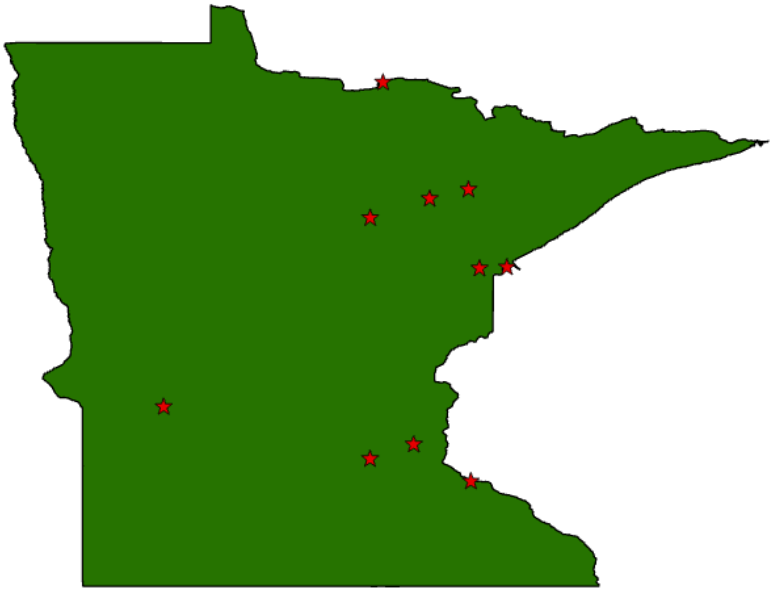
Economic Contributions of Wood-based Biomass Power Generation Industries in Minnesota: 2017 Version



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Executive Summary

Decarbonization of the electricity sector calls for a greater reliance on renewable energy sources including biomass for generating electricity. In 2022, approximately 31% of the total electricity generated in Minnesota came from renewable energy sources, 27% from coal, 24% from nuclear power, and 18% from natural gas (U.S. Energy Information Administration, 2023a). Of the total renewable electricity generated within the state, the majority came from wind energy (~75%), followed by solar (~13%), biomass (~7%), and others respectively. About two-thirds of the electricity produced using biomass came from wood and wood-derived fuel (U.S. Energy Information Administration, 2023a). Woody biomass is unique in that it is one of the few renewable energy sources that can provide 24/7 baseload power. Wood-based biomass for energy reduces greenhouse gas emissions over traditional fossil fuels, generates income and employment opportunities in rural forest-dependent communities, provides the market outlet for unwanted materials, reduces the amount of garbage ending up in landfill sites, and has positive effects on forests' health if done sustainably.

This report provides an overview of electric power generation industries in Minnesota and estimates the economic contributions of wood-based biomass power generation industries on the state's economy. It is one of the 14 coordinated and comparable state reports produced across the country. The forest statistics information used in the report comes from the U.S. Forest Service's Forest Inventory and Analysis data, and the economic data come from the 2017 Impact Analysis for Planning (IMPLAN), a commercially available economic input-output (IO) model.

To help quantify the economic effects of wood-based biomass power generation industry on Minnesota's economy, the economic contribution analysis was conducted using impact analysis for planning (IMPLAN), an input-output modeling software, and 2017 IMPLAN data using the Analysis-by-Parts (ABP) technique. IMPLAN does not have a separate sector to represent the wood-based biomass power generation industry and incorporates it as a part of electric power generation using the biomass sector (noted by IMPLAN sector 45 in cloud version of IMPLAN data). This sector also includes other sources of biomass such as agricultural

byproducts, landfill gas, municipal solid waste, black liquor, and sludge waste. Hence, to estimate the economic contributions resulting from only the wood-based biomass portion of the total mix, the ABP method was used. APB allows the user to create a customized industry sector by using the information about that sector's budgetary spending pattern and labor income. The supplementary data for conducting the economic contribution analysis was obtained from the mail survey of biomass power generation industries located in the 20-state Northeast Midwest study region conducted by the Michigan Department of Natural Resources in the Fall of 2022 and a review of the existing literature on wood-based biomass power generation in the U.S. The economic contribution estimates presented in this report are expressed in 2017 dollars.

The cost per MWh of electricity produced using wood and wood-derived fuel for Minnesota was obtained from the mail survey of biomass power plants located in the twenty Northeast and Midwest U.S. states. It was estimated to be $63/MWh. In Minnesota, the wood-based biomass power generation industry directly employed 106 people and generated $82 million in direct output to the state's economy in 2017. Including ripple effects, the industry created a total of 1,274 jobs and contributed $199 million in total output to the state's economy. In terms of tax contributions, the industry generated ~$12 million at the state and local levels and ~$13 million at the federal level in 2017. The social accounting matrix multiplier for industry output was found to be 2.4, which means that for $1 million in output in the state's wood-based biopower industry, an additional $1.4 million in output was supported in the rest of the economy. In terms of employment, the top three industries affected by the state's wood-based power generation industry included the commercial logging industry, electric power generation using biomass industry, and support activities for agriculture and logging industry.

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 wastes, 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 by-products 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 portions 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 to 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 the 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 the 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

There is a growing interest in generating a greater share of electric power using renewable energy sources in the United States. This interest stems from increasing concerns over the negative environmental, human health, and economic effects of continued reliance on non-renewable fossil fuels for energy. Further, the emphasis on renewable electricity generation is important for ensuring energy security and for creating opportunities for local and rural development.

The U.S. electricity consumption has continuously risen over the years reaching a total of 4.05 trillion kilowatt hours in 2022 (US Energy Information Administration (EIA) 2023b). To keep up with the increasing demand, the U.S. electricity generation has also increased substantially over the years. In 2022, the U.S. generated a total of 4.24 trillion kilowatt hours of electricity (US EIA 2023c). The same year, the U.S. electric power industry accounted for approximately 33% of the total U.S. energy-related CO_2 emissions (US EIA 2023d). This is because most of the electricity produced in the country (60%) comes from fossil fuel sources such as coal, natural gas, and petroleum (US EIA 2023c). Approximately 18% of the electricity produced in 2022 was generated using nuclear energy and 22% using renewable energy sources (US EIA 2023c). Despite making considerable progress in transitioning to clean energy over the last two decades, the U.S. electricity sector still accounts for about a quarter of the U.S. climate pollution (Center for American Progress, 2023). Approximately 357 billion kilowatt hours of electricity were produced using renewable energy sources in the U.S. in 2000. By 2022, the amount of electricity produced using renewable energy sources increased to reach over 900 billion kilowatt hours (US EIA 2023e). This is an impressive increment. Nonetheless, for improved environmental outcomes associated with the electric power generation industry in the future, a greater share of electricity production in the country needs to come from renewable energy sources.

Over the years, state and local governments have played a pivotal role in promoting the use of renewable energy sources for producing electricity. This has been done through the implementation of focused sectoral strategies and incorporation of performance standards along with supporting policies (Center for American Progress, 2023). As of 2022, 36 U.S. states

and the District of Columbia have established a renewable portfolio standard (RPS) or a renewable energy goal, which are policies established for promoting the use of renewable energy sources for producing electricity. Additionally, some states have set clean energy targets or goals moving forward (U.S. EIA 2023f).

Approximately 31% of the total electricity generated in Minnesota in 2022 came from renewable energy sources, mostly wind energy. Of the total renewable energy generated, biomass contributed about seven percent with two-thirds of it coming from wood and wood-derived fuel (US EIA 2023a). Biomass is an important source of renewable energy that is used for facility heating, electric power generation, and combined heat and power generation. It includes a variety of materials, including wood and wood processing wastes, agricultural crops and waste materials, biogenic materials in municipal solid waste as well as animal manure and human sewage (US EIA 2023g). Biomass can be converted into electric power and heat through several different methods, the most common being direct combustion. Other methods include gasification, pyrolysis, and anaerobic digestion (US EIA 2023g). One of the primary benefits of using biomass for power generation is that it can provide baseload or firm power, unlike other renewable energy sources such as solar and wind (Bracmort 2016).

The utilization of woody biomass for power generation offers numerous societal, economic, and environmental benefits. Wood-based biomass for energy reduces greenhouse gas emissions over traditional fossil fuels, generates income and employment opportunities in rural forest-dependent communities, reduces the amount of garbage ending up in landfill sites, and has positive effects on forests' health if extraction is done following sustainability standards (National renewable energy laboratory 2023, Gan and Smith 2007). Substantial volumes of woody biomass are removed annually by private, state, and federal forestland managers in the process of managing forests to protect it against wildfires, insects, diseases, and invasive species. Additionally, woody biomass can also result from natural disasters such as hurricanes and tornadoes as well as urban cleanup activities (USDA Forests and Rangelands 2023). Most of the materials resulting from these management activities can decay or be burned in place or hauled to landfills in the absence of market outlet such as biomass power generation (USDA Forests and Rangelands 2023). Biomass power generation, therefore, offers an important

avenue for the disposal of woody biomass, thus contributing to improving air quality, visibility, and public health by reducing the smoke created by burning woody biomass. It also helps to offset the high costs of forest management activities, hazardous fuel treatment operations, restoration activities, and post-harvest cleanup operations by providing an economic value to nonmerchantable and low value wood (Page-Dumroese et al. 2022). Biomass power generation thus indirectly contributes to reduce wildfires and helps to preserve wildlife habitat and watersheds while creating economic opportunities for the communities (USDA Forests and Rangelands 2023). Additionally, when manufacturers of wood products make products such as lumber, furniture, pallets, and paper, they generate substantial amounts of residues that can be underutilized in absence of markets for such products. Less than 50% of the tree that is harvested ends up in the final product leaving a large volume of residues that can be used for energy generation (Abbuelh et al. 2004).

Since biomass-based electricity production requires a high initial investment and the facilities are likely to use local feedstock for energy production compared to electricity generation using fossil fuel sources, they are likely to have greater impacts on local income (Faaij et al. 1998). Besides, power generated from woody biomass, if managed sustainably, may qualify as carbon neutral, since CO_2 released during power generation is displacing CO_2 emissions from fossil fuels and can be sequestered through the production of additional trees (International Energy Agency 2022). However, to be considered truly carbon neutral, a full supply chain including all emissions associated with production, processing, transportation, and the use of biomass for energy production needs to be considered (International Energy Agency 2022).

Despite the above listed benefits of using biomass for energy generation, the use of woody biomass in electricity production in the U.S. in general (Figure 1) and Minnesota more specifically has remained almost stagnant over the past two decades. In Minnesota, woody biomass contributed about 1.0% of the total electricity produced in-state in 2000. In 2010, it contributed about 1.7% and in 2022, about 1.5% of the total electricity produced in the state (US EIA 2023h).

In 2017, there were a total of 247 biopower facilities using wood and wood-derived fuels across the county (US EIA 2023i). Out of these, 10 were located in Minnesota (Figure 2).

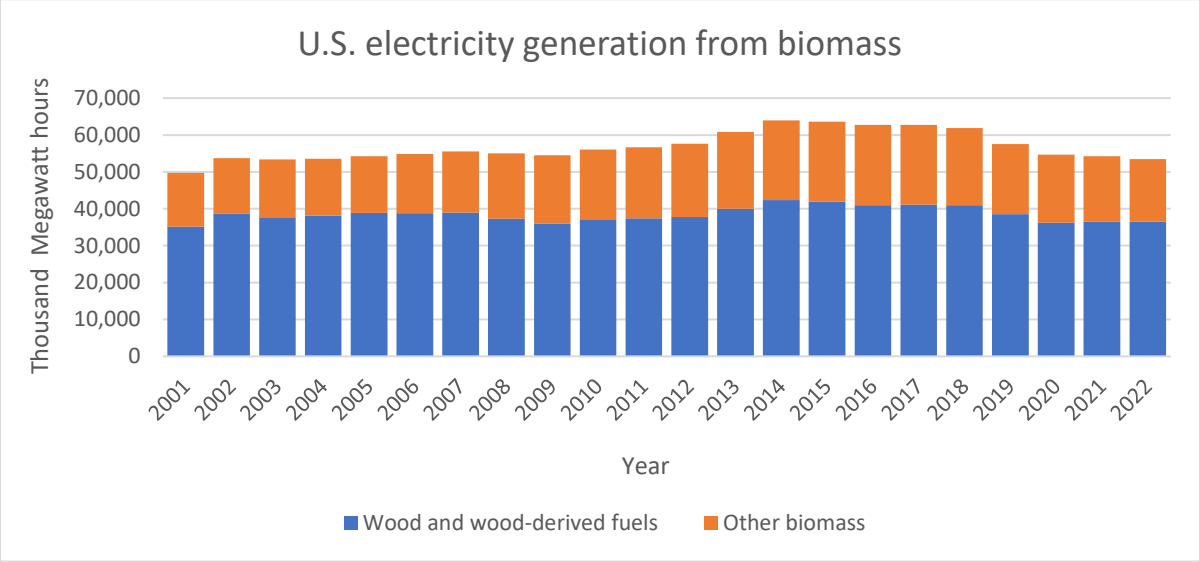

Figure 1. U.S. electricity generation from biomass, 2001 to 2022. (Source: U.S. Energy Information Administration 2023i).

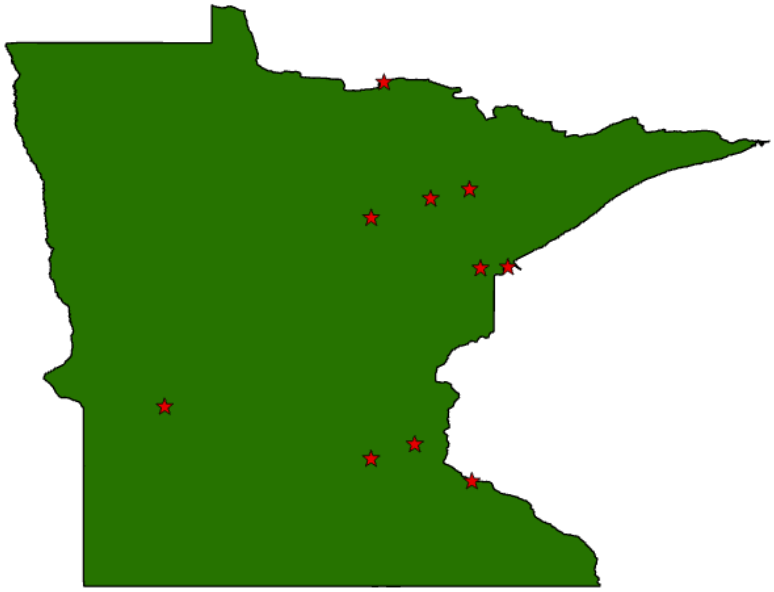

Figure 2. Map depicting the locations of biomass power plants using wood and wood-derived fuels in Minnesota in 2017 (Source: U.S. Energy Information Administration 2023i).

Estimating the economic contributions of wood-based biomass power generation industry in a region can help emphasize the ripple effects of this industry to the regional economy and help to advocate for its sustenance and expansion in the future. Realizing this, in 2022, the Michigan Department of Natural Resources (MI DNR) Forest Resources Division contracted with a research team at Michigan State University, Department of Forestry along with its collaborators (from North Carolina State University, Oklahoma State University, University of Idaho, SUNY College of Environmental Sciences and Forestry, and the Michigan Biopower) to conduct the economic contribution analysis of wood-based biomass power generation industry to the regional economy of the twenty-state Northeast and Midwest U.S. states for calendar years 2017 and 2022 respectively.

As part of this project, a 2017 regional report highlighting the economic contributions of wood-based biomass power generation industry to the regional economy of the Northeast and Midwest U.S. states has been developed. Accompanying this regional report, are individual state reports developed for fourteen participating states summarizing the economic contributions of wood-based biomass power generation industry to the respective state's economy. Fourteen participating states include California, Connecticut, Georgia, Illinois, Maine, Massachusetts, Michigan, Minnesota, New Hampshire, New York, Pennsylvania, Vermont, Virginia, and Wisconsin. This report is one of the individual state reports developed for the state of Minnesota. Its purpose is to summarize the economic contributions of wood-based biomass power generation industry to Minnesota's economy.

The next sections of the report shed light on the status of the electric power generation industry in Minnesota; briefly discuss the condition of forest resources within the state; outline the methods employed for conducting the economic contribution analysis of wood-based biomass power-generating industries in Minnesota; and discuss the findings obtained from the analysis.

Electric power generation in Minnesota in 2017

In 2017, the electric power industry in Minnesota produced a total of 58.7 million Megawatt hours of electricity. Coal was the major source of electricity generated across the state followed by nuclear power and wind energy respectively (Figure 3). Out of the total electricity generated, approximately 2% or 1.3 million Megawatt hours were produced using wood and wood-derived fuel (Figure 3) (US EIA 2023i).

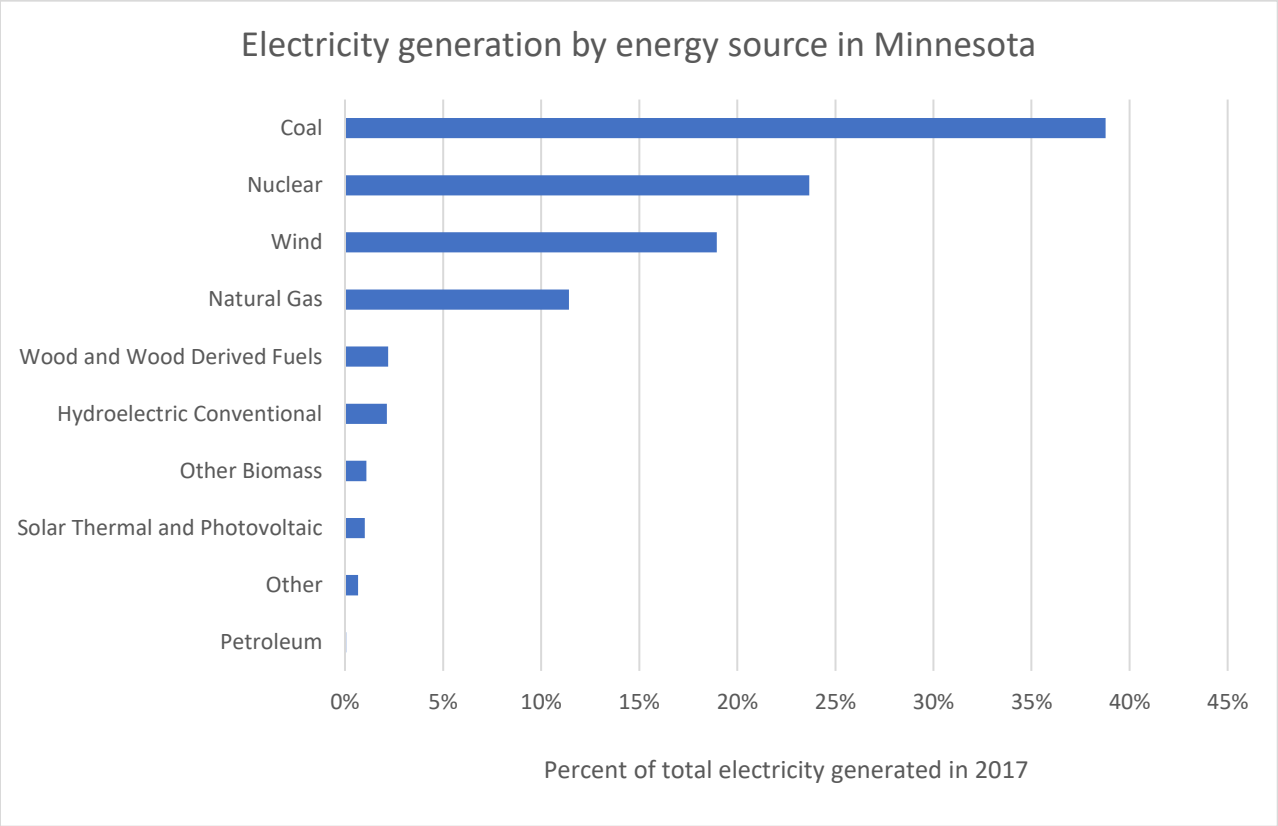

Figure 3. Percentage of total electricity generated in Minnesota in 2017 by energy source (Source: U.S. Energy Information Administration 2023i).

Collectively the electric power generation industry employed 10,950 people in 2017 which is equivalent to 0.29% of total jobs in the state the same year (IMPLAN 2017). The direct economic effects resulting from various power-generating industries within the state including biomass are listed in Table 1.

Table 1. The direct economic effects of power generating industries in Minnesota based on 2017 IMPLAN data.

IMPLAN Sector Code (Electric Power Generation)	Energy Source	Employment	Labor Income (Millions of 2017 dollars)	Value-Added	Output
39	Hydroelectric	501	$57.3	$139.0	$324.2
40	Fossil fuel	2,000	$308.9	$928.8	$2,563.2
41	Nuclear	1,415	$235.5	$495.1	$1,214.8
42	Solar	27	$3.6	$5.7	$12.3
43	Wind	278	$30.3	$174.6	$405.2
44	Geothermal	-	-	-	-
45	Biomass	236	$23.8	$55.0	$182.5
46	All other	233	$42.7	$(12.8)	$39.3
47	Electric power transmission and distribution	6,260	$971.0	$2,938.3	$8,343.0
	Total electric power generation, transmission and distribution	10,950	$1,673.0	$4,723.7	$13,084.6
	Total All Sectors	**3,759,672**	**227,343**	**356,150**	**669,125**

Forest Resources of Minnesota

Minnesota has an estimated 17.6 million acres of forests which cover approximately 33% of the state's total land area (USDA Forest Service, Forest Inventory and Analysis 2023). Most of the forests in Minnesota (45%) are under private ownership, followed by the state and local governments (39%), and the federal government (16%) respectively (Figure 4). Aspen/birch is the major forest type found in Minnesota, followed by Spruce/fir and Oak/hickory forest types (Table 2).

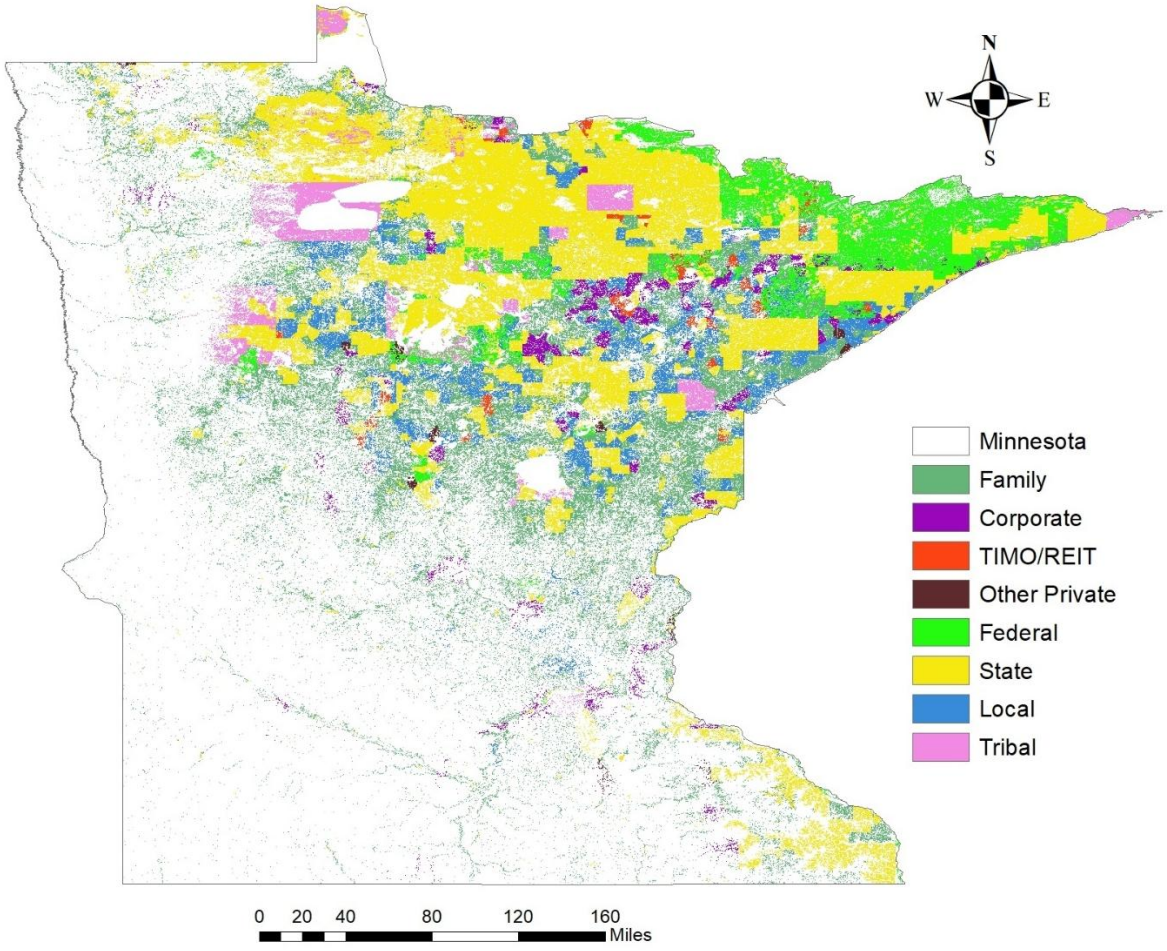

Figure 4. Forest ownership in Minnesota (Data source: Sass et al. 2020).

Table 2. Forestland area in Minnesota by forest type (Source: USDA Forest Service, Forest Inventory and Analysis 2023).

Forest Type Group	Acres	Percentage
Aspen / birch group	6,415,679	36%
Spruce / fir group	4,326,619	24%
Oak / hickory group	2,270,532	13%
Elm / ash / cottonwood group	1,647,850	9%
Maple / beech / birch group	1,225,770	7%
White / red / jack pine group	1,072,148	6%
Others	707,210	4%
Total	17,665,808	100%

The merchantable bole volume of live trees on timberlands in Minnesota is estimated to be ~21 billion cubic feet (Table 3). The average annual net growth is 526 million cubic feet, annual removals are 264 million cubic feet, and annual mortality is 285 million cubic feet. Annual growth in the timberlands exceeded the removals by a ratio of 2.0, meaning that for each cubic foot of timber harvested in the region, about 2.0 cubic feet of timber grew in the timberlands. However, this ratio varies by ownership type. The growth to removals ratio in national forests is 3.1. In private forests, it is 2.7, and 1.5 in the case of forests under state and local government (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 1.3% of the standing volume and annual mortality in the timberlands are slightly greater than annual removals (Table 3).

Table 3. Characteristics of state growing stock in Minnesota in 2023 (million cubic feet) (Source: USDA Forest Service, Forest Inventory and Analysis 2023).

Ownership	Net Volume	Annual Net Growth	Annual Removals	Annual Mortality	Growth/Removals
Total	20,809	526	264	285	2.0
National Forest	3,013	74	24	47	3.1
Other federal	16	1	-	0	-
State and local	6,631	194	132	97	1.5
Private	11,149	257	97	139	2.7

Methods

The analysis was conducted using impact analysis for planning (IMPLAN) software and 2017 IMPLAN data using the Analysis-by-Parts (ABP) technique. The ABP technique was chosen because it allows the user to create a customized industry sector by using the information about that sector's budgetary spending pattern and labor income (Lucas 2022). So far IMPLAN does not have a separate sector to represent wood-based biomass power generation. Instead, it is incorporated as a part of the electric power generation using the biomass industry. This means that it includes power generation from all sources of biomass including agricultural byproducts, landfill gas, municipal solid waste, woody biomass, black liquor, and sludge waste. To separate the economic contributions associated with wood-based power generation from power generation using all forms of biomass, the analysis-by-parts (ABP) technique was used. The resulting economic contributions are measured in terms of full- and part-time employment, industry output, value-added, labor income, other property income, and business taxes.

The information about industry spending patterns for the biomass power generation industry using woody biomass was obtained from Dahal et al. (2020) and corroborated or supplemented (where applicable) with the information collected through the mail survey of biomass power generation plants located in the twenty state Northeast-Midwest region. In fall 2022, Michigan Department of Natural Resources conducted a mail survey of 120 biomass power industries located in the 20-state Northeast-Midwest region along with California, Georgia, and Virginia to collect the financial and resources utilization data for the year 2017. Overall, 11 responses were obtained (9.2% response rate), out of which nine responses were from the Northeast-Midwest region. The data obtained from these responses were used to inform and supplement the industry spending pattern for wood-based biomass power generation industries for regional and state level reports for participating states. The average operation and maintenance expenditure for the wood-based biomass power generation industry used for the economic contribution analysis is listed in Table 4.

The survey also asked respondents to indicate the total amount of electricity produced in 2017 using wood and wood-derived fuel along with the total cost of production. This information was used to estimate the cost per megawatt hour of electricity produced. It was estimated to be $63/MWh on average when weighed by the size of production. The details of the survey method along with the information collected are included in the twenty-state Northeast-Midwest biopower economic contribution analysis report.

The per unit cost of electricity produced using wood and wood-derived fuel was multiplied by the total electricity produced using wood and wood-derived fuel within a state to obtain the direct output from the wood-based biomass power-generation industry in that state. 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 (2023i). In Minnesota, ~1.3 million Megawatt hours of electricity were generated using wood and wood-derived fuel in 2017. At the rate of $63/MWh of electricity produced, this translated into a direct output of $81.7 million for the wood-based biomass power generation industry in the state. The direct output was then allocated into intermediate input and value-added following the percentage breakdown of output into its component parts for IMPLAN sector 45 (electricity generation using biopower industry) using 2017 IMPLAN data for Minnesota. According to it, approximately 69.9% of the output of the biomass power generation industry was comprised of intermediate inputs and 30.1% was value-added. Value added was further broken down into employee compensation (12.5%), proprietor income (0.5%), other property type income (10.2%), and taxes on production and imports (6.9%) following IMPLAN sector 45's percentage breakdown for Minnesota. The total number of employees in the wood-based biomass power generation industry was obtained by dividing total output by output per worker information obtained for sector 45 from IMPALN 2017 data (online version). In total, there were 106 people employed in the wood-based biomass power generation industry in Minnesota 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 the 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 $1.5 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 state.

Table 4. Average operation and maintenance expenditures in 2017 US$ for the wood-based biomass power generation industry (as per Dahal et al. 2020 and supplemented with information collected from a mail survey of the wood-based power generation industry in the Northeast and Midwest U.S. states).

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

The results obtained from the economic contribution analysis indicated that in Minnesota, the wood-based biomass power generation industry directly employed 106 individuals in 2017 with a labor income of $11 million, value-added of $25 million, and output or sales of $82 million in 2017 US dollars (Table 5). Including ripple effects, the industry supported a total of 1,274 jobs with $59 million in labor income. The industry contributed a total of $86 million in value-added and $199 million in total output to the economy of Minnesota (Table 5). The top three industries affected in terms of employment by wood-based biomass power generation industry in the state include commercial logging (IMPLAN sector 16), electric power generation using biomass (IMPLAN sector 45), and support activities for agriculture and forestry (IMPLAN sector 19) (Table 6).

SAM multipliers for employment, labor income, value-added, and output across the state were estimated to be 12.1, 5.5, 3.5, 2.4 respectively. Output multiplier of 2.4 indicates that every $1 million in output in the state's wood-based biopower industry supported an additional $1.4 million in output to the rest of the economy. 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. Consequently, employment multipliers are substantially higher than output, labor income, or value-added multipliers. It should be noted that IMPLAN employment is jobs including part-time, seasonal workers and proprietors head count, hence sectors that add lots of part-time, low-hour service jobs tend to increase the employment count though labor income and output remain modest.

The wood based biopower industry in Minnesota contributed about $12 million in annual state and local taxes and close to $13 million in federal taxes in 2017 (Table 7).

Table 5. Economic contributions of wood-based biomass power generation industry in Minnesota in 2017 US dollars using IMPLAN software version (3.1.1001.12) and 2017 IMPLAN data.

States Included	Economic Contributions of Wood-based Biomass Power Generation Industry				
		Employment (Jobs)	Labor Income ($MM 2017)	Value-added	Output
Minnesota	Direct Contributions	106	$10.6	$24.6	$81.7
	Indirect Contributions	883	$33.8	$36.6	$75.1
	Induced Contributions	286	$14.4	$24.4	$42.4
	Total Contribution	1,274	$58.8	$85.6	$199.1
	SAM Multiplier	12.1	5.5	3.5	2.4

Table 6. The top five industries affected in terms of employment by wood-based biomass power generation industry in Minnesota in 2017

		Impact			
	Industry affected (IMPLAN Sector)	Direct	Indirect	Induced	Total
1	Commercial logging (16)	0	628	0	628
2	Electric power generation – Biomass (45)	106	0	0	106
3	Support activities for agriculture and forestry (19)	0	58	0	58
4	Commercial and industrial machinery and equipment repair and maintenance (515)	0	39	1	39
5	Forestry, forest products, and timber tract production (15)	0	30	0	30

Table 7. Total Tax contributions of Wood-based Biomass Power Generation Industry in Minnesota in 2017 US dollars ($MM) using online version of 2017 IMPLAN data.

Impact Type	Sub-county general	Sub-county special districts	County	State	Federal	Total
Direct	$0.85	$0.63	$0.78	$3.59	$2.74	$8.59
Indirect	$0.40	$0.30	$0.37	$2.62	$6.71	$10.40
Induced	$0.34	$0.25	$0.31	$1.83	$3.25	$5.99
Total	$1.59	$1.18	$1.45	$8.04	$12.71	$24.98

Summary

This study assessed the economic contributions of wood-based biomass power generation industry in Minnesota 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 Minnesota was found to directly support 106 jobs and contribute $82 million in output to the state's economy. Including direct, indirect, and induced effects, the industry contributed a total of 1,274 jobs and $199 million in output in Minnesota.

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