Economic Contributions of Wood-based Biomass Power Generation Industries in the Northeast and Midwest: 2017 Version

Prepared for
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Executive Summary

The decarbonization of the electricity sector requires increased reliance on renewable energy sources, including biomass. Currently, approximately 60% of U.S. electricity is generated from fossil fuels, 18% from nuclear energy, and 22% from renewable sources. Of the total renewable electricity, about 6% is produced from biomass, primarily wood and wood-derived fuels. Unlike most renewables, woody biomass can provide continuous, 24/7 baseload power. When sourced sustainably, wood-based biomass offers multiple benefits: it reduces greenhouse gas emissions compared to fossil fuels, supports rural forest-based economies through job creation and income generation, utilizes low-value or unwanted forest materials, reduces landfill waste, and can enhance forest health.

To assess the economic contributions of wood-based biomass power generation in the Northeast and Midwest, the Michigan Department of Natural Resources secured funding from the U.S. Forest Service through a Landscape Scale Restoration Grant. This 20-state report summarizes the regional economic contribution of the sector in 2017. In addition, individual state-level reports were developed for fourteen participating states in the region, including California, Virginia, and Georgia.

The economic contribution analysis was conducted using IMPLAN (Impact Analysis for Planning), an input-output modeling software, and 2017 IMPLAN data, applying the Analysis-by-Parts (ABP) technique. IMPLAN does not have a distinct sector for wood-based biomass power generation; instead, it includes this activity within the broader “Electric power generation using biomass” sector (Sector 45 in the cloud version of 2017 IMPLAN dataset). This sector also encompasses other biomass sources such as agricultural byproducts, landfill gas, municipal solid waste, black liquor, and sludge waste. To isolate the economic contributions of wood-based biomass specifically, the ABP method was employed. ABP enables the creation of a customized sector based on a defined budgetary spending pattern and labor income profile.

Supplementary data for this analysis were sourced from a mail survey of biomass power generation facilities across the 20-state study region, conducted by the Michigan Department of Natural Resources in Fall 2022, along with a review of relevant literature on wood-based

biomass power generation in the U.S. All economic contribution estimates presented in this report are expressed in 2017 dollars.

In 2017, fourteen of the twenty states in the study region generated electricity from wood and wood-derived fuels, producing a total of 10.04 million megawatt-hours (MWh). Delaware, Illinois, Indiana, New Jersey, Rhode Island, and West Virginia did not generate any electricity from these sources during that year. Based on a mail survey of biomass power plants conducted in the region, the average cost of electricity generation using wood-based biomass was estimated at $63 per MWh.

The wood-based biomass power generation industry directly employed 722 people and contributed $632 million in direct output to the regional economy in 2017. When accounting for indirect and induced (ripple) effects, the industry supported a total of 8,242 jobs and generated $1.61 billion in total economic output. In terms of tax contributions, the industry added $100.5 million to state and local revenues and close to $117.0 million to federal revenues.

The social accounting matrix for industry output was estimated at 2.6, indicating that every $1 million in direct industry output supported an additional $1.6 million in output across the broader regional economy. The top three industries most affected by the wood-based biomass power generation industry in terms of employment were commercial logging, electric power generation using biomass, and support activities for agriculture and forestry.

Glossary

Biomass: Renewable organic material that comes from plants and animals. It contains stored chemical energy from the sun. Sources of biomass for energy include wood and wood processing waste, agricultural crops and waste materials, biogenic materials in municipal solid waste, animal manure and human sewage.

Woody Biomass: It encompasses biomass obtained from the trees and woody plants, including limbs, tops, needles, leaves, and other woody parts, grown in a forest, woodland, or rangeland environment, that are the byproducts of forest management.

Biopower: Biopower technologies convert biomass fuels into heat and electricity. There are three main methods of releasing the energy stored in biomass to produce biopower: burning, bacterial decay and conversion to gas/liquid fuel.

Net Electric Power Generation: Generation is a measure of electricity produced over time. Some portion of the electricity produced by the power plants is used internally to operate these plants. Net generation excludes electricity use for power plant operations.

Power Plant Capacity: It is the maximum level of electricity that a power plant can supply at a specific point in time under certain conditions.

Nameplate Capacity: Nameplate generator capacity is determined by the generator's manufacturer and indicates the maximum output of electricity a generator can produce without exceeding design thermal limits.

Kilowatt (kW): A standard unit for measuring electricity. 1 kW is equivalent to 1,000 Watts.

Kilowatt hour (kWh): One kW of electricity generated or used for one hour.

Megawatt (MW): 1,000 kW

Megawatt hour (MWh): 1,000 kWh

Economic Contribution Terms

Direct effects/contributions: The economic activities (e.g., output, employment, labor income, and value-added) associated with an industry or sector in the study area. These can describe the current economic sectors or changes in those sectors.

Employment: The number of full- and part-time jobs associated with an industry plus self-employed individual.

Indirect effects/contributions: The impact of local industries purchasing goods and services from other industries, leading to others' outputs, employment, and labor income.

Induced effects/contributions: The impact of labor income (employee compensation and proprietor income) via goods and services purchased due to direct and indirect spending by industries.

Labor income: The dollar total of employee compensation and proprietor income; the latter is associated with self-employed individuals.

Output: The dollar measure of production within an area; it is also viewed as sales.

Type I multiplier: These multipliers are derived by dividing the sum of direct and indirect effects by the direct effects.

Social Accounting Matrix (SAM) multipliers: These multipliers are derived by dividing the sum of direct, indirect, and induced effects by the direct effects. The social accounts include payments made between households, households and government, and more. These are available for output, employment, labor income, and value-added and are used to assess effects of changes in industry activity (i.e., "ripple effects").

Total effects/contributions: The sum of direct, indirect, and induced effects.

Value-added (also known as gross state product, or GSP): The sum of labor income, other property income (e.g., rents and profits), and indirect business taxes (e.g., excise and sales taxes). It is the difference between an industry's total output and the cost of its intermediate inputs. The sum of value-added for all economic sectors within the state equals the total GSP.

Introduction

Global and U.S. interest in renewable energy sources for power generation has grown in response to mounting concerns over the environmental, health, and economic impacts of climate change, which are intensified by continued dependence on fossil fuels. In addition to reducing greenhouse gas emissions, renewable energy contributes to energy security and supports local and rural economic development.

In 2022, electricity accounted for 20.4% of final energy consumption globally which is an increase of 3 percentage points from 2010 (Enerdata, 2023). This rise is driven by growing electricity demand across the industrial, residential, and service sectors, as well as the increased adoption of electric vehicles in road transportation (Enerdata, 2023). Despite this shift, the electricity sector remains a major emitter, releasing 13 gigatonnes of CO_2 in 2021, more than one-third of global energy-related emissions (IEA, 2022).

Expanding the use of renewable energy in electricity generation is a key strategy to reduce these emissions and move toward a more sustainable and resilient energy system.

In 2022, electricity consumption in the United States reached a record 4.05 trillion kilowatt-hours—approximately 14 times higher than consumption levels in 1950 (U.S. Energy Information Administration, 2023a). This upward trend is expected to continue in the coming decades, as electricity consumption is closely tied to technological advancement and economic growth. To meet growing demand, U.S. electricity generation has steadily increased over time, reaching a peak of 4.24 trillion kilowatt-hours in 2022 (U.S. EIA, 2023b) (Figure 1).

As of 2022, fossil fuels—namely coal, natural gas, and petroleum—accounted for 60% of total electricity generation, while nuclear energy contributed 18% and renewable sources made up 22% (U.S. EIA, 2023b). Notably, the share of renewable energy in the electricity mix has risen

significantly over the past decade, with substantial growth observed in the wind and solar energy sectors (Figure 2).

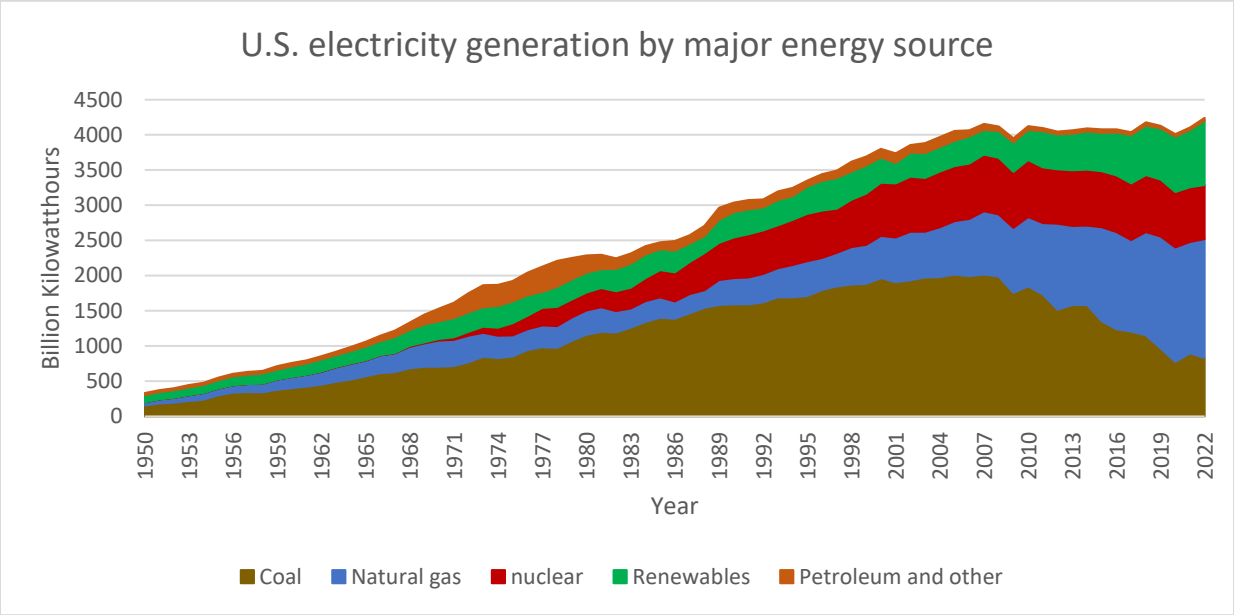

Figure 1. U.S. electricity generation by major energy source from 1950 to 2022. (U.S. Energy Information Administration 2023b)

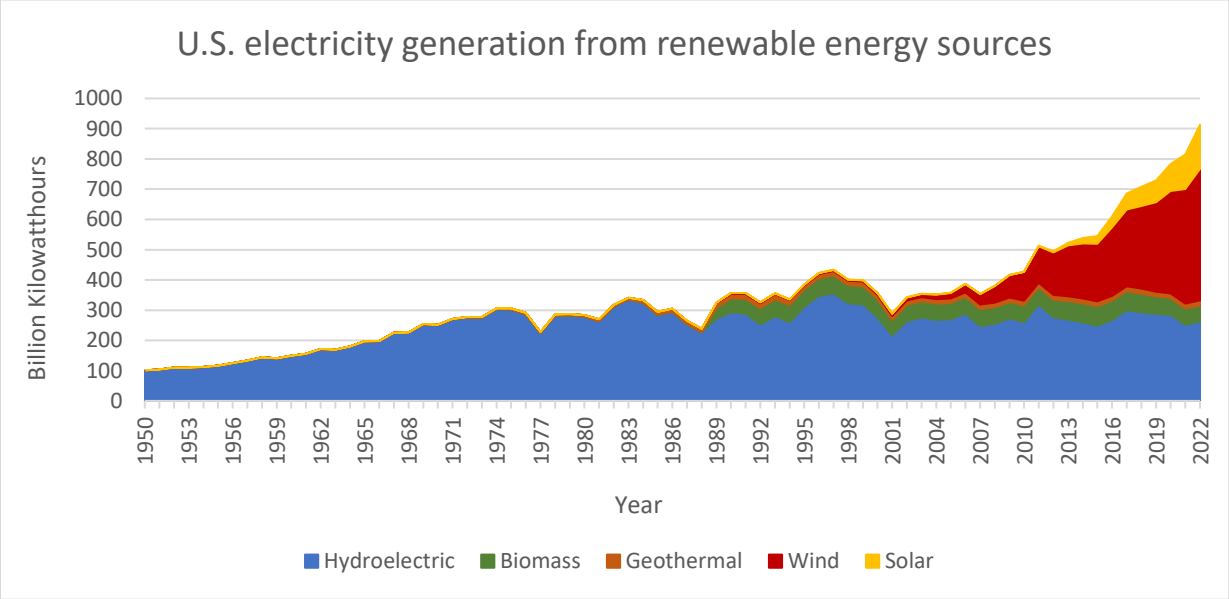

Figure 2. U.S. electricity generation from renewable energy sources from 1950 to 2022. (Source: U.S. Energy Information Administration 2023b).

Biomass is a key renewable energy source used for facility heating, electric power generation, and combined heat and power (CHP) systems. It encompasses a wide range of organic materials, including wood and wood processing residues, agricultural crops and waste, biogenic components of municipal solid waste, animal manure, and human sewage (U.S. EIA, 2023c). Biomass can be converted into electricity and heat through several methods, with direct combustion being the most common. Other technologies include gasification, pyrolysis, and anaerobic digestion (U.S. EIA, 2023c).

In 2022, biomass-based electricity accounted for 1.3% of total U.S. electricity generation from all energy sources, with woody biomass making up the largest share (Figure 3) (U.S. EIA, 2023d). Specifically, approximately 68.4% of electricity generated from biomass that year came from wood and wood-derived fuels (U.S. EIA, 2023d).

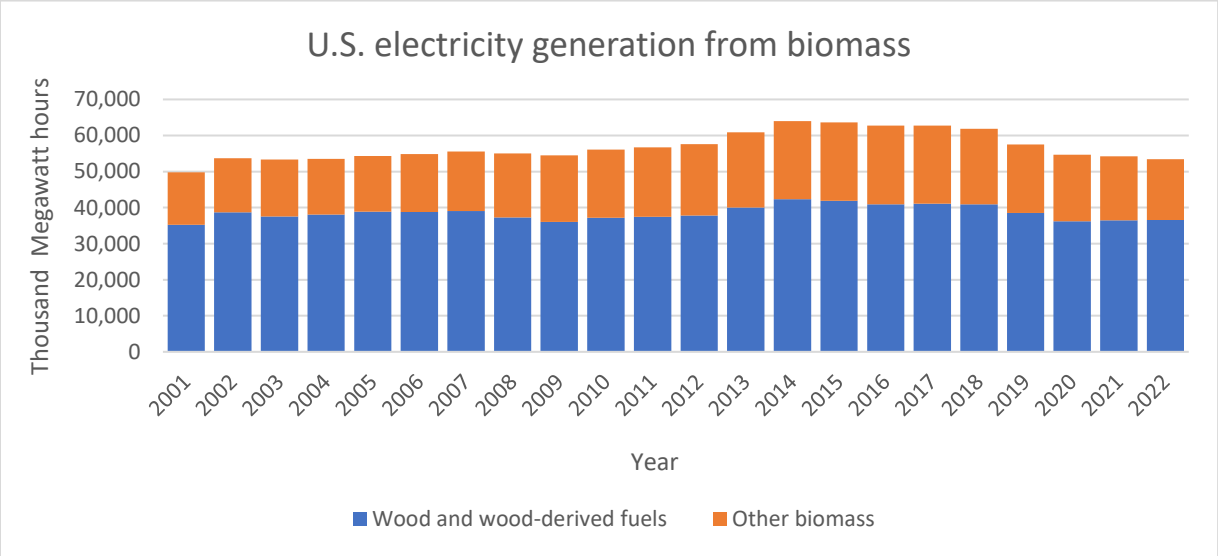

Figure 3. U.S. electricity generation from biomass, 1950 to 2022. (Source: U.S. Energy Information Administration 2023d).

One of the key advantages of biomass for power generation is its ability to provide baseload, or firm, power unlike intermittent renewable sources such as solar and wind (Bracmort, 2015). The use of woody biomass for electricity generation offers a range of societal, economic, and environmental benefits. Compared to fossil fuels, wood-based biomass helps reduce greenhouse gas emissions, supports income and job creation in rural, forest-dependent communities, and decreases the volume of waste sent to landfills. Additionally, when harvested

and utilized according to sustainability standards, it can contribute positively to forest health (National Renewable Energy Laboratory, 2023; Gan and Smith, 2007).

Substantial volumes of woody biomass are removed annually by private, state, and federal forest managers as part of efforts to protect forests from wildfires, insect infestations, diseases, and invasive species. Additional sources of woody biomass include natural disasters such as hurricanes and tornadoes, as well as urban tree cleanup and maintenance activities (USDA Forests and Rangelands, 2023). In the absence of viable market outlets like biomass power generation, much of this material is left to decay, is burned in place, or is sent to landfills (USDA Forests and Rangelands, 2023).

Biomass power generation provides a critical use for this material, helping to reduce open burning and thereby improve air quality, visibility, and public health. It also helps offset the high costs associated with forest management, hazardous fuel reduction, ecological restoration, and post-harvest cleanup by assigning economic value to non-merchantable and low-value wood (Page-Dumroese et al., 2022). In doing so, biomass energy contributes indirectly to wildfire risk reduction, while supporting the conservation of wildlife habitat and watersheds and promoting economic development in rural communities (USDA Forests and Rangelands, 2023).

Additionally, the wood products manufacturing sector—including industries that produce lumber, furniture, pallets, and paper—generates significant volumes of wood residues. Without strong market demand, these residues are often underutilized. Notably, less than 50% of a harvested tree typically becomes part of the final product, leaving substantial leftover material that can be repurposed for energy generation (Abbuelh et al., 2004).

Biomass-based electricity production typically requires significant upfront investment; however, because these facilities often rely on locally sourced feedstock, they can have a stronger impact on local income compared to fossil fuel-based power generation (Faaij et al., 1998). Additionally, when managed sustainably, woody biomass power may be considered carbon neutral. This is because the CO_2 emitted during power generation displaces emissions from fossil fuels and can be reabsorbed by new tree growth (IEA, 2022).

However, to truly qualify as carbon neutral, the entire biomass supply chain must be evaluated including emissions from harvesting, processing, transportation, and energy conversion (IEA, 2022). Only by accounting for all life cycle emissions can the net climate benefit of biomass energy be accurately assessed (IEA 2022).

A recent study by Mirzaee et al. (2022) examined the relationship between biopower generation and forest conditions in the Northeastern United States, focusing on timberland structure indicators and carbon stocks from 2005 to 2017. Using Forest Inventory and Analysis (FIA) data, the authors assessed areas surrounding wood-using and coal-burning power plants. The study found that wood-using power plants in the Eastern U.S. had no negative net impact on the number of live and dead trees or on associated carbon stocks. In fact, results indicated a positive temporal trend in both the number of live trees and carbon stored in live trees in regions with ongoing biopower generation.

These findings suggest that, when implemented under sustainability standards, wood-based biopower generation can play a constructive role in supporting zero-emission renewable energy goals while maintaining or enhancing forest carbon stocks.

Despite the numerous benefits of using biomass for energy generation, biomass-based electricity production in the U.S. has remained relatively stagnant over the past two decades (Figure 3). According to the Energy Information Administration (U.S. EIA 2023d), there were 824 biopower-generating facilities across the country, of which 247 were wood-based facilities in 2017 (Figure 4).

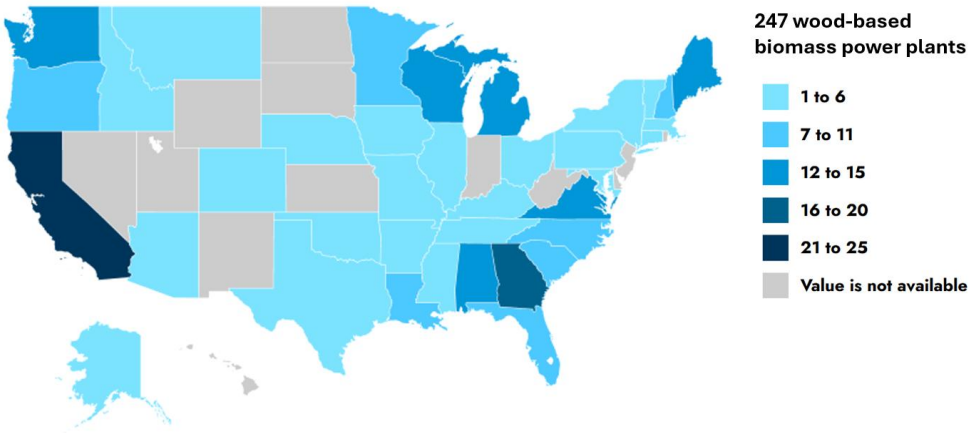

Figure 4. Map depicting the distribution of 247 biomass power plants using wood and wood-derived fuels in 2017 (Source: U.S. Energy Information Administration 2023d).

Estimating the economic contributions of the wood-based biomass power generation industry helps highlight its ripple effects on the regional economy and can support efforts to sustain and expand the industry. In 2022, the Michigan Department of Natural Resources (MI DNR) Forest Resources Division commissioned a research team from the Michigan State University Department of Forestry along with collaborators from North Carolina State University, Oklahoma State University, the University of Idaho, SUNY College of Environmental Science and Forestry, and Michigan Biopower to conduct an economic contribution analysis of the wood-based biomass power generation industry. This analysis covered 20 Northeast and Midwest U.S. states, along with California, Georgia, and Virginia, for the 2017 and 2022 calendar years.

The 20-state region includes: Connecticut, Delaware, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia, and Wisconsin. Of these, fourteen states were designated as participating states in the study: California, Connecticut, Georgia, Illinois, Maine, Massachusetts, Michigan, Minnesota, New Hampshire, New York, Pennsylvania, Vermont, Virginia, and Wisconsin.

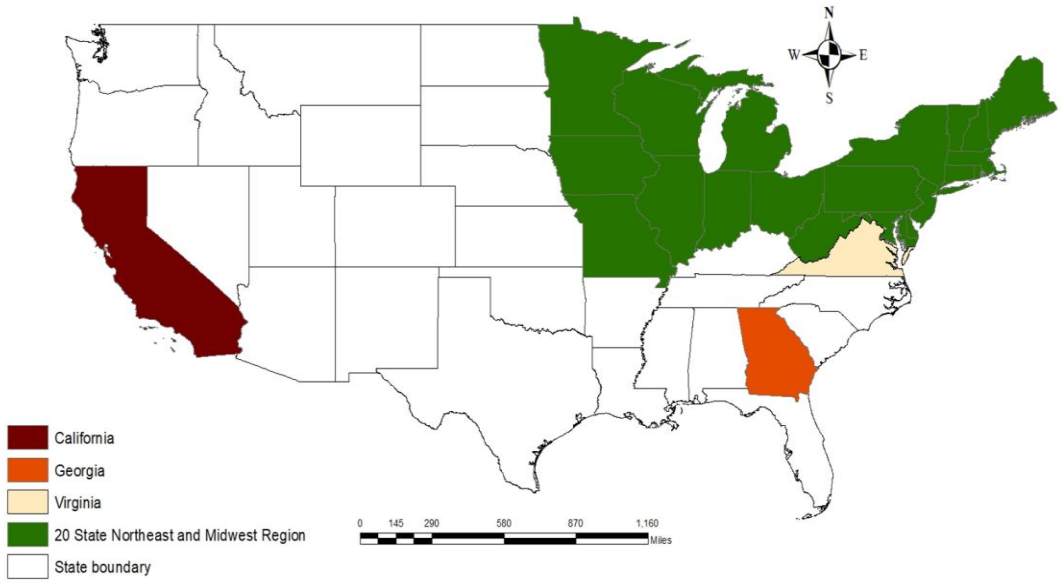

Figure 5. Study area illustrating 20 Northeast-Midwest states and California, Georgia, and Virginia.

Following the acceptance of the project proposal, the Michigan State University research team conducted multiple meetings with project partners to reach consensus on the analytical methods to be used, the supplementary data required for the economic contribution analysis, and the structure of the regional and state-level reports. This report presents the findings from the economic contribution analysis of the wood-based biomass power generation industry in the twenty-state region for the year 2017. In addition to the regional analysis, individual state-level reports were prepared for each of the participating states as part of the project.

The sections that follow outline the project objectives; provide an overview of electric power generation and forest resources across the twenty-state study region in 2017; describe the methodology used for the economic contribution analysis; and present and discuss the key findings.

Objectives of the project

1. Conduct an economic contribution analysis of wood-based biomass power generation industries for 20 Northeast Midwest U.S. states- as a region, and 14 participating states including California, Georgia and Virginia using supplementary data collected by the project partners.
2. Produce a report documenting the methods used for analysis for the Northeast-Midwest region and each participating state detailing the economic contributions of the wood-based biomass power generation sector using 2017 and 2022 impact analysis for planning (IMPLAN) data.
3. Disseminate information about the methods adopted and findings obtained with concerned stakeholders and the public via webinars and presentations.
4. Convene a meeting of economists familiar with power generation technologies to discuss and develop an analysis method for producing comparable estimates of economic valuation among the most prevalent power generation technologies – coal,

natural gas, nuclear, geothermal, solar, and wind power generation – and woody biomass power generation.

5. Document the resulting recommendations and consensus method in a publishable journal manuscript draft.

Electric power generation in the Northeast and Midwest in 2017

In 2017, approximately 1.42 billion megawatt hours of electricity were generated in the twenty-states study region. Coal was the major source of electricity generated across the region followed by nuclear and natural gas respectively (Figure 6). Out of the total electricity generated, approximately 0.7% or 10.04 million Megawatt hours were produced using wood and wood-derived fuel (Figure 6) (US EIA 2023d).

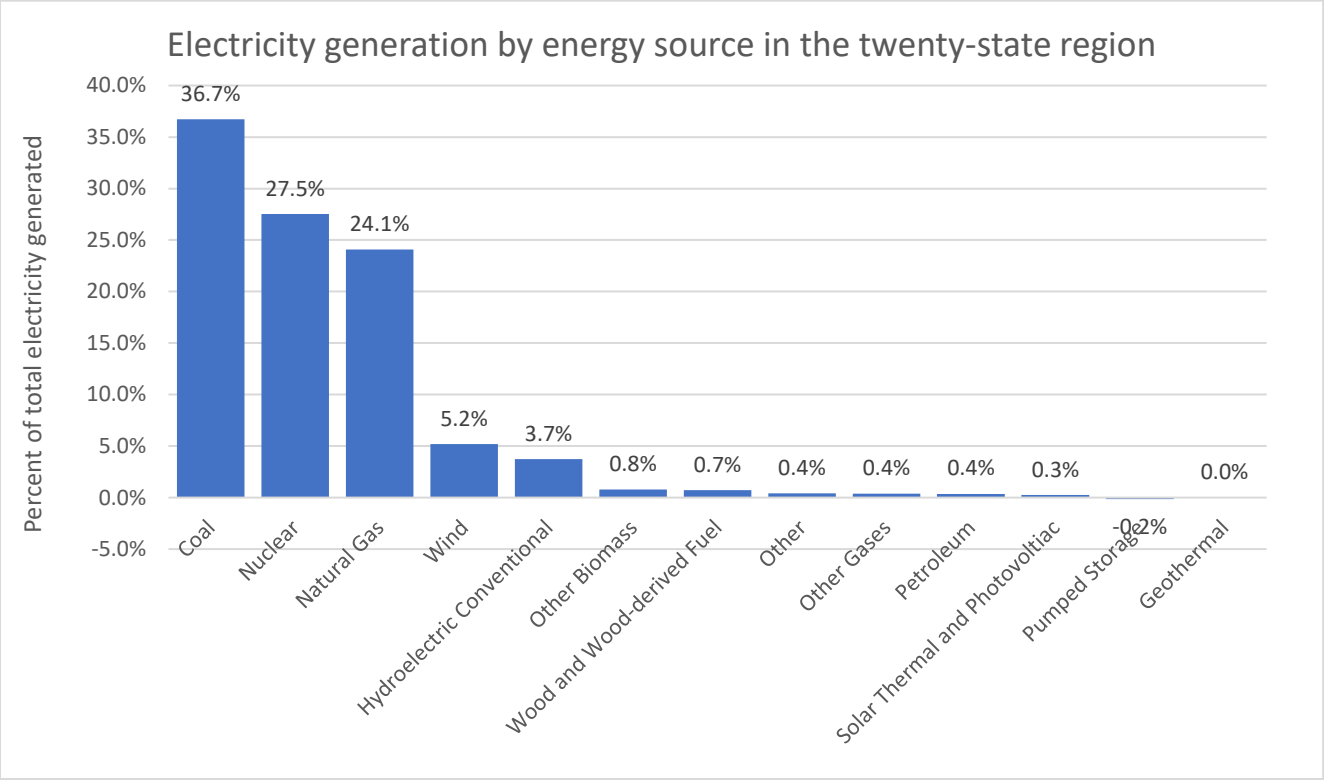

Figure 6. Percentage of total electricity generated in the twenty-state region in 2017 by energy source (Source: U.S. Energy Information Administration 2023d).

Collectively the electric power generation industry employed 187,306 people in 2017 across the region which is equivalent to 0.24% of total jobs in the region the same year (IMPLAN 2017). The direct economic effects resulting from various power generating industries in the study region including biomass are listed in Table 1.

Table 1. The direct economic effects of power generating industries in the twenty-state Northeast and Midwest region based on online version of 2017 IMPLAN data.

IMPLAN Sector Code (Electric Power Generation)	Energy Source	Employment	Labor Income	Value-Added	Output
			(Millions of 2017 dollars)		
39	Hydroelectric	3,837	823	1,522	2,941
40	Fossil fuel	44,137	7,666	26,418	62,477
41	Nuclear	22,956	4,691	11,615	23,290
42	Solar	1,366	337	476	806
43	Wind	2,227	491	1,766	3,615
44	Geothermal	36	9	17	28
45	Biomass	1,594	294	536	1,397
46	All other	760	176	84	254
47	Electric power transmission and distribution	110,393	17,890	64,875	160,191
	Total electric power generation, transmission, and distribution	**187,306**	**32,378**	**107,309**	**255,000**
	Total All Sectors	**78,404,147**	**$4,999,945**	**$8,066,286**	**14,322,205**

Forest resources in the Northeast and Midwest

The twenty-state Northeast and Midwest region is heavily forested, with forestlands covering approximately 43% of the total land area equivalent to 174.3 million acres (USDA Forest Service, Evalidator, 2023). Of this forested area, 94% is classified as timberland, meaning it is capable of producing commercial timber. Forest ownership in the region is predominantly private, accounting for 73% of total forestland, followed by state and local governments (19%) and the federal government (8%) (Figure 7).

The dominant forest type groups in the region include Oak/Hickory and Maple/Beech/Birch, followed by Spruce/Fir and Aspen/Birch forests (Table 2).

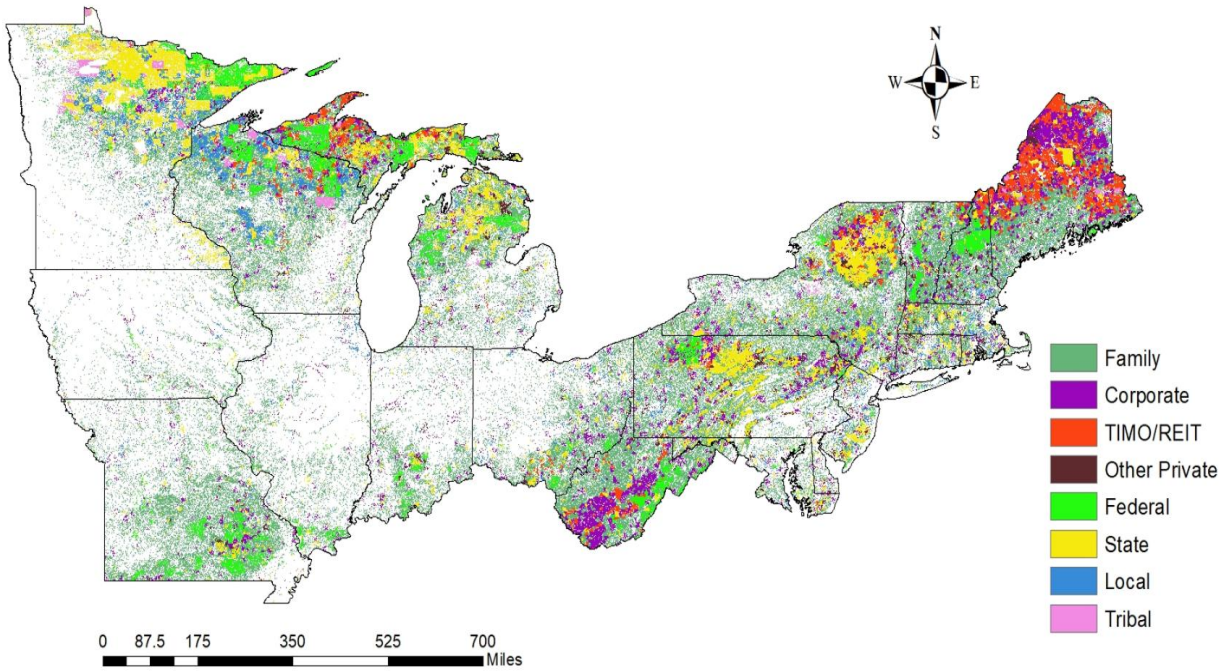

Figure 7. Forest ownership in the twenty-state study region (Data source: Sass et al. 2020).

Table 2. Forestland area in the twenty-state Northeast and Midwest region by forest type (Source: USDA Forest Service, Evalidator 2023).

Forest Type Group	Acres	Percentage
Oak / hickory group	62,739,804	36%
Maple / beech / birch group	45,041,827	26%
Spruce / fir group	15,894,581	9%
Aspen / birch group	15,241,156	9%
Elm / ash / cottonwood group	12,627,818	7%
White / red / jack pine group	9,626,093	6%
Oak / pine group	5,774,755	3%
Others	7,331,740	4%
Total	174,277,773	100%

The merchantable bole volume of live trees on timberlands in the Northeast and Midwest are estimated to be 336.03 billion cubic feet (Table 3). The average annual net growth is 6.62 billion cubic feet, annual removals are 3.01 billion cubic feet, and annual mortality is 3.03 billion cubic feet. Annual growth in the timberlands exceeded the removals by a ratio of 2.2, meaning that for each cubic foot of timber harvested in the region, about 2.2 cubic feet of timber grew in the timberlands. However, this ratio varies by ownership type. The growth to removals ratio in national forests is 4.4. In private forests, it is 2.5, 2.0 in the case of forests under state and local government, and 1.5 in forests under other federal ownership (Table 3). This suggests variation in management focus on timberlands owned by different forest ownership types. Across the region, the annual removals are close to 1% of the standing volume and annual mortality in the timberlands are greater than annual removals (Table 3).

Table 3. Characteristics of regional growing stock in 2023 (million cubic feet) (Source: USDA Forest Service, Evalidator 2023).

Ownership	Net Volume	Annual Net Growth	Annual Removals	Annual Mortality	Growth/Removals
Total	336,028	6,622	3,010	3,031	2.2
National Forest	24,926	397	90	240	4.4
Other federal	2,719	43	29	29	1.5
State and local	49,975	950	481	478	2.0
Private	258,409	5,226	2,118	2,265	2.5
Not available		6	292	19	0.0

Methods

The analysis was conducted using IMPLAN (Impact Analysis for Planning) software and 2017 IMPLAN data, employing the Analysis-by-Parts (ABP) technique. This method was selected because it enables the creation of a customized industry sector based on detailed information about the sector's budgetary spending patterns and labor income (Lucas, 2022).

IMPLAN does not currently offer a distinct sector for wood-based biomass power generation. Instead, this activity is included within the broader "Electric Power Generation using Biomass" sector, which encompasses power generation from a variety of biomass sources, including agricultural byproducts, landfill gas, municipal solid waste, black liquor, sludge waste, and woody biomass. To isolate the economic contributions of wood-based power generation specifically, the ABP technique was applied. The estimated economic contributions are reported in terms of full- and part-time employment, industry output, value-added, and labor income. Industry spending patterns for the woody biomass power generation sector were primarily obtained from Dahal et al. (2020) and, where applicable, corroborated or supplemented with data collected through a mail survey of biomass power generation facilities located within the study region.

In Fall 2022, the Michigan Department of Natural Resources (MDNR) conducted a mail survey targeting 120 biomass power facilities located in the 20-state study region, as well as in California, Georgia, and Virginia, to collect financial and resource utilization data for the year 2017. A total of 11 responses were received, yielding a response rate of 9.2%. Of these, nine responses were from facilities within the 20-state region and were included in the analysis. The low response rate is likely attributable to the reluctance of facilities to disclose proprietary business information.

The survey asked respondents to report on several key metrics, including the number of employees, whether they produced electricity using woody biomass in 2017, the amount of electricity generated from woody biomass, the volume of wood consumed (in tons), fuel costs, employee compensation, and total production costs. Descriptive statistics derived from the survey responses are presented in Table 4.

Table 4. The descriptive statistics of the data collected through the mail survey of biomass power generating industries in the study region in 2017 (Source: Michigan Department of Natural Resources).

S.N.	Information Collection Category	Summary statistics (Number of Respondent Biopower Industries)	
		Total	Average
1.	Number of Employees	217 (N=8)	27 (N=8)
2.	Electricity Produced	2.0 million MWH (N= 9)	221,746 MWH (N=9)
3.	Wood Consumed	2.4 million tons (N=9)	266,999 tons (N=9)
4.	Employee Compensation (US$)	$12.8 million (N=5)	$2.6 million (N=5)
5.	Fuel Purchases (US$)	62,233,386 (N=8)	7,779,173 (N= 8)
6.	Total Cost (US$)	106.3 million (N=8)	13.3 million (N=8)
7.	Cost/MWH ($/MWH) weighted by production size)		62.94

Each of the respondent biomass power generating industries in the study region employed on average 27 employees and generated on average 221,746 MWH of electricity in 2017. The range of power produced by the respondents spanned from a high of 420,497 MWH to a low of 147,784 MWH. The respondents consumed on average 266,999 tons of woody biomass per business at an average cost of $25.7 per ton of wood. Fuel cost as a percentage of the total cost reported by the respondents ranged from a low of 31% to a high of 77%, with an average of 56% when weighed by the size of production. Similarly, employee compensation as a percentage of total cost ranged from a high of 20% to a low of 14%, with an average of 17% when weighed by the size of production. Total cost per MWH of electricity produced ranged from a high of $84/MWH to a low of $40/MWH with the average of $63/MWH when weighed by the size of production. The percentage breakdown of employee compensation and fuel cost as a percentage of the total cost of production obtained from our mail survey closely resemble those obtained by Dahal et al. (2020) in which the authors noted employee compensation to be 15.6% and biomass cost to be 58.6% of the total operation and maintenance cost of wood-

based biomass power generating industry. Analysis of the industry spending pattern of respondent biomass power industries in terms of some other categories suchas gasoline retail, consulting fee, supplies and insurance also resembled those used by Dahal et al. 2020. Therefore, to estimate the economic contribution of wood-based biomass power generating industry in the study region, we adopted the spending pattern of the wood-based biomass power industry proposed by Dahal et al. 2020. The only slight modification in industry spending pattern was made in sector 20 (Natural gas) spending as per the responses obtained from the mail survey in the study region.

The average operation and maintenance expenditure for the wood-based biomass power generation industry used for the economic contribution analysis for the twenty-state study region is listed in Table 5. Information about the total electricity produced by the electric power generation industry using wood and wood-derived fuels in 2017 was obtained from US EIA (2023d). Fourteen out of the twenty states in the study region produced electricity using wood and wood-derived fuels in 2017 which amounted to a total of 10.04 million Megawatt hours (MWh). Cost per MWh of electricity produced using wood and wood-derived fuel was obtained from the mail survey of biomass power plants located in the study region. It was estimated to be $63/MWh (Table 4).

Direct output from the wood-based biomass power generation industry in the study region was estimated at $632.3 million, calculated by multiplying total regional electricity production by the unit cost of electricity generated from woody biomass. Of this output, 61.7% represented intermediate input used within the industry itself, while 38.3% constituted value-added. The value-added share was further distributed into employee compensation (7.3%), proprietor income (13.8%), other property-type income (8.4%), and taxes on production and imports (1.9%). These percentages were based on the gross absorption and value-added structure of the biomass power generation industry (IMPLAN Sector 45, cloud version).

Direct employment was estimated by dividing total direct output in 2017 by the output-per-employee ratio for Sector 45 in the IMPLAN model for the twenty-state region. This calculation

yielded an estimated 722 direct jobs in the wood-based biomass power generation industry in the study region in 2017.

When estimating the economic contribution of the biomass power generation industry in IMPLAN using the ABP technique, the local purchase percentage (LPP) for all other items in the industry spending pattern except woody biomass, was set to default SAM value. For woody biomass, LPP was set to 100%. This is because all wood used by the biomass power generation industry is sourced locally as per the findings obtained from the mail survey (within 60 miles radius). Since it is not possible to precisely identify the location of production, transport, and purchase of other items included in the industry spending pattern for wood-based biomass power generation industry, LPP was set to default SAM values for those items. Like Dahal et al. (2020), we estimated total taxes (including emission fee) to be 1.85% of total operation and maintenance cost, which amounted to $11.6 million. This was modeled separately, and the resulting indirect and induced effects obtained from tax contributions were added to the total economic contribution summary for the region.

Table 5. Average operation and maintenance expenditures in 2017 US$ for wood-based biomass power generating industry (as per Dahal et al. 2020 and supplemented with information collected from mail survey of wood-based power generating industry in the study region).

IMPLAN Sector	Cost category (sector)	MM US$ per year	%
16	Biomass	7.94	58.6%
20	Natural Gas	0.01	0.05%
39	Utilities	0.38	2.8%
49	Water	0.22	1.6%
60	Building expenses	0.06	0.4%
154	Oil and diesel	0.11	0.8%
162	Chemical	0.17	1.3%
167	Supplies (consumable, urea, ammonia)	0.26	1.9%
384	Office supplies and expenses	0.03	0.2%
408	Gasoline (retail)	0.02	0.1%
433	Communication	0.03	0.2%
444	Insurance	0.21	1.6%
453	Equipment rental	0.01	0.1%
457	Outside support services (water treatment, vendor services)	0.08	0.6%
462	Consulting fees	0.05	0.4%
470	Office administrative service	0.14	1.0%
474	Travel and entertainment	0.02	0.1%
476	Janitorial	0.04	0.3%
479	Ash freight and waste management	0.4	3.0%
512	Vehicle repair	0.02	0.1%
515	Maintenance	0.98	7.2%
50001	Employee compensation	2.12	15.6%
	Total taxes (including emission fee)	0.25	1.8%
	Total operation and maintenance cost	13.55	100.0%

Results

In 2017, the twenty Northeast-Midwest states generated a total of 10.03 million MWh of electricity from wood and wood-derived fuels. Wood-based biopower generation was heavily concentrated in a handful of states (Table 6). Maine, Michigan, New Hampshire, Minnesota, and Wisconsin were the leading producers, together accounting for 77% of total regional generation. Maine alone produced 2.5 million MWh and generated $159.3 million in direct output while supporting 198 jobs, the largest contribution of any state. Michigan and New Hampshire followed with 1.50 and 1.47 million MWh, respectively, supporting 106 and 100 direct jobs respectively.

Mid-sized producers, including New York, Pennsylvania, Vermont, Ohio, and Connecticut, contributed more modest amounts, ranging from 208 to 620 thousand MWh, and supported between 9 and 44 direct jobs. Massachusetts and Missouri recorded some amount of electricity generation from wood and wood-derived fuels but 2017 IMPLAN models for these two states did not show measurable modeled employment for this sector, reflecting either very small facilities, limited reporting, or minimal economic activity captured in IMPLAN. Several other states such as Delaware, Illinois, Indiana, New Jersey, Rhode Island, and West Virginia reported no utility-scale wood-based biopower generation in 2017.

Overall, the data illustrates a regional industry dominated by a few states with long-standing biomass power infrastructure, while most other states contribute only marginally to overall production and employment.

Table 6. Electricity generation, direct economic output, and direct employment associated with wood and wood-derived biomass power generation across Northeast and Midwest states in 2017.

State	Electricity generated (Thousand Megawatt Hours)	Direct Output (2017 Dollars)	Direct Employment
Connecticut	208	$13,108,725	16
Iowa	2	$119,070	0.2
Massachusetts	131	$8,241,219	
Maryland	120	$7,581,294	4
Maine	2,529	$159,322,401	198
Michigan	1,508	$89,349,441	106
Minnesota	1,296	$81,653,166	106
Missouri	56	$3,550,932	
New Hampshire	1,472	$92,745,576	100
New York	620	$39,057,165	44
Ohio	258	$16,240,581	9
Pennsylvania	522	$32,910,444	41
Vermont	436	$27,467,433	36
Wisconsin	878	$55,288,863	52

Results obtained from the economic contribution analysis indicated that across the region, the wood-based biomass power generation industry directly employed 722 individuals in 2017 with a labor income of $133.0 million, value-added of $242.4 million, and an output or sales of $632.3 million in 2017 US dollars (Table 7). Including ripple effects, the industry supported a total of 8,242 jobs with $568.7 million in labor income. The industry contributed a total of $822.9 million in value-added and $1.61 billion in total output to the economy of the Northeast and the Midwest (Table 7). The top five industries affected in terms of employment by wood-based biomass power generation industry in the study region include commercial logging (IMPLAN sector 16), electric power generation using biomass (IMPLAN sector 45), support activities for agriculture and forestry (IMPLAN sector 19), commercial and industrial machinery and equipment repair and maintenance (IMPLAN sector 515), and hospitals (IMPLAN sector 490) (Table 8).

The Social Accounting Matrix (SAM) multiplier for industry output in the region was estimated at 2.6, indicating that every $1 million in output from the wood-based biopower industry supported an additional $1.6 million in economic activity across the broader regional economy. The SAM multipliers for employment, labor income, and value-added were estimated to be 11.4, 4.3 and 3.4 respectively. The relatively high employment multiplier compared to output, labor income, and value-added multipliers, reflect the biomass power industry's supply chain and spending patterns. It reflects the wood-based biomass power sector's dependence on labor-intensive upstream industries, especially commercial logging and forestry support services. These industries generate many jobs per dollar of spending, but with relatively modest wages and value added per worker. Additional induced effects in service industries and retail further increase job counts.

IMPLAN sector data confirm that the upstream industries supplying wood-based biopower are exceptionally labor intensive. In 2017, the commercial logging industry in the twenty-state Northeast Midwest region supported a total of 36,398 jobs and generated $3.45 billion in output, or 10.6 jobs per $1 million of output. Labor intensity is even higher for support activities for agriculture and forestry, which supported 136,532 jobs and $4.77 billion in output, equivalent to 28.6 jobs per $1 million of output. These industries generate large numbers of jobs relative to their output because they rely heavily on manual labor, small firms, and seasonal or part-time workers, while producing relatively modest value added per employee. Consequently, when biomass power plants purchase fuel from these sectors, the indirect and induced employment effects increase substantially raising employment multipliers even though multipliers for labor income and output remain comparatively modest.

The wood based biopower industry in our study region contributed approximately $110.5 million in annual state and local taxes and $117.0 million in federal taxes in 2017 (Table 9).

Table 7. Economic contributions of wood-based biomass power generation industry in the Northeast and the Midwest in 2017 US dollars using IMPLAN software and 2017 IMPLAN data.

States Included	Economic Contributions of Wood-based Biomass Power Generation Industry				
		Employment (Jobs)	Labor Income ($MM 2017)	Value-added	Output
Twenty States (CT, DE, IL, IN, IA, ME, MD, MA, MI, MN, MO, NH, NJ, NY, OH, PA, RI, VT, WV, and WI)	Direct Contributions	722	$133.0	$242.4	$632.3
	Indirect Contributions	4,556	$274.0	$299.4	$505.6
	Induced Contributions	2,964	$161.7	$281.1	$477.9
	Total Contribution	8,242	$568.7	$822.9	$1,615.8
	SAM Multiplier	11.4	4.3	3.4	2.6

Table 8. The top five industries affected in terms of employment by wood-based biomass power generation industry in the twenty-state region in 2017

	Industry affected (IMPLAN Sector)	Impact			
		Direct	Indirect	Induced	Total
1	Commercial logging (16)	0	2,923	0	2,923
2	Electric power generation – Biomass (45)	722	0	0	722
3	Support activities for agriculture and forestry (19)	0	415	2	417
4	Commercial and industrial machinery and equipment repair and maintenance (515)	0	246	5	251
5	Hospitals (490)	0	0	158	158

Table 9. Tax contributions of wood-based biomass power generation industry in 2017 US dollars ($MM) using 2017 IMPLAN data.

Impact	Sub County General	Sub County Special Districts	County	State	Federal	Total
Direct	$13.8	$12.1	$5.9	$26.7	$28.3	$86.8
Indirect	$4.4	$3.3	$1.8	$13.6	$51.4	$74.5
Induced	$6.4	$5.2	$2.6	$14.7	$37.3	$66.2
Total	$24.5	$20.6	$10.2	$55.1	$117.0	$227.5

Summary

This study assessed the economic contributions of wood-based biomass power generation industry in the twenty-state Northeast and Midwest U.S. region using IMPLAN, an input-output analysis software and 2017 IMPLAN data. It provides a snapshot of the economic effects of wood-based biomass power generation industry in terms of employment generated, value-added contributed and output produced using analysis by parts technique. The ABP technique was used to separate the economic contributions of wood-based biomass power generation from the contributions of biomass power generation in general, which also includes biomass sources other than wood and wood-derived fuel. The wood-based biomass power generation industry in the region was found to directly support 722 jobs and contribute $632 million in output to the regional economy. Including indirect and induced effects, the industry contributed a total of 8,242 jobs and $1.6 billion in output to the economies of the Northeast and Midwest U.S. states.

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