. Bureau of Labor Statistics datasets from the Quarterly Census of Employment and Wages (Bureau of Labor Statistics 2023a). Employment estimates for wood chip form biomass fuel were scaled to match the model scenario (Moran 2024) (We Energies 2024). The IMPLAN application was used to estimate fuel expenses related to woody biomass fuel by combining fuel-related workforce headcounts with production values for the forestry, forest products, and timber tract production industry. The resulting values were in alignment with costs found in other reports after adjusting for inflation (IRENA 2012). Nuclear fuel employment and wage data were based on previous work related to domestic fuel cycle production capabilities (Jenson, Hoffman and Williams 2023). It is important to note these nuclear-fuel-cycle-related estimates are for existing fleet gigawatt-scale reactors and may not directly apply to the fuel types and quantities that will be required for next generation nuclear facilities including SMRs.

Table 2 provides a summary of relevant inputs and assumptions used for modeling economic impacts related to fuel production activities. Economic impact results are presented in Section 4.

Table 2. Annual fuel activities economic model inputs.

Annual Fuel Production Activities Economic Model Inputs				
Metric	Coal (Including Mining and Transportation)	Natural Gas (Extraction and Distribution)	Nuclear (Mining, Enrichment, Fabrication)	Biomass (Wood chip Processing, Transportation)
Facility Size (MWe)	1,000	600	1,000	50
MWh per Year	3,705,480	3,090,528	8,155,560	275,940
Fuel Production Jobs Required to Support Facility	232	133	106	139
Fuel-related Jobs Per MWe	0.23	0.22	0.11	2.78
Labor Cost (Including Wages, Taxes, Benefits)	$31,866,946	$26,874,210	$10,380,392	$10,392,415
*Fuel Requirement	2,418,309(st)	22,624,179(tcf)	20.4(mt)	625,000(t)
Fuel Price (U.S. Avg. 2022) for Electric Power Sector	$39.32/st	$4.38 /tcf	$9.62/mt	$25.00/t
Total Fuel Cost	$95,083,069	$99,139,153	$78,475,848	$15,623,398
Fuel $/MWh	$25.66	$32.08	$9.62	$56.62

*Units: st=short ton, tcf=thousand cubic feet, mt=metric ton, t=ton

Labor cost source: (Bureau of Labor Statistics 2023a)

Fuel price sources: (EIA 2023c) (Jenson, Hoffman and Williams 2023) (IRENA 2012)

3.1.1.2 *Construction & Equipment Manufacturing*

Construction and equipment manufacturing is an important part of the total life cycle economic impact of electricity generating technology. With exception of some data found in the JEDI models mentioned previously, most of the data necessary for carrying out the construction and economic impact for equipment manufacturing were collected from the Sargent & Lundy report (Sargent & Lundy 2024).

When estimating construction impacts, it is necessary to model the impacts of the building itself separately from the manufacturing of equipment that will be housed within the building. The purchase of land is not modeled; so, in cases where land expenses were included in capital costs, those expenses were extracted from the total OCC. It should be noted that the biomass case includes a carbon capture system with 95% efficiency. The carbon capture equipment alone added $134.8 million to the cost of the facility, constituting 28% of the total plant cost. Also important to the overall economic impact is the operating life of the equipment and facilities.

Labor costs were included in most of the Sargent & Lundy cases. In some instances, it was required to estimate construction labor costs using IMPLAN's capabilities. Labor costs were used to refine the IO model and increase the accuracy of its results.

Nuclear construction and equipment cost data were taken from an Idaho National Laboratory (INL) study (Abou-Jaoude, et al. 2024) instead of the Sargent & Lundy report. This decision was made for several reasons. The INL study contains additional granularity around costs, which enables more accurate IO modeling. The INL study also provides a range of cost data which the Sargent & Lundy report does not. Given the uncertainty of nuclear costs due to its limited recent deployment, it was determined that a range on construction and equipment cost data was necessary. Subsequently, where a range is used, nuclear costs are categorized as either "moderate" (also flagged as MOD, meaning lower costs) or "conservative" (also flagged as CON, meaning higher costs). Finally, it should also be noted that the costs found in the INL study have also been adopted as the standard for nuclear capital costs by other reputable sources such as the 2024 NREL-ATB (National Renewable Energy Laboratory 2024a).

Additionally, note that the asset lifetime used for nuclear was 60 years, instead of the Sargent & Lundy report's estimate of 40 years. This is intuitive given the average age of the existing fleet is 42 years and 87 of 92 of those reactors have been approved to operate up to 60 years (Larson 2023). Table 3 details all the construction and equipment inputs used for IO modeling.

Table 3. Construction and equipment model input values.

Construction and Equipment Model Input Values									
Technology	Asset Life (Years)	MWe	Lifetime MWh	Capacity Factor	Capital Cost	Land	Equipment	Capital Cost (Less Land and Equip.)	Construction Labor Cost
Conventional Hydro	50	100	14,892,000	34%	$707,254,000	$256,000	$136,181,000	$570,817,000	*$236,651,548
Coal	40	1,000	147,168,000	42%	$4,102,644,615	$14,769,231	$1,284,486,154	$2,803,389,231	$1,204,803,077
Natural Gas	40	600	124,041,600	59%	$520,561,369	$792,176	$214,718,826	$305,050,367	$97,799,511
Battery (4-hour)	20	70	2,048,088	17%	$122,110,800	$252,000	$87,993,267	$33,865,533	*$14,040,105
Biomass	40	50	11,037,600	63%	$631,553,000	$3,700,000	$222,578,000	$405,275,000	$181,190,000
Geothermal	40	100	24,528,000	70%	$396,294,000	$12,000,000	$167,558,000	$216,736,000	*$89,855,260
Wind	25	300	22,338,000	34%	$446,628,000	$0	$258,402,000	$188,226,000	*$78,035,472
Solar	35	50	3,525,900	23%	$75,116,000	$0	$45,965,000	$29,151,000	*$12,085,536
Nuclear - Moderate	60	1,000	488,808,000	93%	$5,750,000,000	$0	$3,687,000,000	$2,063,000,000	$1,212,401,461
Nuclear - Conservative	60	1,000	488,808,000	93%	$7,750,000,000	$0	$4,970,000,000	$2,780,000,000	$1,774,410,840

Primary Data Source: EIA/Sargent-Lundy, "Capital Cost and Performance Characteristics for Utility-Scale Electric Power Generating Technologies." January 2024.

Nuclear Data Source: Abou-Jaoude, et al. 2024

Note: Source data was scaled to fit model scenarios.

*Construction Labor: Some construction labor costs were not included in the EIA/Sargent-Lundy report. In these cases, values were estimated using the IMPLAN economic model.

Land Value: Land values that appear as "$0" were either excluded from the capital cost to begin with or were included as a lease expense in operations and maintenance.

Dollar Year: 2023

3.1.2 Annual Operations Model

The annual operations models only included staffing inside the "fence" of the generating facility. This means staffing outside of the facility boundaries was not included. Average annual employment estimates for annual operations were sourced from the JEDI models mentioned previously, which leveraged industry expert inputs. In some cases, news reports and feedback from utility managers were used to increase the accuracy for solar, biomass, and hydro.[c] In the case of nuclear-powered electricity, which is not represented in the JEDI models, a combination of sources was used to calculate average jobs per megawatt electric (MWe) in the existing fleet and applied to a 1,000 MWe facility (see Appendix B). Total labor cost was estimated by taking per worker labor cost estimates from BLS data (Bureau of Labor Statistics 2023a) and multiplying it by the number of estimated workers for a given technology. Note that BLS labor costs were adjusted to include employee wages, taxes, and benefits (Bureau of Labor Statistics 2023b).

Annual operations modeling also requires an estimation of total revenue generated from each facility. As previously mentioned in Section 3.1, it was assumed that revenue across technologies was held constant, and therefore, total annual revenue differs only because of installed capacity and capacity factor. Recall that the value used for the price of electricity was $56/MWh, the weighted average wholesale electricity rate across the United States (EIA 2024b). Table 4 provides an overview of all the inputs used in the annual operations IO models.

There was no supporting data available to indicate battery storage would be responsible for measurable annual impacts from annual operations. For this reason, several metrics used as model inputs were set at zero for battery storage. This includes average annual employment and total labor costs. Revenue from battery storage was determined by multiplying the annual amount of energy to be discharged if operating a 4-hour capacity battery, as determined using a 16.7% capacity factor (National Renewable Energy Laboratory 2024a).

[c] Additional sources for solar, biomass and hydro operations data: (Moran 2024), (Electrek 2024), (WV Public Broadcasting 2024), (American Press 2023), (Solar Quarter 2024), (The Center Square 2024), (WWNYTV 2022), (Vail Daily 2024), (Illinois Country Living 2015), (Seven Days VT 2022), (Steamboat Pilot 2023).

Table 4. Annual operations model input values.

Technology	Installed MWe Capacity	Average Annual Jobs	Jobs per MWe	Total Labor Cost (Including: Wages, taxes, benefits)	Per Worker Labor Costs (BLS)	Avg Capacity Factor (EIA)	MWh per Year	Revenue from Electricity Sales*
Hydro	100	3	0.03	$584,489	$194,830	34%	299,592	$16,804,190
Coal	1,000	143	0.14	$27,327,362	$190,440	42%	3,705,480	$207,841,302
Natural Gas	600	25	0.04	$4,822,714	$190,440	59%	3,090,528	$173,348,491
Nuclear	1,000	544	0.54	$121,681,318	$223,638	93%	8,155,560	$457,447,406
Solar	50	1.2	0.02	$212,954	$175,332	23%	102,054	$5,724,234
Wind (On Shore)	300	14	0.05	$2,266,158	$166,629	34%	880,380	$49,380,735
Geothermal	100	28	0.28	$5,001,125	$181,227	70%	613,200	$34,394,542
Biomass w/CC	50	38	0.76	$6,270,773	$164,085	63%	275,940	$15,477,544
Battery	70	0	0.00	$0	$0	16.7%	102,404	$5,743,888

*Revenue calculation based on $56/MWh

4. ECONOMIC IMPACT RESULTS

There are a variety of factors that contribute to higher or lower economic impact results. Factors that increase economic impacts include high paying jobs, abundant local supply chains, reduced imports, and high labor requirements. In this study, the economic impact results are normalized to a per lifetime net electricity generation in megawatt years (MWe-yr) unit of measurement. The asset lifetime of facilities and equipment becomes an especially important factor when evaluating the impact of equipment manufacturing and facility construction. Also important is the overall cost of construction and equipment. If the asset lifetime is long, then construction cost is distributed across many years of useful life and the impact would be distributed over a greater period of time and a greater amount of electricity being produced. This would reduce the per MWe-yr impact of that generating technology. In an equation calculating these per MWe-yr impacts presented later in this section, the numerator of the equation includes the actual impact itself while the denominator includes the total amount of electricity being produced over the lifetime of the asset. In summary, the large denominator created by a long asset lifetime, or high capacity factors, would result in a lower per MWe-yr impact.

Once the model inputs for pre-generation and annual operations were compiled, they were entered into the IO application. The completed results were then further analyzed in spreadsheets where they could be normalized for comparison in a per MWe-yr unit of electricity standard measurement. This was done to make results comparable across technologies and to the LCOE figures. It should be noted that LCOE calculations are done in per MWh units which makes results of this study slightly different. In the case of equipment manufacturing and construction, the economic impact results were divided by the total lifetime number of MWe-yr's worth of electricity that will be produced by the given facility, as demonstrated by Equation 1.

$$\text{Impact/MWe-yr} = \frac{Lifetime\ Economic\ Impact}{Nameplate \times CapacityFactor \times AssetLifetime} \quad (1)$$

Adjustment based on asset lifetime was not a necessary for annual operations or fuel manufacturing because those values were already in annual terms. Those values only needed to be divided by annual electricity production which is a function of annual production in MW multiplied by the technology capacity factor, as seen in Equation 2.

$$\text{Impact/MWe-yr} = \frac{Annual\ Economic\ Impact}{Nameplate \times Capacity\ Factor} \quad (2)$$

In many cases, the equipment initially installed during construction of the generating facility will need repairs and/or replacement over the lifetime of the facility. Economic activity associated with those efforts are included in the annual operations models. Therefore, it was not required to run independent models reflecting that type of economic activity.

All activities that are involved in generating electricity create different levels of economic activity. Also, some characteristics of each technology result in different levels of economic activity. Table 5 shows the contributing factors that can help determine the magnitude of economic impact from those activities or technology characteristics. In the case of labor requirements, nuclear, geothermal, and biomass require more labor than other generating technologies. That would result in a greater magnitude of economic impact for nuclear electricity generation which is indicated by a dark green shade in the table. Although these attributes increase the economic impact, they may have an adverse impact on overall profitability. Other technologies received a light green shade in the table because their lower labor requirement does not contribute to total economic impact as much as a higher labor requirement would. Operating life is very low for technologies like solar, wind, and storage so this would result in a greater magnitude of impact when looking at the impacts of those technologies in a per MWe-yr unit of measurement. The other technologies would have a lower magnitude of impact because of long operating lifetimes.

Several of the electricity generating technologies that were evaluated have relatively high capacity factors. These technologies include hydro, nuclear, geothermal, and biomass. These technologies have a total economic impact that is slightly penalized because of their high capacity factor. High capacity factors lead to increased electricity production which again would result in a higher denominator in the per MWe-yr impact calculation. Relatively low capacity factors are typical in solar, wind, and battery storage.

If fuel is required for electricity generation, this would result in increased economic activity and would yield higher economic impacts and create an additional layer of cost. For those technologies that do not require fuel, economic impacts are lower compared to those that do have a fuel requirement and are designated with a dark gray shade in Table 5 for not being applicable. Construction and equipment costs also have a role in determining economic impacts. Technologies like hydro, coal, nuclear, and biomass bring additional economic benefits from their higher costs in construction. Technologies like nuclear, biomass, and battery storage result in higher economic impacts because of the increased equipment costs relative to other technologies. Industries that have higher wages also contribute more impact to local economies as those wages are spent throughout the community which in turn stimulate additional economic activity. The industries with higher wage rates include hydro, coal, natural gas, and nuclear.

Table 5. Factors affecting per MWe-yr economic impact results.

Factors Affecting Magnitude of Economic Impacts										
Weight	Factor	Hydro	Coal	Natural Gas	Nuclear	Solar	Wind	Geothermal	Biomass	Battery
Low — High	Labor Requirements	Lower	Lower	Lower	Higher	Lower	Lower	Higher	Higher	Lower
	Operating Life	Lower	Lower	Lower	Lower	Higher	Higher	Lower	Lower	Higher
	Capacity Factor	Lower	Higher	Higher	Lower	Higher	Higher	Lower	Lower	Higher
	Fuel Required	No impact	Higher	Higher	Higher	No impact	No impact	No impact	Higher	No impact
	Construction Costs	Higher	Higher	Lower	Higher	Lower	Lower	Lower	Higher	Lower
	Generating Equipment Costs	Lower	Lower	Lower	Higher	Lower	Lower	Lower	Higher	Higher
	Wages	Higher	Higher	Higher	Higher	Lower	Lower	Lower	Lower	Lower

Table 5 - Color Key		
No Impact Contribution	Lower Impact Contribution	Higher Impact Contribution
(gray)	(light green)	(dark green)

Table 6 provides an example of how economic impact results are converted to a per MWe-yr unit of measurement. In this table, the nuclear construction and equipment manufacturing impacts are divided by the expected total lifetime number of MWe-yr's worth of electricity that is produced by the nuclear facility. The jobs impact is initially reported in job years which total nearly 22,000 jobs-years. These jobs are the equivalent of multiple years of construction employment added together. If the construction and equipment manufacturing process normally take 5 years, then these jobs would equate to roughly 4,400 workers per year (i.e., 22,000 "direct" job-years / 5 years = 4,400 jobs per year). The lifetime of a nuclear facility is expected to reach 60 years and possibly more. Multiplying the net generation of a nuclear facility (931 MW) by 60 years results in 55,860 MWe-yrs based on a 93.1% capacity factor for a 1-gigawatt nuclear facility.

In Table 6, the row labeled direct impacts is reflective of impacts related to construction and equipment manufacturing industries themselves. In the case of generating facility annual operations, this “Direct” row is related to the impacts stemming from the annual operations of the generating facility itself. In the case of fuel production, this “Direct” row is related to the impacts stemming from the companies directly involved in producing fuel. The indirect impact row shows the impacts related to supply chain activity supporting construction and equipment manufacturing, referred to later in this report as supply chain impacts. Induced impacts are the result of employees in the direct and indirect impact categories spending their paychecks, later referred to as “community” impacts. The combined total is listed in the last row of the table. The value-added column is referred to as contributions to GDP, and the output column results are equivalent to total business revenues received by industries impacted by these activities.

Table 6. Example of impact conversion.

Nuclear Construction and Equipment Manufacturing Impact Example – Moderate (Impact/55,860 MWe-yr)								
Impact	Jobs	Labor Income	Value-Added	Output	Jobs/MWe-yr	Labor Income/ MWe-yr	Value-Added/ MWe-yr	Output/ MWe-yr
Direct	21,917	$2,448,009,899	$3,208,241,588	$5,750,000,000	0.39	$43,824	$57,434	$102,936
Indirect	16,831	$1,518,117,950	$2,442,636,266	$5,174,959,963	0.30	$27,177	$43,728	$92,642
Induced	28,055	$1,836,528,177	$3,349,381,901	$5,941,805,960	0.50	$32,877	$59,960	$106,370
Total	66,803	$5,802,656,027	$9,000,259,755	$16,866,765,923	1.20	$103,879	$161,122	$301,947

4.1 Aggregated Economic Impact Results

The following section provides the results of aggregating the economic impacts for fuel production, generating facility construction, equipment manufacturing, and electricity generation. These "combined" impacts provide an estimated number of jobs and dollar value of economic activity for the different electricity generating technologies being analyzed. Detailed tables containing economic impacts for all four categories (i.e., jobs, labor income, GDP, and business revenue) are included in Appendix A. In each case, these impacts are subdivided into three categories.

1. **Combined Impact:** These impacts include the combined economic activity from the generating facility itself, the fuel producers, construction companies, and the generating facility equipment manufacturers. Some examples include power plants, mining companies, turbine manufacturers, and construction management firms.
2. **Supply Chain Impact:** These impacts include economic activity from industries that support the companies identified in the combined impact. Some examples include drilling equipment manufacturers, cement manufactures, employment agencies, and engineering firms.
3. **Community Impact:** These impacts include economic activity resulting from employees in the combined and supply chain categories receiving paychecks and spending them within their local economy. Some examples include grocery stores, medical offices, car dealerships, and movie theaters.

4.1.1 Aggregated Jobs Impact

Job creation is a frequently discussed economic impact. From a community perspective, job creation can result in population growth, a sustaining source of income to local businesses, and increased tax base. This is especially important to communities faced with the looming closure of existing generating facilities. Each electricity generating technology utilizes labor in various quantities which can result in cost differences that are important to long-term financial sustainability. A decision to select one technology over another will also be determined by other factors including reliability and environmental impact. The following results help illustrate the aggregated job-related impacts from each electricity generating technology.

Results of the aggregated jobs impact found in Figure 3 show biomass creates more than double the number of jobs per MWe-yr compared to coal, the next highest job creating technology. Biomass is estimated to create 11.5 jobs per MWe-yr of production when combining the four measures using Equation 3. This level of impact is due to biomass's relatively low capacity factor combined with high operating and construction costs and labor intensive operations and fuel production process.

$$\text{Combined Impacts} = \mathit{Generating\ Facility\ Annual\ Operations} + \mathit{Fuel\ Production\ Activities} + \mathit{Generating\ Facility\ Construction} + \mathit{Generating\ Equipment\ Manufacturing} \quad (3)$$

Solar and wind both showed a total jobs impact of 3.6, the lowest of any technology. Nuclear, which had the highest capacity factor and the longest asset lifetime, is expected to create between 4.8 and 5.2 jobs per MWe-yr depending on construction and equipment costs.

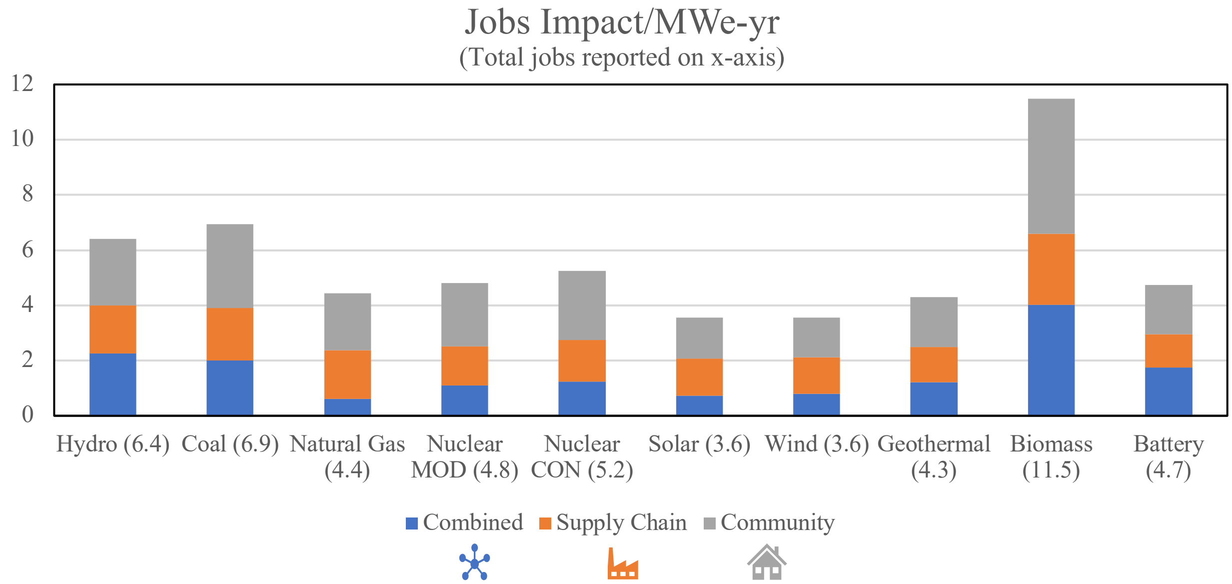

Figure 3. Jobs impact per MWe-yr.

The distribution of impacts between the combined, supply chain, and community categories is reflective of the multiple factors which become clearer when looking at the source of economic impacts. Figure 4 provides a detailed look at how each of the different impact categories contributes to the total lifetime jobs impact per MWe-yr.

Only four technologies required a fuel source, which contributed to the total impacts in various amounts. Half of the total jobs impact from natural gas was due to fuel production activities. Fuel production contributed the least in the case of nuclear. In many cases, fuel production activities take place away from the generating facility which results in rail-, truck-, or pipeline-transportation-related job creation. Nuclear power's use of energy dense fuel sources, like uranium, contributed to the lower fuel-related jobs impact when compared to other technologies. Nuclear reactors in the United States are typically refueled at intervals of 12, 18, or 24 months (World Nuclear Association 2024).

Construction-related activities are expected to create four jobs per MWe-yr for hydro and biomass generation facilities, higher than any other technology. It is important to remember that construction-related impacts are concentrated at the front end of the asset life and are temporary in nature. Job impacts reported in per MWe-yr units have been distributed across the lifetime of the facility and the total amount of electricity being produced to make comparisons across technology types possible.

Job creation related to annual operations of the generating facility is of particular interest to host communities. These jobs are permanent in nature and result in positive long-term contributions to local economies. Biomass and nuclear contributed the most generation-related jobs per MWe-yr, 4.5 and 3.1, respectively. Battery storage was the only technology to not create measurable annual operations jobs. It is likely there are workers who monitor battery facilities and provide maintenance when needed, but there was no data available to facilitate annual operations-related economic impact modeling efforts.

Equipment-manufacturing-related activities for battery facilities resulted in the highest number of jobs compared to other technology. Battery manufacturing is expected to support 3 jobs per MWe-yr while biomass-related equipment manufacturing is estimated to support 2 jobs per MWe-yr. The lowest jobs impact from equipment manufacturing was observed in natural gas at 0.1 jobs per MWe-yr.

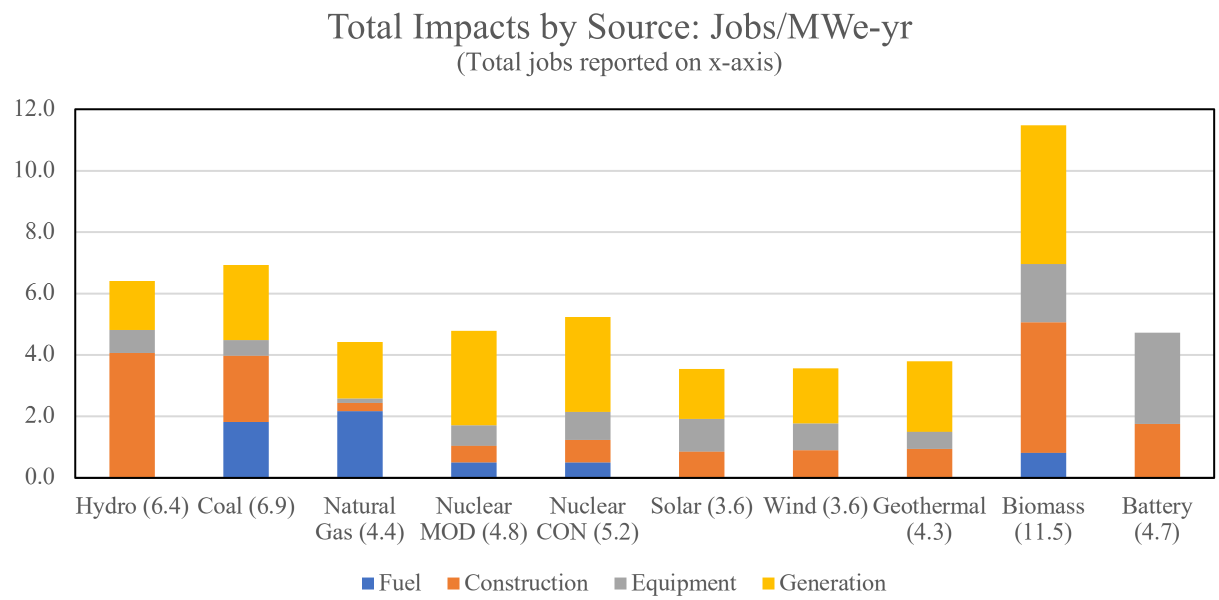

Figure 4. Jobs impact by source.

4.1.2 Aggregated Labor Income Impact

Labor income impacts include income earned through wages or salaries and include benefits and costs from employee and employer side payroll taxes. Labor income impact results are highly correlated with jobs impacts. Figure 5 shows the distribution of labor income between the combined, supply chain, and community impact categories. Similar to the jobs impact, solar and wind have the lowest labor income impact per MWe-yr. In both cases, the supply chain and community impacts account for 75% of the total economic impact, which is higher than the other technologies being compared.

Biomass again showed the highest level of impact per MWe-yr and was the only technology to yield more than $1 million of labor impact per MWe-yr. The higher level of employment and subsequently higher labor income may be a contributing factor for the biomass industry's decline in recent years. Many of the sources used to estimate employment levels at biomass facilities were reporting on closures of existing facilities and subsequent job losses. Wood-based biomass net electricity production peaked in 2014 at over 15 million kilowatt-hours (kW-hr) and fell to 9.5 million kW-hr in 2023, a 36.5% decrease (EIA 2024c).

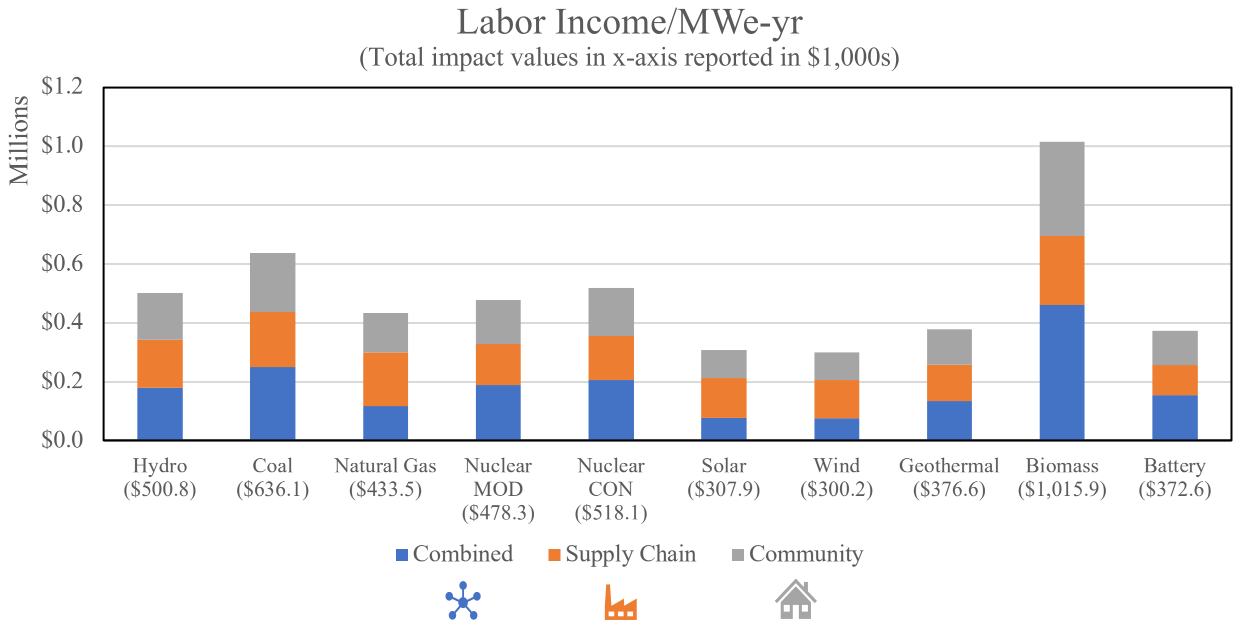

Figure 5. Labor income impact per MWe-yr.

The distribution of labor income by source in Figure 6 mirrors the results from the total income by source jobs impacts discussed in Section 4.1.1.

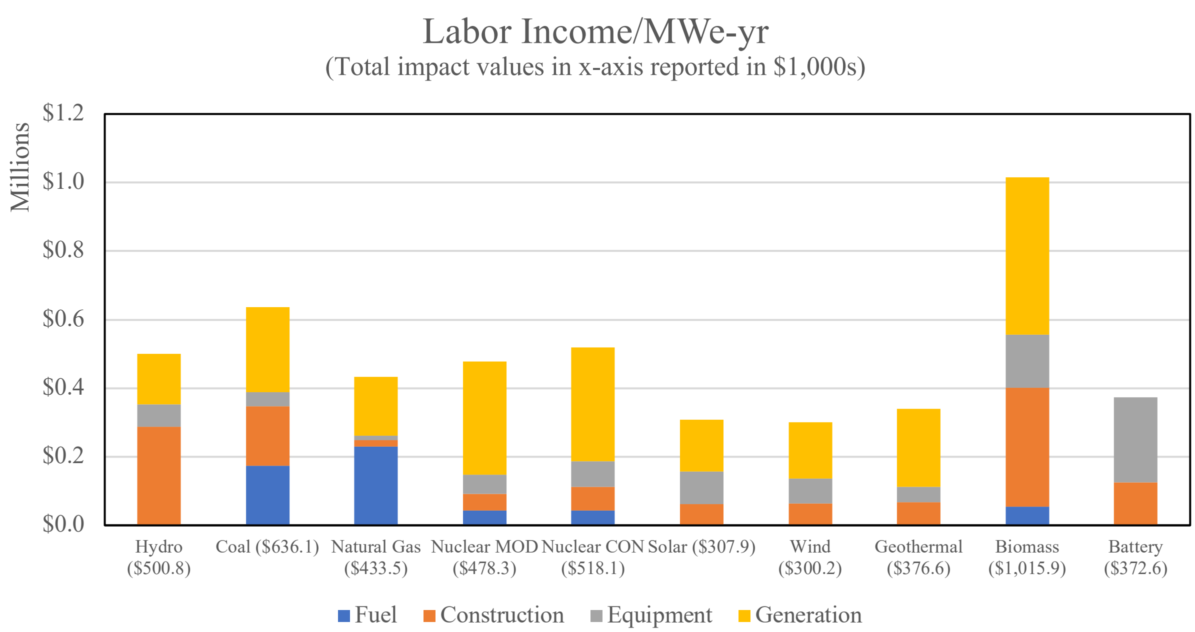

Figure 6. Labor income impact by source.

4.1.3 Aggregated Gross Domestic Product Impact

GDP measures the market value of final goods and services produced within the United States. It does not include imports from other countries and excludes any potential double counting that could come from intermediate goods (products used to make other goods or services). For these reasons, measuring GDP contributions per MWe-yr is an important way to evaluate benefits to the U.S. economy. In service dominated industries, the contribution to GDP and total labor income can be very closely related. It is important to recognize that all models used in this report assume all equipment, construction activities, and fuel required for electricity production were sourced within the United States. Annual operations for electricity generating facilities are also assumed to take place domestically. The model does allow for some imports of raw materials if none are available to fulfill industry demands. Any level of imports will reduce the economic impact. In practice, some electricity generating technologies depend heavily on imported equipment. As mentioned in Section 3, the solar industry imports 88% of photovoltaic panels. The U.S. nuclear industry has a history of importing large forgings and other necessary equipment from foreign sources (World Nucelar News 2023). Foreign conflicts and the COVID-19 pandemic have highlighted efforts to increase domestic production for many industries.

After applying the production assumptions to the IO models, the rank and order of total impacts changes slightly when moving from jobs and labor income impacts to GDP contribution impacts. Biomass and coal continue to have the highest GDP per MWe-yr. The other technologies change the order to some degree. Natural gas, nuclear, and hydro all fall between $931,000 and $1,027,000 in GDP per MWe-yr. Solar, wind, and geothermal range between $715,000 and $788,000. Battery storage was the only technology to fall below the $700,000 mark, coming in at $612,000 per MWe-yr. As seen in Figure 7, for most cases, the impacts were split more evenly between the combined, supply chain, and community categories.

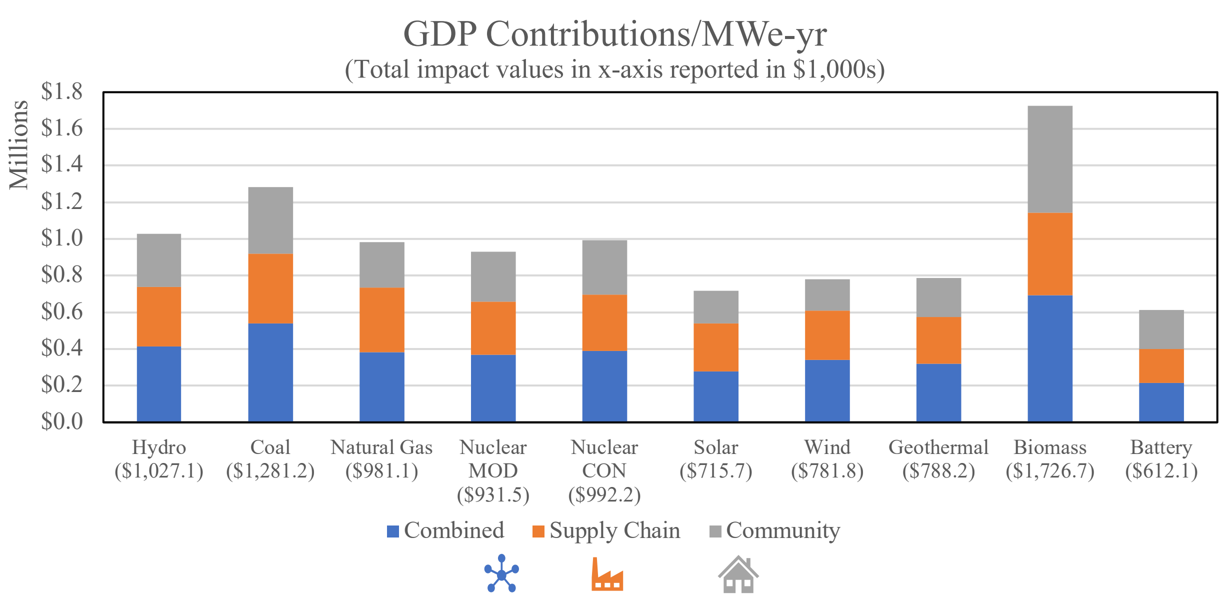

Figure 7. GDP contributions per MWe-yr.

See Figure 8 for detailed GDP contribution estimates by source. Apart from battery storage, the largest source of GDP contributions for all technologies was from the annual operations of the generating facility itself. In per MWe-yr terms, biomass and hydro both had the highest construction-related impacts, over $547,000 and nearly $477,000, respectively. Natural gas power plant construction resulted in the smallest per MWe-yr contribution to GDP of all technologies being evaluated, coming in close to $32,000. The cost of nuclear construction is a frequent topic of discussion. After accounting for lifetime electricity production, nuclear facility construction is expected to contribute between $72,000 and $102,000 per MWe-yr.

The highest fuel-production-related contributions to GDP were observed with natural gas at $426,000 per MWe-yr. In fact, 43% of the total natural gas contribution to GDP was from fuel-related activities compared to around 4% for biomass.

Equipment-manufacturing-related GDP contributions were the lowest with natural gas at $65,000 per MWe-yr. In contrast, battery manufacturing contributes more than $405,000 per MWe-yr to GDP, nearly double the amounts of other technologies in the analysis.

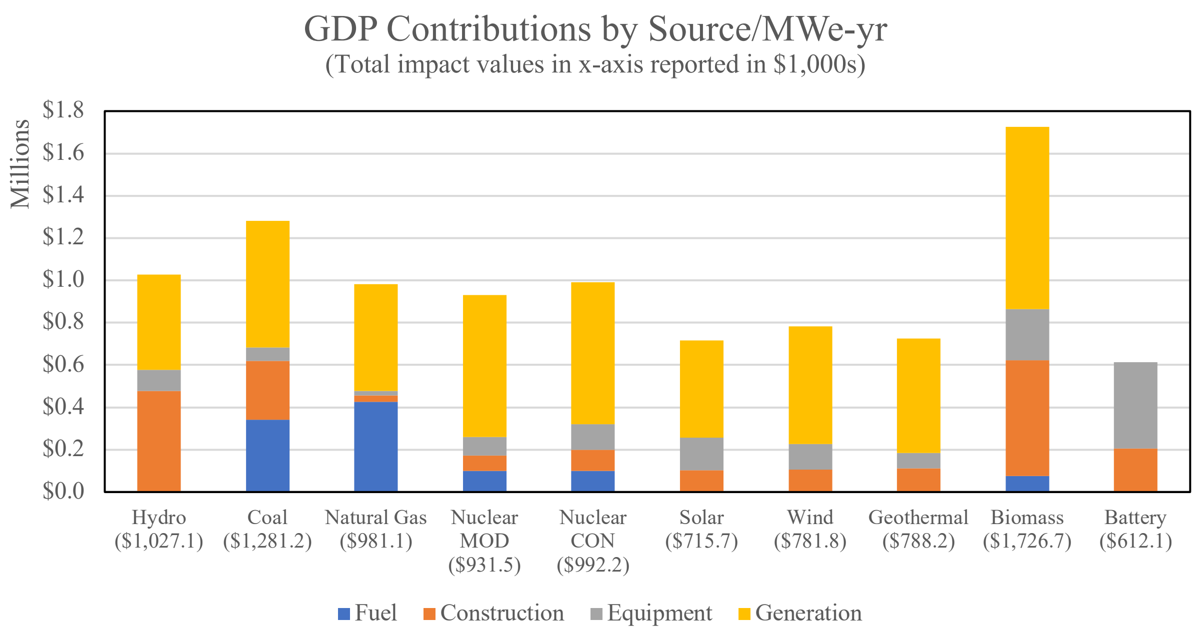

Figure 8. GDP contribution impact by source.

4.1.4 Aggregated Business Revenue Impact

The dollar value of economic output is referred to in this report as business revenue, assuming that all potential production or output is eventually sold at market. The “combined” impacts for potential revenues received, which include the generating facility electricity sales, sales of generating equipment manufacturers, generating facility construction revenue, and revenue from those businesses involved in fuel production, ranged from $521,000 per MWe-yr for battery storage to $1.03 million for biomass. Natural gas, coal, and hydro received between $809,000 and $933,000. All other technologies were between $669,000 and $714,000. Supply-chain-related impacts ranged between $532,000 and $759,000 apart from biomass and battery storage. Again, battery-storage- and biomass-related supply chain activities represented both ends of the impact spectrum. Biomass-related supply chains received nearly $923,000 in revenues while battery storage was at the bottom end of the scale with $408,000. At the community level, the biomass industry provided the most revenue per MWe-yr, at nearly $1.04 million. Figure 9 provides an overview of each technology and their associated levels of business revenue.

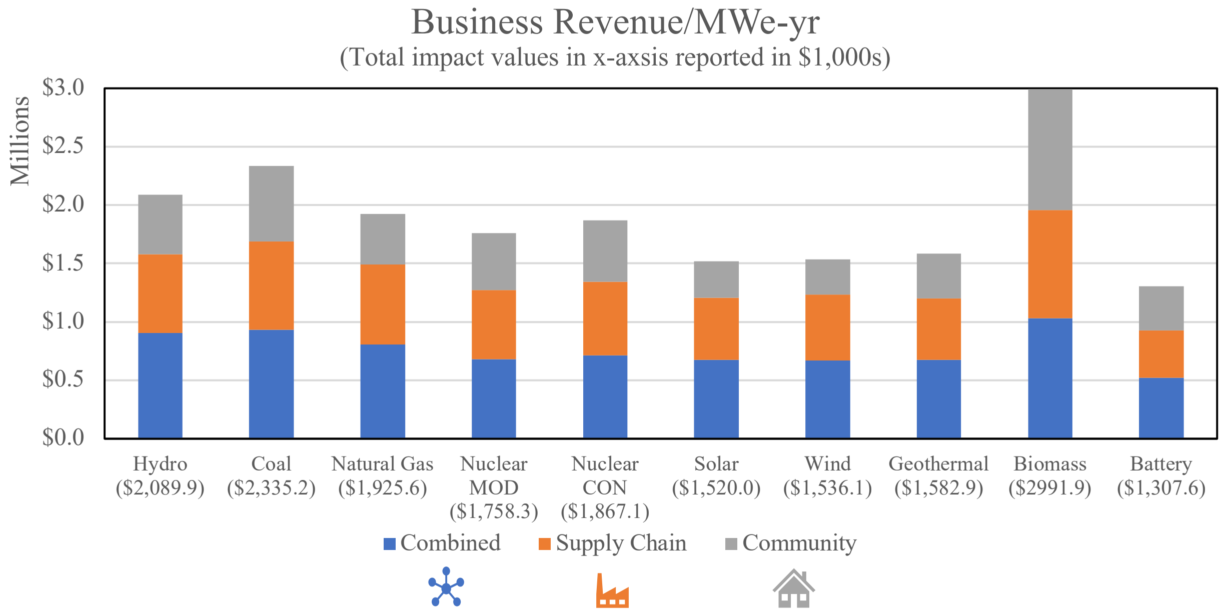

Figure 9. Business revenue per MWe-yr.

Since battery storage is not responsible for generating electricity, it does not contribute revenue by itself. In application, electricity production from other forms of technology could direct their output toward battery storage for future sales. That revenue could be captured at the generating source or when it is discharged from the batteries. No matter how that revenue is allocated, the revenue received per MWe-yr would remain unchanged at the generating facility level, since all cases are being paid the same wholesale price of $56/MW-hr for electricity. For this reason, the generation portion of business revenue in Figure 10 is similar for all generators. Much of the difference that is observed from the generation source of impacts is the result of community-related spending differences between generating technologies.

As a reminder, revenues estimated in this section of the analysis are distributed to businesses across the United States. Even though the generating facility is receiving the greatest portion of business revenue, it is likely that its supply chain is distributed across the country. Equipment manufacturers capture between $45,000 and $941,000 in revenue per MWe-yr, with natural gas on the low end and battery storage on the high end. In some cases, the supply chain is distributed across the world. The nuclear industry has depended on sources of equipment, uranium, and low enriched uranium from foreign producers. By sourcing within the United States, the economic benefits would increase beyond current levels.

Construction-related business revenues were highest for hydro and biomass facilities, $845,000 and $886,000, respectively. Fuel-production-related revenue per MWe-yr was lowest for biomass, coming in at $113,000. The highest total fuel-related revenue impact was for natural gas at $713,000 per MWe-yr. Changes in natural gas prices would alter this result.

Biomass's combined value of business revenue from all four sources was just short of $3 million per MWe-yr, again the highest of all technologies in the study. Nuclear-related business revenues fell in the middle of the nine technologies being compared.

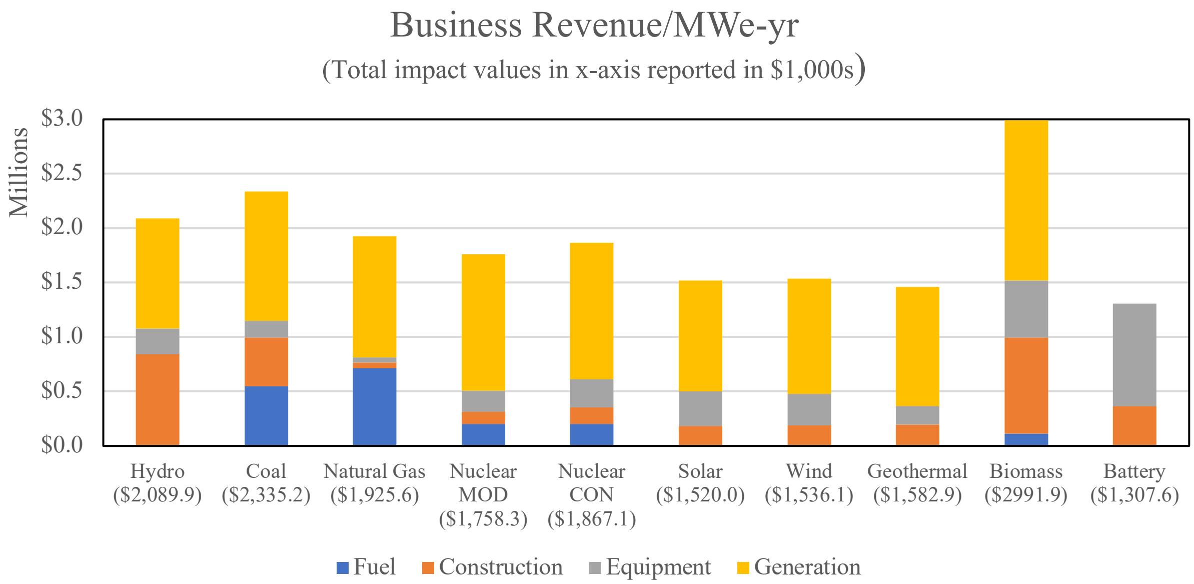

Figure 10. Business revenue impact by source.

4.2 Comparison of per MWe and per MWe-yr Results for Annual Operations

An alternative to comparing economic impacts in per MWe-yr terms is to evaluate the impacts after dividing them by only the installed capacity of the generating facility. This approach does not account for capacity factors and applies better to annual operations-related impacts. Construction and equipment manufacturing impacts should still account for asset lifetimes for fair comparison. Equation 4 is used for the per MWe conversion.

$$\text{Impact/MWe} = \frac{Annual\ Economic\ Impact}{Nameplate\ Capacity} \quad (4)$$

Figure 11 and Figure 12 illustrate the difference between comparing impacts on a per MWe-yr and a per MWe basis. Annual operations job impacts evaluated using the per MWe-yr approach show biomass electricity generation is responsible for creating or sustaining 4.5 jobs. The next highest technology was nuclear at 3.1 jobs per MWe-yr. Hydro and solar had the least impact, each creating or sustaining 1.6 jobs per MWe-yr. See Figure 11 for more detail. Technologies with limited labor requirements yielded the lowest job impacts.

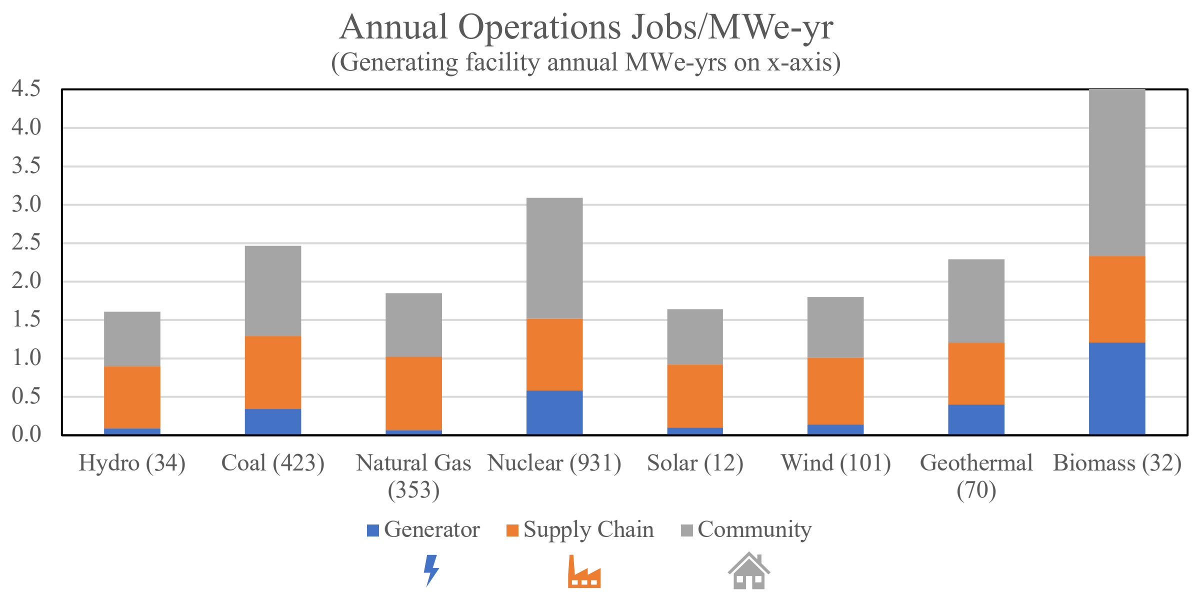

Figure 11. Generating facility annual operations jobs per MWe-yr.

In Figure 12, there is no adjustment based on capacity factors. In this case, the economic impact is divided by the maximum generation capability of the facility. By this measure, nuclear has the highest jobs impact potential, creating or sustaining 2.9 jobs per MWe. Battery storage is not included in the annual operations impact scenarios because that technology is not responsible for generating electricity, only storing it. As battery storage technology gains prevalence, it can effectively increase the capacity factor of technologies like solar and wind. By doing this, those technologies will see a reduction in economic impact as measured in per MWe-yr terms due to effectively higher electricity production. At the same time, the combined cost of a solar or wind generating facility plus the cost of battery storage would increase and result in more economic impact than systems without battery storage.

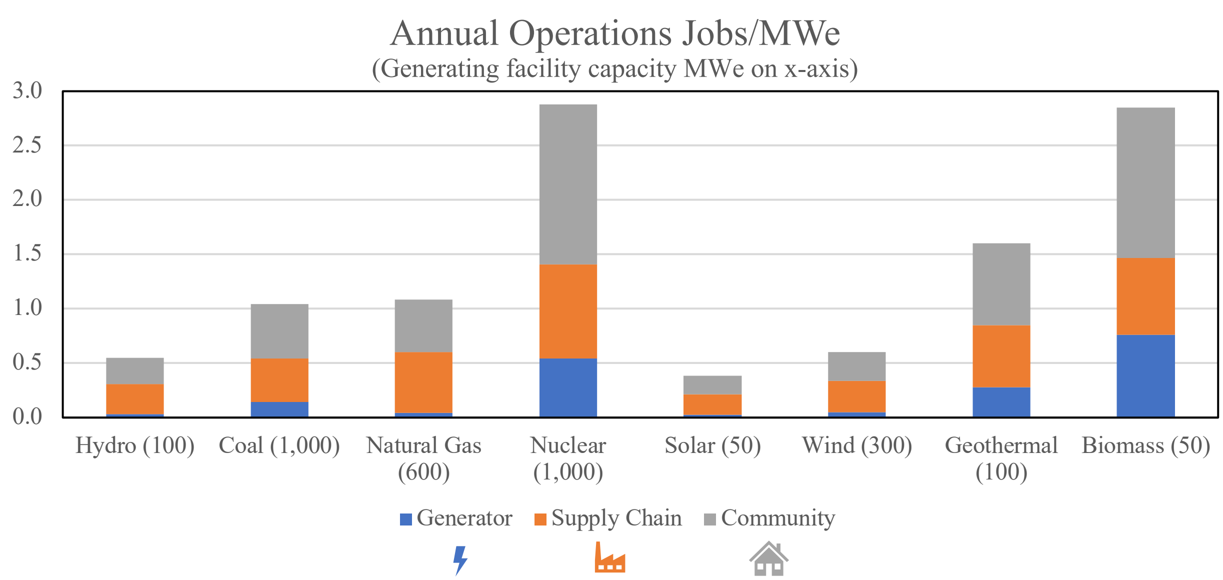

Figure 12. Generating facility annual operations jobs per MWe installed capacity.

After applying the per MWe equation to the labor income impacts, nuclear electricity generating technology yields the most impact across all measures. Labor income impacts for nuclear exceeded $300,000 per MWe—three times the impact of coal and natural gas and six times as much impact as hydro and wind. See Figure 13 for additional results.

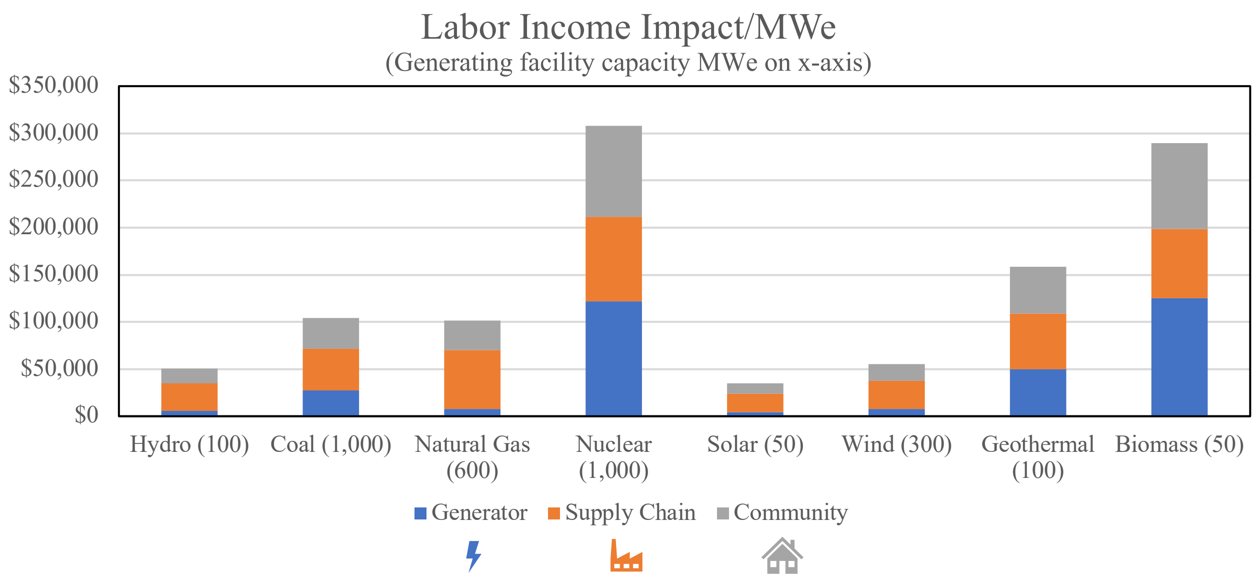

Figure 13. Generating facility annual operations labor income per MWe installed capacity.

Nuclear electricity GDP contributions per MWe also surpassed all other forms of generating technology. Annual operations of a nuclear electricity generating facility are expected to reach more than $625,000 per MWe of installed capacity. See Figure 14 for additional results.

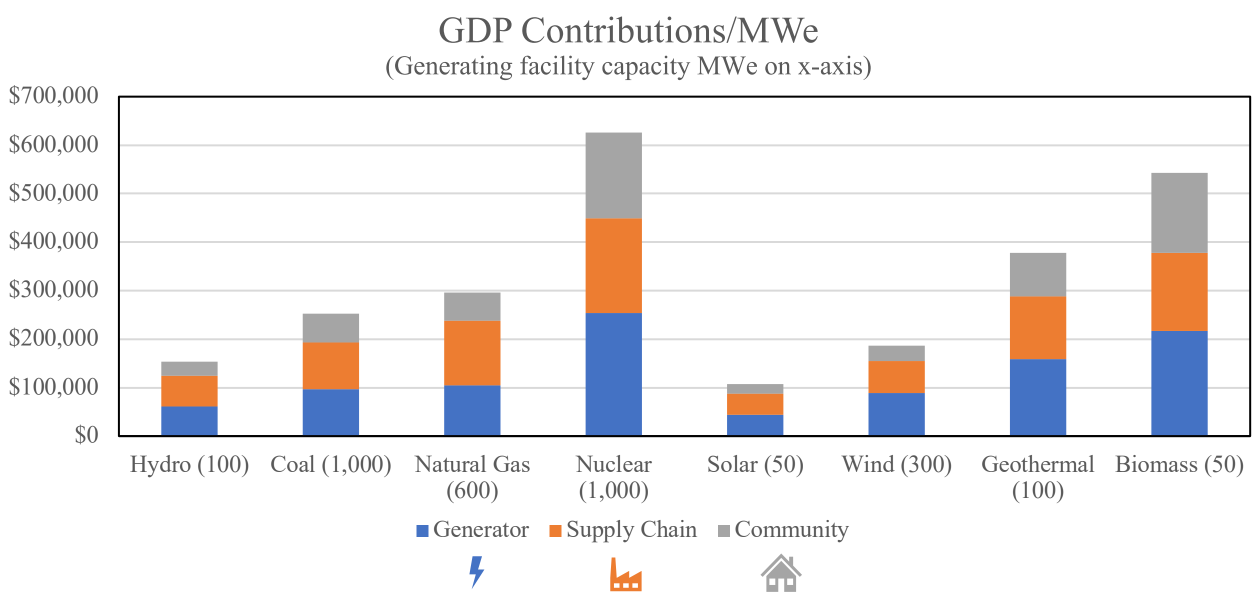

Figure 14. Generating facility annual operations GDP contributions per MWe installed capacity.

Nuclear is also estimated to contribute the most business revenue. Model results show total business revenue per MWe for nuclear could almost reach $1.2 million. Biomass was the next highest revenue producer at $927,000. All other forms of electricity generation fell below $800,000. See Figure 15 for additional impact results.

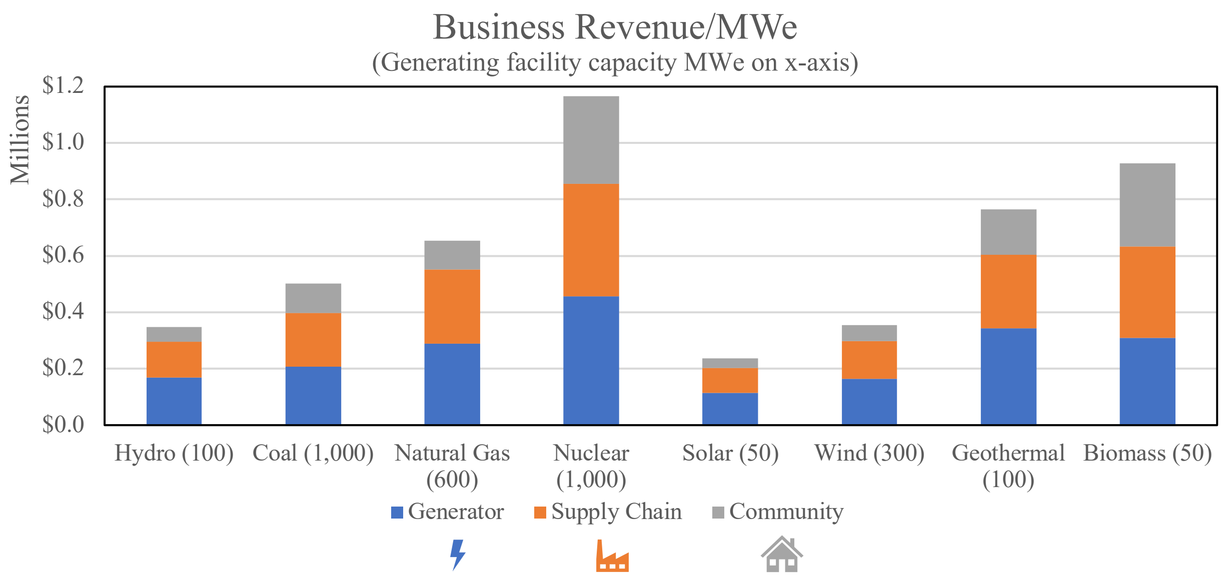

Figure 15. Generating facility annual operations business revenue per MWe installed capacity.

5. HISTORICAL ELECTRICITY GENERATION TRENDS

Historical trends for electricity generation provide context for energy choices in the United States and additional insight about the potential relationship between economic impact and electricity production. Some of the electricity generating technologies that produced high levels of economic impact in Section 4 show declining electricity production trends. Figure 16 shows total net generation by technology between 2000 and 2023 in millions of kilowatt-hours. Data shows that generation relies heavily on natural gas, likely because of the large quantities of historically low-priced natural gas in the United States, while coal-powered electricity production has a downward trend.

The U.S. transition toward cleaner energy combined with rising operating and maintenance costs and aging infrastructure are contributing factors to the closure of coal-fired generators. Wind and solar are trending up slightly over time with support of the Inflation Reduction Act (Institute for Energy Economics and Financial Analysis 2023). Nuclear, hydro, and geothermal appear to be relatively flat. Woody biomass electricity generation was 8,545 million kWh in 2023 after falling from the 2014 high point of 15,027. Elimination of state tax credits for biomass is a contributing factor to some biomass-fueled power plant closures and declining electricity production (Dwyer 2023).

In Section 4, the economic impact results for wind and solar were consistently lower per MWe-yr and per MWe than the other technologies, yet these options show sustained growth in electricity production over time. Coal-powered electricity production recently dropped below nuclear and was consistently second behind biomass when comparing economic impacts per MWe-yr.

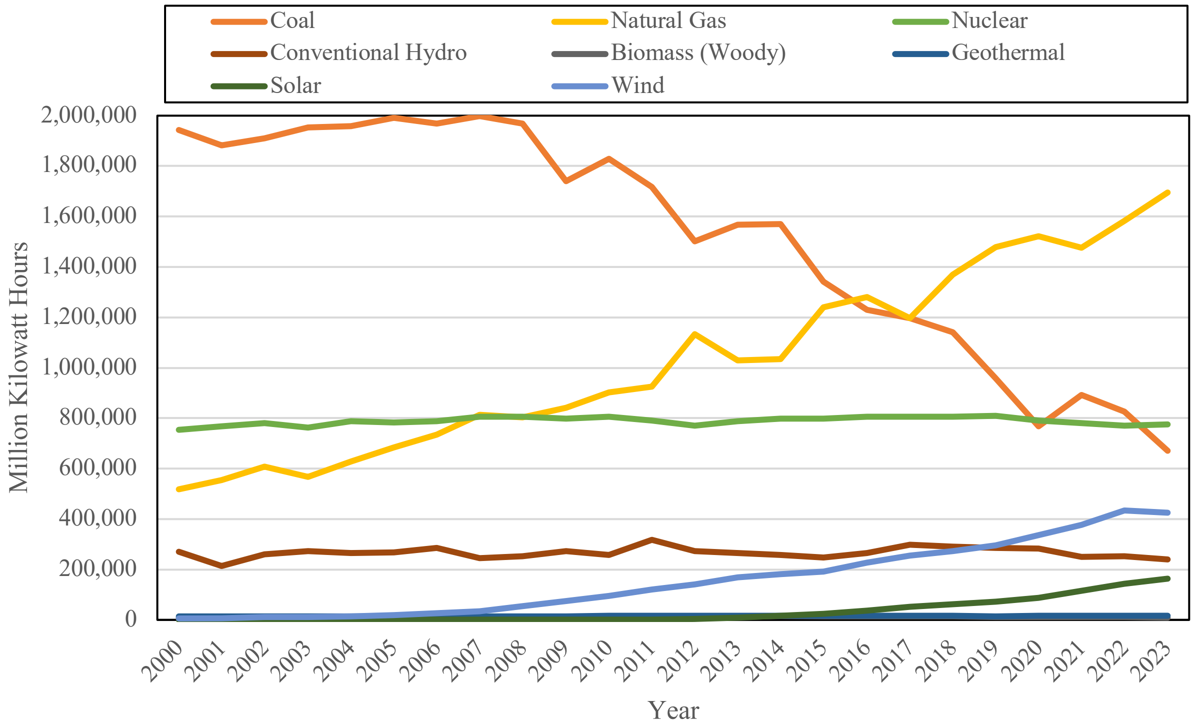

Figure 16. Historical generation trends by technology.

6. ELECTRICITY GENERATING TECHNOLOGY EDUCATION LEVELS

When comparing the socioeconomic impacts of different generation technologies, it is useful to understand the educational requirements for each technology's respective workforce. It is expected that workers at a solar plant would have different skills and education than those at a nuclear plant; but determining how average education attainment changes by generator type provides context for workforce needs and the impact it has on society. To accomplish this, staffing patterns for each type of generating technology was obtained from BLS (Bureau of Labor Statistics 2023c). This was combined with data on typical educational levels by job type (Bureau of Labor Statistics 2023d). Combining the two datasets allows education level distribution to be compared across the generating technologies based on their mix of occupations. Figure 17 showcases these generated distributions.

BLS groups education levels into eight categories, ranging from no formal educational credential to doctoral or professional degree with multiple levels in between. For simplicity, education levels were aggregated into four categories. It should be noted that within the BLS occupation database, coal and natural gas generation technologies are grouped under a single fossil fuel category and therefore are shown a single category. Additionally, BLS does not specifically track energy storage as a generation type within the jobs category but does report an "Other" generation type. Consequently, the "Other" generation job data was included.

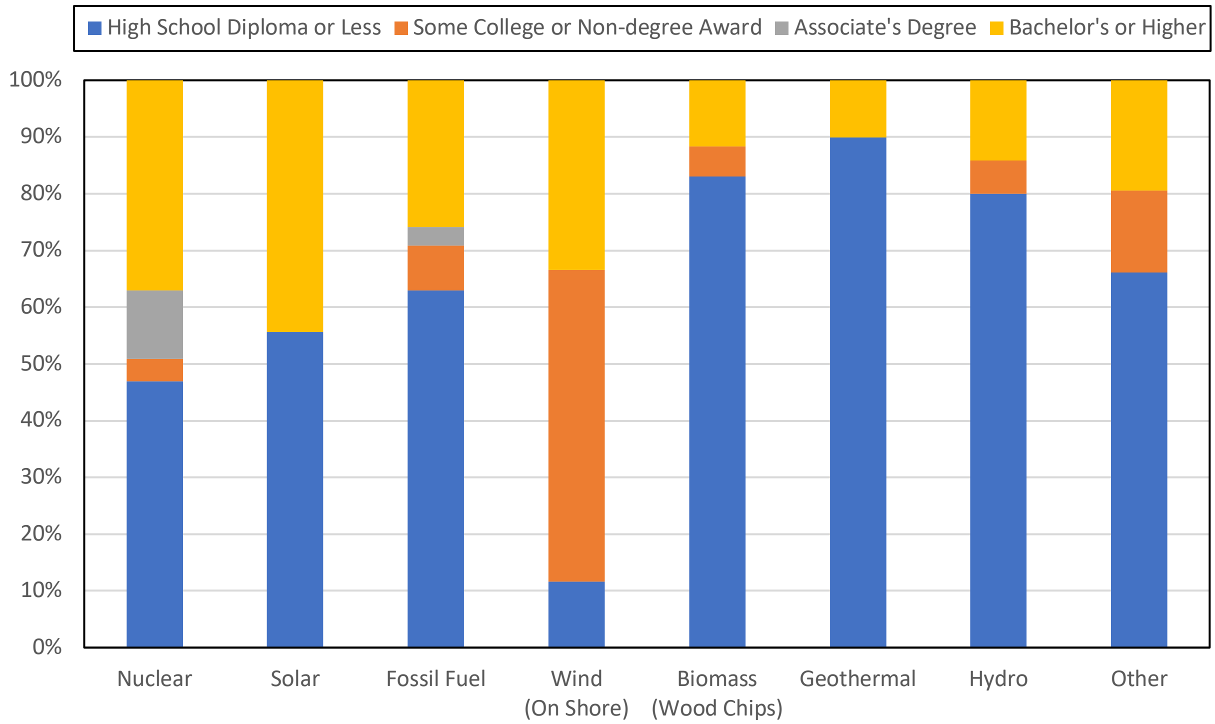

Figure 17. Education distribution by generation technology for operations.

A comparison of the results demonstrates just how different education distribution can be between technologies. Biomass, geothermal, and hydro have the highest concentration of jobs that require a high school diploma or less (80%–90%). This is followed by the “Other” category, fossil fuel (60%–70%), and finally solar (~55%), nuclear (~45%), and wind (~10%). Most technologies have less than 10% of their workforce completing the “Some College or Non-degree Award” education levels, except for the “Other” category (~15%) and wind (~55%). Last, “Other,” hydro, geothermal, and biomass have the lowest concentration of jobs that require an associate’s degree or more (10%–20%). Fossil fuel and wind have roughly the same level of associate’s degrees (~30%), and finally, nuclear and solar have the highest proportion of jobs with an associate’s degree or more (45%–50%).

Educational overlap and differences can be better explained when considering the types of job roles each technology requires. For example, most technologies require plant operators which typically require a high school diploma. Most employ electrical engineers which typically require a bachelor’s degree. However, some technologies have unique staffing requirements. Nuclear plants employ nuclear engineers, which is not a role found in the other technologies, and these engineers require, on average, a bachelor’s degree. Natural gas and coal plants employ more industrial machinery mechanics who typically require a high school diploma. This, in turn, shifts the educational balance of nuclear plants toward higher formal education, while natural gas and coal plant employees typically have less formal education. A unique outlier in Figure 17 is wind, which requires significantly higher concentrations of workers with some college or non-degree awards. This stems from wind employing a substantial number of wind turbine service technicians. This role requires a non-degree award and skews the wind distribution to look distinctly different from all other technologies.

Generally, it can be concluded that solar and nuclear require the most education for generating facility operations workers while biomass, geothermal, and hydro require the lowest levels of education.

Typically, it is expected that roles requiring more education also pay higher wages. A BLS survey of industry-wide average salaries confirms this expectation to some extent (Bureau of Labor Statistics 2023a). Figure 18Figure 18 highlights this BLS data graphically and shows nuclear with the highest average pay, which also has the highest levels of education, but shows solar and wind with some of the lowest average pay despite having the second and third highest education levels.

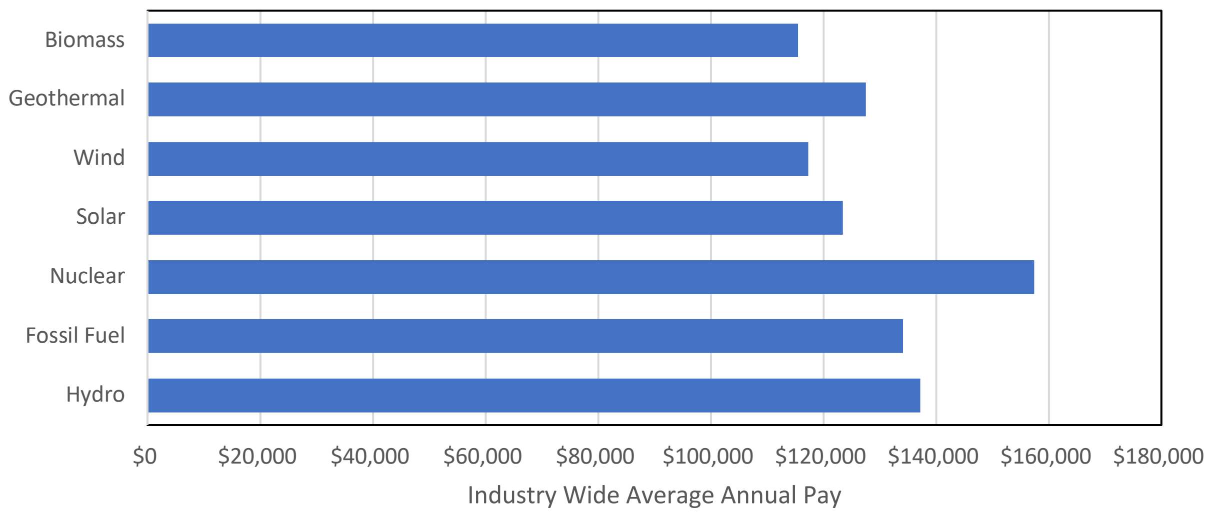

Figure 18. Industry average salaries by generation technology.

Knowing general educational requirements for generation technologies is important context for communities where these technologies are deployed because it may require added educational investment and/or training opportunities for technologies with higher levels of education.

7. SUMMARY AND CONCLUSIONS

The results shown in this report are intended to add context to the very complex process of selecting a generation technology. The economic models show woody biomass electricity generation consistently yields the highest economic impact in per MWe-yr terms. Biomass and coal always ranked first and second, respectively, for economic impacts due to their relatively high labor utilization and use of fuel for electricity production. Both generating technologies had an expected facility lifetime of 40 years, which would result in more frequent replacement-related economic activities than compared to nuclear at 60 years. Biomass is estimated to create 11.5 jobs per MWe-yr of production. Solar and wind both showed a total jobs impact of 3.6, the least in the comparison, which also correlates with those technologies having the lowest LCOE values. Nuclear, which had the highest capacity factor and the longest asset lifetime, is expected to create between 4.8 and 5.2 jobs per MWe-yr depending on construction and equipment costs.

Electricity generation trends and accompanying news reports show there is a significant decline in biomass- and coal-based electricity generation over time. Meanwhile, financial benefits through the Inflation Reduction Act have contributed to growth in clean energy sources. Forms of electricity generation that show flat or positive electricity net generation growth demonstrate different levels of per MWe-yr socioeconomic benefits after aggregating results for fuel production, construction, equipment manufacturing, and annual operations. Nuclear, natural gas, and hydro power contributed similar levels of economic impact but fell behind biomass and coal. Solar- and wind-based electricity generation produced the least economic impact across all categories, even without adjusting for the level of imports which would further reduce the impact on the economy. It is possible that if combined with battery storage, the economic impact of wind and solar would increase but so would their capital costs. Battery storage impacts were limited to equipment manufacturing and construction- or installation-related activities. Most economic impacts associated with battery storage were from manufacturing the battery storage equipment itself.

When results were normalized to per MWe units instead of per MWe-yr, nuclear-powered electricity provided the highest annual operations economic impacts across all measures. By this measure, nuclear-based electricity production resulted in 2.9 jobs per MWe for annual operations. Annual operations-related impacts also have the greatest long-term impact on the communities where the technology is deployed. Nuclear required the largest concentration of workers with education beyond a high school diploma and had the highest pay per worker, more than $157,000 annually.

The modeling results could be interpreted in multiple ways. From the perspective of communities where these technologies are deployed, those with high-upfront and long-term operating costs might appear the most attractive because they can result in additional economic activity. From the perspective of a utility, minimizing cost might be an important factor. In that sense, utilities may look favorably upon the technology with the lowest costs and potentially the lowest employment requirements to help maximize return on investment. Some utilities may place less weight on the cost of a given technology but instead weigh its other attributes such as dispatchability or environmental impact. This is particularly true in the case of a utility trying to balance a large energy portfolio with a variety of assets with distinctly different non-cost attributes.

A look at historical power trends showcases that electricity generating technology decisions are a function of more parameters than socioeconomic impact. The utility-based stakeholders that make these investments must determine how to balance energy portfolio needs, carbon emission commitments, and cost considerations. The communities that are home to these facilities will push for technologies that provide the maximum number of jobs, income, and community revenue as possible. Finally, federal and state governments will consider the impacts on GDP, labor markets, and local investment as they consider legislation that subsidizes certain generator types. Results of this report will assist in technology selection by facilitating a new viewpoint from multiple angles with socioeconomic metrics. These new metrics should accompany traditionally relied upon LCOE calculations that are used by utilities, communities, and government stakeholders for making fully informed energy transition decisions.

8. REFERENCES

Abou-Jaoude, Abdalla, Levi Morin Larsen, Nahuel Guaita, Ishita Trivedi, Frederick Carl Joseck, Christopher Shawn Lohse, Edward Hoffman, Nicolas Stauff, Koroush Shirvan, and Adam Stein. 2024. *Meta-Analysis of Advanced Nuclear Reactor Cost Estimations.* Idaho Falls: Idaho National Laboratory. https://www.osti.gov/biblio/2371533.

American Press. 2023. *'Giant leap into the future': Groundbreaking kicks off $150M solar project Read more at: https://www.americanpress.com/2023/05/23/giant-leap-into-the-future-groundbreaking-kicks-off-150m-solar-project/.* May 23. Accessed August 8, 2024. https://www.americanpress.com/2023/05/23/giant-leap-into-the-future-groundbreaking-kicks-off-150m-solar-project/.

Applied Economics. 2015. *Economic Impacts of Palo Verde Nuclear Generating Station on Arizona.* Phoenix: Applied Economics. http://large.stanford.edu/courses/2016/ph241/chandler2/docs/ae-2010.pdf.

Berkman, Mark, and Dean Murphy. 2015. *New York's Upstate Nuclear Power.* Boston: The Brattle Group. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B7F5ED662-DA11-41BC-99EE-D6EC5ACC509E%7.

Berkman, Mark, and Dean Murphy. 2017. *Ohio Nuclear Power Plants' Contribution to the State Economy.* Boston: The Brattle Group. https://d3n8a8pro7vhmx.cloudfront.net/nuclearmatters/pages/211/attachments/original/1494337829/Ohio-Nuclear-Report-Brattle-21April2017_%281%29.pdf?1494337829.

Bureau of Labor Statistics. 2023d. *Education and training assignments by detailed occupation.* Bureau of Labor Statistics. September. Accessed January 2024. https://www.bls.gov/emp/tables/education-and-training-by-occupation.htm.

—. 2023b. *Employee Benefits.* Accessed August 8, 2024. https://www.bls.gov/ebs/.

—. 2023c. *Industry-occupation matrix data, by industry.* September. Accessed January 2024. https://www.bls.gov/emp/tables/industry-occupation-matrix-industry.htm.

—. 2023a. *Quaterly Census of Employment and Wages.* Accessed August 1, 2024. https://www.bls.gov/cew/downloadable-data-files.htm.

Dwyer, Brian. 2023. *Fort Drum's biomass plant set to close less than a decade after its foundation.* March 30. Accessed August 27, 2024. https://spectrumlocalnews.com/nys/watertown/news/2023/04/04/fort-drum-s-biomass-plant-set-to-close-less-than-a-decade-after-its-foundation.

EIA. 2023c. *Annual Coal Report.* October 3. Accessed August 1, 2024. https://www.eia.gov/coal/annual/.

—. 2024c. *Monthly Energy Review.* July 2024. Accessed August 6, 2024. https://www.eia.gov/totalenergy/data/monthly/pdf/sec7_6.pdf.

—. 2023b. *Natural Gas Annual.* September 29. Accessed August 1, 2024. https://www.eia.gov/naturalgas/annual/.

EIA. 2023a. *Solar panel shipments set a record high in 2022 as capacity continued to grow.* Washington: Energy Information Administration. https://www.eia.gov/todayinenergy/detail.php?id=60261#:~:text=In%202022%2C%20about%2088%25%20of,)%20and%20small%2Dscale%20solar.

—. 2024a. *Wholesale Electricity and Natural Gas Market Data.* Accessed August 1, 2024. https://www.eia.gov/electricity/wholesale/.

—. 2024b. *Wholesale Electricity and Natural Gas Market Data.* July 24. Accessed August 8, 2024. https://www.eia.gov/electricity/wholesale/.

Electrek. 2024. *Pennsylvania's largest solar farm will replace its largest coal plant.* March 21. Accessed August 8, 2024. https://electrek.co/2024/03/21/pennsylvanias-largest-solar-farm-will-replace-its-largest-coal-plant/.

Illinois Country Living. 2015. *Old coal plant converted to renewable biomass shutting down.* December. Accessed August 8, 2024. https://icl.coop/old-coal-plant-converted-to-renewable-biomass-shutting-down/.

Institute for Energy Economics and Financial Analysis. 2023. *U.S. on track to close half of coal capacity by 2026.* April 3. Accessed August 27, 2024. https://ieefa.org/resources/us-track-close-half-coal-capacity-2026.

IRENA. 2012. *RENEWABLE ENERGY TECHNOLOGIES: COST ANALYSIS SERIES.* International Renewable Energy Agency.

Jenson, William Dunkley, Ed Hoffman, and Kent Williams. 2023. *Economic Impact of Closing the Nuclear Fuel Cycle.* United States: Idaho National Laboratory.

Larson, Aaron. 2023. *Subsequent License Renewal: Extending Nuclear Power Reactors to 80 Years of Operation (and Maybe More).* June 15. Accessed August 10, 2025. https://www.powermag.com/subsequent-license-renewal-extending-nuclear-power-reactors-to-80-years-of-operation-and-maybe-more/.

Lazard. 2023. *Lazard's Levelized Cost of Energy Analysis Version 16.0.* New York City: Lazard. https://www.lazard.com/media/nltb551p/lazards-lcoeplus-april-2023.pdf.

Moran, Carly. 2024. *More than 70 unemployed following biomass plant shutdown.* June 14. Accessed August 1, 2024. https://www.thecentersquare.com/michigan/article_e9e2b8b2-29b7-11ef-b708-9b44d17d3147.html.

Murphy, Dean, and Mark Berkman. 2019. *The Impacts of Illinois Nuclear Power Plants on the Economy and the Environment.* Boston: The Brattle Group. https://www.remi.com/wp-content/uploads/2019/11/872-The-Impacts-of-Illinois-Nuclear-Power-Plants-on-the-Economy-and-the-Environment.pdf.

National Renewable Energy Laboratory. 2024a. *Annual Technology Baseline.* Accessed August 7, 2024. https://atb.nrel.gov/electricity/2024/utility-scale_battery_storage.

National Renewable Energy Laboratory. 2024b. *Jobs and Economic Development Impact Models.* Golden: National Renewable Energy Laboratory. https://www.nrel.gov/analysis/jedi/models.html.

—. 2024c. *Nuclear.* Accessed 2024. https://atb.nrel.gov/electricity/2024/nuclear.

Nuclear Energy Institute. 2001. *Economic Benefits of Millstone Power Station.* Washington: Nuclear Energy Institute. https://www.nrc.gov/docs/ML0419/ML041910428.pdf.

Nuclear Energy Institute. 2008. *Economic Benefits of North Anna Power Station.* Washington: Nuclear Energy Institute. https://www.nrc.gov/docs/ML0829/ML082960083.pdf.

Nuclear Energy Institute. 2004. *Economic Benefits of Palo Verde Nuclear Generation Station.* Washington: Nuclear Energy Institute. http://large.stanford.edu/courses/2016/ph241/chandler2/docs/paloverde-nei.pdf.

Nuclear Energy Institute. 2015d. *Economic Impact of Florida Power & Light Company's Nuclear Power Plants.* Washington: Nuclear Energy Institute. https://www.fpl.com/clean-energy/pdf/economic-study.pdf.

Nuclear Energy Institute. 2018. *Economic Impacts of the Columbia Generating Station.* Washington: Nuclear Energy Institute. https://www.energy-northwest.com/energyprojects/Columbia/Documents/NEI_EconomicImpacts-ColumbiaGeneratingStation-010918.pdf.

Nuclear Energy Institute. 2015b. *Economic Impacts of The Indian Point Energy Center.* Washington: Nuclear Energy Institute. http://large.stanford.edu/courses/2017/ph241/arguello1/docs/nei.pdf.

Nuclear Energy Institute. 2015c. *Economic Impacts of The R.E. Ginna Nuclear Power Plant.* Washington: Nuclear Energy Institute. http://large.stanford.edu/courses/2018/ph241/green1/docs/nei-feb15.pdf.

Nuclear Energy Institute. 2015a. *The Economic Benefits of Texas' Nuclear Power Plants.* Washington: Nuclear Energy Institute. https://www.nei.org/resources/reports-briefs/economic-benefits-texas-nuclear-power-plants.

Nuclear Energy Institute. 2014. *The Impact of Exelon's Nuclear Fleet on the Illinois Economy.* Washington: Nuclear Energy Institute. https://www.remi.com/topics-and-studies/the-impact-of-exelons-nuclear-fleet-on-the-illinois-economy/.

Patrick Mayeda, Kenneth Riener. 2013. "Economic Benefits of Diablo Canyon Power Plant: An Economic Impact Study." San Louis Obispo. https://www.pge.com/includes/docs/pdfs/shared/edusafety/systemworks/dcpp/PGE_Economic_Impact_Report_Final.pdf.

Sargent & Lundy. 2024. *Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies.* Washington D.C.: U.S. Energy Information Administration.

Seven Days VT. 2022. *Ryegate Power Station Shuts Down Due to Wood Supply Crunch.* December 5. Accessed August 8, 2024. https://www.sevendaysvt.com/news/ryegate-power-station-shuts-down-due-to-wood-supply-crunch-37081638.

Solar Quarter. 2024. *ACCIONA Energía Launches Operations at Red-Tailed Hawk Solar Plant in Texas.* May 30. Accessed August 8, 2024. https://solarquarter.com/2024/05/30/acciona-energia-launches-operations-at-red-tailed-hawk-solar-plant-in-texas.

Steamboat Pilot. 2023. *Xcel Energy plans biomass plant at Hayden Generating Station.* September 23. Accessed August 8, 2024. https://www.steamboatpilot.com/news/xcel-energy-plans-biomass-plant-at-hayden-generating-station/.

The Center Square. 2024. *More than 70 unemployed following biomass plant shutdown.* June 14. Accessed August 8, 2024. https://www.thecentersquare.com/michigan/article_e9e2b8b2-29b7-11ef-b708-9b44d17d3147.html.

Vail Daily. 2024. *Gypsum's biomass plant has closed, apparently permanently, leaving facility's future in doubt* . April 17. Accessed August 8, 2024. https://www.vaildaily.com/news/gypsums-biomass-plant-has-closed-apparently-permanently-leaving-facilitys-future-in-doubt/.

We Energies. 2024. *Rothschild Biomass Cogeneration Plant.* Accessed August 1, 2024. https://www.we-energies.com/company/rothschild-biomass-cogenerationplant.

World Nucelar News. 2023. *Doosan starts forging components for NuScale SMR.* May 5. Accessed August 6, 2024. https://world-nuclear-news.org/Articles/Doosan-starts-forging-components-for-NuScale-SMR.

World Nuclear Association. 2024. *Nuclear Power Reactors.* April 30. Accessed August 6, 2024. https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/nuclear-power-reactors.

WV Public Broadcasting. 2024. *Nicholas County Solar Project Receives $129 Million Federal Grant.* March 21. Accessed August 8, 2024. https://wvpublic.org/nicholas-county-solar-project-receives-129-million-federal-grant/.

WWNYTV. 2022. *Biomass plant that powers Fort Drum to close in March.* December 21. Accessed August 8, 2024. https://www.wwnytv.com/2022/12/21/biomass-plant-that-powers-fort-drum-close-march/.

Appendix A

Detailed Economic Impacts

Table A-1. Detailed combined impacts per MWe-yr.

Hydro				
Impact Category	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Fuel	0.00	$0	$0	$0
Construction	4.06	$287,097	$476,549	$844,790
Equipment	0.75	$65,823	$101,508	$230,383
Operations	1.61	$147,885	$449,043	$1,014,700
Total	6.41	$500,805	$1,027,101	$2,089,873
Coal				
Impact Category	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Fuel	1.81	$173,931	$342,149	$546,036
Construction	2.17	$174,189	$276,532	$451,936
Equipment	0.49	$40,925	$65,201	$149,668
Operations	2.47	$247,008	$597,274	$1,187,600
Total	6.94	$636,053	$1,281,156	$2,335,240
Natural Gas				
Impact Category	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Fuel	2.17	$229,237	$426,035	$713,225
Construction	0.27	$19,265	$31,710	$55,399
Equipment	0.15	$12,177	$19,401	$44,534
Operations	1.84	$172,851	$503,972	$1,112,429
Total	4.43	$433,531	$981,117	$1,925,587
Biomass w/Carbon Capture				
Impact Category	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Fuel	0.83	$54,600	$74,544	$112,672
Construction	4.25	$346,322	$547,145	$885,758
Equipment	1.88	$155,602	$243,052	$521,927
Operations	4.52	$459,347	$861,913	$1,471,619
Total	11.48	$1,015,871	$1,726,654	$2,991,976

Table A-1. Continued.

Battery				
Impact Category	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Fuel	0.00	$0	$0	$0
Construction	1.76	$124,578	$206,786	$366,574
Equipment	2.97	$248,029	$405,343	$941,045
Operations	0.00	$0	$0	$0
Total	4.73	$372,607	$612,128	$1,307,619
Geothermal				
Impact Category	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Fuel	0.00	$0	$0	$0
Construction	0.94	$66,573	$110,504	$195,894
Equipment	0.56	$46,165	$75,374	$172,375
Operations	2.29	$226,286	$540,393	$1,091,942
Total	3.79	$339,024	$726,272	$1,460,211
Wind				
Impact Category	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Fuel	0.00	$0	$0	$0
Construction	0.91	$64,432	$106,950	$189,593
Equipment	0.86	$71,277	$119,223	$288,616
Operations	1.80	$164,520	$555,641	$1,057,939
Total	3.57	$300,229	$781,814	$1,536,148
Solar				
Impact Category	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Fuel	0.00	$0	$0	$0
Construction	0.87	$61,488	$102,063	$180,929
Equipment	1.04	$96,177	$155,188	$319,952
Operations	1.64	$150,273	$458,497	$1,019,120
Total	3.55	$307,937	$715,747	$1,520,001
Nuclear (Moderate)				
Impact Category	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Fuel	0.51	$43,828	$98,659	$203,859
Construction	0.52	$47,380	$72,436	$109,545
Equipment	0.67	$56,498	$88,686	$192,403
Operations	3.09	$330,610	$671,682	$1,252,497
Total	4.80	$478,317	$931,463	$1,758,303

Table A-1. Continued.

Nuclear (Conservative)				
Impact Category	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Fuel	0.51	$43,828	$98,659	$203,859
Construction	0.72	$67,544	$102,280	$151,440
Equipment	0.90	$76,150	$119,533	$259,325
Operations	3.09	$330,610	$671,682	$1,252,497
Total	5.24	$518,132	$992,154	$1,867,120

Table A-2. Detailed generating facility annual operations impacts, with net MWe capacity in parentheses.

Hydro (34)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	3	$584,489	$6,148,223	$16,804,190	0.09	$17,090	$179,773	$491,351
Indirect	28	$2,893,063	$6,327,859	$12,787,621	0.81	$84,592	$185,025	$373,907
Induced	24	$1,580,098	$2,881,197	$5,110,922	0.71	$46,202	$84,246	$149,442
Total	55	$5,057,650	$15,357,278	$34,702,733	1.61	$147,885	$449,043	$1,014,700

Coal (423)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	143	$27,327,362	$97,021,750	$207,841,302	0.34	$64,604	$229,366	$491,351
Indirect	402	$44,548,219	$96,161,807	$189,029,841	0.95	$105,315	$227,333	$446,879
Induced	498	$32,608,910	$59,463,449	$105,483,728	1.18	$77,090	$140,576	$249,371
Total	1,043	$104,484,492	$252,647,006	$502,354,871	2.47	$247,008	$597,274	$1,187,600

Natural Gas (353)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	25	$4,822,714	$62,950,799	$173,348,491	0.07	$13,670	$178,432	$491,351
Indirect	335	$37,155,111	$80,203,040	$157,658,932	0.95	$105,315	$227,333	$446,879
Induced	290	$19,003,960	$34,647,379	$61,457,360	0.82	$53,866	$98,207	$174,199
Total	651	$60,981,784	$177,801,218	$392,464,783	1.84	$172,851	$503,972	$1,112,429

Table A-2. Continued.

Nuclear (931)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	544	$121,681,316	$253,233,411	$457,447,406	0.58	$130,700	$272,002	$491,351
Indirect	865	$89,842,438	$196,508,384	$397,113,047	0.93	$96,501	$211,072	$426,545
Induced	1,471	$96,274,153	$175,594,282	$311,513,861	1.58	$103,409	$188,608	$334,601
Total	2,879	$307,797,907	$625,336,077	$1,166,074,314	3.09	$330,610	$671,682	$1,252,497

Solar (12)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	1	$212,954	$2,177,066	$5,724,234	0.10	$18,279	$186,873	$491,351
Indirect	10	$990,768	$2,167,080	$4,379,337	0.82	$85,044	$186,015	$375,909
Induced	8	$546,956	$997,341	$1,769,176	0.72	$46,949	$85,609	$151,861
Total	19	$1,750,678	$5,341,487	$11,872,747	1.64	$150,273	$458,497	$1,019,120

Wind (101)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	14	$2,266,158	$26,513,447	$49,380,735	0.14	$22,549	$263,815	$491,351
Indirect	88	$9,102,028	$19,908,407	$40,231,799	0.87	$90,567	$198,094	$400,316
Induced	79	$5,166,046	$9,420,107	$16,710,342	0.79	$51,403	$93,732	$166,272
Total	181	$16,534,232	$55,841,962	$106,322,875	1.80	$164,520	$555,641	$1,057,939

Table A-2. Continued.

Geothermal (70)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	28	$5,001,125	$15,920,368	$34,394,542	0.40	$71,445	$227,434	$491,351
Indirect	57	$5,886,028	$12,874,351	$26,017,097	0.81	$84,086	$183,919	$371,673
Induced	76	$4,952,840	$9,032,817	$16,024,285	1.08	$70,755	$129,040	$228,918
Total	160	$15,839,993	$37,827,536	$76,435,924	2.29	$226,286	$540,393	$1,091,942

Biomass w/Carbon Capture (32)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	38	$6,270,773	$10,862,123	$15,477,544	1.21	$199,072	$344,829	$491,351
Indirect	35	$3,672,141	$8,031,930	$16,231,292	1.12	$116,576	$254,982	$515,279
Induced	69	$4,526,525	$8,256,210	$14,647,155	2.19	$143,699	$262,102	$464,989
Total	142	$14,469,439	$27,150,263	$46,355,991	4.52	$459,347	$861,913	$1,471,619

Table A-3. Detailed equipment manufacturing impacts, with net MWe capacity in parentheses.

Hydro (1,710)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	335	$40,895,430	$47,647,089	$136,181,000	0.20	$23,915	$27,864	$79,638
Indirect	405	$36,318,825	$61,461,363	$143,395,204	0.24	$21,239	$35,942	$83,857
Induced	540	$35,343,575	$64,470,965	$114,379,419	0.32	$20,669	$37,702	$66,889
Total	1,280	$112,557,830	$173,579,417	$393,955,623	0.75	$65,823	$101,508	$230,383

Coal (16,920)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	2,360	$239,853,359	$307,869,739	$865,203,077	0.14	$14,176	$18,196	$51,135
Indirect	2,657	$234,475,562	$397,454,974	$961,320,032	0.16	$13,858	$23,490	$56,816
Induced	3,332	$218,123,485	$397,869,943	$705,860,679	0.20	$12,891	$23,515	$41,718
Total	8,349	$692,452,407	$1,103,194,656	$2,532,383,788	0.49	$40,925	$65,201	$149,668

Natural Gas (14,112)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	586	$59,524,791	$76,404,524	$214,718,827	0.04	$4,218	$5,414	$15,215
Indirect	659	$58,190,174	$98,637,034	$238,572,325	0.05	$4,123	$6,990	$16,906
Induced	827	$54,132,053	$98,740,018	$175,174,570	0.06	$3,836	$6,997	$12,413
Total	2,072	$171,847,018	$273,781,577	$628,465,722	0.15	$12,177	$19,401	$44,534

Table A-3. Continued.

Nuclear (Moderate) (55,860)								
Impact	Employment	Labor Income	Value Added	Output	Jobs/MWe-yr	Labor Income/MWe-yr	Value Added/MWe-yr	Output/MWe-yr
Direct	9,734	$997,862,117	$1,332,014,214	$3,686,993,990	0.17	$17,864	$23,846	$66,004
Indirect	12,519	$1,160,086,915	$1,801,489,035	$3,830,882,879	0.22	$20,768	$32,250	$68,580
Induced	15,244	$998,046,580	$1,820,488,030	$3,229,731,210	0.27	$17,867	$32,590	$57,818
Total	37,497	$3,155,995,612	$4,953,991,280	$10,747,608,080	0.67	$56,498	$88,686	$192,403

Solar (408)								
Impact	Employment	Labor Income	Value Added	Output	Jobs/MWe-yr	Labor Income/MWe-yr	Value Added/MWe-yr	Output/MWe-yr
Direct	85	$11,966,795	$18,239,286	$45,965,000	0.21	$29,348	$44,732	$112,728
Indirect	152	$14,899,900	$22,512,608	$44,531,685	0.37	$36,542	$55,212	$109,213
Induced	189	$12,349,438	$22,526,086	$39,963,708	0.46	$30,287	$55,245	$98,010
Total	426	$39,216,133	$63,277,979	$130,460,393	1.04	$96,177	$155,188	$319,952

Wind (2,513)								
Impact	Employment	Labor Income	Value Added	Output	Jobs/MWe-yr	Labor Income/MWe-yr	Value Added/MWe-yr	Output/MWe-yr
Direct	530	$53,969,747	$79,055,583	$258,402,000	0.21	$21,480	$31,465	$102,847
Indirect	770	$68,993,611	$118,122,785	$285,131,650	0.31	$27,460	$47,014	$113,485
Induced	857	$56,120,797	$102,369,091	$181,614,242	0.34	$22,337	$40,744	$72,284
Total	2,158	$179,084,155	$299,547,460	$725,147,891	0.86	$71,277	$119,223	$288,616

Table A-3. Continued.

Geothermal (2,800)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	425	$42,813,429	$59,344,779	$167,558,001	0.15	$15,291	$21,195	$59,842
Indirect	517	$45,783,674	$77,527,077	$183,497,424	0.18	$16,351	$27,688	$65,535
Induced	621	$40,664,856	$74,175,208	$131,594,298	0.22	$14,523	$26,491	$46,998
Total	1,563	$129,261,960	$211,047,064	$482,649,723	0.56	$46,165	$75,374	$172,375

Biomass w/Carbon Capture (1,260)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	661	$63,499,159	$83,747,902	$222,578,000	0.52	$50,396	$66,467	$176,649
Indirect	760	$70,445,281	$109,199,929	$234,049,627	0.60	$55,909	$86,667	$185,754
Induced	949	$62,113,805	$113,297,737	$201,000,968	0.75	$49,297	$89,919	$159,525
Total	2,369	$196,058,245	$306,245,568	$657,628,595	1.88	$155,602	$243,052	$521,927

Nuclear (Conservative) (55,860)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	13,119	$1,344,944,592	$1,795,323,506	$4,969,426,682	0.23	$24,077	$32,140	$88,962
Indirect	16,874	$1,563,595,407	$2,428,093,917	$5,163,363,881	0.30	$27,991	$43,467	$92,434
Induced	20,547	$1,345,193,216	$2,453,701,258	$4,353,115,979	0.37	$24,082	$43,926	$77,929
Total	50,540	$4,253,733,216	$6,677,118,681	$14,485,906,542	0.90	$76,150	$119,533	$259,325

Table A-3. Continued.

Battery (234)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	209	$21,802,896	$29,132,088	$87,993,266	0.90	$93,254	$124,603	$376,361
Indirect	208	$18,012,502	$32,486,711	$73,210,997	0.89	$77,042	$138,951	$313,135
Induced	278	$18,173,896	$33,150,318	$58,812,170	1.19	$77,733	$141,789	$251,549
Total	695	$57,989,293	$94,769,117	$220,016,434	2.97	$248,029	$405,343	$941,045

Table A-4. Detailed Generating facility construction impacts, with net MWe capacity in parentheses.

Hydro (1,710)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	3,371	$236,651,548	$354,544,309	$570,817,000	1.97	$138,393	$207,336	$333,811
Indirect	1,193	$99,064,278	$177,400,229	$371,895,208	0.70	$57,932	$103,743	$217,483
Induced	2,372	$155,219,976	$282,954,202	$501,878,300	1.39	$90,772	$165,470	$293,496
Total	6,936	$490,935,802	$814,898,740	$1,444,590,507	4.06	$287,097	$476,549	$844,790

Coal (16,920)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	16,555	$1,527,873,138	$2,106,866,574	$2,803,389,231	0.98	$90,300	$124,519	$165,685
Indirect	5,859	$486,523,230	$871,245,762	$1,826,447,040	0.35	$28,754	$51,492	$107,946
Induced	14,255	$932,879,177	$1,700,817,126	$3,016,915,333	0.84	$55,135	$100,521	$178,305
Total	36,669	$2,947,275,545	$4,678,929,461	$7,646,751,604	2.17	$174,189	$276,532	$451,936

Table A-4. Continued.

Natural Gas (14,112)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	1,801	$132,954,330	$195,957,411	$305,050,367	0.13	$9,421	$13,886	$21,616
Indirect	638	$52,940,950	$94,804,473	$198,744,553	0.05	$3,751	$6,718	$14,083
Induced	1,314	$85,976,486	$156,733,013	$278,001,555	0.09	$6,092	$11,106	$19,700
Total	3,753	$271,871,766	$447,494,898	$781,796,476	0.27	$19,265	$31,710	$55,399

Nuclear (Moderate) (55,860)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	12,183	$1,450,147,782	$1,876,227,374	$2,063,006,010	0.22	$25,960	$33,588	$36,932
Indirect	4,312	$358,031,035	$641,147,231	$1,344,077,083	0.08	$6,409	$11,478	$24,062
Induced	12,811	$838,481,597	$1,528,893,870	$2,712,074,750	0.23	$15,010	$27,370	$48,551
Total	29,306	$2,646,660,415	$4,046,268,475	$6,119,157,843	0.52	$47,380	$72,436	$109,545

Solar (35)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	172	$12,085,536	$18,106,190	$29,151,000	0.42	$29,640	$44,405	$71,492
Indirect	61	$5,059,104	$9,059,636	$18,992,282	0.15	$12,407	$22,219	$46,578
Induced	121	$7,926,914	$14,450,162	$25,630,376	0.30	$19,441	$35,439	$62,858
Total	354	$25,071,555	$41,615,988	$73,773,658	0.87	$61,488	$102,063	$180,929

Table A-4. Continued.

Wind (2,513)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	1,112	$78,035,472	$116,910,423	$188,226,000	0.44	$31,059	$46,532	$74,916
Indirect	393	$32,666,289	$58,497,444	$122,631,855	0.16	$13,002	$23,283	$48,809
Induced	782	$51,183,541	$93,303,699	$165,493,573	0.31	$20,372	$37,136	$65,868
Total	2,287	$161,885,302	$268,711,566	$476,351,428	0.91	$64,432	$106,950	$189,593

Geothermal (2,800)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	1,280	$89,855,260	$134,618,477	$216,736,000	0.46	$32,091	$48,078	$77,406
Indirect	453	$37,614,148	$67,357,868	$141,206,516	0.16	$13,434	$24,056	$50,431
Induced	901	$58,936,151	$107,436,117	$190,560,364	0.32	$21,049	$38,370	$68,057
Total	2,634	$186,405,559	$309,412,462	$548,502,880	0.94	$66,573	$110,504	$195,894

Biomass w/Carbon Capture (1,260)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	2,393	$227,894,973	$311,597,786	$405,275,000	1.90	$180,869	$247,300	$321,647
Indirect	847	$70,334,758	$125,952,587	$264,042,294	0.67	$55,821	$99,962	$209,557
Induced	2,111	$138,135,752	$251,851,802	$446,738,132	1.68	$109,632	$199,882	$354,554
Total	5,351	$436,365,483	$689,402,175	$1,116,055,426	4.25	$346,322	$547,145	$885,758

Table A-4. Continued.

Nuclear (Conservative) (55,860)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	16,421	$2,094,851,534	$2,669,132,722	$2,780,573,318	0.29	$37,502	$47,783	$49,778
Indirect	5,811	$482,563,569	$864,154,964	$1,811,582,156	0.10	$8,639	$15,470	$32,431
Induced	18,267	$1,195,578,271	$2,180,090,750	$3,867,261,501	0.33	$21,403	$39,028	$69,231
Total	40,498	$3,772,993,374	$5,713,378,436	$8,459,416,975	0.72	$67,544	$102,280	$151,440

Battery (234)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	200	$14,040,105	$21,034,468	$33,865,533	0.86	$60,052	$89,968	$144,848
Indirect	71	$5,877,303	$10,524,833	$22,063,865	0.30	$25,138	$45,016	$94,371
Induced	141	$9,208,918	$16,787,157	$29,775,525	0.60	$39,388	$71,801	$127,355
Total	412	$29,126,327	$48,346,458	$85,704,924	1.76	$124,578	$206,786	$366,574

Table A-5. Detailed construction and equipment manufacturing combined impacts, with net MWe capacity in parentheses

Hydro								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	3,706	$277,546,977	$402,191,397	$706,998,000	2.17	$162,308	$235,200	$413,449
Indirect	1,598	$135,383,103	$238,861,593	$515,290,412	0.93	$79,171	$139,685	$301,339
Induced	2,912	$190,563,551	$347,425,167	$616,257,718	1.70	$111,441	$203,173	$360,385
Total	8,216	$603,493,631	$988,478,157	$1,838,546,130	4.80	$352,920	$578,057	$1,075,173

Table A-5. Continued.

Coal								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	18,916	$1,767,726,497	$2,414,736,313	$3,668,592,308	1.12	$104,476	$142,715	$216,820
Indirect	8,516	$720,998,792	$1,268,700,735	$2,787,767,072	0.50	$42,612	$74,982	$164,762
Induced	17,586	$1,151,002,663	$2,098,687,069	$3,722,776,012	1.04	$68,026	$124,036	$220,022
Total	45,018	$3,639,727,952	$5,782,124,117	$10,179,135,392	2.66	$215,114	$341,733	$601,604

Natural Gas								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	2,387	$192,479,120	$272,361,935	$519,769,194	0.17	$13,639	$19,300	$36,832
Indirect	1,297	$111,131,124	$193,441,508	$437,316,878	0.09	$7,875	$13,708	$30,989
Induced	2,141	$140,108,539	$255,473,032	$453,176,126	0.15	$9,928	$18,103	$32,113
Total	5,825	$443,718,784	$721,276,474	$1,410,262,198	0.41	$31,443	$51,111	$99,934

Nuclear (Moderate)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	21,917	$2,448,009,899	$3,208,241,588	$5,750,000,000	0.39	$43,824	$57,434	$102,936
Indirect	16,831	$1,518,117,950	$2,442,636,266	$5,174,959,963	0.30	$27,177	$43,728	$92,642
Induced	28,055	$1,836,528,177	$3,349,381,901	$5,941,805,960	0.50	$32,877	$59,960	$106,370
Total	66,803	$5,802,656,027	$9,000,259,755	$16,866,765,923	1.20	$103,879	$161,122	$301,947

Table A-5. Continued.

Solar								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	258	$24,052,331	$36,345,476	$75,116,000	0.63	$58,988	$89,137	$184,221
Indirect	213	$19,959,005	$31,572,244	$63,523,966	0.52	$48,949	$77,430	$155,791
Induced	310	$20,276,352	$36,976,247	$65,594,084	0.76	$49,727	$90,684	$160,868
Total	780	$64,287,688	$104,893,967	$204,234,050	1.91	$157,664	$257,251	$500,881

Wind								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	1,642	$132,005,219	$195,966,006	$446,628,000	0.65	$52,539	$77,996	$177,762
Indirect	1,164	$101,659,899	$176,620,229	$407,763,504	0.46	$40,462	$70,297	$162,294
Induced	1,639	$107,304,338	$195,672,791	$347,107,815	0.65	$42,708	$77,880	$138,152
Total	4,445	$340,969,457	$568,259,026	$1,201,499,319	1.77	$135,709	$226,173	$478,209

Geothermal								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	1,705	$132,668,689	$193,963,256	$384,294,001	0.81	$63,176	$92,363	$182,997
Indirect	970	$83,397,823	$144,884,945	$324,703,940	0.46	$39,713	$68,993	$154,621
Induced	1,522	$99,601,007	$181,611,325	$322,154,661	0.72	$47,429	$86,482	$153,407
Total	4,196	$315,667,518	$520,459,526	$1,031,152,602	2.00	$150,318	$247,838	$491,025

Table A-5. Continued.

Biomass w/Carbon Capture								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	3,054	$291,394,132	$395,345,689	$627,853,000	2.42	$231,265	$313,766	$498,296
Indirect	1,607	$140,780,038	$235,152,516	$498,091,921	1.28	$111,730	$186,629	$395,311
Induced	3,059	$200,249,557	$365,149,538	$647,739,100	2.43	$158,928	$289,801	$514,079
Total	7,721	$632,423,728	$995,647,743	$1,773,684,021	6.13	$501,924	$790,197	$1,407,686

Nuclear (Conservative)								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	29,540	$3,439,796,126	$4,464,456,228	$7,750,000,000	0.53	$61,579	$79,922	$138,740
Indirect	22,685	$2,046,158,976	$3,292,248,881	$6,974,946,037	0.41	$36,630	$58,938	$124,865
Induced	38,813	$2,540,771,488	$4,633,792,009	$8,220,377,480	0.69	$45,485	$82,954	$147,160
Total	91,038	$8,026,726,590	$12,390,497,117	$22,945,323,516	1.63	$143,694	$221,813	$410,765

Battery								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	409	$35,843,001	$50,166,556	$121,858,799	1.75	$153,306	$214,570	$521,210
Indirect	279	$23,889,805	$43,011,544	$95,274,863	1.19	$102,181	$183,967	$407,506
Induced	418	$27,382,814	$49,937,475	$88,587,696	1.79	$117,121	$213,591	$378,904
Total	1,107	$87,115,620	$143,115,575	$305,721,357	4.73	$372,607	$612,128	$1,307,619

Table A-6. Detailed fuel production impacts.

Nuclear								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	106	$12,194,955	$36,186,017	$78,475,848	0.11	$13,099	$38,868	$84,292
Indirect	178	$15,850,864	$32,401,067	$70,048,046	0.19	$17,026	$34,802	$75,240
Induced	195	$12,758,210	$23,264,380	$41,268,835	0.21	$13,704	$24,989	$44,327
Total	478	$40,804,029	$91,851,464	$189,792,729	0.51	$43,828	$98,659	$203,859

Coal								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	232	$33,777,254	$71,193,430	$95,083,069	0.55	$79,852	$168,306	$224,783
Indirect	187	$17,017,133	$31,991,197	$62,189,323	0.44	$40,230	$75,629	$147,020
Induced	348	$22,778,337	$41,544,246	$73,701,006	0.82	$53,849	$98,213	$174,234
Total	767	$73,572,724	$144,728,873	$230,973,397	1.81	$173,931	$342,149	$546,036

Natural Gas								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	133	$31,731,761	$65,090,848	$99,139,152	0.38	$89,943	$184,498	$281,007
Indirect	249	$24,113,314	$39,577,472	$71,534,407	0.71	$68,348	$112,181	$202,762
Induced	382	$25,029,814	$45,636,661	$80,952,127	1.08	$70,946	$129,356	$229,456
Total	765	$80,874,889	$150,304,981	$251,625,686	2.17	$229,237	$426,035	$713,225

Table A-6. Continued.

Woody Biomass								
Impact	**Employment**	**Labor Income**	**Value Added**	**Output**	**Jobs/MWe-yr**	**Labor Income/MWe-yr**	**Value Added/MWe-yr**	**Output/MWe-yr**
Direct	139	$10,392,415	$11,976,036	$15,623,398	0.39	$29,457	$33,946	$44,284
Indirect	59	$2,748,162	$3,161,159	$4,327,873	0.17	$7,790	$8,960	$12,267
Induced	94	$6,122,219	$11,162,051	$19,799,346	0.27	$17,353	$31,638	$56,121
Total	292	$19,262,797	$26,299,246	$39,750,617	0.83	$54,600	$74,544	$112,672

Appendix B

Nuclear Annual Operations Employment

The data shown in Table B-1 were used to calculate the annual operations model inputs for nuclear power plants. Total employment and total nameplate capacity were summed across all plants included in the studies shown, then the sum of total employment was divided by the sum of total nameplate capacity. This resulted in the "Jobs/MWe" metric used within this report of 0.544. This value was then multiplied by the size of the nuclear plant modeled in this study (1,000) to arrive at the final employment number of 544 identified in Table 4. Most of the nuclear plants operate more than one reactor. Some labor efficiency would exist when operating multiple reactors that would not apply if operating a single 1,000 MWe nuclear reactor. Actual staffing for a single reactor may require additional employees.

Table B-1. Data on nuclear plant employment across the United States.

Source	Plant(s) Included in Study	Jobs /MW	Employment	Nameplate Capacity (MWe)
(Nuclear Energy Institute 2004)	Palo Verde	0.53	2,055	3,900
(Nuclear Energy Institute 2015a)	Texas Combined	0.42	2,061	4,960
(Nuclear Energy Institute 2018)	Columbia	0.82	990	1,207
(Nuclear Energy Institute 2008)	North Anna Power Station	0.53	960	1,806
(Nuclear Energy Institute 2015b)	Indian Point	0.49	1,000	2,061
(Applied Economics 2015)	Palo Verde	0.73	2,900	4,000
(Murphy and Berkman 2019)	LaSalle+Byron+Dresden+Braidwood	0.38	3,273	8,680
(Nuclear Energy Institute 2001)	Millstone Power Station	0.55	1,464	2,680
(Nuclear Energy Institute 2014)	Exelon's Nuclear Fleet	0.51	5,896	11,541
(Nuclear Energy Institute 2015c)	R.E. Ginna	1.20	700	581
(Berkman and Murphy, Ohio Nuclear Power Plants' Contribution to the State Economy 2017)	Davis-Besse and Perry	0.62	1,340	2,176
(Berkman and Murphy, New York's Upstate Nuclear Power 2015)	Nine Mile Point, Ginna, and Fitzpatrick	0.69	2,305	3,345
(Nuclear Energy Institute 2015d)	St. Lucie and Turkey Point	0.71	1,400	1,968
(Patrick Mayeda 2013)	Diablo Canyon	0.66	1,483	2,240