



**Duluth Energy Future Report Chapter 1:**

**Economic Modeling of Proposed Biomass  
and Solar Initiatives**

## Research Team

### UMD Labovitz School of Business and Economics Bureau of Business and Economic Research

Monica Haynes, Director  
Gina Chiodi Gensing, Editor/Writer  
Travis Eisenbacher, Undergraduate Research Assistant  
Karen Haedtke, Executive Administrative Specialist  
Bureau of Business and Economic Research  
11 East Superior Street, Suite 210  
Duluth, MN 55802  
(218) 726-7895  
[www.d.umn.edu/lbse/bber.php](http://www.d.umn.edu/lbse/bber.php)

### Contributing Authors from Energy Transition Lab

Ellen Anderson, Executive Director  
Megan Butler, Graduate Research Assistant  
Law School  
N130E Mondale Hall  
229 19th Avenue South  
Minneapolis MN 55455  
University of Minnesota | umn.edu  
[www.energytransition.umn.edu](http://www.energytransition.umn.edu)



***This report was made possible by a grant from the  
McKnight Foundation.***

We thank our many project stakeholders who contributed data to the analysis including Duluth Energy Systems, Ecolibrium 3, the Great Plains Institute, Innovative Power Systems (IPS), and the Natural Resources Research Institute (NRRI). We would also like to thank those who reviewed the report and provided valuable comments including: Anna Dirkswager of Clean Energy Economy Minnesota, Kathryn Fernholz of Dovetail Partners, Bret Pence and Jodi Slick of Ecolibrium 3, Brendan Jordon of the Great Plains Institute, Pamela Kramer of the Local Initiatives Support Corporation (LISC), Brendon Slotterback of the McKnight Foundation, Neal Young and Kari Howe of the Minnesota Department of Employment and Economic Development (MN DEED), Ken Jacobson of the Minnesota Department of Natural Resources (MN DNR) Division of Forestry, Ben Bagdon of Minnesota Forest Industries (MFI), Kristopher J. Spenningsby of Minnesota Power.

*Bureau of Business and Economic Research  
Labovitz School of Business and Economics  
University of Minnesota Duluth*

## Table of Contents

TABLE OF CONTENTS .....	III
TABLE OF FIGURES .....	III
TABLE OF TABLES .....	IV
EXECUTIVE SUMMARY .....	VI
INTRODUCTION .....	1
STUDY AREA.....	2
REGIONAL ECONOMIC PROFILE .....	6
INPUT-OUTPUT MODELING.....	9
PROJECTS .....	10
I.    GRAND MARAIS BIOMASS DISTRICT HEATING SYSTEM.....	11
II.   DULUTH STEAM PLANT RETROFIT AND BIOMASS CONVERSION.....	13
III.  TORREFACTION PROCESSING PLANT .....	15
IV.   BIORENEWABLE CHEMICAL PRODUCTION PLANTS .....	18
V.    SOLAR POWER PRODUCTION ARRAYS .....	19
OVERALL IMPACTS.....	21
APPENDIX A.  DETAILED INPUTS AND METHODOLOGY .....	25
I.    GRAND MARAIS BIOMASS DISTRICT HEATING SYSTEM.....	25
II.   DULUTH STEAM PLANT RETROFIT AND BIOMASS CONVERSION.....	27
III.  TORREFACTION PROCESSING PLANT .....	30
IV.   BIORENEWABLE CHEMICAL PRODUCTION PLANTS .....	31
V.    SOLAR POWER PRODUCTION ARRAYS .....	33
APPENDIX B.  DEFINITIONS USED IN THIS REPORT .....	35
APPENDIX C.  IMPLAN ASSUMPTIONS .....	36
BIBLIOGRAPHY .....	37

## Table of Figures

FIGURE 1. MINNESOTA'S ARROWHEAD REGION AND DOUGLAS COUNTY, WISCONSIN .....	5
FIGURE 2. REGIONAL OUTPUT BY INDUSTRY, IN MILLIONS OF DOLLARS.....	6
FIGURE 3. TOP SECTORS IMPACTED BY BIOMASS PROJECTS' CONSTRUCTION (EMPLOYMENT) .....	22
FIGURE 4. TOP SECTORS IMPACTED BY BIOMASS PROJECTS' OPERATIONS (EMPLOYMENT) .....	23

*Bureau of Business and Economic Research  
Labovitz School of Business and Economics  
University of Minnesota Duluth*

## Table of Tables

TABLE 1. REGIONAL EMPLOYMENT AND OUTPUT IN RELATED IMPLAN INDUSTRY SECTORS (2014) .....	7
TABLE 2. ANNUAL FEEDSTOCK REQUIREMENTS FOR BIOMASS PROJECTS .....	8
TABLE 3. BIOMASS DISTRICT HEATING SYSTEM DIRECT INPUTS (CONSTRUCTION AND OPERATIONS).....	11
TABLE 4. IMPACTS OF GRAND MARAIS BIOMASS DISTRICT HEATING SYSTEM - CONSTRUCTION .....	12
TABLE 5. DETAILED IMPACTS OF GRAND MARAIS BIOMASS DISTRICT HEATING SYSTEM – TYPICAL YEAR OPERATIONS .....	13
TABLE 6. DULUTH STEAM PLANT DIRECT INPUTS (CONSTRUCTION AND OPERATIONS) .....	14
TABLE 7. DETAILED IMPACTS OF DULUTH STEAM PLANT PHASE I – CONSTRUCTION .....	14
TABLE 8. DETAILED IMPACTS OF DULUTH STEAM PLANT PHASE II – CONSTRUCTION .....	15
TABLE 9. DETAILED IMPACTS OF DULUTH STEAM PLANT PHASE II – TYPICAL YEAR OPERATIONS .....	15
TABLE 10. TORREFACTION PLANT DIRECT INPUTS (CONSTRUCTION AND OPERATIONS) .....	17
TABLE 11. DETAILED IMPACTS OF TORREFACTION PLAN – CONSTRUCTION .....	17
TABLE 12. DETAILED IMPACTS OF TORREFACTION PLAN – TYPICAL YEAR OPERATIONS .....	17
TABLE 13. BIORENEWABLE CHEMICAL PRODUCTION PLANTS DIRECT INPUTS (CONSTRUCTION AND OPERATIONS) .....	18
TABLE 14. DETAILED IMPACTS OF BIORENEWABLE CHEMICAL PRODUCTION PLANTS - CONSTRUCTION .....	19
TABLE 15. DETAILED IMPACTS OF BIORENEWABLE CHEMICAL PRODUCTION PLANTS – TYPICAL YEAR OPERATIONS.....	19
TABLE 16. SOLAR POWER PRODUCTION ARRAYS DIRECT INPUTS (CONSTRUCTION AND OPERATIONS) .....	20
TABLE 17. DETAILED IMPACTS OF SOLAR POWER PRODUCTION ARRAYS – CONSTRUCTION .....	20
TABLE 18. COMBINED EFFECT OF CONSTRUCTION PROJECTS, BY PROJECT TOTAL EFFECT .....	21
TABLE 19. COMBINED EFFECT OF TYPICAL YEAR OF OPERATIONS, BY PROJECT TOTAL EFFECT.....	22
TABLE 20. BIOMASS DISTRICT HEATING SYSTEM CONSTRUCTION BUDGET.....	25
TABLE 21. IMPLAN SECTOR(S) USED FOR MODELING IMPACTS FROM CONSTRUCTION.....	26
TABLE 22. BIOMASS DISTRICT HEATING SYSTEM OPERATIONS BUDGET .....	26
TABLE 23. IMPLAN SECTOR(S) USED FOR MODELING IMPACTS FROM OPERATIONS.....	27
TABLE 24. DULUTH STEAM PLANT PHASE I CONSTRUCTION BUDGET .....	27
TABLE 25. IMPLAN SECTOR(S) USED FOR MODELING IMPACTS FROM PHASE I CONSTRUCTION .....	28
TABLE 26. DULUTH STEAM PLANT PHASE II CONSTRUCTION BUDGET.....	28
TABLE 27. IMPLAN SECTOR(S) USED FOR MODELING IMPACTS FROM PHASE II CONSTRUCTION .....	28
TABLE 28. DULUTH STEAM PLANT PHASE II OPERATIONS BUDGET.....	29
TABLE 29. IMPLAN SECTOR(S) USED FOR MODELING IMPACTS FROM PHASE II OPERATIONS .....	29
TABLE 30. TORREFACTION PLANT CONSTRUCTION BUDGET .....	30

*Bureau of Business and Economic Research  
Labovitz School of Business and Economics  
University of Minnesota Duluth*

TABLE 31. IMPLAN SECTOR(S) USED FOR MODELING IMPACTS FROM CONSTRUCTION.....	30
TABLE 32. TORREFACTION PLANT OPERATIONS BUDGET .....	30
TABLE 33. IMPLAN SECTOR(S) USED FOR MODELING IMPACTS FROM OPERATIONS.....	31
TABLE 34. BIO-RENEWABLE CHEMICAL PRODUCTION PLANTS CONSTRUCTION BUDGET .....	31
TABLE 35. IMPLAN SECTOR(S) USED FOR MODELING IMPACTS FROM CONSTRUCTION.....	31
TABLE 36. BIO-RENEWABLE CHEMICAL PRODUCTION PLANTS OPERATIONS BUDGET .....	32
TABLE 37. IMPLAN SECTOR(S) USED FOR MODELING IMPACTS FROM OPERATIONS.....	32
TABLE 38. SOLAR ARRAY CONSTRUCTION BUDGET.....	33
TABLE 39. IMPLAN SECTOR(S) USED FOR MODELING IMPACTS FROM CONSTRUCTION.....	33

## Executive Summary

In early 2015, several dozen community leaders from Duluth’s city government, local businesses, electric utility company, nonprofit organizations, and the University of Minnesota Duluth participated in a charrette to determine an Energy Future Vision for the city.<sup>1</sup> The goal was to capture “the ambitions and concerns” of the key stakeholders, with relevant economic, social, environmental, [and] sustainability aspects.” One of the group’s priority conclusions was the need to understand jobs and economic development impacts of different energy options. They asked the Energy Transition Lab to help Duluth analyze the economic and jobs implications of more locally produced energy from biomass<sup>2</sup> and solar energy.

As part of this research on Duluth’s Energy Future Planning, the Energy Transition Lab approached UMD’s Bureau of Business and Economic Research (BBER) to assist in the economic modeling required for the project. The modeling consisted of five proposed projects, which focused on the increased use of biomass and solar. Each of the five projects was selected based on local feasibility and interest. Projects selected for modeling included the following:

- I. The Grand Marais Biomass District Heating System
- II. The Duluth Energy Systems Plant Retrofit and Biomass Conversion
- III. A Torrefaction Processing Plant
- IV. Two Biorenewable Chemical Production Plants
- V. Solar Power Production Arrays

The study area for this economic impact study included the seven Minnesota counties of the Arrowhead region (Aitkin, Carlton, Cook, Itasca, Koochiching, Lake, and St. Louis) and Douglas County, Wisconsin.<sup>3</sup> All impact amounts are local to the study area, as the model does not consider impacts occurring beyond that area; this is true of reported impacts throughout this report.

These five projects, were they to occur, could represent a significant increase in the use and production of renewable energy in the Arrowhead region. Four of the five projects included in the analysis involve the use of biomass as a fuel source or feedstock. The total economic impacts from the construction of these four projects could support nearly 1,600 jobs in the eight-county region, an additional \$83 million in labor income, and would contribute roughly \$154 million in value-added spending to the region’s Gross Regional Product (GRP).

The combined effects for a typical year of operations from the four projects would equate to more than 1,000 new jobs in the eight-county study area (Employment), an additional \$54 million in wages, benefits, and proprietor income (Labor Income), and an \$80 million contribution to the region’s GRP (Value Added).

The four biomass projects include two public utilities projects (the Duluth Energy Systems retrofit and

---

<sup>1</sup> The charrette was led by Ecolibrium3 in partnership with the city of Duluth and facilitated by the Great Plains Institute and Rocky Mountain Institute. Participants included other Minnesota energy experts, such as the University of Minnesota’s Energy Transition Lab, Minnesota Power, and Minnesota Environmental Quality Board (EQB) staff.

<sup>2</sup> For the purposes of this report, the term “biomass” is understood to include all vegetative matter and forms of wood. Note that electricity and thermal energy production optimally use forest residuals like limbs, tops, and other waste wood; biorenewable chemical production would use more solid wood without bark.

<sup>3</sup> When modeling the impacts of the increased use of solar, the state of Minnesota was used as an alternate study area.

conversion and the Grand Marais district heating system) and two manufacturing projects (the biochemical production plants and the torrefaction plant). While the biorenewable chemical production plants are not energy-producing facilities, they were included in the analysis because they share a key characteristic with biomass energy production plants: they use wood as a feedstock that displaces fossil fuels. The fifth project involves the expansion of solar in the city of Duluth, which would also be classified within the Public Utilities industry. In addition, all five projects have some construction expenses associated with their implementation.

#### Combined Effects of Construction, by Project Total Effect

<i>Total Effects<sup>4</sup></i>	<i>Employment</i>	<i>Labor Income</i>	<i>Value Added</i>	<i>Output</i>
Grand Marais Biomass Heat	82	\$3,876,663	\$5,798,608	\$12,325,949
Duluth Energy Systems Plant (Phase I and II)	314	\$17,393,102	\$32,463,835	\$74,749,525
Torrefaction Plant	198	\$10,673,648	\$14,822,298	\$32,142,508
Biorenewable Chemical Plants	1,001	\$51,688,473	\$101,441,030	\$287,387,547
<b>Combined Effects of Biomass Projects<sup>5</sup></b>	<b>1,595</b>	<b>\$83,631,886</b>	<b>\$154,525,771</b>	<b>\$406,605,529</b>
Solar Arrays (Total Effects on State of MN) <sup>6</sup>	92	\$1,810,855	\$2,276,953	\$3,379,198

SOURCE: IMPLAN, BBER

The table above shows the total effects (sum of direct, indirect, and induced effects) of each of the five projects, as well as the combined effects of the four biomass projects. The combined effects represent the potential impacts to the eight-county region were all four projects to occur. It is estimated that the construction of the four biomass projects would contribute roughly \$154 million to the GRP of the eight-county region, while the solar projects would contribute nearly \$2 million in additional wages and benefits and approximately \$2.2 million towards the state's GRP.

#### Combined Effects of Typical Year Operations, by Project Total Effect

<i>Total Effects</i>	<i>Employment</i>	<i>Labor Income</i>	<i>Value Added</i>	<i>Output</i>
Grand Marais Biomass Heat	7	\$353,852	\$582,299	\$1,132,337
Duluth Steam Plant Retrofit	18	\$903,460	\$1,506,490	\$3,756,277
Torrefaction Plant	156	\$7,547,354	\$9,717,150	\$27,212,162
Biorenewable Chemical Plants	882	\$44,857,938	\$68,243,966	\$288,265,137
<b>Combined Effects of Biomass Projects</b>	<b>1,063</b>	<b>\$53,662,604</b>	<b>\$80,049,905</b>	<b>\$320,365,913</b>

SOURCE: IMPLAN, BBER

The table above shows the combined effects for a typical year of operations from the four biomass projects,

<sup>4</sup> The values given under each category (Employment, Labor Income, etc.) for each of the projects are the "Total Effect" from the impact analysis for that project, or in other words, the sum of the Direct, Indirect, and Induced effects. See the Projects chapter for detailed effects on each of the projects included in the study.

<sup>5</sup> The values given under each category for the "Combined Effects of Biomass Projects" are results of the combined modeling for the four biomass projects. Due to how IMPLAN models are designed, the Combined Effects are equal to the sum of the "Total Effects" from each of the four projects.

<sup>6</sup> Because the solar project was analyzed with a different study area (MN rather than just the eight-county region), the effects must be reported separately from those of the biomass projects.

equating to more than 1,000 new jobs in the eight-county study area (Employment), nearly \$54 million in wages, benefits, and proprietor income (Labor Income), and an \$80 million contribution to the region's GRP (Value Added). Overall, an additional \$320 million in annual local production (i.e. sales and revenue) would be created in the region as a result of the four proposed facilities. While the solar projects might require some operational costs, in maintenance and repairs, these costs do not consistently occur on an annual basis and are small by comparison. For that reason, solar operational expenses were not modeled, and their impacts only appear in the construction table.

The study region is home to a significant forestry industry. According to a recent DNR report,<sup>7</sup> timber availability is high, particularly on private lands, and there is a need for additional utilization and management. According to project stakeholders, the four biomass projects included in this study would require approximately 625,000 tons of biomass each year, the equivalent of approximately 300,000 cords. This represents roughly 9% of 2012 harvest levels. Additionally, 280 of the jobs<sup>8</sup> created from the operations of the biomass projects would come from increased spending on woody biomass. This could represent a 30% increase in jobs within the Commercial Logging sector, which employed 891 workers in 2014, and would be a potentially large boost to an industry hard-hit by job losses.<sup>9</sup>

For both construction and operations, the largest effects come from the biorenewable chemical plants, which represent more than 70% of the combined effects from construction of the four projects and roughly 90% of the impacts from operations. The smallest effects come from the Grand Marais biomass heating project, which represents 3% of the total economic output from the four construction projects and less than 1% of the total operational output. The Duluth Energy Systems plant retrofit requires a significant construction investment and, therefore, represents a significant share of the overall employment and output impact for the construction of the four biomass projects. Once the construction project is complete though, the city expects very little change in the operating costs. For that reason, the net impacts from operating the plant would be small by comparison.

★ ★ ★

---

<sup>7</sup> Minnesota's Forest Resources 2014 [http://files.dnr.state.mn.us/forestry/um/forestresourcesreport\\_14.pdf](http://files.dnr.state.mn.us/forestry/um/forestresourcesreport_14.pdf)

<sup>8</sup> Employment numbers (from U.S. Department of Commerce secondary data) treat both full- and part-time individuals as being employed, so employment estimates throughout this report represent an employment headcount, not FTE. The logging industry employs a large number of part-time and seasonal workers, so this should be taken into consideration when interpreting employment impacts.

<sup>9</sup> TSS Consultants, 2013 <http://www.sacdm.net/tssconsultants/reports/2013-10-Wood-Fiber-Supply-Availability-Potential-Utilization-Analysis.pdf>



# Duluth's Energy Future Economic Modeling

## Introduction

On February 19, 2015, community leaders from Duluth's city government, local businesses, electric utility company, and nonprofit organizations and the University of Minnesota Duluth participated in an Energy charrette. The goal of the charrette was to determine an Energy Future Vision for the city<sup>10</sup> by capturing "the ambitions and concerns" of the key stakeholders, with relevant economic, social, environmental, [and] sustainability aspects".<sup>11</sup> The three main opportunities for clean energy in the region that arose during the charrette included locally produced biomass, solar, and energy efficiency. One of the group's priority conclusions was the need to understand the impact that different energy options would potentially have on local economic development. The group asked the Energy Transition Lab to help Duluth analyze the economic and jobs implications of the increased use of biomass<sup>12</sup> and solar in the region.

In spring 2015, the Energy Transition Lab was awarded grant funding from the McKnight Foundation to conduct research on Duluth's Energy Future Planning. The project brought together University of Minnesota and industry experts in bioenergy, solar, energy storage, law, economics, sustainable building design, combined heat and power, and other disciplines to analyze forward-looking renewable energy scenarios for Northeastern Minnesota and Douglas County, Wisconsin, to provide actionable, cost-effective models for Net Zero Energy building retrofits, and to analyze opportunities and barriers for combined heat and power in Duluth.

As part of its research on Duluth's Energy Future Planning, the Energy Transition Lab approached the UMD Labovitz School of Business and Economics' Bureau of Business and Economic Research (BBER) to assist in the economic modeling of the forward-looking renewable energy scenarios for the study area.<sup>13</sup> The modeling consisted of five proposed projects, which focus on the increased use of biomass and solar. Economic impacts of energy efficiency improvements are difficult to measure accurately using the IMPLAN model, so they were not included. Each of the five projects was selected based on local feasibility and interest as well as data availability.

Projects selected for modeling included the following:

- I. The Grand Marais Biomass District Heating System
- II. The Duluth Energy Systems Plant Retrofit and Biomass Conversion
- III. A Torrefaction Processing Plant
- IV. Biorenewable Chemical Production Plants
- V. Solar Power Production Arrays

The analysis begins with background information about Minnesota's timber and clean energy industries followed by a description of the study area used in modeling the impacts of the five projects, a brief overview of the regional economic profile, and an explanation of input-output modeling. The chapter entitled Projects describes each project in detail, summarizes the inputs required for modeling, and provides each project's estimated economic impacts. Finally, the combined results of all five projects are provided in the final chapter of the report, Overall Impacts.

---

<sup>10</sup> See Note 1.

<sup>11</sup> The charrette also served as impetus for the Rocky Mountain Institute's Community Energy Resource Guide [http://www.rmi.org/community\\_energy\\_guide](http://www.rmi.org/community_energy_guide)

<sup>12</sup> See Note 2.

<sup>13</sup> The other two topics, Net Zero Energy building retrofits and combined heat and power, will be addressed separately in the full version of the final report.

## **Background**

### **Minnesota's Forest Industry**

Timber harvests in Minnesota have been steadily declining since 2000.<sup>14</sup> Declining demand for paper and construction materials<sup>15</sup> accompanied by a sharp reduction in the volume of timber harvested by private landowners<sup>16</sup> has resulted in steadily increasing stumpage prices.<sup>17</sup> As shown in Minnesota's Department of Natural Resources (DNR) land ownership maps<sup>18</sup>, the majority of forested land in the state is under private ownership. Without increases in the volume of timber offered by public agencies to offset the shortage of supply from private woodlots, stumpage prices have continued to increase. The volume of timber being offered by public agencies has actually decreased over the past year further exacerbating the increase in prices. The recession of the mid-2000s also strongly affected Minnesota's forest industry. During this period, four large reconstituted wood products manufacturing plants and many small sawmills closed, amounting to an annual decline in production by one million cords in Minnesota equating to a cumulative loss of over 1,500 jobs, \$430 million in industrial output, \$200 million value-added, and \$14 million state and local tax payments.<sup>19,20</sup> Due to these recent trends, it has been projected that the number of small logging businesses in Minnesota will continue to decline.<sup>21</sup>

The decline in the forest industry and resulting job losses has presented special management concerns for Minnesota's aging forest resources. The loss of management infrastructure necessary to maintain healthy forests has resulted in increased risk of disease and insect damage as well as increased fire risk due to the buildup of brush and dead/downed trees.<sup>22</sup> The increasing use of Minnesota's supply of forest biomass to produce energy and other value-added products is one solution that could boost the local economy while encouraging the sustainable management of the state's valuable natural resource base.

### **The Potential Benefits of Biomass**

The feasibility of using locally grown forest biomass in Northern Minnesota for energy and other value-added products has been studied extensively due to locally produced biomass's potential to generate significant economic and environmental benefits. Economic benefits of using forest biomass as a renewable source for electricity, heat and other value added products can include the stabilization and reduction of long-term energy costs,<sup>23</sup> supporting the local economy through job creation,<sup>24</sup> preventing "dollar drain" through the

---

<sup>14</sup> Miller, 2013 [http://www.dovetailinc.org/land\\_use\\_pdfs/lccmr\\_resources/community\\_bioenergy.pdf](http://www.dovetailinc.org/land_use_pdfs/lccmr_resources/community_bioenergy.pdf)

<sup>15</sup> IBID

<sup>16</sup> See Note 9.

<sup>17</sup> These facts are supported by many reports including:

- The MNDNR's 2015 Stumpage Review ([http://files.dnr.state.mn.us/forestry/timber\\_sales/stumpage/stumpage-review-report-2015.pdf](http://files.dnr.state.mn.us/forestry/timber_sales/stumpage/stumpage-review-report-2015.pdf))
- The 2013 TSS Consultants Wood Fiber Supply Availability and Potential Utilization Analysis
- The 2014 Minnesota Forest Resources Council's Report on the Competitiveness of Minnesota's Primary Forest Products Industry
- MNDNR's Minnesota Forest Resources 2014 report.

<sup>18</sup> <http://www.dnr.state.mn.us/forestry/biomass/maps.html>

<sup>19</sup> See Note 9.

<sup>20</sup> Another recent study also found that there could be a shortage of younger generation loggers entering the workforce in the future (Blinn et al., 2015).

<sup>21</sup> Minnesota Forest Resources Council, 2014

[http://mn.gov/frc/docs/MFRC\\_POLICY\\_Forest\\_Industry\\_Competitiveness\\_Report\\_2014-12-01.pdf](http://mn.gov/frc/docs/MFRC_POLICY_Forest_Industry_Competitiveness_Report_2014-12-01.pdf)

<sup>22</sup> See Note 14.

<sup>23</sup> Step 2 Study: Grand Marais Biomass District Heating System Report #GM-14-001-0. FVB, 2014

<sup>24</sup> IBID

production of locally generated energy,<sup>25</sup> and increasing energy security due to reliance upon local rather than imported fuel.<sup>26</sup> In her 2014 study on biobased fuels, Tuck also suggests that the production of value-added products using woody biomass would serve to increase the price of Minnesota's currently low-valued forest resources.<sup>27</sup>

Biomass energy projects can also improve forest health and management as well as reduce the risk of forest fires by preventing the buildup of hazardous fuels.<sup>28, 29</sup> Forest management treatments (harvesting) can be used to regenerate forest stands at risk from increasing mortality rates due to insects, disease, and old age. Forest treatments are possible and most economical to achieve when there are markets for the various forest products generated from harvests.<sup>30</sup> In this way, markets for biomass-based energy and other products can help Minnesota utilize its aging forest resources and support efforts to maintain healthier forest conditions in the state.<sup>31</sup>

While research related to carbon emissions from biomass energy is still ongoing, studies have shown that replacing fuels such as coal or propane with biomass can decrease net carbon dioxide emissions. However, the emissions profile of woody biomass energy depends upon several variable factors including the use of sustainable forestry and harvesting practices, the type of fuel being replaced, the source of the biomass, and the efficiency of the energy generating system.<sup>32, 33, 34, 35</sup>

In these ways, markets for biomass-based energy and other products have the potential to support the declining timber industry in Minnesota while helping to maintain sustainable harvests and encouraging the use and management of Minnesota's forest resources.

### **Barriers to Biomass**

According to the Minnesota Forest Resources Council,<sup>36</sup> factors that typically affect demand for biomass energy include the price of energy alternatives; policies at the local, state, or federal level; technological development; and demand for products, such as saw logs and pulp (demand for these products can reduce the cost of biomass removal and transport). For communities and organizations interested in investing in biomass energy systems, one of the greatest barriers to the use of biomass for energy production is the low cost of fuels, such as coal, natural gas, and propane.<sup>37</sup> In Minnesota, biomass projects tend to look very attractive when the costs of coal, natural gas, and propane are high but lose support when market conditions change.<sup>38</sup> For more details on fluctuating energy costs over time, see Appendix D for a comparison of energy

---

<sup>25</sup> A feasibility study conducted in Grand Marais ([www.cookcountylenergy.org/groups/biomass](http://www.cookcountylenergy.org/groups/biomass)) has projected that a district heating system fueled by locally produced biomass would significantly reduce "dollar drain" by retaining between \$18 and \$35 million dollars within the local community over a 25-year period.

<sup>26</sup> According to an analysis prepared for the Minnesota Department of Employment and Economic Development (DEED, <http://www.mn.gov/deed/data/research/clean-energy.jsp>), Minnesota has spent at least \$13 billion annually since 2010 to import fossil fuels because the state has no natural deposits of coal, natural gas or petroleum.

<sup>27</sup> <http://www.extension.umn.edu/community/economic-impact-analysis/reports/docs/2014-Economic-Contribution-Biobased-Fuels.pdf>

<sup>28</sup> See Note 21.

<sup>29</sup> See Note 14.

<sup>30</sup> USDA Northern Research Station Forest Inventory and Analysis <http://www.nrs.fs.fed.us/featured/2014/09/>

<sup>31</sup> IBID

<sup>32</sup> Bratkovich, 2009 [http://www.dovetailinc.org/report\\_pdfs/2009/dovetaildistheat0409.pdf](http://www.dovetailinc.org/report_pdfs/2009/dovetaildistheat0409.pdf)

<sup>33</sup> Spitzer, 2006 [http://ec.europa.eu/research/energy/pdf/gp/gp\\_events/biorefinery/bs4\\_03\\_spitzer\\_en.pdf](http://ec.europa.eu/research/energy/pdf/gp/gp_events/biorefinery/bs4_03_spitzer_en.pdf)

<sup>34</sup> EPA, 2016 <https://www3.epa.gov/climatechange/ghgemissions/biogenic-emissions.html>

<sup>35</sup> Greene, 2016 <http://www.forestindustry.com/guest-columns/forest-biomass-receives-carbon-neutral-classification-in-sen/>

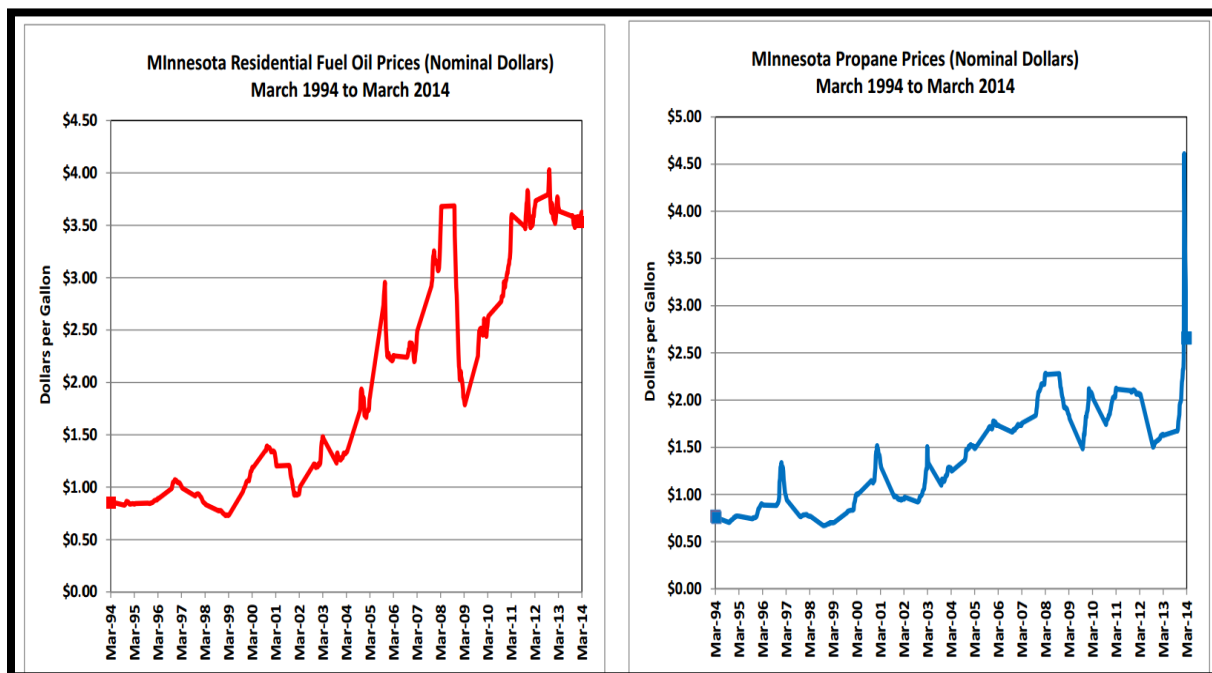
<sup>36</sup> See Note 21.

<sup>37</sup> Kent Jacobsen, MN DNR.

<sup>38</sup> IBID

costs and expenditures in Minnesota between 1970 and 2013. Proponents of biomass argue that converting to biomass will provide a resilient hedge if the costs of coal, petroleum, and natural gas fluctuate or increase at historic rates (see Figure 1).<sup>39,40</sup> In addition, many communities in the Arrowhead region and Northern Minnesota that lack access to natural gas and rely primarily upon fuel oil and propane find biomass to be a financially attractive alternative for electricity and for thermal energy generation.<sup>41, 42</sup>

**Figure 1. Historic Fuel Oil and Propane Prices, 2002 to 2014**



SOURCE: FVB ENERGY INC. REPORT # GM-14-001-0

### **Minnesota's Growing Clean Energy Economy**

Despite the challenge of fluctuating fossil fuel prices, electricity generated from woody biomass<sup>43</sup> topped 1 million MWh in 2014, which is double the amount generated in 2001. For comparison, electric generation from natural gas was reported at 3.8 million MWh in 2014.<sup>44</sup> In addition, the Minnesota Department of Employment and Economic Development (DEED) recently published the Minnesota Clean Energy Economy Profile, which reports that bioenergy generation in Minnesota (from sources including woody biomass, grasses, corn, soy, municipal solid waste, and gas) increased by 42% between 2007 and 2012.<sup>45</sup> While many factors affect bioenergy production, the adoption of Minnesota's renewable energy standard in 2007 is seen

<sup>39</sup> As Appendix D shows, while the price of natural gas has been decreasing recently, over the long-term its price is very volatile.

<sup>40</sup> See Note 14.

<sup>41</sup> IBID

<sup>42</sup> Haugen, 2013 <http://midwestenergynews.com/2013/01/15/beyond-the-reach-of-natural-gas-boom-minnesota-towns-look-to-biomass/>

<sup>43</sup> In addition to woody biomass, electricity generated from other forms of biomass reached 612,241 MWh in 2014. Other forms of biomass include agricultural byproducts, landfill gas, biogenic municipal solid waste, and other solid liquid and gas forms of biomass and sludge waste. Source: U.S. EIA State Electricity Profiles <http://www.eia.gov/electricity/state/minnesota/>

<sup>44</sup> U.S. EIA State Electricity Profiles <http://www.eia.gov/electricity/state/minnesota/>

<sup>45</sup> Minnesota Clean Energy Economy Profile: How Industry Sectors are Advancing Economic Growth [http://www.mn.gov/deed/images/mn\\_cleanenergy-economy-profile-fullreport.pdf](http://www.mn.gov/deed/images/mn_cleanenergy-economy-profile-fullreport.pdf)

as one of the main catalysts for this sharp increase.<sup>46</sup> Employment in bioenergy<sup>47</sup> has also doubled in the past 10 years, and bioenergy made up 11.9% of employment in the Clean Energy sector in Minnesota in 2014.<sup>48</sup>

According to the 2014 Minnesota Clean Energy Economy Profile, clean energy including biomass, solar, wind, and energy efficiency is one of the most rapidly growing sectors in the state. Clean energy employment in Minnesota has been steadily growing and increased by 78% between 2000 and 2013 showing steady growth even during the economic recession of the mid-2000s.<sup>49, 50</sup> The state's solar energy capacity alone increased 9,670% from 118kW to 11,550 KW between 2000 and 2012.<sup>51</sup> While solar energy and energy efficiency companies currently generate the most revenue within Minnesota (due to their common locally based value chain functions),<sup>52</sup> there is potential to expand other forms of clean energy in the state.

## Study Area

This report focuses on the potential economic impacts of five proposed biomass and solar investments in Duluth and the Arrowhead region of Northeast Minnesota. The geographic scope for this economic impact study includes eight counties consisting of Minnesota's Arrowhead region (Aitkin, Carlton, Cook, Itasca, Koochiching, Lake, and St. Louis) in Northeast Minnesota and Douglas County, Wisconsin<sup>53</sup> (see Figure 2).

**Figure 2. Minnesota's Arrowhead Region and Douglas County, Wisconsin**



The Arrowhead region provides an ideal setting for this analysis due to the areas's rich forest resource-base<sup>54,55</sup> as well as the potential positive impact that investments in clean energy and renewable chemicals

---

<sup>46</sup> IBID

<sup>47</sup> Including woody biomass and other forms of biomass listed above

<sup>48</sup> See Note 45.

<sup>49</sup> In addition, the Clean Energy Trust's 2016 Clean Jobs Midwest Survey reports that Minnesota is currently home to over 54,000 clean energy jobs involving energy efficiency, renewable energy, advanced grid, advanced transportation and clean fuels (Clean Energy Trust <http://www.cleanjobsmidwest.com/state/minnesota/>)

<sup>50</sup> See Note 45.

<sup>51</sup> IBID

<sup>52</sup> IBID

<sup>53</sup> Douglas County, Wisconsin, located on the Wisconsin/Minnesota state line across the border from Duluth, is included in the study area because it is likely that construction employment generated by projects conducted in Duluth will impact it. When modeling the impacts of the increased use of solar, the state of Minnesota was used as an alternate study area.

<sup>54</sup> See Note 14.

<sup>55</sup> See Note 45.

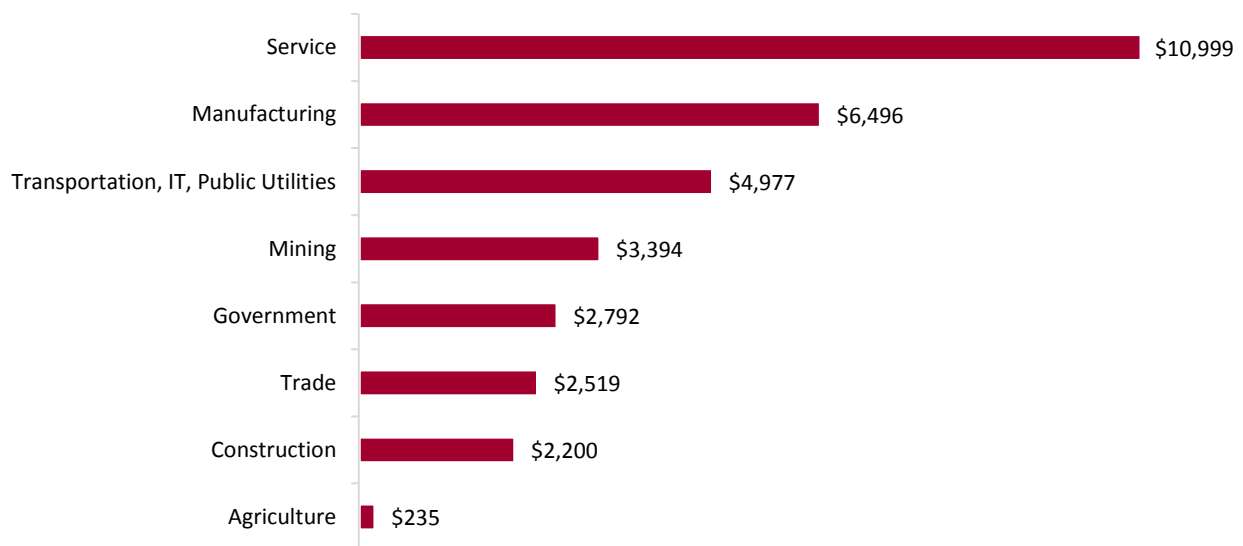
could potentially have on the region’s economy.<sup>56</sup> According to a recent report by DEED, there are currently 317 clean energy jobs<sup>57</sup> in Northeast Minnesota. While this number represents a 146% increase from the year 2000, Northeast Minnesota currently has fewer jobs in this rapidly growing sector compared to other regions in the state.<sup>58</sup> Given the downturn in the Timber and Forestry sector and Minnesota’s overly mature forest resources, which are no longer being harvested at their appropriate rotation ages,<sup>59</sup> the region’s abundant surplus forest material is currently underutilized.<sup>60</sup> Transitioning from imported fossil fuels to local and regionally sourced bioenergy and other clean energy resources may provide the region with opportunities to take advantage of Minnesota’s growing Clean Energy sector<sup>61</sup> and sustainably spur local economic growth.

### **Regional Economic Profile**

The purpose of this study is to estimate the economic impacts of the selected projects on the economy of Northeastern Minnesota. To provide context for that discussion, the following section provides an overview of the regional economy.

Figure 3 shows the total regional output by industry for the major industry sectors in the study area. The Service industry represents the greatest contributor to overall regional output, followed by Manufacturing and then the combined industrial sector of Transportation, Information Technology, and Public Utilities.

**Figure 3. Regional Output by Industry, in Millions of Dollars**



SOURCE: IMPLAN, 2016

Four of the five projects included in the analysis involve the use of biomass as a fuel or feedstock source. These include two public utilities projects (the Duluth Energy Systems retrofit and conversion and the Grand

<sup>56</sup> See Note 14.

<sup>57</sup> In this context, “clean energy jobs” refers to employment in the following sectors: Energy Efficiency, Wind Power, Solar Energy, Bioenergy, and Smart Grid.

<sup>58</sup> See Note 45.

<sup>59</sup> See Note 21.

<sup>60</sup> See Note 14.

<sup>61</sup> See Note 45.

Marais district heating system) and two manufacturing projects (the biochemical production plants and the torrefaction plant).<sup>62</sup> The fifth scenario involves the expansion of solar in the city of Duluth, which would also be classified within the Public Utilities industry. In addition, all five projects have some construction expenses associated with their implementation.

**Table 1. Regional Employment and Output in Related IMPLAN Industry Sectors (2014)**

<i>IMPLAN Sector</i>	<i>Employment</i>	<i>Output</i>
Electric power transmission and distribution	1,012	\$1,259,626,953
Electric power generation - Fossil fuel	866	\$1,149,272,583
Wholesale trade	4,527	\$869,834,656
Construction of other new nonresidential structures	2,102	\$323,950,867
Scientific research and development services	1,458	\$301,356,110
Maintenance and repair construction of nonresidential structures	1,759	\$297,582,092
Construction of new power and communication structures	1,273	\$236,603,943
Architectural, engineering, and related services	1,675	\$226,774,551
Reconstituted wood product manufacturing	253	\$134,667,633
Waste management and remediation services	562	\$108,136,314
Commercial logging	891	\$83,405,746
Construction of new manufacturing structures	513	\$71,632,751
Other basic organic chemical manufacturing	33	\$68,916,016
Extraction of natural gas and crude petroleum	267	\$58,476,341
Natural gas distribution	83	\$50,129,337
Sawmills	110	\$29,445,677
Water, sewage and other systems	46	\$10,668,255
Coal mining*	-	\$0
Electric power generation – Solar*	-	\$0

\*According to IMPLAN datasets, sector did not exist in Arrowhead region in 2014

SOURCE: IMPLAN, 2016

Table 1 shows a complete list of the IMPLAN sectors selected for modeling the impacts of the selected projects.<sup>63</sup> These sectors include items such as Construction, Electric Power Generation (such as fossil fuel and renewable sources) Commercial Logging, and Manufacturing. Estimated employment and output values for the year 2014 are shown in the right column. The Electric Power Transmission and Distribution sector reported the highest levels of output in 2014, followed by Electric Power Generation from Fossil Fuel. Wholesale Trade had high levels of output as well and employed more than 4,500 workers. Other major sectors in terms of employment include Construction (various types), Maintenance and Repair Construction

<sup>62</sup>It is important to clarify that biomass will be utilized by these projects in two different ways. The Grand Marais district heating system and Duluth Energy Systems plant retrofit projects will utilize locally produced biomass as a fuel source, which will be burned for energy. The torrefaction and biorenewable chemical production plants will utilize locally produced biomass as a raw material for the production of value-added energy products. The project stakeholders provided the projected employment and biomass usage estimates for their respective projects.

<sup>63</sup> IMPLAN allows for impacts to be modeled on industry sectors (e.g. Commercial Logging), commodities (e.g. Logs and Roundwood), or a combination of the two. For this analysis, both industry sectors and commodities were selected for modeling, depending on the type of project or the description of the budget item. For simplicity, only industry sectors are shown in Table 1. A more detailed description of sectors and commodities used in modeling each project is in Appendix A.

of Nonresidential Structures, and Architectural, Engineering, and Related Services. These five projects, were they to occur, could represent a significant increase in the employment and production of several of the sectors identified in Table 1.

### ***Biomass Feedstock Availability***

Four of the five projects included in this analysis use woody biomass as a feedstock. Were these projects all to occur, this could also represent a substantial increase in production for the forestry industry, particularly the Commercial Logging and Sawmills sectors. As can be seen in Table 1 on the previous page, the Commercial Logging sector employed nearly 900 workers in 2014 and produced \$83.4 million in output, while the Sawmills sector in the study area employed just over 100 workers and produced \$29.4 million in output.

Minnesota currently contains about 17.4 million acres of forested land, and 15.6 million acres of this land (about 90%) is able to produce a commercially viable harvest.<sup>64</sup> According to a 2014 report conducted by Minnesota’s Department of Natural Resources (DNR),<sup>65</sup> the total wood harvested and utilized from timberland by industry and fuelwood users in Minnesota was 2.93 million cords in 2012 and was between 2.4 and 2.7 million cords in 2013. These estimates are down by nearly 850,000 cords from 2005 harvest levels. The same report indicates that timber availability is high, particularly on private lands, and there is a need for additional utilization and management. The DNR estimates that the state can likely support an additional 1.5 to 2.0 million cords of annual harvest beyond the 2.9 million cord level without causing any damage to forest regeneration, soil productivity, water quality, wildlife habitat, or aesthetic value.<sup>66</sup>

**Table 2. Annual Feedstock Requirements for Biomass Projects**

<i>Project</i>	<i>Annual Feedstock Estimates (tons of green biomass)</i>	<i>Cords</i>
Grand Marais Biomass District Heating System	5,400	2,348
Duluth Energy Systems Plant Retrofit and Biomass Conversion	42,000	18,261
Torrefaction Processing Plant	260,000	113,043
Biorenewable Chemical Production Plants	319,000	138,696
Total	626,400	272,348

*SOURCES: NRRI, FVB ENERGY INC. REPORT # GM-14-001-0, DULUTH ENERGY SYSTEMS, GREAT PLAINS INSTITUTE*

According to project stakeholders,<sup>67</sup> the four biomass projects included in this study would require approximately 626,000 tons of locally harvested<sup>68</sup> biomass each year, the equivalent of approximately 272,000 cords. Different types of woody feedstock will have different conversion factors from cords to raw biomass. The conversion factor from dry-tons of biomass to cords used for this report is 1.15 dry tons per cord (or 2.3 green tons per cord), and was developed by NRRI based upon the average species mix for forests in Minnesota<sup>69</sup>.

<sup>64</sup> See Note 21.

<sup>65</sup> See Note 7.

<sup>66</sup> See Note 21.

<sup>67</sup> In this context, the term “project stakeholders” refers to representatives from Duluth Energy Systems, Ecolibrium 3, RREAL, NRRI, and the Great Plains Institute who familiar with the projects.

<sup>68</sup> In the context of this study, biomass harvesting and associated economic and jobs impacts were assumed to occur within the study area.

<sup>69</sup> NRRI developed the conversion factors utilized in this report based upon the following Research Note published by the



The estimated amount of annual feedstock required (272,000 cords) represents roughly 9% of 2012 harvest levels. Due to the current excess quantity of unharvested forest biomass in the state<sup>70</sup> as well as the need for additional utilization and management, the proposed biomass projects would utilize approximately 14-18% of the additional 1.5 to 2 million cords of additional annual harvest that the state's forests can sustainably support.<sup>71, 72</sup>

---

**The biomass projects included in this study would require approximately 275,000 cords annually. The additional harvest that would be supported by these projects is within the state's sustainable harvest levels.<sup>70, 71</sup>**

---

In addition to the amount of physical biomass that can be sustainably harvested, the economic and social availability of biomass in Northeast Minnesota should also be considered.<sup>73</sup> Economic availability refers to the availability of biomass at different price points, while social availability refers to the amount of biomass that is available for use based upon landowner/societal land management objectives.<sup>74</sup> While publicly owned forests sell most of their available timber annually, Minnesota has a high percentage of privately owned land on which a significant portion of the state's additional forests are situated.<sup>75</sup> The potential projects could add value to privately held forest resources, which could help to maintain those lands as forest and reduce development, parcelization, threat of wildfire, and land conversion.<sup>76</sup> Research conducted by the University of Minnesota's Department of Forest Resources focusing upon the physical, economic, and social availability of biomass for energy concluded that the existing demand for biomass products constrains the expansion of the forest biomass industry in the state more than the available supply of biomass.<sup>77</sup> This research indicates that there is potential to increase biomass harvest within the state without facing constraints to availability.

### ***Input-Output Modeling***

This study uses the IMPLAN<sup>78</sup> Group's input-output modeling data and software (IMPLAN version 3.1). The IMPLAN database contains county, state, zip code, and federal economic statistics, which are specialized by region, not estimated from national averages. Using classic input-output analysis in combination with region-specific Social Accounting Matrices and Multiplier Models, IMPLAN provides a highly accurate and adaptable model for its users. IMPLAN data files use the following federal government data sources:

- U.S. Bureau of Economic Analysis Benchmark Input-Output Accounts of the U.S.
- U.S. Bureau of Economic Analysis Output Estimates

---

USDA's Northern Research Station: Miles and Smith. (2009). Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America.

<sup>70</sup> See notes 14, 16, and 17

<sup>71</sup> See Note 7.

<sup>72</sup> See Note 21.

<sup>73</sup> 2010 Outlook for Forest Biomass Availability in Minnesota: Physical, Environmental, Economic and Social Availability.

<http://conservancy.umn.edu/bitstream/handle/11299/107779/211.pdf;jsessionid=02DE990262E0CB08859817119C7AB1A4?sequence=1>

<sup>74</sup> IBID

<sup>75</sup> See Note 18.

<sup>76</sup> Source: Anna Dirkswager, Clean Energy Economy Minnesota.

<sup>77</sup> See Note 73.

<sup>78</sup> www.implan.com

*Bureau of Business and Economic Research  
Labovitz School of Business and Economics  
University of Minnesota Duluth*

- U.S. Bureau of Economic Analysis Regional Economic Information Systems (REIS) Program
- U.S. Bureau of Labor Statistics Covered Employment and Wages (CEW) Program
- U.S. Bureau of Labor Statistics Consumer Expenditure Survey
- U.S. Census Bureau County Business Patterns
- U.S. Census Bureau Decennial Census and Population Surveys
- U.S. Census Bureau Economic Censuses and Surveys
- U.S. Department of Agriculture Census

IMPLAN data files consist of the following components: employment, industry output, value added, institutional demands, national structural matrices, and inter-institutional transfers. Economic impacts are made up of direct, indirect, and induced impacts. The data used was the most recent IMPLAN data available, which is for the year 2014. All data are reported in 2016 dollars.

Some limitations of the modeling and impact results should be mentioned. First, IMPLAN is a fixed-price model. This means that the modeling software assumes no price adjustment in response to supply constraints or other factors. As mentioned previously, fuel prices can fluctuate significantly from year to year, and can be highly unpredictable. Furthermore, most of the projects included in the analysis have no confirmed timeline for construction or operations. This creates even more uncertainty regarding what the cost competitiveness of renewable energy technologies would be once the projects become operational. Therefore, rather than attempt to estimate the additional costs (or benefits) to consumers and other affected stakeholders, this analysis uses current prices and data to estimate the economic effects of the proposed projects. No negative impacts to government or consumers was included, as it was beyond the scope of the analysis. Similarly, impacts of additional tax revenues from this economic activity were not included in the results of this analysis.

Although a comprehensive Cost-Benefit Analysis approach might have better captured the full extent of the economic effects of the five chosen projects, such a complex and intensive analysis would require much greater depth of information than was available as well as many more assumptions about future events and price levels and was beyond the scope of this study.

More details on the assumptions and limitations of these models can be found in Appendix C, IMPLAN Assumptions.

## Projects

The following section provides more detail on each of the five projects included in the economic impact analysis. For each project, a brief overview of the project is included, followed by the estimated construction and operational budgets and, lastly, the results of the economic impact modeling.<sup>79, 80</sup>

For each proposed project, data required for modeling was provided by feasibility reports and representatives familiar with the project. For the construction portion of each project, inputs included major construction expenditures, employment estimates, employee compensation, and the percentage of local labor and equipment purchases. For the operations portion of the analysis, required inputs included the estimated employment, annual expenditures, and labor income required to run and maintain the facility

---

<sup>79</sup> For all projects, detailed inputs and methodology used in modeling are available in Appendix A

<sup>80</sup> Note that in the model, fuel (or feedstock) source was differentiated between sawmill residuals and commercial logging when such data was available. Further discussion and details regarding this for each project can be found in Appendix A

once it is operational. In addition, project representatives were asked to estimate the percentage of expenditures that would likely be purchased locally. Typical operational expenditures included feedstock purchases, electricity costs, maintenance expenses, and employee wages and benefits. More details on each project’s data sources and inputs are available in Appendix A, Detailed Inputs and Methodology.

The BBER worked closely with the Energy Transition Lab in determining key assumptions in the collection of data and the development of the IMPLAN models. The research team worked under the assumption that project stakeholders provided good-faith estimates for the proposed projects. In instances where data was not provided by representatives affiliated with the project, the research team relied on IMPLAN estimates and secondary data sources as inputs.

## ***I. Grand Marais Biomass District Heating System***

One of the projects currently being considered in Minnesota’s Northeast region is a biomass district heating system located in Grand Marais. District energy systems like the one being proposed for Grand Marais use central plants to provide thermal energy to multiple buildings. This approach replaces the need for individual, building-based boilers, furnaces, and cooling systems. Underground pipelines distribute thermal energy in the form of hot water, steam, or chilled water from the heating plant to each of the connected buildings. Energy is then extracted at the buildings, and the water is brought back to the plant through return pipes to be heated or cooled again.<sup>81</sup> District energy heating and cooling plants, especially those that generate electricity, are far more efficient than conventional heating, cooling, and electrical systems<sup>82</sup>

According to the results of a 2014 feasibility study conducted by FVB Energy Inc., the proposed system in Grand Marais would be fueled by woody biomass and would deliver heat to 18 local customers, mostly in the public sector.<sup>83</sup> The Cook County Local Energy Project (CCLEP) and its partners have sponsored studies of the feasibility of a biomass district heating system motivated by the following goals:

- Stabilization and reduction of long-term energy costs
- Increased energy security by using local fuels
- Improved forest management
- Retention of energy dollars in the local economy
- Creation of local jobs
- Reduction of carbon emissions

The study asserts that biomass district heating in Grand Marais is technically viable. The proposed fuel source, low-value sawmill waste material or logging slash, is both available in ample supply and at a cost-competitive price, according to the study. The proposed biomass district heating plant would be located in the Cedar Grove Business Park, with a 6.8 million Btu per hour (MMBtu/hr) biomass boiler and additional propane boilers for peaking and back-up.

**Table 3. Biomass District Heating System Direct Inputs (Construction and Operations)**

	<i>Direct Employment</i>	<i>Total Spending</i>	<i>% Spent Locally</i>	<i>Direct Local Spending</i>
Construction	50	\$12,300,000	66%	\$8,093,037
Operations	2	\$490,392	100%	\$490,392

SOURCE: FVB ENERGY INC. REPORT # GM-14-001-0

<sup>81</sup> Biomass Energy Resource Center <http://www.biomasscenter.org/what-we-do/our-expertise/district-heating>

<sup>82</sup> International District Energy Association <http://www.districtenergy.org/what-is-district-energy/>

<sup>83</sup> See Note 23.

Table 3 shows inputs used in modeling the effects of the Biomass District Heating System. The construction costs for the project are expected to total approximately \$12 million with more than \$8 million of that anticipated to be spent within the study area. The second row contains the budget for a typical year of operations. According to project stakeholders, the annual cost to operate the plant will be almost \$500,000, all of which would be spent within the study area.

The following tables summarize the economic impacts from the Grand Marais district heating system on the eight-county study area. Impacts are broken out by construction (Table 4) and operations (Table 5, page 13). These effects must be considered separately. Construction generates a temporary increase in economic activity during the period in which it occurs. After the completion of the construction project, this additional activity will cease, and the economic impacts will no longer be felt in that region. Conversely, the economic effects of the operation of the facility or plant represent the annual on-going impacts of the plant or facility as long as it is operational.

For all projects, the inputs provided by project stakeholders represent the direct effects and are the basis for quantifying the full economic effects of the project. Indirect Effects show the measurement of increased spending between commercial, government, and service industries as a result of the direct effects. Induced Effects measure the amount of increased spending by residential households as a result of the direct effects. Total Effect is the sum of Direct, Indirect, and Induced Effects.

**Table 4. Detailed Impacts of Grand Marais Biomass District Heating System - Construction**

<i>Impact Type</i>	<i>Employment</i>	<i>Labor Income</i>	<i>Value Added</i>	<i>Output</i>
Direct Effect	50	\$2,674,105	\$3,838,736	\$8,093,037
Indirect Effect	15	\$571,686	\$852,189	\$2,096,630
Induced Effect	17	\$630,872	\$1,107,683	\$2,136,281
<b>Total Effect</b>	<b>82</b>	<b>\$3,876,663</b>	<b>\$5,798,608</b>	<b>\$12,325,949</b>

SOURCE: IMPLAN, 2016

Table 4 shows the economic impacts of the proposed Grand Marais district heating system construction project. The far left column of Table 4, labeled Employment, indicates the number of jobs that the construction project is estimated to support directly and indirectly. Employment estimates are in terms of jobs, not in terms of full-time equivalent employees. For construction projects, jobs are typically short-term and temporary, meaning the effects will be felt during the project and will cease upon its completion. According to the results of this analysis, it is estimated that the construction of the district heating system would support 82 jobs in the region.

The second column, Labor Income, is an estimate of all employee compensation, including wages, benefits, and proprietor income. It is estimated that the District Heating System project would contribute nearly \$4 million in employee wages and benefits in the study area over the life of the construction project. Column three, labeled Value Added, shows the economic impacts of the expenditures that the projects would put specifically towards wages, rents, interest, and profits related to its construction. Value Added represents the contribution to GRP made by an individual producer, industry, or sector. The project is estimated to have a total Value Added impact of roughly \$6 million in the study area during the construction period (2016). The last column, Output, is the value of all local production required to sustain construction activities. Based on the estimates provided by project stakeholders, construction of this project is expected to add more than \$12 million regionally, in Direct, Indirect, and Induced spending effects.

**Table 5. Detailed Impacts of Grand Marais Biomass District Heating System – Typical Year Operations**

<i>Impact Type</i>	<i>Employment</i>	<i>Labor Income</i>	<i>Value Added</i>	<i>Output</i>
Direct Effect	2	\$147,500	\$297,306	\$490,392
Indirect Effect	3	\$148,772	\$183,882	\$446,952
Induced Effect	2	\$57,580	\$101,111	\$194,993
<b>Total Effect</b>	<b>7</b>	<b>\$353,852</b>	<b>\$582,299</b>	<b>\$1,132,337</b>

SOURCE: IMPLAN, 2016

Table 5 shows a similar breakout of operational effects. According to the results, the effects for a typical year of operations from the project would equate to seven new jobs in the eight-county study area (Employment), approximately \$350,000 in wages, benefits, and proprietor income (Labor Income), and a contribution of over \$580,000 to the region’s GRP (Value Added). Overall, an additional \$1.1 million in annual local production would be required to sustain the proposed facility.

## **II. Duluth Energy Systems Plant Retrofit and Biomass Conversion**

Duluth Energy Systems is a city-owned steam plant that has provided the Canal Park and central business districts with stable, reliable heat since 1932.<sup>84</sup> In December of 2013, the city commissioned a five-year master plan to improve the efficiency of the system, enhance environmental stewardship, improve cost competitiveness, and identify opportunities for growth. The recommendations from the plan included:<sup>85</sup>

- Implement hot water heating to select areas currently served by steam
- Add customers within the current boundaries of the system
- Enhance the flexibility of the fuel mix by integrating the use of locally derived biomass

The implementation of this plan consists of two phases. Phase I includes the conversion of the steam distribution system to hot water distribution for the one-mile section of Superior Street, which will be entirely reconstructed during the three construction seasons of 2017 through 2019. The reconstruction will include the replacement or renewal of all under-street utilities including the existing 1930s vintage steam pipes. Several additional modifications to the current district energy system will also be required when the system is converted from steam to hot water. The modifications that will occur during Phase I of the project include changes to the Duluth Energy Systems plant that will enable it to produce hot water for distribution, installation of service laterals to each building in the energy system, and the installation of additional system interfaces between additional customers’ buildings and the district energy system.

Because the Great Lakes Aquarium (GLA), which is located on the south or “lake” side of the I-35 freeway is currently served from the steam system on Superior Street, Phase I also includes extending the hot water system currently serving the Duluth Entertainment and Convention Center (DECC) to GLA. This will require modifications to the DECC heating system in order to improve its efficiency, thereby “freeing up” sufficient thermal energy to heat the GLA.

Phase II includes the installation of equipment at the existing Duluth Energy Systems plant that will allow locally derived woody biomass (wood chips) produced from waste wood, such as logging slash to be consumed for the production of hot water at the district heating plant. Upon completion of this phase,

<sup>84</sup> Duluth Energy Systems <http://www.duluthenergysystems.com/about/>

<sup>85</sup> Duluth Steam Master Plan, December 2013 [http://www.duluthenergysystems.com/wp-content/uploads/2013/01/Duluth-Master-Plan-Final\\_December2013.pdf](http://www.duluthenergysystems.com/wp-content/uploads/2013/01/Duluth-Master-Plan-Final_December2013.pdf)

approximately 25% of the system’s fuel input requirement will be met with biomass<sup>86</sup>.

The timing of this large-scale project in Duluth has been engineered to coincide with street renovation work that is scheduled to take place in Downtown Duluth. By combining Phase I of the project with scheduled street renovations, Duluth will be able to significantly reduce the cost of the project.<sup>87</sup> All Phase I activities were modeled as occurring in the year 2019. All Phase II activities were modeled as occurring in the year 2016. All results’ dollar amounts were reported in current 2016 dollars.

**Table 6. Duluth Energy Systems Plant Direct Inputs (Construction and Operations)**

	<i>Direct Employment</i>	<i>Total Spending</i>	<i>% Spent Locally</i>	<i>Direct Local Spending</i>
Construction Phase I	68	\$43,315,000	77%	\$33,250,000
Construction Phase II	45	\$5,000,000	68%	\$3,380,000
Operations	3	\$1,060,000	100%	\$1,060,000

*SOURCE: DULUTH ENERGY SYSTEMS*

Table 6 shows the direct inputs used in modeling the effects of the Duluth Energy Systems Plant retrofit and biomass conversion. The inputs are broken out by Phase I and II of construction and a typical year of operation. The first phase of construction, which involves the reconstruction of Superior Street, is the more financially intensive portion of the project, with a budget of more than \$43 million (\$33 million direct local spending). The second phase of construction is anticipated to cost approximately \$5 million, with about \$3 million of that expected to be spent within the study area. The last row of Table 6 shows the budget for a typical year of operations for the plant once construction is complete. Project stakeholders anticipate about a \$1 million increase in the current operating budget for the plant, which will be spent locally.

**Table 7. Detailed Impacts of Duluth Energy Systems Plant Phase I – Construction**

<i>Impact Type</i>	<i>Employment</i>	<i>Labor Income</i>	<i>Value Added</i>	<i>Output</i>
Direct Effect	68	\$6,750,000	\$15,316,034	\$40,280,647
Indirect Effect	98	\$5,022,905	\$7,577,342	\$15,406,781
Induced Effect	59	\$2,216,310	\$3,889,989	\$7,503,529
<b>Total Effect</b>	224	\$13,989,215	\$26,783,365	\$63,190,957

*SOURCE: IMPLAN, 2016*

The results of modeling are shown in Tables 7-9. The majority of the impacts from the construction project will come from Phase I and total \$40 million<sup>88</sup> in direct spending. For Phase I, the City of Duluth expects to directly employ 68 local workers. The construction will result in an estimated total payroll of \$6.8 million. As a result of local input purchases and the spending of labor income, Phase I of the construction project is expected to support more than 220 jobs through direct, indirect, and induced spending in the study region and will lead to roughly \$27 million in wages, rents, interest, and profits (Value Added).

<sup>86</sup> See Note 85.

<sup>87</sup> See Note 86.

<sup>88</sup> Equipment spending is subject to margining and is the reason that the total direct spending shown in Table 7 is different than what was originally seen in Table 6. For more information on margins, see the “Margins” definition in Appendix B.

**Table 8. Detailed Impacts of Duluth Energy Systems Plant Phase II – Construction**

<i>Impact Type</i>	<i>Employment</i>	<i>Labor Income</i>	<i>Value Added</i>	<i>Output</i>
Direct Effect	45	\$1,378,569	\$2,380,359	\$5,000,000
Indirect Effect	29	\$1,471,280	\$2,327,663	\$4,682,802
Induced Effect	15	\$554,038	\$972,448	\$1,875,766
<b>Total Effect</b>	<b>89</b>	<b>\$3,403,887</b>	<b>\$5,680,470</b>	<b>\$11,558,568</b>

SOURCE: IMPLAN, 2016

The impacts from Phase II of the project are anticipated to provide a smaller, but still significant, impact for the region. This phase of the construction project is estimated to support nearly 90 jobs in the eight-county region and generate \$5.7 million in wages, rents, interest, and profits (Value Added).

**Table 9. Detailed Impacts of Duluth Energy Systems Plant Phase II – Typical Year Operations**

<i>Impact Type</i>	<i>Employment</i>	<i>Labor Income</i>	<i>Value Added</i>	<i>Output</i>
Direct Effect	3	\$250,000	\$575,092	\$1,060,000
Indirect Effect	11	\$506,429	\$673,265	\$2,198,418
Induced Effect	4	\$147,031	\$258,133	\$497,859
<b>Total Effect</b>	<b>18</b>	<b>\$903,460</b>	<b>\$1,506,490</b>	<b>\$3,756,277</b>

SOURCE: IMPLAN, 2016

The operational impacts from the steam plant retrofit and conversion are likely to be small. However, unlike the construction impacts, they are recurring annually for the life of the plant. Project stakeholders expect that the changes to the steam plant will require three additional employees and about \$1 million in additional annual expenses for the city. Through increased spending on the part of industry and employees, these direct effects will generate a total effect of nearly 20 jobs, \$900,000 in new wages and benefits, and contribute more than \$1.5 million to the regional economy (Value Added).

One interesting point to note is regarding the size of the indirect effects from the plant's operations. Typically, a facility's direct effects are the largest, while indirect and induced effects are relatively small. In this case, however, the indirect effects are larger due to the unique nature of the plant's expenditures. The switch to woody biomass as a primary energy source adds \$1.3 million in new spending to the region's timber industry.<sup>89</sup> Most of the indirect effects shown in Table 9 are the result of that spending.

### **III. Torrefaction Processing Plant**

Torrefaction is a thermal process to convert biomass into a coal-like material, which has better fuel characteristics than the original biomass.<sup>90, 91</sup> In a solid form, this fuel has significant advantages over common biomass fuels, such as standard wood pellets or chips<sup>92</sup>. According to the Natural Resources Research Institute (NRRRI), one ton of torrefied material is roughly equivalent (95%) to one ton of western

<sup>89</sup> The net effect on the Duluth Steam Plant's annual budget (\$1.06 million) is the result of an increase in spending on woody biomass combined with a decrease in spending on coal plus labor and additional expenses. See Appendix A for more details.

<sup>90</sup> Biomass Technology Group BV ([www.btgworld.com/en/rtd/technologies/torrefaction](http://www.btgworld.com/en/rtd/technologies/torrefaction))

<sup>91</sup> In the case of the torrefaction plant, a small amount of locally produced woody biomass would likely be utilized as a source of process energy, but the bulk of it would be utilized as the principle feedstock in the production of value-added torrefied wood material.

<sup>92</sup> NRRRI Website, 2015: <http://www.nrrri.umn.edu/news/2015/autumn2015.htm>

(Powder River Basin) coal in energy content.<sup>93</sup> According to NRRI, the energy needed for the torrefaction process will be derived from 10% of the same biomass feedstock that will be converted into the torrefied material. According to the Coalition for Sustainable Rail, it is more energy efficient to torrefy certain biomaterials than to mechanically dry them in wood chip production.<sup>94</sup> With its pilot facility in Coleraine, MN NRRI is currently undergoing studies to confirm the efficiency projections for the torrefaction process.<sup>95</sup> In addition, compared to coal, burning torrefied material reduces mercury emissions and decreases treatment costs on flue gas.<sup>96</sup> Torrefied material is also a more homogenous product and easier to transport and store compared to unconverted biomass.<sup>97</sup> Recently, UMD's Natural Resources Research Institute (NRRI) has begun working to develop this technology and to expand it more broadly for commercial use.<sup>98</sup>

In addition, the local production of torrefied material could also further facilitate the conversion from coal to woody biomass for energy suppliers in Northern Minnesota.<sup>99</sup> Because torrefied material is designed to have compatible properties with coal, the use of such material in existing plant infrastructure would not require expensive retrofits.<sup>100</sup> As Jim Green, General Manager, from Duluth Energy Systems pointed out in a recent interview, the ability to purchase locally produced torrefied material at an affordable price would allow plants that currently burn coal to integrate biomass more cost effectively. This would allow local energy producers to avoid the high capital costs involved in converting infrastructure to accept biomass while also reducing their emissions profile.<sup>101, 102</sup>

Project stakeholders feel that the Arrowhead region would be an ideal location for the construction of a torrefaction plant. While the project is still in the planning process and no specific location has yet been designated, for the purpose of this scenario, it is assumed that the torrefaction plant will be constructed within the Arrowhead region.

---

With its project in Coleraine, MN, the NRRI hopes to develop a means of reducing CO<sub>2</sub> emissions from the existing energy system while keeping the costs of conversion reasonable  
(Don Fosnacht, NRRI)

---

---

<sup>93</sup>Minnesota imports coal from the western United States. While coal sourced from the eastern United States has a higher energy content per pound, it is typically not utilized in Minnesota due to the material's relatively high sulfur content and emissions profile compared to coal mined from the west (Don Fosnacht, NRRI).

<sup>94</sup> <http://csrail.org/torrefied-biomass/>

<sup>95</sup> See Note 93.

<sup>96</sup> IBID

<sup>97</sup> See Note 95.

<sup>98</sup> See Note 93.

<sup>99</sup> NRRI <http://www.nrri.umn.edu/default/pt.asp?id=1771>

<sup>100</sup> IBID

<sup>101</sup> Phone Interview with Jim Green, Duluth Energy Systems, April 8, 2016

<sup>102</sup> Ontario Power Generation provides one example of how a coal plant was converted to run off torrefied material: <http://www.opg.com/about/environment/Documents/OPGBiomassConversion.pdf>



**Table 10. Torrefaction Plant Direct Inputs (Construction and Operations)**

	<i>Direct Employment</i>	<i>Total Spending</i>	<i>% Spent Locally</i>	<i>Direct Local Spending</i>
Construction	98	\$32,034,357	60%	\$19,282,331
Operations	19	\$12,465,000	87%	\$10,852,500

SOURCE: NATURAL RESOURCES RESEARCH INSTITUTE (NRRI) - UNIVERSITY OF MINNESOTA

Table 10 shows the inputs provided by project stakeholders for the proposed torrefaction plant, which would produce 100,000 tons of torrefied material annually. These inputs represent the anticipated budget for construction and operations as well as the amount of local purchases for the two phases of the project. One notable point to mention here is with regards to the construction budget. While the total spending on construction for the project is fairly large (\$32 million), much of that spending is on specialized equipment, of which only 10% is expected to be purchased within the study area.<sup>103</sup> For that reason, the direct local spending is less than \$20 million.

**Table 11. Detailed Impacts of Torrefaction Plan – Construction**

<i>Impact Type</i>	<i>Employment</i>	<i>Labor Income</i>	<i>Value Added</i>	<i>Output</i>
Direct Effect	98	\$5,662,036	\$8,041,200	\$18,110,561
Indirect Effect	56	\$3,344,309	\$3,854,784	\$8,387,210
Induced Effect	45	\$1,667,303	\$2,926,314	\$5,644,737
<b>Total Effect</b>	<b>198</b>	<b>\$10,673,648</b>	<b>\$14,822,298</b>	<b>\$32,142,508</b>

SOURCE: IMPLAN, 2016

**Table 12. Detailed Impacts of Torrefaction Plan – Typical Year Operations**

<i>Impact Type</i>	<i>Employment</i>	<i>Labor Income</i>	<i>Value Added</i>	<i>Output</i>
Direct Effect	19	\$1,440,000	\$2,208,482	\$12,465,000
Indirect Effect	104	\$4,879,440	\$5,351,756	\$10,588,197
Induced Effect	33	\$1,227,914	\$2,156,912	\$4,158,965
<b>Total Effect</b>	<b>156</b>	<b>\$7,547,354</b>	<b>\$9,717,150</b>	<b>\$27,212,162</b>

SOURCE: IMPLAN, 2016

Tables 11 and 12 show the detailed impacts of the economic modeling. Like the previous impacts, these tables show how the initial spending (direct effect<sup>104</sup>) ripples through the economy due to increased inter-industry spending (indirect effect) and increased spending on the part of local households (induced effect). The total effect is the sum of these three measures.

As previously noted, the relatively large indirect effects from the plant's operations are the result of the use of woody biomass as the main feedstock utilized in the production of torrefied material. According to project stakeholders from the NRRI, while the torrefaction process can utilize any type of woody biomass, the ideal feedstock for the torrefaction plant would be composed primarily of waste residue from normal logging

<sup>103</sup> Estimate from Brigid Tuck, UMN Extension, based on similar studies

<sup>104</sup> Equipment spending is subject to margining and is the reason that the total direct spending shown in Table 11 is different than what was originally seen in Table 10. For more information on margins, see the "Margins" definition in Appendix B.

operations or other low-value (or high fire risk) woody biomass.<sup>105</sup> According to project stakeholders, more than 60% of the torrefaction processing plant’s annual budget would be spent on woody biomass. In total, the plant is estimated to contribute \$7.8 million annually to the region’s timber industry.<sup>106</sup> Most of the indirect effects shown in Table 12 are the result of that spending.

#### **IV. Biorenewable Chemical Production Plants**

Two biorenewable chemical production plants are currently being considered for development in the Northeast region of the state. These facilities would turn locally produced roundwood into cellulosic sugars that are then used to produce wood-derived advanced biofuels and biobased chemicals.<sup>107</sup> The renewable chemicals produced are designed to replace current petroleum-derived chemicals and renewable fuels in compliance with the federal Renewable Fuel Standard.

When planning the siting of projects, it is important to take feedstock availability and potential sources of competition for roundwood into account. According to current projections, both plants are expected to be located in Northeast Minnesota within the Arrowhead region. However, the exact locations of the two plants included in this analysis is confidential. In addition, all data for this scenario has been aggregated so that readers cannot infer which companies are involved.

Together, both facilities are expected to produce about 510 million pounds of renewable chemicals annually. This would amount to approximately \$336 million worth of bio-based chemicals and advanced biofuels.<sup>108</sup>

**Table 13. Biorenewable Chemical Production Plants Direct Inputs (Construction and Operations)**

	<i>Direct Employment</i>	<i>Total Spending</i>	<i>% Spent Locally</i>	<i>Direct Local Spending</i>
Construction	600	\$258,000,000	88%	\$227,188,500
Operations	165	\$152,269,000	75%	\$114,727,995

SOURCE: GREAT PLAINS INSTITUTE

Table 13 shows the inputs used in modeling the effects of the biorenewable chemical production plants. The construction costs for the two projects are expected to total approximately \$258 million, with more than \$227 million of that anticipated to be spent within the study area. The second row contains the budget for a typical year of operations. According to project stakeholders, the annual cost to operate the plants will be approximately \$152 million, of which approximately \$115 million would be spent within the study area.

Tables 14 and 15 show the detailed impacts of the plants’ construction and operations. The construction impacts are slightly larger than the operational impacts but are considered short-term and temporary. On the other hand, the operational impacts represent the effects of operating the plants. These impacts can be considered to be recurring, as long as the plants are operational.

<sup>105</sup> Don Fosnacht and Richard Kiesel, NRRRI

<sup>106</sup> See Appendix A for more details.

<sup>107</sup> See Note 27.

<sup>109</sup> Like the torrefaction plant, the two proposed biorenewable chemical plants would utilize locally produced woody biomass as the principle feedstock in the production of value-added products rather than as a source of energy. IBID

**Table 14. Detailed Impacts of Biorenewable Chemical Production Plants - Construction**

<i>Impact Type</i>	<i>Employment</i>	<i>Labor Income</i>	<i>Value Added</i>	<i>Output</i>
Direct Effect	600	\$34,223,171	\$73,826,194	\$224,361,387
Indirect Effect	176	\$9,052,568	\$12,847,558	\$34,542,480
Induced Effect	225	\$8,412,735	\$14,767,278	\$28,483,680
<b>Total Effect</b>	<b>1,001</b>	<b>\$51,688,473</b>	<b>\$101,441,030</b>	<b>\$287,387,547</b>

SOURCE: IMPLAN, 2016

The construction of the two biorenewable chemical plants, with a combined budget of roughly \$250 million, would generate approximately \$225 million in direct spending within the study area.<sup>109, 110</sup> Overall, the two projects are estimated to support approximately 1,000 jobs. Most of those workers would be directly employed in the construction of the plants. Project stakeholders anticipate needing 600 workers to complete the construction projects. Another 176 jobs are the result of increased spending between commercial, government, and service industries as a result of the direct effects (i.e. Indirect Effects). Finally, an additional 225 jobs would be supported through increased spending by residential households. The employees of the biorenewable chemical plants spend the income they earn on housing, utilities, groceries, and other goods. These represent induced effects.

**Table 15. Detailed Impacts of Biorenewable Chemical Production Plants – Typical Year Operations**

<i>Impact Type</i>	<i>Employment</i>	<i>Labor Income</i>	<i>Value Added</i>	<i>Output</i>
Direct Effect	165	\$10,400,000	\$15,609,997	\$152,269,001
Indirect Effect	522	\$27,158,068	\$39,816,658	\$111,276,825
Induced Effect	196	\$7,229,870	\$12,817,311	\$24,719,311
<b>Total Effect</b>	<b>882</b>	<b>\$44,857,938</b>	<b>\$68,243,966</b>	<b>\$288,265,137</b>

SOURCE: IMPLAN, 2016

While the total effects from the operations of the plants are similar in magnitude to the total effects from construction, the direct inputs are much smaller, whereas the indirect effects are very large. This is the result of increased spending on woody biomass, of which the plants are expected to spend approximately \$20 million annually.<sup>111</sup>

## **V. Solar Power Production Arrays**

This section describes the aggregated costs associated with several solar energy projects that have been proposed for Duluth, MN. These projects include a range of sizes and locations from 10 kW rooftop projects to very large ground-mounted projects. In total, these projects add up to the installation of 2482kW of solar in Duluth. The list below describes each individual solar project that is included in this summary.

<sup>109</sup> The biorenewable chemical production plants are likely to receive significant economic development incentives. While it is best practice in economic modeling to create a balanced budget scenario, in which taxpayers or government entities are negatively impacted to reflect the cost of the incentive, this was beyond the scope of this study, as the amount of the incentive and the burden of cost is currently unknown. A future study, once funding sources are known, could incorporate this technique.

<sup>110</sup> Equipment spending is subject to margining and is the reason that the total direct spending shown in Table 14 is different than what was originally seen in Table 13. For more information on margins, see the “Margins” definition in Appendix B.

<sup>111</sup> Source: Brendan Jordan, Great Plains Institute

- A 40kW and a 1000kW Community Solar Project, which Minnesota Power has submitted in its proposal to Public Utilities Commission (PUC)
- Five 10kW rooftop solar projects. These solar projects will be placed on five duplexes with a total installed wattage of 50Kw.
- A 70kW solar array on the city public works building. This includes storage for critical load backup and demand management.
- A 160kW ground mounted community solar project.
- A Community Solar Garden Rural Renewable Energy Alliance (RREAL) project. This will be a 250kW ground mounted array.
- Four ground-mounted solar projects at city pumping stations totaling 912kW in size.

**Table 16. Solar Power Production Arrays Direct Inputs (Construction and Operations)**

	<i>Direct Employment</i>	<i>Total Spending</i>	<i>% Spent Locally</i>	<i>Direct Local Spending</i>
Construction	82	\$6,058,740	35%	\$2,096,030
Operations	--	--	--	--

SOURCE: *ECOLIBRIUM 3, RREAL, AND BARBOSE, WEAVER & DARGHOUTH, 2015*

Table 16 shows the estimated construction costs for the construction of all solar projects. Of these costs, it is likely that the smaller solar installations of 70kW or less will be built by contractors from within the Arrowhead Region. It is likely that the most of the installations larger than 70kW will be done by contractors from within Minnesota, but it is not very likely that they will be from the Arrowhead region due to the lack of contractors with expertise with large-scale solar projects in the region. For this reason, the study area for modeling the impacts of solar was expanded to include all of the state of Minnesota and Douglas County, WI.

The data collected from project stakeholders suggested that the operational expenditures as a result of the solar projects would be minimal and would not likely occur on an annual basis.<sup>112</sup> Because of this, operational impacts were not modeled.

The following shows the total impacts for the six proposed solar projects, which range in size from small rooftop panels to large community solar gardens. The results in Table 17 represent the overall impacts to the state of Minnesota from the construction of these projects. As mentioned previously, the alternate study area was used for the solar project modeling, as much of the construction labor and materials were expected to be purchased within the state but not within the Arrowhead region.

**Table 17. Detailed Impacts of Solar Power Production Arrays – Construction**

<i>Impact Type</i>	<i>Employment</i>	<i>Labor Income</i>	<i>Value Added</i>	<i>Output</i>
Direct Effect	82	\$1,313,255	\$1,420,485	\$1,784,935
Indirect Effect	1	\$82,988	\$154,883	\$344,001
Induced Effect	9	\$414,612	\$701,585	\$1,250,262
<b>Total Effect</b>	92	\$1,810,855	\$2,276,953	\$3,379,198

<sup>112</sup> Some of the operational expenditures that might occur in the solar projects could include the need to update inverters, occasional repairs, monitoring, snow removal, and project maintenance costs for the larger-scale community projects.

## Overall Impacts

This section provides the direct, indirect, and induced economic impacts of construction and operational activities for the five main projects, measured in employment, output, and value added.

Tables 18 and 19 summarize the combined economic impacts from the four biomass projects on the eight-county study area and the effects of the solar projects on the state of Minnesota. Impacts are broken out by construction (Table 18) and operations (Table 19). These results show the total effects of the Grand Marais biomass district heating system, the Duluth Energy Systems retrofit and biomass conversion project, the torrefaction plant, and the biorenewable chemical production plants, as well as the proposed solar power production arrays. Because the solar power production arrays project was modeled using a different study area, the project effects are not directly comparable to the four biomass projects.

Construction and operations effects must be considered separately. Construction generates a temporary increase in economic activity during the period in which it occurs. After the completion of the construction project, this additional activity will cease, and the economic impacts will no longer be felt in that region. Conversely, the economic effects of the operation of the facility or plant represent the annual ongoing impacts of the plant or facility as long as it is operational.

**Table 18. Combined Effects of Construction, by Project Total Effect**

<i>Total Effects</i>	<i>Employment</i>	<i>Labor Income</i>	<i>Value Added</i>	<i>Output</i>
Grand Marais Biomass Heat	82	\$3,876,663	\$5,798,608	\$12,325,949
Duluth Energy Systems Plant (Phase I and II)	314	\$17,393,102	\$32,463,835	\$74,749,525
Torrefaction Plant	198	\$10,673,648	\$14,822,298	\$32,142,508
Biorenewable Chemical Plants	1,001	\$51,688,473	\$101,441,030	\$287,387,547
<b>Combined Effects of Biomass Projects</b>	<b>1,595</b>	<b>\$83,631,886</b>	<b>\$154,525,771</b>	<b>\$406,605,529</b>
Solar Arrays (Total Effects on State of MN)	92	\$1,810,855	\$2,276,953	\$3,379,198

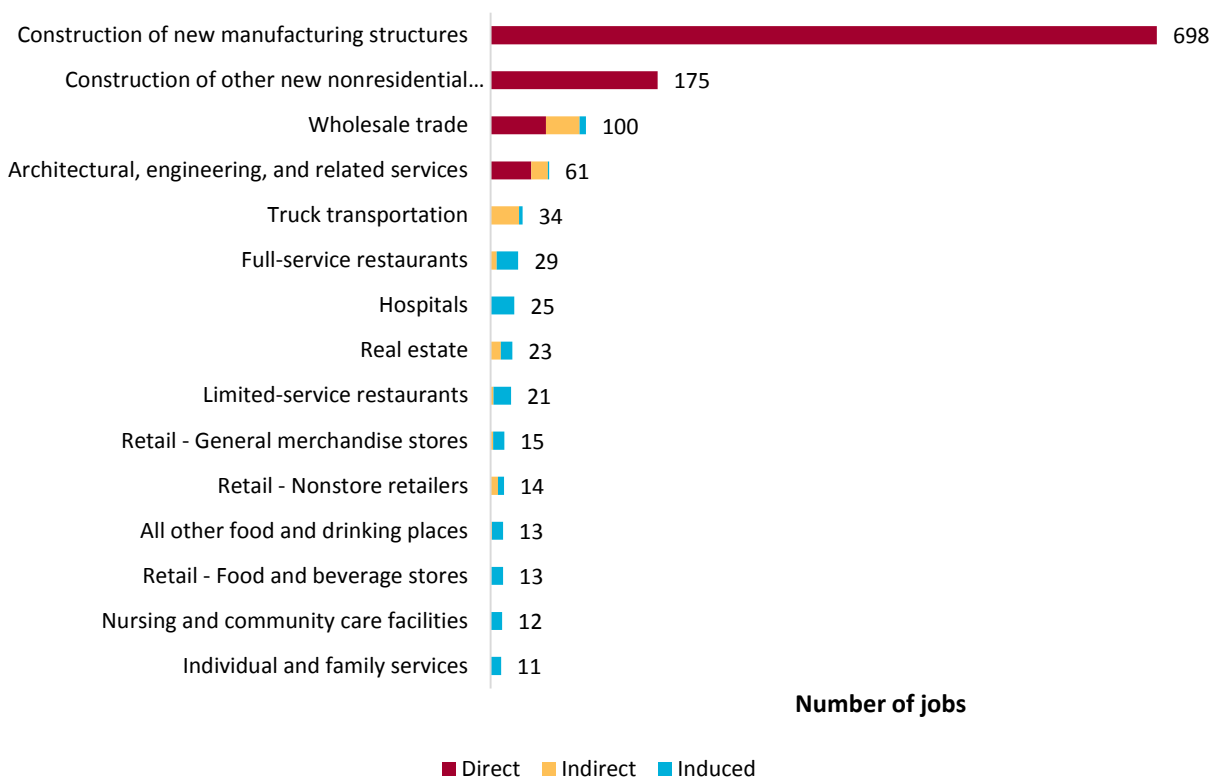
SOURCE: IMPLAN, BBER

Table 18 shows the combined economic impacts of the proposed construction projects, by each project's total effect. The left-most column of Table 18, Employment, indicates the number of jobs that the construction projects are estimated to support directly and indirectly. Employment estimates are in terms of jobs, not in terms of full-time equivalent employees. For construction projects, these jobs are typically short-term and temporary, meaning the effects will be felt during the project and will cease upon its completion. According to the results of this analysis, it is estimated that combined construction of the four projects would support approximately 1,600 jobs in the region. The solar projects would support over 90 jobs in Minnesota.

The second column, Labor Income, is an estimate of all employee compensation, including wages, benefits, and proprietor income. It is estimated that the biomass proposed projects would contribute to over \$83 million in employee wages and benefits in the study area over the life of the projects. Column three, Value Added, shows the economic impacts of the expenditures that the projects would put specifically towards wages, rents, interest, and profits related to its construction. Value Added represents the contribution to GRP made by an individual producer, industry, or sector. It is also a measure of how much the size of the economy increases as a result of the projects' direct spending. The four projects are estimated to have a total Value Added impact of more than \$154 million in the study area during the construction period (2016). The last column, Output, is the value of all local spending required to sustain activities. Based on the estimates

provided by project stakeholders, construction of these four projects is expected to add more than \$406 million to output regionally in total effects (sum of direct, indirect, and induced) within the eight-county region. The solar projects would contribute nearly \$2 million in additional wages and benefits, \$2.2 million towards the state’s GRP, and more than \$3 million in gross output.

**Figure 4. Top Sectors Impacted by Biomass Projects’ Construction (Employment)**



SOURCE: IMPLAN, 2016

It is not surprising that the top sectors most impacted by the biomass construction projects are in the Construction industry. Figure 4 shows the top sectors impacted by the four biomass projects, as measured by employment. Construction of New Manufacturing Structures and Construction of Other New Nonresidential Structures would see the greatest employment numbers as a result of the four projects, followed next by Wholesale Trade, and then Architectural, Engineering and Related Services.

**Table 19. Combined Effects of Typical Year Operations, by Project Total Effect**

Total Effects	Employment	Labor Income	Value Added	Output
Grand Marais Biomass Heat	7	\$353,852	\$582,299	\$1,132,337
Duluth Energy Systems Plant Retrofit	18	\$903,460	\$1,506,490	\$3,756,277
Torrefaction Plant	156	\$7,547,354	\$9,717,150	\$27,212,162
Biorenewable Chemical Plants	882	\$44,857,938	\$68,243,966	\$288,265,137
<b>Combined Effects of Biomass Projects</b>	<b>1,063</b>	<b>\$53,662,604</b>	<b>\$80,049,905</b>	<b>\$320,365,913</b>

SOURCE: IMPLAN, 2016

Table 19 shows a similar breakout of operational effects by project. According to the results, the combined effects for a typical year of operations from the four projects would equate to more than 1,050 new jobs in the eight-county study area (Employment), an additional \$54 million in wages, benefits, and proprietor income (Labor Income), and an \$80 million contribution to the region’s GRP (Value Added). Overall, an additional \$320 million in annual local production would be required to sustain the four proposed facilities. The solar projects were not included, as they are expected to have little to no operational impacts.

For both construction and operations, the largest effects come from the biorenewable chemical plants, which represents more than 70% of the combined effects from construction of the four projects and roughly 90% of the impacts from operations. The smallest effects come from the Grand Marais biomass heating project, which represents 3% of the total output from the four construction projects and less than 1% of the total operational output. The Duluth Energy Systems plant retrofit requires a significant construction investment and, therefore, represents a significant share of the overall employment and output impact from the construction of the four biomass projects. Once the construction project is complete, the city expects very little change in the operating costs. For that reason, the impacts from operating the Duluth Energy Systems plant would be very small by comparison.

**Figure 5. Top Sectors Impacted by Biomass Projects’ Operations (Employment)**



SOURCE: IMPLAN, 2016

Of the 1,063 jobs created by the four biomass projects, more than one quarter of them are expected to be within the Commercial Logging sector. Interestingly, these jobs are all indirectly supported by the projects as a result of increased spending on woody biomass. Other major sectors impacted by the projects (as measured by number of jobs created) are Other Basic Organic Chemical Manufacturing, Other Local

Government Enterprises, and Support Activities for Agriculture and Forestry.



## Appendix A. Detailed Inputs and Methodology

The following shows detailed budget information and sectors used for modeling the impacts of each of the five projects as well as an explanation of methodology used in developing the economic models. Each project section includes detailed budgets for the project's construction and operations, the IMPLAN sectors (or commodities) used for modeling the project impacts, and any modeling assumptions used while creating the models.

For each project, budgets for construction and operations were provided by project stakeholders. Whenever possible, any specific budget items were modeled using a method called Analysis by Parts. Analysis by Parts is the process of splitting or parsing an impact analysis into smaller and more specific parts. This technique allows the user to specify the amount of commodity inputs, the proportion of local labor income, and the proportion of local purchases. Depending on the project, impacts were modeled as industry change activities (e.g. increase in production in Commercial Logging), commodity change activities (e.g. increase in purchase of Logs and Roundwood), or a combination of the two. Industry change activities are most appropriate when the affected industry is clearly defined and has a typical production pattern, as is the case with most of the construction projects in this analysis. Commodity changes are more appropriate when a firm's spending pattern falls outside the typical model but specific expenditures are provided, as is the case for most of the biomass projects included in the analysis.

Unless otherwise noted, all construction projects were assumed to commence and conclude within one year, meaning that the reported impacts (in the Projects section of the report) represent the final outcomes from the project in total. Should a given project take longer than one year, the total impacts and outcomes would be roughly the same, but effects would be distributed over a longer period. Similarly, all activities (both construction and operations) were modeled as occurring in the year 2016, unless noted otherwise.

### I. Grand Marais Biomass District Heating System

Table 20. Biomass District Heating System Construction Budget

<i>Budget Item</i>	<i>Total Spending</i>	<i>% Spent Locally</i>	<i>Direct Local Spending</i>
Design Build Package	\$2,093,210	100%	\$2,093,210
Construction Package	\$5,999,827	100%	\$5,999,827
Equipment	\$4,206,963	0%	\$0
<b>Total</b>	<b>\$12,300,000</b>		<b>\$8,093,037</b>

SOURCE: FVB ENERGY INC. REPORT # GM-14-001-0

Table 20 shows the budget for the proposed construction of the Grand Marais District Heating plant. The budget items were developed using information from the 2014 feasibility study conducted by FVB Energy Inc.<sup>113</sup> The total cost used in the model assumed the competitive re-bid budget of \$12.3 million, as indicated in the study. The same breakdown into the construction expenses and equipment expenses was then applied to each of the three categories (Plant, Energy Transfer Stations, and Distribution System) in the budget using simple ratios.

IMPLAN requires that, for construction modeling, the full value of the structure be included in the study area and that non-local purchases be accounted for by the Regional Purchasing Coefficients in the Industry

<sup>113</sup> See Note 23.

Spending Pattern.<sup>114</sup> The logic behind this reasoning is that while these inputs may come from outside the study area, they now make up part of the value of the structure. For that reason, 100% of the Design Build Package and Construction Package costs were considered to be spent within the study area.<sup>115</sup> The percentage spent within the study area on Equipment (0%) was modified based on the estimates provided in the feasibility study.

Employee compensation and the number of people employed in construction was estimated using IMPLAN based on the model’s typical level of compensation and employment for a project of this size within this industry.

**Table 21. IMPLAN Sector(s) Used for Modeling Impacts from Construction**

<i>Sector</i>	<i>Description</i>
58	Construction of other new nonresidential structures

SOURCE: IMPLAN, 2016

Table 21 shows the IMPLAN sector used in modeling. The Construction Package and Design Build Package budget items were both represented in the model with IMPLAN sector Construction of other new nonresidential structures, as each item’s typical expenditures would be included by this same IMPLAN sector. No equipment expenses were considered in the model’s inputs, since none of the equipment would be locally sourced.

**Table 22. Biomass District Heating System Operations Budget**

<i>Budget Item</i>	<i>Total Spending</i>	<i>% Spent Locally</i>	<i>Direct Local Spending</i>
Biomass Fuel	\$167,420	100%	\$167,420
Maintenance	\$77,969	100%	\$77,969
Ash Disposal	\$2,316	100%	\$2,316
Administration	\$60,000	100%	\$60,000
Labor	\$87,500	100%	\$87,500
Electricity	\$9,880	100%	\$9,880
Propane	\$85,307	100%	\$85,307
<b>Total</b>	<b>\$490,392</b>		<b>\$490,392</b>

SOURCE: FVB ENERGY INC. REPORT # GM-14-001-0

Table 22 shows the Biomass District Heating System budget for a typical year of operations. According to project stakeholders, the annual cost to operate the plant will be approximately \$500,000, all of which would be spent within the study area.<sup>116</sup> It should be noted that Electricity and Propane are considered local purchases, as the distributors of these products are located within the study area. However, the fuel sources for these purchases are not locally produced. Therefore, much of the direct local spending does eventually “leak” from the region. Historically, Minnesota has received propane by the Cochin pipeline coming south

<sup>114</sup> IMPLAN Support Forum [https://implan.com/index.php?option=com\\_kunena&view=category&Itemid=1841&layout=list](https://implan.com/index.php?option=com_kunena&view=category&Itemid=1841&layout=list)

<sup>115</sup> The estimate of 100% only affects the first round of direct spending. Indirect and induced spending estimates were based on IMPLAN spending patterns.

<sup>116</sup> The original budget for the Biomass District Heating System included an item called debt service. This item is in reference to the way in which the plant will be funded and is expected to occur only for the ramp-up phase of the project. Only the typical (those which would be recurring) operational expenditures were considered in the model’s inputs, and the debt service budget item was excluded, as it is not considered a recurring expense.

from Canada, the Mid-American pipeline flowing north from Kansas, and from rail deliveries. The Cochin pipeline, which historically supplied 40% of Minnesota’s propane, is now cut off permanently by reversing its flow to carry light condensate used to dilute thick oil taken from Canadian Oil Sands. Moving forward, Minnesota will have to rely on distant pipeline shipments and/or rail or truck shipment, which is more expensive than previous pipeline transportation.

**Table 23. IMPLAN Sector(s) Used for Modeling Impacts from Operations**

<i>Sector</i>	<i>Description</i>
16	Logs and roundwood
20	Natural gas and crude petroleum
41	Electricity
62	Maintained and repaired nonresidential structures
134	Saws
471	Waste management and remediation services
5001	Employee Compensation

SOURCE: IMPLAN, 2016

The IMPLAN industries selected for modeling the impacts from operations are shown in Table 23. The sectors were selected based on the descriptions given for operating activities in the feasibility study report. The Biomass Fuel budget item corresponds to the IMPLAN sectors for Saws and Logs and Roundwood. Fuel purchases were estimated to come from about 30% sawdust (represented in the Saws sector) and 70% field trimmings (represented in the Logs and Roundwood sector), so the total budgeted amount was allocated accordingly within the model.

The Propane and Electricity expenses were included in the model as Natural Gas and Crude Petroleum and Electricity, respectively. Maintenance expenses for the plant were included in the model with the IMPLAN sector Maintained and repaired nonresidential structures. The Ash Disposal item was represented within the model with the sector Waste management and remediation services. Expenses listed for Administration and Labor were combined and included in the model under the IMPLAN sector for Employee Compensation.

## II. Duluth Energy Systems Plant Retrofit and Biomass Conversion

**Table 24. Duluth Energy Systems Plant Phase I Construction Budget**

<i>Budget Item</i>	<i>Total Spending</i>	<i>% Spent Locally</i>	<i>Direct Local Spending</i>
Site Preparation and Construction	\$17,000,000	100%	\$17,000,000
Equipment	\$15,000,000	50%	\$7,500,000
Engineering	\$3,815,000	52%	\$2,000,000
Wages and salaries	\$7,500,000	90%	\$6,750,000
<b>Total</b>	<b>\$43,315,000</b>		<b>\$33,250,000</b>

SOURCE: DULUTH ENERGY SYSTEMS

Table 24 shows the construction budget items for Phase I of the project. The overall budget for the reconstruction of Superior Street and modifications to the plant is anticipated to cost just over \$43 million, with the largest costs being in site preparation and construction (\$17 million). Based on estimates from project stakeholders, approximately \$33 million of the overall budget is expected to be spent within the study area.

**Table 25. IMPLAN Sector(s) Used for Modeling Impacts from Phase I Construction**

<i>Sector</i>	<i>Description</i>
58	Construction of other new nonresidential structures
395	Wholesale trade distribution services
449	Architectural, engineering, and related services
5001	Employee Compensation

SOURCE: IMPLAN, 2016

The IMPLAN industries selected for modeling the impacts from construction are shown in Table 25. These sectors were selected based on the descriptions given by project stakeholders for construction activities. Equipment expenses were included in the model using the IMPLAN sector Wholesale trade distribution services. The Engineering budget item corresponds to the IMPLAN sector Architectural, engineering, and related services. Additional Wages and Salaries were represented in the model as a change to Employee Compensation. The remaining portion of the budget, Site Preparation and Construction, was included under the IMPLAN sector Construction of other new nonresidential structures.

According to project stakeholders, the operations for the Steam Plant are expected to remain essentially unchanged during Phase I of the project. Therefore, no operational impacts were modeled for this phase.

**Table 26. Duluth Energy Systems Plant Phase II Construction Budget**

<i>Budget Item</i>	<i>Total Spending</i>	<i>% Spent Locally</i>	<i>Direct Local Spending</i>
Site Preparation and Construction	\$2,200,000	100%	\$2,200,000
Equipment	\$2,500,000	40%	\$1,000,000
Engineering	\$300,000	60%	\$180,000
<b>Total</b>	<b>\$5,000,000</b>		<b>\$3,380,000</b>

SOURCE: DULUTH ENERGY SYSTEMS

Table 26 shows the construction budget for Phase II of the Duluth Energy Systems project. This portion of the project, which involves the integration of woody biomass as a fuel source, has a much smaller budget, with an anticipated \$5 million in total spending and \$3.3 million in direct local spending.

**Table 27. IMPLAN Sector(s) Used for Modeling Impacts from Phase II Construction**

<i>Sector</i>	<i>Description</i>
58	Construction of other new nonresidential structures
395	Wholesale trade distribution services
449	Architectural, engineering, and related services
5001	Employee Compensation

SOURCE: IMPLAN, 2016

The IMPLAN industries selected for modeling the impacts from construction are shown in Table 27. These sectors were selected based on the descriptions given by project stakeholders for construction activities. Equipment expenses were included in the model using the IMPLAN sector Wholesale trade distribution services. The Engineering budget item corresponds to the IMPLAN sector Architectural, engineering, and related services. The remaining portion of the budget, Site Preparation and Construction, was included under the IMPLAN sector Construction of other new nonresidential structures. Employee compensation in construction was estimated using IMPLAN based on the model's typical level of compensation for a

project of this size within this industry.

**Table 28. Duluth Energy Systems Plant Phase II Operations Budget**

<i>Budget Item</i>	<i>Total Spending</i>	<i>% Spent Locally</i>	<i>Direct Local Spending</i>
Feedstock Purchases	\$1,300,000	100%	\$1,300,000
Maintenance	\$50,000	100%	\$50,000
Coal consumption	(\$590,000)	100%	(\$590,000)
Wages and Salaries	\$250,000	100%	\$250,000
Electricity	\$50,000	100%	\$50,000
<b>Total</b>	<b>\$1,060,000</b>		<b>\$1,060,000</b>

SOURCE: DULUTH ENERGY SYSTEMS

Table 28 shows the Duluth Energy Systems Plant budget for a typical year of operations. According to project stakeholders, the annual cost to operate the plant will be just over \$1 million, all of which would be spent within the study area.

**Table 29. IMPLAN Sector(s) Used for Modeling Impacts from Phase II Operations**

<i>Sector</i>	<i>Description</i>
22	Coal
41	Electricity
62	Maintained and repaired nonresidential structures
134	Saws
5001	Employee Compensation

SOURCE: IMPLAN, 2016

Table 29 shows the IMPLAN industries selected for modeling the impacts from operations. These sectors were selected based on the descriptions given for operating activities from project stakeholders. The coal consumption expense was included as an impact to the IMPLAN sector for coal in order for the budget to correctly reflect the net spending done by the plant. However, the commodity has no local effect in the study area because there is no production of it locally. As a result, the spending was 100% local as a budget item but did not actually result in any local impacts. Feedstock Purchases corresponds with the IMPLAN sector Saws. The fuel used by the plant was stated as green wood chips, and wood chip production is included in the Saws sector as it represents sawmills and related industries. The budget item Electricity was modeled in the IMPLAN sector Electricity. Maintenance expenses for the plant were included in the model with the IMPLAN sector Maintained and repaired nonresidential structures. Additional Wages and Salaries were represented in the model as a change to Employee Compensation.

### III. Torrefaction Processing Plant

**Table 30. Torrefaction Plant Construction Budget**

<i>Budget Item</i>	<i>Total Spending</i>	<i>% Spent Locally</i>	<i>Direct Local Spending</i>
Site Prep	\$5,912,973	100%	\$5,912,973
Engineering	\$3,896,453	100%	\$3,896,453
Other Construction	\$8,056,013	100%	\$8,056,013
Equipment	\$14,168,918	10%	\$1,416,892
<b>Total</b>	<b>\$32,034,357</b>		<b>\$19,282,331</b>

SOURCE: NATURAL RESOURCES RESEARCH INSTITUTE (NRRI)- UNIVERSITY OF MINNESOTA

The anticipated construction budget for the proposed torrefaction plant is shown in Table 30. Budget items include site preparations, engineering costs, other construction costs, and equipment purchases. The total spending is expected at roughly \$32 million, with nearly \$20 million of that predicted to be spent locally.

**Table 31. IMPLAN Sector(s) Used for Modeling Impacts from Construction**

<i>Sector</i>	<i>Description</i>
53	Construction of new manufacturing structures
395	Wholesale trade
449	Architectural, engineering, and related services
5001	Employee Compensation

SOURCE: IMPLAN, 2016

Based on the descriptions given for construction activities, IMPLAN industries were selected for modeling. These sectors are shown in Table 31. Both the Site Prep and Other Construction items from the budget were represented in the model with the IMPLAN sector 53 – Construction of New Manufacturing Structures. Equipment expenses were included in the model using sector 395 – Wholesale Trade. The Engineering budget item corresponds to the IMPLAN sector Architectural, Engineering, and Related services.

Employee compensation and the number of people employed in construction were estimated using IMPLAN based on the model’s typical level of compensation and employment for a project of this size within this industry.

**Table 32. Torrefaction Plant Operations Budget**

<i>Budget Item</i>	<i>Total Spending</i>	<i>% Spent Locally</i>	<i>Direct Local Spending</i>
Feedstock Purchases	\$7,800,000	100%	\$7,800,000
Wages and Salaries	\$1,440,000	100%	\$1,440,000
Other	\$3,225,000	50%	\$1,612,500
<b>Total</b>	<b>\$12,465,000</b>		<b>\$10,852,500</b>

SOURCE: NATURAL RESOURCES RESEARCH INSTITUTE (NRRI)- UNIVERSITY OF MINNESOTA, IMPLAN

Table 32 shows the Torrefaction Plant budget for a typical year of operations. According to project stakeholders, the annual cost to operate the plant will be approximately \$12 million, of which nearly \$11 million would be spent within the study area. Wage and salary estimates were based on IMPLAN averages for the industry.

**Table 33. IMPLAN Sector(s) Used for Modeling Impacts from Operations**

<i>Sector</i>	<i>Description</i>
16	Logs and roundwood
138	Reconstituted wood product manufacturing
5001	Employee Compensation

SOURCE: IMPLAN, 2016

The IMPLAN sectors selected for modeling the plant’s operating expenses are shown in Table 33. Feedstock Purchases are categorized in the Logs and Roundwood sector. The fuel used by the plant was stated as hardwood/softwood timber, and the Logs and Roundwood sector represents the timber production/ logging industry. Additional Wages and Salaries were represented in the model as a change to Employee Compensation. The remaining budget, under the Other item, was included in the model under the sector 138 – Reconstituted Wood Product Manufacturing. This sector is representative of compression modified wood manufacturing, which would be structurally the most similar to torrefied wood manufacturing.

#### **IV. Biorenewable Chemical Production Plants**

**Table 34. Bio-renewable Chemical Production Plants Construction Budget**

<i>Budget Item</i>	<i>Total Spending</i>	<i>% Spent Locally</i>	<i>Direct Local Spending</i>
Site Development	\$3,720,000	100%	\$3,720,000
Other Construction	\$220,045,000	100%	\$220,045,000
Equipment	\$34,235,000	10%	\$3,423,500
<b>Total</b>	<b>\$258,000,000</b>		<b>\$227,188,500</b>

SOURCE: GREAT PLAINS INSTITUTE

Table 34 shows the construction budget items for the two plants. The overall budget is estimated at \$258 million. Based on estimates from project stakeholders, approximately \$227 million of the overall budget is expected to be spent within the study area. The difference between the two spending estimates is the result of leakages from equipment purchases outside the study area.

**Table 35. IMPLAN Sector(s) Used for Modeling Impacts from Construction**

<i>Sector</i>	<i>Description</i>
53	Construction of new manufacturing structures
395	Wholesale trade

SOURCE: IMPLAN, 2016

The IMPLAN sectors selected for modeling the impacts from construction are shown in Table 35. Sectors were selected based on descriptions given for construction activities from project stakeholders. The Site Development and Other Construction budget items were modeled using sector 53 – Construction of New Manufacturing Structures. Equipment expenses were included in the Wholesale trade sector.

Construction of each plant was assumed to occur simultaneously, meaning that there should be no overlap in spending or employment (shared resources) between the two plants. Employee compensation for the 600 local people employed in construction was estimated using IMPLAN based on the model’s typical level of compensation for a project of this size within this industry. For the purposes of this analysis, all expenses and employment estimated from each of the two plants were combined and modeled as a single event.

**Table 36. Bio-renewable Chemical Production Plants Operations Budget**

<i>Budget Item</i>	<i>Total Spending</i>	<i>% Spent Locally</i>	<i>Direct Local Spending</i>
Feedstock Purchases	\$19,582,000	100%	\$19,582,000
Utilities	\$47,204,990	100%	\$47,204,990
Wages and Salaries	\$10,400,000	100%	\$10,400,000
Other	\$75,082,010	50%	\$37,541,000
<b>Total</b>	<b>\$152,269,000</b>		<b>\$114,727,995</b>

SOURCE: GREAT PLAINS INSTITUTE

Table 36 shows an estimated operating budget for the two plants during a typical year of operations. According to project stakeholders, the annual cost to operate the plants would be just over \$152 million, of which approximately \$114 million would be spent within the study area.

**Table 37. IMPLAN Sector(s) Used for Modeling Impacts from Operations**

<i>Sector</i>	<i>Description</i>
16	Logs and roundwood
20	Natural gas and crude petroleum
41	Electricity
49	Electricity transmission and distribution
50	Natural gas distribution
51	Water, sewage and other systems
165	Other basic organic chemical manufacturing
5001	Employee Compensation

SOURCE: IMPLAN, 2016

The sectors selected for modeling the operational impacts of the plants are shown in Table 37. The Utilities line item was assumed to consist of water, sewage, gas, and electricity, and the total expense given was allocated among sectors 20, 41, 49, 50, and 51 accordingly. Feedstock Purchases corresponds with the IMPLAN sector Logs and Roundwood (sector 16) in the model. The fuel used by the plants was stated as roundwood, and the Logs and Roundwood sector represents the timber production/ logging industry. It is important to note that, unlike the other projects included in this analysis, the biorenewable chemical plants would likely utilize a more solid form of wood fiber with a limited amount of bark. Because this form of roundwood is more valuable, timber availability for this type of woody feedstock could be more competitive than the other projects included in this analysis.

Additional Wages and Salaries were represented in the model as a change to Employee Compensation. The remaining budget, under the Other item, was included in the model under the sector Other basic organic chemical manufacturing. This sector is representative of organic chemical manufacturing, which would be structurally the most similar to bio-renewable chemical manufacturing.



## V. Solar Power Production Arrays

**Table 38. Solar Array Construction Budget**

<i>Budget Item</i>	<i>Total Spending</i>	<i>% Spent in MN</i>	<i>Direct Spending in MN</i>
Labor	\$1,313,255	100%	\$1,313,255
Interconnection Fees	\$544,025	100%	\$544,025
Additional Development Costs	\$238,750	100%	\$238,750
Materials/Equipment	\$3,255,478	0%	\$0
Other Costs	\$707,233	0%	\$0
<b>Total</b>	<b>\$6,058,740</b>		<b>\$2,096,030</b>

SOURCE: ECOLIBRIUM 3, RREAL, IPS SOLAR, AND BARBOSE, WEAVER & DARGHOUTH, 2015<sup>117</sup>

Table 38 shows the estimated construction costs for the construction of all solar projects. Of these costs, it is likely that most of them will be from within Minnesota, but it is not very likely that they will be from the Arrowhead region due to the lack of contractors with expertise with large-scale projects in the region. For this reason, the study area for modeling the impacts of solar was expanded to include all of the state of Minnesota and Douglas County, WI.

It was assumed that none of the spending on Materials/Equipment and Other Costs would be occurring locally. These expenditures represent the costs associated with the actual solar panels, inverters, monitoring equipment, mounting equipment, hardware, etc. that would all likely be purchased together. Because our sources indicated that the panels would not be purchased from a Minnesota manufacturer, the spending would effectively be leakages from the study area and have no impact within the model.

**Table 39. IMPLAN Sector(s) Used for Modeling Impacts from Construction**

<i>Sector</i>	<i>Description</i>
49	Electric power transmission and distribution
456	Scientific research and development services
5001	Employee Compensation

SOURCE: IMPLAN, 2016

Table 39 shows the IMPLAN sectors selected for modeling the impacts from construction. These sectors were selected based on the descriptions given for construction activities from project stakeholders. The Interconnection Fees budget item was modeled within the IMPLAN sector Electric power transmission and distribution. These would be fees paid to connect the power production from the solar panels with the electrical grid. One of the budget items within the Community Solar Garden RREAL project included “Additional Development Costs” totaling roughly \$225,000. This represented research and development related costs associated with it being a pilot project, and so was modeled under the IMPLAN sector Scientific research and development services. Labor expenditures and the number of people employed in construction, a total of 82, were given and included in the model as a labor income change using the IMPLAN sector

<sup>117</sup> Ecolibrium 3 provided information on the construction costs related to all of the solar projects except the Community Solar Projects. RREAL provided a cost estimate for the RREAL community solar project. The final solar cost estimates were gained from the Barbose Weaver & Darghouth (2015) report. Laura Burrington of IPS (Innovative Power Systems) Solar provided feedback and guidance related to construction/operation cost breakdowns (labor costs, material costs, interconnection costs etc.).

#### Employee Compensation.

Moreover, our sources suggest that not only would these impacts be short-term and nonrecurring but also that most would be in fact occurring over a period of just weeks – employment included. As a result, while it is always true that the number of jobs indicated in such an analysis do not represent FTEs (full-time equivalent jobs), it is especially true in this case.

The data implied that the operations expenditures as a result of the solar projects would be essentially unchanged. Because of this, there would be no net impact due to operations, and operational impacts were not modeled.

## Appendix B. Definitions Used in This Report

**Backward Linkages:** The interconnection of an industry to other industries from which it purchases its inputs in order to produce its output. It is measured as the proportion of intermediate consumption to the total output of the sector (direct backward linkage) or to the total output multiplier (total backward linkage). An industry has significant backward linkages when its production of output requires substantial intermediate inputs from many other industries.<sup>118</sup>

**Direct Effect:** Initial new spending in the study area resulting from the project.

**Employment:** Estimates (from U.S. Department of Commerce secondary data) are in terms of jobs, not in terms of full-time equivalent employees. Therefore, these jobs may be temporary, part-time, or short-term.

**Gross Output:** The value of local production required to sustain activities.

**Indirect Effect:** The additional inter-industry spending from the direct impact.

**Induced Effect:** The impact of additional household expenditures resulting from the direct and indirect impact.

**Labor Income:** All forms of employment income, including employee compensation (wages and benefits) and proprietor income.

**Leakages:** Any payments made to imports or value added sectors that do not in turn re-spend the dollars within the region.

**Multipliers:** Total production requirements within the Study Area for every unit of production sold to Final Demand. Total production will vary depending on whether Induced Effects are included and the method of inclusion. Multipliers may be constructed for output, employment, and every component of Value Added.

**Value Added:** A measure of the impacting industry's contribution to the local community; it includes wages, rents, interest, and profits.

---

<sup>118</sup> IMPLAN, 2015

## Appendix C. IMPLAN Assumptions

The following are suggested assumptions for accepting the impact model:<sup>119</sup>

**Backward Linkages:** IMPLAN is a backward-linkage model, meaning that it measures the increased demand on industries that produce intermediate inputs as a result of increases in production. However, if an industry increases production, there will also be an increased supply of output for other industries to use in their production. Models that measure this type of relationship are called forward-linkage models. To highlight this concept, consider the example of a new sawmill beginning its operations in a state. The increased production as a result of the sawmill's operations will increase the demand for lumber, creating an increase in activity in the logging industry, as well as other supporting industries such as electric transmission and distribution. IMPLAN's results will include those impacts, but will exclude effects on any wood product manufacturers located nearby that might be impacted by the newly available supply of lumber.

**Fixed Production Patterns:** Input-output (I-O) models assume inputs are used in fixed proportion, without any substitution of inputs, across a wide range of production levels. This assumption assumes that an industry must double its inputs (including both purchases and employment) to double its output. In many instances, an industry will increase output by offering overtime, improving productivity, or technology.

**Industry Homogeneity:** I-O models typically assume that all firms within an industry have similar production processes. Any industries that fall outside the typical spending pattern for an industry should be adjusted using IMPLAN's Analysis-by-Parts technique.

**Fixed Prices and No Supply Constraints:** IMPLAN is a fixed-price model. This means that the modeling software assumes no price adjustment in response to supply constraints or other factors. In other words, the model assumes that firms can increase their production as needed and are not limited by availability of labor or inputs and that firms in the local economy are not operating at full capacity.

**Employment:** IMPLAN input-output is a production-based model, and employment numbers (from U.S. Department of Commerce secondary data) treat both full- and part-time individuals as being employed.

**Leakages:** A small area can have a high level of leakage. Leakages are any payments made to imports or value added sectors, which do not in turn re-spend the dollars within the region. What's more, a study area that is actually part of a larger functional economic region will likely miss some important linkages. For example, workers who live and spend outside the study area may actually hold local jobs.

---

<sup>119</sup> Bureau of Economic Analysis [https://www.bea.gov/papers/pdf/WP\\_IOMIA\\_RIMSII\\_020612.pdf](https://www.bea.gov/papers/pdf/WP_IOMIA_RIMSII_020612.pdf)

# Appendix D Energy Costs in Minnesota over Time<sup>120</sup>

Table ET1. Primary Energy, Electricity, and Total Energy Price and Expenditure Estimates, Selected Years, 1970-2013, Minnesota

Year	Primary Energy															Nuclear Fuel	Biomass Wood and Waste <sup>1a</sup>	Total <sup>1b</sup> (i)	Electric Power Sector <sup>1c</sup> (j)	Retail Electricity	Total Energy <sup>1d</sup> (k)
	Coal			Natural Gas <sup>a</sup>	Petroleum						Total										
	Coking Coal	Steam Coal	Total		Distillate Fuel Oil	Jet Fuel <sup>b</sup>	LPG <sup>c</sup>	Motor Gasoline <sup>d</sup>	Residual Fuel Oil	Other <sup>e</sup>											
Prices in Dollars per Million Btu																					
1970	0.59	0.42	0.48	0.66	1.08	0.75	1.79	2.97	0.59	1.38	2.02	—	0.98	1.28	0.84	6.10	1.87				
1975	1.80	0.68	0.83	1.17	2.51	2.09	3.72	4.63	1.80	2.97	3.59	0.24	1.32	2.13	0.53	8.54	3.18				
1980	—	1.11	1.11	2.85	6.72	6.47	5.89	9.55	3.52	6.01	7.54	0.44	1.98	4.42	0.97	15.25	6.50				
1985	—	1.51	1.51	5.13	7.57	5.93	8.98	9.73	4.05	7.13	8.43	0.50	2.17	5.21	1.22	15.81	6.23				
1990	—	1.81	1.81	3.87	7.94	5.68	9.13	9.56	2.50	5.60	8.40	0.48	1.27	4.55	1.12	15.68	8.06				
1995	—	1.21	1.21	3.73	7.00	4.00	7.95	9.46	2.41	5.65	7.83	0.48	1.22	4.42	1.25	16.40	7.74				
1996	—	1.12	1.12	4.39	7.54	4.79	9.81	10.50	2.98	5.92	8.70	0.48	1.12	4.55	1.25	16.90	8.25				
1997	—	1.14	1.14	4.58	7.80	4.65	9.51	10.45	3.07	5.58	8.53	0.47	1.05	5.05	1.25	16.48	8.45				
1998	—	1.13	1.13	4.13	6.64	3.54	7.95	9.11	2.04	5.28	7.48	0.48	1.15	4.47	1.95	16.78	7.89				
1999	—	1.16	1.16	4.26	7.27	4.03	8.00	9.70	2.26	5.94	7.92	0.48	1.26	4.74	1.92	17.12	8.20				
2000	—	1.16	1.16	5.86	9.98	6.53	11.17	12.27	3.84	6.44	10.37	0.45	1.42	6.23	1.87	17.25	9.87				
2001	—	1.06	1.06	7.19	9.52	5.85	12.41	12.00	3.92	6.23	10.24	0.47	1.95	6.53	2.14	17.55	10.41				
2002	—	1.10	1.10	5.50	8.89	5.50	10.11	11.24	3.13	6.79	9.64	0.46	1.97	5.69	1.80	17.04	9.55				
2003	—	1.11	1.11	7.43	9.86	6.44	12.29	12.50	4.58	6.71	10.68	0.44	1.85	6.55	1.97	17.66	10.81				
2004	—	1.11	1.11	8.24	12.05	8.90	13.85	14.67	5.03	6.94	12.61	0.44	1.97	7.65	1.55	18.32	12.13				
2005	—	1.18	1.18	9.99	15.49	13.02	16.67	17.57	5.39	7.63	15.58	0.46	2.75	8.47	2.30	19.43	14.44				
2006	—	1.28	1.28	9.86	18.35	14.70	18.49	20.21	7.96	11.45	18.37	0.46	2.77	10.58	2.47	20.31	16.07				
2007	—	1.55	1.55	9.31	20.83	16.16	20.57	22.49	8.06	15.47	20.41	0.51	2.53	11.93	2.68	21.85	17.10				
2008	—	1.73	1.73	9.99	25.96	22.79	24.45	25.45	10.50	15.47	24.41	0.48	2.96	12.94	2.65	22.89	19.04				
2009	—	1.73	1.73	7.80	17.28	12.70	19.64	19.13	7.53	15.18	17.87	0.71	2.58	9.56	2.21	23.91	15.24				
2010	—	1.82	1.82	7.00	21.09	16.39	21.13	22.34	8.90	18.02	21.38	0.84	2.97	10.84	2.41	24.72	16.97				
2011	—	2.01	2.01	7.01	25.80	22.75	24.05	25.29	13.74	19.42	27.01	0.90	3.35	15.11	2.45	25.45	19.70				
2012	—	2.09	2.09	5.56	28.10	23.15	22.05	29.42	12.62	19.57	27.51	0.91	3.23	18.31	2.32	26.06	20.02				
2013	—	2.12	2.12	6.26	27.80	22.48	23.40	28.88	10.29	20.39	27.30	0.97	3.51	19.21	2.65	27.69	19.70				
Expenditures in Million Dollars																					
1970	8.6	68.2	75.9	220.6	140.5	14.7	60.7	688.9	14.9	67.2	986.8	—	3.8	1,288.9	-66.2	427.5	1,650.2				
1975	45.4	113.9	159.3	381.4	355.7	66.5	123.0	1,172.9	38.4	137.2	1,899.8	25.5	5.7	2,474.2	-146.6	769.9	3,097.4				
1980	—	269.7	269.7	785.0	837.2	186.2	167.3	2,319.4	56.3	209.9	3,778.3	48.6	14.3	4,915.9	-355.3	1,481.2	6,065.8				
1985	—	340.9	340.9	1,283.0	875.8	251.4	164.9	2,314.7	19.8	309.2	3,942.2	61.4	18.8	5,754.5	-440.8	2,062.8	7,377.0				
1990	—	427.9	427.9	1,066.5	905.7	154.0	199.0	2,399.4	11.9	301.2	3,981.2	61.2	33.3	5,639.0	-505.9	2,491.4	7,524.5				
1995	—	407.8	407.8	1,241.4	937.5	226.1	284.7	2,679.9	5.8	320.5	4,454.5	66.2	47.3	6,399.2	-622.5	2,983.1	8,759.8				
1996	—	397.5	397.5	1,596.1	1,108.6	288.7	424.4	3,004.9	8.3	319.8	5,164.8	60.4	42.0	7,998.2	-613.6	3,017.3	9,802.0				
1997	—	390.9	390.9	1,595.7	1,078.5	287.3	362.3	3,037.9	8.3	342.8	5,115.9	53.9	39.3	7,967.0	-655.0	3,069.7	9,801.7				
1998	—	402.2	402.2	1,286.2	945.9	215.0	215.2	2,750.1	8.1	327.4	4,471.8	58.1	39.1	6,487.7	-662.9	3,206.1	9,021.6				
1999	—	395.2	395.2	1,379.8	1,011.2	287.7	258.0	3,028.7	3.7	370.3	4,959.6	66.4	41.8	7,058.2	-655.0	3,311.5	9,709.8				
2000	—	434.1	434.1	1,596.7	1,442.8	452.2	408.4	3,909.6	16.7	423.8	6,693.4	61.2	52.9	9,725.9	-979.5	3,477.2	12,223.7				
2001	—	375.5	375.5	2,306.7	1,398.2	383.0	412.5	3,894.7	17.3	370.5	6,476.3	57.3	67.3	9,902.8	-1,083.3	3,601.4	12,421.0				
2002	—	396.4	396.4	1,904.9	1,273.5	345.3	417.5	3,718.0	14.0	355.5	6,133.7	65.3	59.0	8,751.9	-583.7	3,580.1	11,548.2				
2003	—	455.5	455.5	2,592.1	1,453.4	437.7	494.8	4,202.5	28.2	384.5	7,000.5	60.8	50.2	10,312.7	-763.1	3,765.6	13,315.2				
2004	—	420.8	420.8	2,771.2	1,855.9	630.8	593.9	4,945.5	45.5	408.2	8,479.7	60.7	62.1	12,085.0	-839.2	3,921.5	15,167.2				
2005	—	446.4	446.4	3,417.4	2,336.2	394.5	683.3	5,910.0	67.5	486.4	10,620.0	62.2	104.6	15,222.7	-1,297.8	4,394.2	18,259.1				
2006	—	476.3	476.3	3,253.3	2,862.3	581.5	709.7	6,759.3	41.8	631.7	12,034.0	63.4	102.4	16,602.1	-1,386.1	4,524.5	19,840.5				
2007	—	568.0	568.0	3,424.0	3,235.1	1,059.3	786.8	7,481.6	66.7	758.9	18,425.9	69.7	114.1	18,287.5	-1,528.4	5,035.1	21,749.9				
2008	—	622.7	622.7	4,057.1	4,092.7	1,323.1	878.3	8,207.4	138.1	715.1	15,353.7	64.8	136.7	20,782.5	-1,437.9	5,313.8	24,658.5				
2009	—	567.1	567.1	2,788.5	2,313.1	662.3	758.2	5,975.0	31.9	639.4	10,679.8	92.1	117.5	14,287.3	-1,126.3	5,155.5	18,325.5				
2010	—	573.0	573.0	2,797.8	3,073.8	848.5	638.9	7,172.8	31.1	715.5	12,475.7	118.1	159.0	16,477.0	-1,250.5	5,650.0	20,879.5				
2011	—	635.5	635.5	2,791.7	4,096.2	1,209.3	714.2	8,700.0	44.5	749.5	15,933.7	112.4	168.9	19,554.5	-1,208.2	5,876.3	24,222.5				
2012	—	598.1	598.1	2,252.3	4,320.9	1,177.5	612.3	9,044.0	10.1	715.0	15,889.3	114.2	167.7	19,182.0	-1,084.8	5,970.9	24,067.5				
2013	—	566.5	566.5	2,838.0	4,958.3	744.0	853.4	8,798.4	6.0	739.2	15,509.3	108.5	170.7	19,519.0	-1,202.7	6,379.2	24,689.5				

<sup>a</sup> Natural gas as it is consumed; includes supplemental gaseous fuels that are commingled with natural gas.  
<sup>b</sup> Through 2004, includes kerosene-type and naphtha-type jet fuel. Beginning in 2005, includes kerosene-type jet fuel only; naphtha-type jet fuel is included in "Other Petroleum."  
<sup>c</sup> Liquefied petroleum gases, includes ethane and olefins.  
<sup>d</sup> Beginning in 1999, includes fuel ethanol blended into motor gasoline.  
<sup>e</sup> Includes asphalt and road oil, aviation gasoline, kerosene, lubricants, and the other petroleum products as described in the Technical Notes, Section 4, "Other Petroleum Products."  
<sup>f</sup> Wood, wood-derived fuels, and biomass waste. Prior to 2001, includes non-biomass waste.  
<sup>g</sup> There is a discontinuity in this time series between 1988 and 1989 due to the expanded coverage of the use of wood and biomass waste beginning in 1988.  
<sup>h</sup> There are no direct fuel costs for hydroelectric, geothermal, wind, photovoltaic, or solar thermal energy.  
<sup>i</sup> From 1981 through 1992, includes fuel ethanol blended into motor gasoline that is not included in the motor gasoline column.  
<sup>j</sup> Electricity imports are included in total primary energy and electric power sector but are not shown separately.  
 Where shown, R = Revised data and (S) = Value less than 0.05 million dollars.  
 Where shown, = No consumption, including cases where adjustments were made. See explanation of adjustments in Section 7 of the Technical Notes.  
 Note: Expenditure totals may not equal sum of components due to independent rounding.  
 Web Page: All data are available at <http://www.eia.gov/state/seds/seds-data-complete.cfm>.  
 Sources: Data sources, estimation procedures, and assumptions are described in the Technical Notes.

<sup>120</sup> State Energy Price and Expenditure Estimates: [http://www.eia.gov/state/seds/sep\\_prices/notes/pr\\_print.pdf](http://www.eia.gov/state/seds/sep_prices/notes/pr_print.pdf)

## Bibliography

- Allen, BJ. (2015). RREAL, Special Project Manager. Phone conversations and email exchanges.
- Barbose, Galen; Samantha Weaver and Naim Darghouth. (2014). Tracking the Sun VII: A Historical Summary of the Installed Price of Photovoltaics in the United States from 1988 to 2013. Lawrence Berkeley National Laboratory. Retrieved from:  
[http://eetd.lbl.gov/sites/all/files/tracking\\_the\\_sun\\_vii\\_report.pdf](http://eetd.lbl.gov/sites/all/files/tracking_the_sun_vii_report.pdf)
- Bess, Rebecca and Zoe O. Ambargis. (2011). Input-Output Models for Impact Analysis: Suggestions for Practitioners Using RIMS II Multipliers. Retrieved from:  
[http://www.bea.gov/papers/pdf/wp\\_iomia\\_rimsii\\_020612.pdf](http://www.bea.gov/papers/pdf/wp_iomia_rimsii_020612.pdf)
- Becker, Dennis R; Jonathan J. Klapperrich, Grant M. Domke, Michael A. Kilgore, Anthony W. D'Amato, Dean A. Current, and Alan R. Ek. (2010). *2010 Outlook for Forest Biomass Availability in Minnesota: Physical, Environmental, Economic and Social Availability*. Staff Paper Series No. 2011. University of Minnesota Department of Forest Resources. Retrieved From:  
<http://conservancy.umn.edu/bitstream/handle/11299/107779/211.pdf;jsessionid=02DE990262E0CB08859817119C7AB1A4?sequence=1>
- Biomass Energy Resource Center. District Heating. Retrieved from: <http://www.biomasscenter.org/what-we-do/our-expertise/district-heating>
- Blinn, Charles R., Tim J. O'Hara, Dave T. Chura, and Matthew B. Russell. (2015). "Minnesota's Logging Businesses: An Assessment of the Health and Viability of the Sector." *Forest Sciences*. 61(2) 381-387
- Bratkovich, Steve; Jim Boyer, Jeff Howe, Kathryn Fernholz, and Alison Lindburg. (2009). Community-Based Bioenergy and District Heating Benefits, Challenges, Opportunities and Recommendations for Woody Biomass. Dovetail Partners, Inc. Retrieved from:  
[http://www.dovetailinc.org/report\\_pdfs/2009/dovetaildistheat0409.pdf](http://www.dovetailinc.org/report_pdfs/2009/dovetaildistheat0409.pdf)
- BTG Biomass Technology Group. Torrefaction. Retrieved from:  
<http://www.btgworld.com/en/rtd/technologies/torrefaction>
- Bunker, Kaitlyn; Stephen Dolg, Erik Fowler, James Mandel, Christa Owens Michelet. (2015). *Community Energy Resource Guide*. Rocky Mountain Institute. Retrieved from:  
[http://www.rmi.org/community\\_energy\\_guide](http://www.rmi.org/community_energy_guide)
- Burrington, Laura. (2016). Innovative Power Systems (IPS) Solar, Project Manager. Conversations and emails.
- Clean Energy Trust. (2016). Clean Jobs Midwest Survey. Retrieved from:  
<http://www.cleanjobsmidwest.com/state/minnesota/>
- Coalition for Sustainable Rail Website. (2016). Torrefied Biomass. Retrieved From: <http://csrail.org/torrefied-biomass>

- Cook County Local Energy Project Website. (2015). Retrieved from:  
<http://www.cookcountylocalenergy.org/groups/biomass>
- Dirkswager, Anna. (2016). Clean Energy Economy Minnesota, formerly Biomass and Renewable Energy Coordinator, Minnesota Department of Natural Resources. Email Exchange.
- Duluth Energy Systems. About Us: Local Energy, Local Solutions. Retrieved from:  
<http://www.duluthenergysystems.com/about/>
- Evergreen Energy. (2013). Duluth Steam Master Plan. Retrieved from:  
[http://www.duluthenergysystems.com/wp-content/uploads/2013/01/Duluth-Master-Plan-Final\\_December2013.pdf](http://www.duluthenergysystems.com/wp-content/uploads/2013/01/Duluth-Master-Plan-Final_December2013.pdf)
- Forest Inventory and Analysis. (2016). United States Department of Agriculture (USDA) Northern Research Station. Retrieved from: <http://www.nrs.fs.fed.us/featured/2014/09/>
- Fosnacht, Don. (2016). Natural Resources Research Institute, Director Center for Applied Research and Technology Development. Phone conversation.
- FVB Energy Inc. (2014). Step 2 Study: Grand Marais Biomass District Heating System. Report # GM-14-001-0. Report prepared for Biobusiness Alliance of Minnesota and Cook County Local Energy Project. Retrieved from:  
<https://docs.google.com/viewer?a=v&pid=sites&srcid=Y29va2NvdW50eWxvY2FsZW5lcmd5Lm9yZ3x3ZWJzaXRlfGd4Ojc5ODI4YmMyMTFIMzcxNGY>
- Green, Jim (2016). Duluth Energy Systems. Interview and email exchanges.
- Greene, John. (2016). *Forest Biomass Receives Carbon-Neutral Classification in Senate Amendment*. Retrieved from: <http://www.forestindustry.com/guest-columns/forest-biomass-receives-carbon-neutral-classification-in-sen/>
- Haugen, Dan. (2013). Beyond the reach of natural gas boom, Minnesota towns look to biomass. *Midwest Energy News*. Retrieved from: <http://midwestenergynews.com/2013/01/15/beyond-the-reach-of-natural-gas-boom-minnesota-towns-look-to-biomass/>
- International District Energy Association Website. What is District Energy? Retrieved from:  
<http://www.districtenergy.org/what-is-district-energy/>
- Jordan, Brendan. (2016). Great Plains Institute, Vice President. Phone conversations and email exchanges.
- Kiesel, Richard. (2016). Natural Resources Research Institute, Director Coleraine Minerals Research Lab. Phone conversations and email exchanges.
- Lifescience Alley and Biobusiness Alliance of Minnesota. (2012). Minnesota Roadmap: Recommendations for Bioindustrial Processing. Retrieved from:  
<http://www.mncorn.org/sites/mncorn.org/files/research/final-reports/201302/MN%20BioIndustrial%20Processing%20Roadmap%20-%20FULL%20REPORT.pdf>

- Miles, Patrick D. and W. Brad Smith. (2009). *Specific Gravity and Other Properties of Wood and Bark for 56 Tree Species Found in North America*. Research Note NRS-38. United States Department of Agriculture (USDA) Northern Research Station. Retrieved from: [http://www.nrs.fs.fed.us/pubs/rn/rn\\_nrs38.pdf](http://www.nrs.fs.fed.us/pubs/rn/rn_nrs38.pdf)
- Miller, Cheryl; Katheryn Fernholz, Steve Bratkovich and Jim Bower (2013). Community-Driven Biomass Energy Opportunities: A Northern Minnesota Case Study. Dovetail Partners Inc. [http://www.dovetailinc.org/land\\_use\\_pdfs/lccmr\\_resources/community\\_bioenergy.pdf](http://www.dovetailinc.org/land_use_pdfs/lccmr_resources/community_bioenergy.pdf)
- Minnesota Clean Energy Economy Profile: How Industry Sectors are Advancing Economic Growth. (2014). Collaborative Economics Inc. Report Prepared for the Minnesota Department of Employment and Economic Development, Department of Commerce, Department of Agriculture, and Environmental Quality Board. Retrieved from: [http://www.mn.gov/deed/images/mn\\_cleanenergy-economy-profile-fullreport.pdf](http://www.mn.gov/deed/images/mn_cleanenergy-economy-profile-fullreport.pdf)
- Minnesota Forest Resources Council. (2014). Report on the Competitiveness of Minnesota's Primary Forest Products Industry. Retrieved from: [http://mn.gov/frc/docs/MFRC\\_POLICY\\_Forest\\_Industry\\_Competitiveness\\_Report\\_2014-12-01.pdf](http://mn.gov/frc/docs/MFRC_POLICY_Forest_Industry_Competitiveness_Report_2014-12-01.pdf)
- Minnesota Department of Natural Resources. (2016). 2015 Minnesota Public Stumpage Price Review and Price Indices. Retrieved from: [http://files.dnr.state.mn.us/forestry/timber\\_sales/stumpage/stumpage-review-report-2015.pdf](http://files.dnr.state.mn.us/forestry/timber_sales/stumpage/stumpage-review-report-2015.pdf)
- Minnesota Department of Natural Resources. (2015). Minnesota's Forest Resources 2014. Retrieved from: [http://files.dnr.state.mn.us/forestry/um/forestresourcesreport\\_14.pdf](http://files.dnr.state.mn.us/forestry/um/forestresourcesreport_14.pdf)
- Minnesota Department of Natural Resources. (2016). Maps Showing Potential Availability of Biomass in Minnesota. Retrieved from: <http://www.dnr.state.mn.us/forestry/biomass/maps.html>
- Natural Resources Research Institute. (2015). NRRI Now: Energy & Timber Set for Win-Win. Retrieved from: <http://www.nrri.umn.edu/news/2015/autumn2015.htm>
- Natural Resources Research Institute. (2015). Pilot Scale Demonstration for Production of Biofuel from Biomass. Retrieved from: <http://www.nrri.umn.edu/default/pt.asp?id=1771>
- Ontario Power Generation. (2015). From Coal to Biomass: Generating a Sustainable Future. Retrieved From: <http://www.opg.com/about/environment/Documents/OPGBiomassConversion.pdf>
- Pence, Bret. (2016). Ecolibrium 3, Director of Community Programs. Email and Conversations.
- Spitzer, Josef. (2006). Greenhouse Gas Emissions of Bioenergy Systems. European Conference on Biorefinery Research. Retrieved from: [http://ec.europa.eu/research/energy/pdf/gp/gp\\_events/biorefinery/bs4\\_03\\_spitzer\\_en.pdf](http://ec.europa.eu/research/energy/pdf/gp/gp_events/biorefinery/bs4_03_spitzer_en.pdf)
- Slick, Jodi. (2016). Ecolibrium 3, Founder and CEO. Email and Conversations.
- TSS Consultants (2013). Wood Fiber Supply Availability and Potential Utilization Analysis. Prepared for



Minnesota Power. Retrieved from <http://www.sacdm.net/tssconsultants/reports/2013-10-Wood-Fiber-Supply-Availability-Potential-Utilization-Analysis.pdf>

Tuck, Brigid. (2014). Economic Contribution of Biobased Products in Minnesota. Prepared for the Great Plains Institute. Retrieved from: <http://www.extension.umn.edu/community/economic-impact-analysis/reports/docs/2014-Economic-Contribution-Biobased-Fuels.pdf>

United States Energy Information Association (EIA) State Energy Price and Expenditure Estimates. (2013). Retrieved from: [http://www.eia.gov/state/seds/sep\\_prices/notes/pr\\_print.pdf](http://www.eia.gov/state/seds/sep_prices/notes/pr_print.pdf)

United States Energy Information Association (EIA) State Electricity Profiles (2014). Retrieved from: <http://www.eia.gov/electricity/state/minnesota/>

United States Environmental Protection Agency (EPA). CO<sub>2</sub> Emissions Associated with Biomass Use at Stationary Sources. Retrieved from: <https://www3.epa.gov/climatechange/ghgemissions/biogenic-emissions.html>