Duluth’s Energy Future

Prepared by the University of Minnesota Energy Transition Lab

This report, guided by input of stakeholders, provides detailed analysis and actionable strategies for three key priorities for Duluth, Minnesota’s clean energy future:
1) Analyzing the economic and jobs impact of potential biomass energy and solar projects;
2) Investigating the potential for Net Zero energy municipal building retrofits, and
3) Understanding the regulatory, policy, and legal barriers to deploying Combined Heat and Power (CHP) in Duluth and the region.
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Executive Summary

On February 19, 2015 an Energy Future Charrette was led by Ecolibrium3 in partnership with the city of Duluth, Minnesota. The Charrette was facilitated by the Great Plains Institute and the Rocky Mountain Institute and included representatives of Duluth’s city government, local businesses, Minnesota Power, the University of Minnesota-Duluth, and other community members as well as key Minnesota partners the Environmental Quality Board (EQB) and the Energy Transition Lab (ETL). The goal of the Charrette was to determine the Energy Future Vision for the city by capturing the “ambitions and concerns” of key stakeholders emphasizing relevant economic, social, environmental, [and] sustainability aspects. The group focused on several key topic areas, including locally produced biomass, solar, combined heat and power, energy efficiency, and economic development. The Energy Transition Lab was asked to analyze and report on the top research priorities. With the input of key stakeholders, the scope of this report was narrowed to three research topics, all focused on Duluth and the surrounding, heavily forested region of northeastern Minnesota:

1. Analyzing the economic and jobs impact of potential biomass and solar energy projects
2. Investigating the potential for Net Zero energy building retrofits
3. Understanding the regulatory, policy, and legal barriers to deploying Combined Heat and Power (CHP) in Duluth

The report is divided into 3 corresponding chapters, including a forthcoming short addendum to chapter 1, which will assess the health impacts of the proposed renewable energy projects.

Chapter 1: Economic Modeling of Proposed Biomass and Solar Initiatives

Summary

This research shows that transitioning from fossil fuels to local and regionally-sourced bioenergy, solar, and other biomass resources has the potential to create significant jobs and economic growth in the city of Duluth and the heavily forested northeast and "Iron Range" regions of Minnesota.

Methods

The University of Minnesota Duluth’s Bureau of Business and Economic Research conducted economic modeling using IMPLAN to determine the potential for jobs and economic growth from renewable energy projects in the city of Duluth and the Northeast region of Minnesota. Five potential projects, which together would represent a significant increase in renewable energy generation in the region, were analyzed:

- The expansion of solar installations in the city of Duluth,
- Two public utilities biomass projects (the Duluth Steam retrofit and conversion and the Grand Marais district heating system) and
- Two manufacturing projects, which would utilize locally produced woody biomass as a feedstock (the biochemical production plants and the torrefaction plant).

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1 Ecolibrium 3 is a local energy nonprofit based in Duluth, Minnesota. Ecolibrium3 website: http://www.ecolibrium3.org/
2 See the Great Plains Institute website: http://www.betterenergy.org/
3 See the Rocky Mountain Institute website: http://www.rmi.org/
4 See Environmental Quality Board (EQB) website: https://www.eqb.state.mn.us/
5 Energy Transition Lab (ETL) website: http://www.energytransition.umn.edu
6 The charrette also served as impetus for the Rocky Mountain Institute’s Community Energy Resource Guide: http://www.rmi.org/community_energy_guide
7 The work was funded by the McKnight Foundation.
ETL’s team compiled the data on proposed projects in the Duluth area. Solar installations modeled included those proposed by the community and by the electric utility, Minnesota Power. The Duluth Steam retrofit is an upgrade of the legacy downtown district energy heating system to a more efficient hot water system, with the ultimate goal of conversion to biomass fuel and cogeneration of electricity. The Grand Marais proposal is for a new biomass-fueled district energy system. The hypothetical biochemical production plant would use wood fiber to create plant-based chemicals. The torrefaction plant would scale up a pilot plant run by the Natural Resources Research Institute (NRRI) to test production of a fuel product with coal-like energy properties, made from woody biomass.

Results

Construction of the four biomass projects would add almost $407 million regionally in combined direct, indirect, and induced spending effects to the eight-county region, and the solar projects would contribute nearly $2 million in additional wages and benefits, $2.2 million towards the state’s GDP, and more than $3 million in gross output. The combined effects for a typical year of operations from the four biomass projects would equate to more than 1,000 new jobs in the eight-county study area, an additional $54 million in wages, benefits, and proprietor income, and an $80 million contribution to the region’s GDP.

Approximately 280 of the jobs created because of these projects would come from increased spending on woody biomass. This could represent more than a 30% increase in jobs within the Commercial Logging sector, which employed 891 workers in 2014. This would be a potentially large boost to an industry hard-hit by job losses. Although some of the biomass impacts come from energy generation, much of the economic effects come from the bio-renewable chemical plants, which don’t produce energy but do displace fossil fuels with their products. These plants have more economic impact because they would use biomass as a feedstock to produce value-added products, which have the potential to generate increased revenue. A 2012 study showed that this industry could grow in Minnesota by 12,000 new jobs by 2025, and northeastern Minnesota is well-positioned to capitalize on that job growth.8

Several dozen stakeholder-experts had an opportunity to review the draft report and provide helpful input.

Conclusion

This report shows clear benefits to a Duluth energy and clean technology strategy that optimizes locally-produced energy resources.

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8Lifescience Alley and Biobusiness Alliance of Minnesota, *Minnesota Roadmap: Recommendations for Biodindustrial Processing* (2012), accessed at http://www.mncorn.org/sites/mncorn.org/files/research/final-reports/201302/MN%20Biodindustrial%20Processing%20Roadmap%20_FULL%20REPORT.pdf. The study projected the biobased industrial products industry could grow by 12,000 new jobs by the year 2025 in Minnesota, based on strengths including a large and emerging cluster of bioindustrial processing company headquarters, plentiful feedstock and infrastructure for integrated biorefinery development, and an established base of large companies in related industries. The report suggested Minnesota has the potential to attract further investment and become an international leader in this industry.
Chapter 1 Addendum: Health Impacts of Renewable Energy Projects

Summary
In addition to the specific research requested by stakeholders, the Energy Transition Lab asked University of Minnesota experts to evaluate the health impacts of the renewable energy projects modeled in Chapter 1, under the assumption that this information would be valuable to community members in addition to the economic impact data. Electricity production in northeastern Minnesota is largely fueled by coal, which is currently more than half of Minnesota Power’s fuel mix and nearly all of Duluth Energy Systems fuel. Coal production emits several harmful pollutants detrimental to human health, in addition to carbon dioxide (CO₂). Our research team’s preliminary results show that renewable energy projects that displace coal will have measurable benefits to human health in the Duluth region.

NOTE: This section will be added when final research and reviews have concluded.


Summary
The Energy Transition Lab (ETL) partnered with the University of Minnesota’s Center for Sustainable Building Research (CSBR) to determine the feasibility and replicability of transforming existing buildings to Net Zero energy. With this analysis, we worked with Duluth city staff and local partners to determine actionable steps for using energy efficiency and renewable energy technologies to transform Duluth’s municipal building stock. The CSBR research team developed a prototype for measuring the impact of energy efficiency measures on public buildings. Using this model the team demonstrated how to transform an existing public building, with a relatively high energy load for comparable building types, into a Net Zero Energy/Carbon Neutral building.

Methods
The ETL and CSBR team worked with city staff and Ecolibirum3 and determined that the project should be focused on a public building. City staff provided energy usage data for city-owned buildings, and the CSBR experts ranked them according to their energy usage compared to similar building types and sizes around the U.S. Firehall #4 was selected as the target building based on several characteristics: 1) its energy usage, above the median compared to similar buildings, 2) the potential for results to be replicated, and 3) the high visibility of Firehalls to community residents.

The CSBR team collected building energy use data, including both electricity and heat (natural gas) and building measurements. They then developed a computer model that measured the potential effect of different energy conservation measures on total energy consumption in the building.

Results
The model showed some significant and somewhat surprising results. The proposed energy conservation measures included adjustments to operations and mechanical systems, along with architectural retrofits, and collectively simulated energy usage reductions from 44%-62%; which, based on current rates would save an estimated $4,700 - $7,600 annually on utility expenditures. The team then determined the size required for enough onsite renewable energy for the building to reach the goal of Carbon Neutral or Net-Zero Energy.

Conclusion
One of the most significant results is that the CSBR team identified some low-cost/no-cost building operations measures that could significantly reduce energy usage, by over 40%. However, more costly retrofits would be needed to achieve further reductions. While the modeling work is not easily replicated without professional assistance, many lessons learned are. Changes to building operations, maintenance, monitoring, and occupant behavior can make possible deep reductions in both heat and electric energy usage. Additionally, the process of selecting a building fleet, assessing building types and benchmarking them to national data, and focusing on a building’s whole energy system is a valuable model for municipalities and building owners. This research provides owners of building fleets with

cost-effective strategies for reducing their energy footprint.

Chapter 3: Combined Heat and Power Opportunities and Barriers

Summary

Combined Heat and Power, also known as cogeneration, is the production of both electricity and useful thermal energy from the same BTU of energy input. CHP is far more efficient than conventional power production, which wastes up to 60% of the energy value of the fuel.\(^\text{10}\) If we can capture the heat or thermal energy released during electricity production, it can be a valuable energy resource instead of being released to the atmosphere as wasted heat. CHP can be deployed in different ways—to capture waste heat from an electricity-producing power plant (top cycling) or to use excess thermal energy from a plant’s processes to also produce electricity (bottom cycling). Although it has potential to save energy, reduce greenhouse gas emissions, and provide resilient, reliable on-site power, there are many barriers that stand in the way of widespread deployment.

CHP can potentially save 35% of energy used compared to separate heat and electricity production and thus save valuable energy dollars.\(^\text{11}\) Its economic potential in Minnesota is 948 megawatts according to a recent study. CHP works well with biomass fuel and it creates jobs.\(^\text{12}\) For these reasons, it’s a high-potential energy future strategy for Duluth, and community stakeholders wisely asked for research to better understand the barriers and opportunities for CHP in northeastern Minnesota.

Methods

ETL reviewed and summarized many expert reports, and this report identifies and summarizes an array of policy, finance, institutional, and regulatory barriers blocking broader deployment of combined heat and power. We reviewed the extensive stakeholder process and expert analysis on CHP led by the Minnesota Department of Commerce-Division of Energy Resources (DOC), and summarize and update this information. In addition to describing the barriers, we examine and summarize potential solutions that can overcome those roadblocks. Through interviews and case studies of organizations that have considered or successfully deployed CHP in Minnesota, the Energy Transition Lab evaluated lessons learned from them and presents conclusions about the most important attributes of successful CHP projects. Additionally, we include information on many of the legal, regulatory, siting, and other platforms that will enable CHP’s development. The report is intended to be accessible to community members who are not technical experts, and it includes many resources for more detailed study.

Conclusion

Based on our analysis and case studies, we see high potential for proposed CHP projects to move forward in Duluth and the surrounding region. In particular, the Western Lake Superior Sanitary District (WLSSD) and Duluth Energy Systems are well-positioned to succeed at developing renewably-fueled CHP in the near term. However, we also see the need for more supportive legislation, regulatory practices, and financing models to achieve CHP’s potential in northeastern Minnesota and statewide. We also conclude that CHP can play a pivotal role in helping Minnesota meet its state policy goals for greenhouse gas reduction, energy efficiency, and renewable energy, while creating jobs and economic benefits.

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\(^\text{11}\) Microgrid Institute for the Minnesota Department of Commerce, Division of Energy Resources (DOC), CHP in Minnesota: Baseline and Value Proposition Factsheet. (2014).

Summary Conclusion

Together, these three areas of research serve to provide a valuable resource for the City of Duluth and to engage key stakeholders in a conversation about how they envision Northeastern Minnesota’s energy future. Ideally this research will help the city of Duluth take some transformational steps towards a cleaner, more sustainable energy system. While the three research topic areas for energy innovation have value individually, Duluth can optimize their energy future opportunities by combining these components into an overall strategy. Ideally, the city would aim to integrate a diverse set of options such as bioenergy and solar along with combined heat and power (CHP), district energy systems, and ambitious energy efficiency into their energy system. By doing so, the city will be able to increase local resiliency while also having positive impacts on the local economy and environment. Thus, this research taken as a whole shows the pathways to developing a truly integrated, modern, and clean energy system. Duluth is unique, a traditionally blue-collar, industrial yet outdoorsy, coal-dependent city with an extreme climate, but it can also serve as a model for energy transition across the United States by showing how to advance to cleaner energy systems and simultaneously benefit the local economy.
DULUTH’S ENERGY FUTURE

Introduction

In early 2015, stakeholders from city government, local businesses and utilities, nonprofits, and the University came together in Duluth, Minnesota for a charrette to envision their energy future. The goal was to capture the stakeholders’ “ambitions and concerns” and incorporate “relevant economic, social, environmental, [and] sustainability aspects.” The group established three key priority areas for additional research, which were 1) economic impacts of energy transition, 2) analysis of deep energy efficiency retrofit opportunities, and 3) understanding opportunities and barriers for combined heat and power deployment in Duluth and the surrounding region. The University of Minnesota’s Energy Transition Lab received a grant from the McKnight Foundation to conduct the research project.

The stakeholder process and resulting research report show that Duluth and the Arrowhead region of northeastern Minnesota have enormous potential to help lead a clean energy transition that benefits the regional economy and community quality of life and is based upon the North Country’s unique natural resources and attributes.

To support Duluth’s Energy Future Vision, this report includes

- The economic data that shows the benefits of local renewable energy production;
- A summary of health impacts related to the potential projects;¹³
- A case study that shows how a typical public building can be transformed to Net-Zero or Carbon Neutral with accessible and often affordable changes in maintenance, operations, retrofits, and renewable energy; and
- An in-depth analysis of the opportunities, barriers, and potential for combined heat and power, including case studies.

Weaving these three research topics together is a vision of an integrated, modern, and sustainable energy system that capitalizes on the unique strengths of Duluth and its surrounding region. To meet the goals of Duluth stakeholders, that vision should include:

- Diverse and local sources of renewable energy,
- A positive jobs and economic impact,
- Significant efficiency improvements and energy savings in existing building stock, and
- State of the art infrastructure upgrades for maximum customer benefit and optimized efficiency, sustainability, and resiliency.

This report can be used to help Duluth plan and implement next steps in their path forward. The three research topics constitute chapters 1, 2, and 3 of this report, with an addendum to be added to chapter 1 that analyzes the health impacts of some of the proposed projects. Each chapter can stand on its own or be read as part of a larger vision for Duluth’s energy future opportunities. This report is intended to stimulate understanding and to enable progress in strategic energy future areas. The authors welcome opportunities to share our findings with communities and stakeholders. We intend the report to be high-level and accessible to non-experts, while providing detailed resources and additional information for those who would like to learn more.

This report quantifies the economic opportunity that Duluth and the entire Northeast region could harvest by beginning to transition from imported fossil fuels to locally and regionally sourced bioenergy, combined heat and power, energy efficiency, and other clean energy resources, along with other value-added opportunities for local timber. Given the positive economic impact projected on the local economy in Chapter 1, the region could fulfill its full potential to be part of the state’s growing clean energy economy¹⁴ and spur sustainable

¹³ This will be included in a supplemental version of the report.
local economic growth and jobs while becoming a national model for locally based clean energy investments.

Chapter 1 highlights the jobs and economic activity potential from renewable energy and biochemical projects. Besides the economic impacts these investments would have on the eight-county study area in Northeast Minnesota, additional benefits of these projects can include:

- The stabilization and reduction of long-term energy costs\(^\text{15}\)
- An increase in resilience and energy security due to reliance upon local rather than imported fuel
- The maintenance of sustainable harvests and improved management of state forest resources, which can improve forest health and reduce the risk of large-scale forest fires.
- Decreased carbon dioxide emissions
- Health benefits from cleaner air

While the solar projects included in this analysis shows smaller economic impacts relative to the four biomass projects, the potential impact that solar investments such as these could have on the state are still significant. According to the Minnesota Clean Energy Profile, the state’s solar energy capacity alone increased 9670% from 118kW in 2000 to 11,550 KW between 2000 and 2012.\(^\text{16}\) In addition, clean energy jobs grew more quickly than other areas of the economy and average annual wages in the Minnesota solar industry are above average at $70,400 on average in 2013.\(^\text{17}\) Projects such as those included in this analysis can contribute to the continued expansion of the solar industry within the state, and help to strengthen the industry’s presence in northeastern Minnesota.

Another opportunity that was highlighted by this analysis is the ability to take advantage of planned infrastructure renovations to incorporate more efficient locally produced energy resources. The timing of Duluth Steam’s plan to convert the district energy system from steam to hot water and incorporate locally produced biomass has been engineered to coincide with street renovation work that is scheduled to take place in downtown Duluth. By combining Phase 1 of the project with scheduled street renovations, Duluth will be able to significantly reduce construction costs.\(^\text{18}\) In addition to the positive economic impacts of the project (for the Duluth Steam Project alone, the switch to woody biomass as a primary energy source adds $1.3 million in new spending to the region’s timber industry), the savings gained from the opportunistic timing of this investment allow the project’s initial costs to be reduced while keeping overall benefits high. Another synergy is the Western Lake Superior Sanitary District (WLSSD) project, envisioning a sustainable energy system that uses wastewater and solid waste from Duluth and the region as an energy resource.

In the Net-Zero energy and combined heat and power sections, Chapters 2 and 3, our research shows that innovative approaches to energy efficiency and energy generation are feasible for Duluth and the surrounding region. While both are investments that require capital outlays, both can produce significant energy savings. The report points out the need for policies and regulations that better incent or value life-cycle benefits that waste less energy, reduce emissions, and improve health impacts.

Much of Duluth and northern Minnesota’s history for the last century was built upon heavy resource- and energy-intensive industries like mining, lumber, shipping, and steel. The traditional energy system served it well, but the world’s energy systems are rapidly transitioning to the future. Energy systems are evolving to become more renewable, lower carbon, flexible, customer-driven, and resilient. In this future, a network of local distributed energy resources will complement a foundation of regional energy grids. Duluth has many commonalities with the industrial heartland of American and communities around the world. If Duluth embraces and helps to lead this path to the future, it can serve as a sterling model for those cities, and demonstrate a transition to clean, local energy sources that create hundreds of jobs, save energy, and benefit the local economy.

\(^{15}\) Note that changes in energy costs and other prices over time are not included within the IMPLAN model in Chapter 1.
\(^{16}\) Minnesota Clean Energy Profile (2014).
\(^{17}\) IBID.
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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.\(^1\) 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\(^2\) 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:

\[
\begin{align*}
\text{I.} & \quad \text{The Grand Marais Biomass District Heating System} \\
\text{II.} & \quad \text{The Duluth Energy Systems Plant Retrofit and Biomass Conversion} \\
\text{III.} & \quad \text{A Torrefaction Processing Plant} \\
\text{IV.} & \quad \text{Two Biorenewable Chemical Production Plants} \\
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\]

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.\(^3\) 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

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\(^1\) 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.

\(^2\) 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.

\(^3\) 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

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

**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

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

**Source:** IMPLAN, BBER

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

---

4 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.

5 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.

6 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, 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 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.

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.

★★★★

7 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)
8 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.
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\(^{10}\) by capturing “the ambitions and concerns” of the key stakeholders, with relevant economic, social, environmental, [and] sustainability aspects”.\(^{11}\) 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\(^{12}\) 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.\(^{13}\) 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.

\(^{10}\) See Note 1.
\(^{11}\) The charrette also served as impetus for the Rocky Mountain Institute’s Community Energy Resource Guide http://www.rmi.org/community_energy_guide
\(^{12}\) See Note 2.
\(^{13}\) 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. Declining demand for paper and construction materials accompanied by a sharp reduction in the volume of timber harvested by private landowners has resulted in steadily increasing stumpage prices. As shown in Minnesota’s Department of Natural Resources (DNR) land ownership maps, 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. Due to these recent trends, it has been projected that the number of small logging businesses in Minnesota will continue to decline.

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. 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, supporting the local economy through job creation, preventing “dollar drain” through the

15 IBID
16 See Note 9.
17 These facts are supported by many reports including:
   - 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
18 See Note 9.
19 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).
21 See Note 14.
22 Step 2 Study: Grand Marais Biomass District Heating System Report #GM-14-001-0. FVB, 2014
23 IBID
production of locally generated energy, and increasing energy security due to reliance upon local rather than imported fuel. 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.

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. 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. 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.

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.

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, 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. 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. For more details on fluctuating energy costs over time, see Appendix D for a comparison of energy

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25 A feasibility study conducted in Grand Marais (www.cookcountylocalenergy.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.

26 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.


28 See Note 21.

29 See Note 14.

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

31 IBID


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


36 See Note 21.

37 Kent Jacobsen, MN DNR.

38 IBID

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_Bureau of Business and Economic Research_  
_Labovitz School of Business and Economics_  
_University of Minnesota Duluth_
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).\textsuperscript{39,40} 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.\textsuperscript{41,42}

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

\textbf{Minnesota’s Growing Clean Energy Economy}

Despite the challenge of fluctuating fossil fuel prices, electricity generated from woody biomass\textsuperscript{43} 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.\textsuperscript{44} 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.\textsuperscript{45} While many factors affect bioenergy production, the adoption of Minnesota’s renewable energy standard in 2007 is seen

\textsuperscript{39}As Appendix D shows, while the price of natural gas has been decreasing recently, over the long-term its price is very volatile.
\textsuperscript{40}See Note 14.
\textsuperscript{41}IBID
\textsuperscript{42}Haugen, 2013 \url{http://midwestenergynews.com/2013/01/15/beyond-the-reach-of-natural-gas-boom-minnesota-towns-look-to-biomass/}
\textsuperscript{43}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 \url{http://www.eia.gov/electricity/state/minnesota/}
\textsuperscript{44}U.S. EIA State Electricity Profiles \url{http://www.eia.gov/electricity/state/minnesota/}
\textsuperscript{45}Minnesota Clean Energy Economy Profile: How Industry Sectors are Advancing Economic Growth \url{http://www.mn.gov/deed/images/mn_cleanenergy-economy-profile-fullreport.pdf}
as one of the main catalysts for this sharp increase.\textsuperscript{46} Employment in bioenergy\textsuperscript{47} 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.\textsuperscript{48}

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.\textsuperscript{49,50} The state’s solar energy capacity alone increased 9,670\% from 118kW to 11,550 kW between 2000 and 2012.\textsuperscript{51} While solar energy and energy efficiency companies currently generate the most revenue within Minnesota (due to their common locally based value chain functions),\textsuperscript{52} 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\textsuperscript{53} (see Figure 2).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Minnesota’s Arrowhead Region and Douglas County, Wisconsin}
\end{figure}

The Arrowhead region provides an ideal setting for this analysis due to the area’s rich forest resource-base\textsuperscript{54,55} as well as the potential positive impact that investments in clean energy and renewable chemicals

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\textsuperscript{46} IBID  
\textsuperscript{47} Including woody biomass and other forms of biomass listed above  
\textsuperscript{48} See Note 45.  
\textsuperscript{49} 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 \url{http://www.cleanjobsmidwest.com/state/minnesota/})  
\textsuperscript{50} See Note 45.  
\textsuperscript{51} IBID  
\textsuperscript{52} IBID  
\textsuperscript{53} Douglas Country, 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.  
\textsuperscript{54} See Note 14.  
\textsuperscript{55} See Note 45.
could potentially have on the region’s economy.\textsuperscript{56} According to a recent report by DEED, there are currently 317 clean energy jobs\textsuperscript{57} 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.\textsuperscript{58} 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,\textsuperscript{59} the region’s abundant surplus forest material is currently underutilized.\textsuperscript{60} 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\textsuperscript{61} and sustainably spur local economic growth.

\textbf{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.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{Regional Output by Industry, in Millions of Dollars}
\end{figure}

\textit{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...
Marais district heating system) and two manufacturing projects (the biochemical production plants and the torrefaction plant). 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)

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

*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. 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

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62It 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.

63IMPLAN 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. According to a 2014 report conducted by Minnesota's Department of Natural Resources (DNR), 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.

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

**Sources:** NRRI, FVB Energy Inc. Report # GM-14-001-0, Duluth Energy Systems, Great Plains Institute

According to project stakeholders, the four biomass projects included in this study would require approximately 626,000 tons of locally harvested 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.

64 See Note 21.
65 See Note 7.
66 See Note 21.
67 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.
68 In the context of this study, biomass harvesting and associated economic and jobs impacts were assumed to occur within the study area.
69 NRRI developed the conversion factors utilized in this report based upon the following Research Note published by the

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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 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.71, 72

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.70, 71

In addition to the amount of physical biomass that can be sustainability harvested, the economic and social availability of biomass in Northeast Minnesota should also be considered.73 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.74 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.75 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.76 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.77 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 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

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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.

70 See notes 14, 16, and 17

71 See Note 7.

72 See Note 21.

73 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=02DE990262EOCB0885981719C7AB1A4?sequence=1

74 IBID

75 See Note 18.

76 Source: Anna Dirkswager, Clean Energy Economy Minnesota.

77 See Note 73.

78 www.implan.com

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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. 79, 80

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

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79 For all projects, detailed inputs and methodology used in modeling are available in Appendix A
80 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

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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.\(^81\) District energy heating and cooling plants, especially those that generate electricity, are far more efficient than conventional heating, cooling, and electrical systems.\(^82\)

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.\(^83\) 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) |
|-----------------------------------|-----------------|-----------------|-----------------|-----------------|
|                                   | Direct Employment | Total Spending  | % Spent Locally | Direct Local Spending |
| 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*


\(^82\) International District Energy Association [http://www.districtenergy.org/what-is-district-energy/](http://www.districtenergy.org/what-is-district-energy/)

\(^83\) 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**

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

*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

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

*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 1932.⁸⁴ 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:⁸⁵

- 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,

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approximately 25% of the system’s fuel input requirement will be met with biomass\textsuperscript{86}.

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.\textsuperscript{87} 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>
<thead>
<tr>
<th>Table 6. Duluth Energy Systems Plant Direct Inputs (Construction and Operations)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct Employment</strong></td>
</tr>
<tr>
<td>Construction Phase I</td>
</tr>
<tr>
<td>Construction Phase II</td>
</tr>
<tr>
<td>Operations</td>
</tr>
</tbody>
</table>

\textit{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>
<thead>
<tr>
<th>Table 7. Detailed Impacts of Duluth Energy Systems Plant Phase I – Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Impact Type</strong></td>
</tr>
<tr>
<td>Direct Effect</td>
</tr>
<tr>
<td>Indirect Effect</td>
</tr>
<tr>
<td>Induced Effect</td>
</tr>
<tr>
<td>Total Effect</td>
</tr>
</tbody>
</table>

\textit{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\textsuperscript{88} 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).

\textsuperscript{86}See Note 85.
\textsuperscript{87}See Note 86.
\textsuperscript{88}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.
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 8. Detailed Impacts of Duluth Energy Systems Plant Phase II – Construction

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

**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.\(^9\) Most of the indirect effects shown in Table 9 are the result of that spending.

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

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

**Source:** IMPLAN, 2016

### 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.\(^90,91\) In a solid form, this fuel has significant advantages over common biomass fuels, such as standard wood pellets or chips.\(^92\) According to the Natural Resources Research Institute (NRRI), one ton of torrefied material is roughly equivalent (95%) to one ton of western

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\(^9\) 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.\(^90\)

\(^91\) 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.

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. With its pilot facility in Coleraine, MN NRRI is currently undergoing studies to confirm the efficiency projections for the torrefaction process. In addition, compared to coal, burning torrefied material reduces mercury emissions and decreases treatment costs on flue gas. Torrefied material is also a more homogenous product and easier to transport and store compared to unconverted biomass. Recently, UMD’s Natural Resources Research Institute (NRRI) has begun working to develop this technology and to expand it more broadly for commercial use.

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. 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. 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.

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$_2$ emissions from the existing energy system while keeping the costs of conversion reasonable.

(Don Fosnacht, NRRI)

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93 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).

94 http://csrail.org/torrefied-biomass/

95 See Note 93.

96 IBID

97 See Note 95.

98 See Note 93.

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

100 IBID

101 Phone Interview with Jim Green, Duluth Energy Systems, April 8, 2016

102 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)

<table>
<thead>
<tr>
<th></th>
<th>Direct Employment</th>
<th>Total Spending</th>
<th>% Spent Locally</th>
<th>Direct Local Spending</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>98</td>
<td>$32,034,357</td>
<td>60%</td>
<td>$19,282,331</td>
</tr>
<tr>
<td>Operations</td>
<td>19</td>
<td>$12,465,000</td>
<td>87%</td>
<td>$10,852,500</td>
</tr>
</tbody>
</table>

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. For that reason, the direct local spending is less than $20 million.

Table 11. Detailed Impacts of Torrefaction Plan – Construction

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

Source: IMPLAN, 2016

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

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

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) 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.

---

103 Estimate from Brigid Tuck, UMN Extension, based on similar studies
104 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.\textsuperscript{105} 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.\textsuperscript{106} Most of the indirect effects shown in Table 12 are the result of that spending.

\textbf{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-deriv ed advanced biofuels and biobased chemicals.\textsuperscript{107} 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.\textsuperscript{108}

\begin{table}[h]
\centering
\begin{tabular}{lrrrr}
\hline
 & \textbf{Direct Employment} & \textbf{Total Spending} & \textbf{% Spent Locally} & \textbf{Direct Local Spending} \\
\hline
Construction & 600 & $258,000,000 & 88\% & $227,188,500 \\
Operations & 165 & $152,269,000 & 75\% & $114,727,995 \\
\hline
\end{tabular}
\caption{Biorenewable Chemical Production Plants Direct Inputs (Construction and Operations)}
\end{table}

\textit{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.

\textsuperscript{105} Don Fosnacht and Richard Kiesel, NRRI
\textsuperscript{106} See Appendix A for more details.
\textsuperscript{107} See Note 27.
\textsuperscript{108} 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

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

**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. 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

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

**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.

**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.

---

109 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.

110 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.

111 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>
<thead>
<tr>
<th>Table 16. Solar Power Production Arrays Direct Inputs (Construction and Operations)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct Employment</strong></td>
</tr>
<tr>
<td>Construction</td>
</tr>
<tr>
<td>Operations</td>
</tr>
</tbody>
</table>

SOURCE: ECOLIBRIUM 3, RREAL, AND BARBOSE, WEAVER & DARGOUTH, 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. 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>
<thead>
<tr>
<th>Table 17. Detailed Impacts of Solar Power Production Arrays – Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact Type</td>
</tr>
<tr>
<td>Direct Effect</td>
</tr>
<tr>
<td>Indirect Effect</td>
</tr>
<tr>
<td>Induced Effect</td>
</tr>
<tr>
<td>Total Effect</td>
</tr>
</tbody>
</table>

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.

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

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

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)**

<table>
<thead>
<tr>
<th>Number of jobs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
</tr>
<tr>
<td>698</td>
</tr>
<tr>
<td>61</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>13</td>
</tr>
<tr>
<td>12</td>
</tr>
</tbody>
</table>

**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**

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

**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)**

<table>
<thead>
<tr>
<th>Sector</th>
<th>Number of jobs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial logging</td>
<td>284</td>
</tr>
<tr>
<td>Other basic organic chemical manufacturing</td>
<td>166</td>
</tr>
<tr>
<td>Other local government enterprises</td>
<td>57</td>
</tr>
<tr>
<td>Support activities for agriculture and forestry</td>
<td>46</td>
</tr>
<tr>
<td>Natural gas distribution</td>
<td>22</td>
</tr>
<tr>
<td>Wholesale trade</td>
<td>22</td>
</tr>
<tr>
<td>Maintenance and repair construction of nonresidential...</td>
<td>22</td>
</tr>
<tr>
<td>Reconstituted wood product manufacturing</td>
<td>20</td>
</tr>
<tr>
<td>Full-service restaurants</td>
<td>19</td>
</tr>
<tr>
<td>Hospitals</td>
<td>16</td>
</tr>
<tr>
<td>Electric power transmission and distribution</td>
<td>15</td>
</tr>
<tr>
<td>Truck transportation</td>
<td>15</td>
</tr>
<tr>
<td>Limited-service restaurants</td>
<td>14</td>
</tr>
<tr>
<td>Real estate</td>
<td>12</td>
</tr>
<tr>
<td>Retail - Nonstore retailers</td>
<td>12</td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>Budget Item</th>
<th>Total Spending</th>
<th>% Spent Locally</th>
<th>Direct Local Spending</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Build Package</td>
<td>$2,093,210</td>
<td>100%</td>
<td>$2,093,210</td>
</tr>
<tr>
<td>Construction Package</td>
<td>$5,999,827</td>
<td>100%</td>
<td>$5,999,827</td>
</tr>
<tr>
<td>Equipment</td>
<td>$4,206,963</td>
<td>0%</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$12,300,000</strong></td>
<td></td>
<td><strong>$8,093,037</strong></td>
</tr>
</tbody>
</table>

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. 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.

---

113 See Note 23.
Spending Pattern. 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. 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>
<thead>
<tr>
<th>Sector</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>58</td>
<td>Construction of other new nonresidential structures</td>
</tr>
</tbody>
</table>

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

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. 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.
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**

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

*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**

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

*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

<table>
<thead>
<tr>
<th>Sector</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>58</td>
<td>Construction of other new nonresidential structures</td>
</tr>
<tr>
<td>395</td>
<td>Wholesale trade distribution services</td>
</tr>
<tr>
<td>449</td>
<td>Architectural, engineering, and related services</td>
</tr>
<tr>
<td>5001</td>
<td>Employee Compensation</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Budget Item</th>
<th>Total Spending</th>
<th>% Spent Locally</th>
<th>Direct Local Spending</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Preparation and Construction</td>
<td>$2,200,000</td>
<td>100%</td>
<td>$2,200,000</td>
</tr>
<tr>
<td>Equipment</td>
<td>$2,500,000</td>
<td>40%</td>
<td>$1,000,000</td>
</tr>
<tr>
<td>Engineering</td>
<td>$300,000</td>
<td>60%</td>
<td>$180,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$5,000,000</strong></td>
<td></td>
<td><strong>$3,380,000</strong></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Sector</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>58</td>
<td>Construction of other new nonresidential structures</td>
</tr>
<tr>
<td>395</td>
<td>Wholesale trade distribution services</td>
</tr>
<tr>
<td>449</td>
<td>Architectural, engineering, and related services</td>
</tr>
<tr>
<td>5001</td>
<td>Employee Compensation</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Budget Item</th>
<th>Total Spending</th>
<th>% Spent Locally</th>
<th>Direct Local Spending</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedstock Purchases</td>
<td>$1,300,000</td>
<td>100%</td>
<td>$1,300,000</td>
</tr>
<tr>
<td>Maintenance</td>
<td>$50,000</td>
<td>100%</td>
<td>$50,000</td>
</tr>
<tr>
<td>Coal consumption</td>
<td>($590,000)</td>
<td>100%</td>
<td>($590,000)</td>
</tr>
<tr>
<td>Wages and Salaries</td>
<td>$250,000</td>
<td>100%</td>
<td>$250,000</td>
</tr>
<tr>
<td>Electricity</td>
<td>$50,000</td>
<td>100%</td>
<td>$50,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1,060,000</strong></td>
<td></td>
<td><strong>$1,060,000</strong></td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>Sector</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>Coal</td>
</tr>
<tr>
<td>41</td>
<td>Electricity</td>
</tr>
<tr>
<td>62</td>
<td>Maintained and repaired nonresidential structures</td>
</tr>
<tr>
<td>134</td>
<td>Saws</td>
</tr>
<tr>
<td>5001</td>
<td>Employee Compensation</td>
</tr>
</tbody>
</table>

**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

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

*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

<table>
<thead>
<tr>
<th>Sector</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>53</td>
<td>Construction of new manufacturing structures</td>
</tr>
<tr>
<td>395</td>
<td>Wholesale trade</td>
</tr>
<tr>
<td>449</td>
<td>Architectural, engineering, and related services</td>
</tr>
<tr>
<td>5001</td>
<td>Employee Compensation</td>
</tr>
</tbody>
</table>

*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

<table>
<thead>
<tr>
<th>Budget Item</th>
<th>Total Spending</th>
<th>% Spent Locally</th>
<th>Direct Local Spending</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedstock Purchases</td>
<td>$7,800,000</td>
<td>100%</td>
<td>$7,800,000</td>
</tr>
<tr>
<td>Wages and Salaries</td>
<td>$1,440,000</td>
<td>100%</td>
<td>$1,440,000</td>
</tr>
<tr>
<td>Other</td>
<td>$3,225,000</td>
<td>50%</td>
<td>$1,612,500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$12,465,000</strong></td>
<td></td>
<td><strong>$10,852,500</strong></td>
</tr>
</tbody>
</table>

*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

<table>
<thead>
<tr>
<th>Sector</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Logs and roundwood</td>
</tr>
<tr>
<td>138</td>
<td>Reconstituted wood product manufacturing</td>
</tr>
<tr>
<td>5001</td>
<td>Employee Compensation</td>
</tr>
</tbody>
</table>

*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

<table>
<thead>
<tr>
<th>Budget Item</th>
<th>Total Spending</th>
<th>% Spent Locally</th>
<th>Direct Local Spending</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Development</td>
<td>$3,720,000</td>
<td>100%</td>
<td>$3,720,000</td>
</tr>
<tr>
<td>Other Construction</td>
<td>$220,045,000</td>
<td>100%</td>
<td>$220,045,000</td>
</tr>
<tr>
<td>Equipment</td>
<td>$34,235,000</td>
<td>10%</td>
<td>$3,423,500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$258,000,000</strong></td>
<td></td>
<td><strong>$227,188,500</strong></td>
</tr>
</tbody>
</table>

*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

<table>
<thead>
<tr>
<th>Sector</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>53</td>
<td>Construction of new manufacturing structures</td>
</tr>
<tr>
<td>395</td>
<td>Wholesale trade</td>
</tr>
</tbody>
</table>

*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

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

**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

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

**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

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

Source: Ecolibrium 3, RREAL, IPS Solar, and Barbose, Weaver & Darghouth, 2015

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

<table>
<thead>
<tr>
<th>Sector</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>49</td>
<td>Electric power transmission and distribution</td>
</tr>
<tr>
<td>456</td>
<td>Scientific research and development services</td>
</tr>
<tr>
<td>5001</td>
<td>Employee Compensation</td>
</tr>
</tbody>
</table>

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.

117 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.

**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.

---

118 IMPLAN, 2015
Appendix C. IMPLAN Assumptions

The following are suggested assumptions for accepting the impact model:119

**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.

---


Bureau of Business and Economic Research
Labovitz School of Business and Economics
University of Minnesota Duluth
Appendix D  Energy Costs in Minnesota over Time

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Natural Gas $/MMBtu</th>
<th>Natural Gas Total</th>
<th>Petroleum $/bbl</th>
<th>Petroleum Total</th>
<th>Electricity $/kWh</th>
<th>Electricity Total</th>
<th>Total Energy ($ MM)</th>
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<tr>
<td>1970</td>
<td>0.32</td>
<td>0.42</td>
<td>0.05</td>
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<td>0.75</td>
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<tr>
<td>1975</td>
<td>0.39</td>
<td>0.62</td>
<td>0.08</td>
<td>2.04</td>
<td>0.84</td>
<td>1.95</td>
<td>2.77</td>
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<tr>
<td>1980</td>
<td>1.19</td>
<td>1.33</td>
<td>0.35</td>
<td>4.22</td>
<td>1.57</td>
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<td>5.69</td>
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<tr>
<td>1985</td>
<td>1.32</td>
<td>1.42</td>
<td>0.52</td>
<td>5.44</td>
<td>2.18</td>
<td>3.57</td>
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<tr>
<td>1990</td>
<td>1.51</td>
<td>1.57</td>
<td>0.62</td>
<td>7.86</td>
<td>3.04</td>
<td>4.42</td>
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<tr>
<td>1995</td>
<td>1.32</td>
<td>1.36</td>
<td>0.61</td>
<td>7.76</td>
<td>3.02</td>
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<tr>
<td>2000</td>
<td>1.80</td>
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<td>0.74</td>
<td>12.25</td>
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<td>2005</td>
<td>2.57</td>
<td>2.58</td>
<td>0.74</td>
<td>16.06</td>
<td>6.01</td>
<td>9.08</td>
<td>22.06</td>
</tr>
<tr>
<td>2010</td>
<td>2.04</td>
<td>2.05</td>
<td>0.75</td>
<td>14.73</td>
<td>5.34</td>
<td>8.07</td>
<td>21.03</td>
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Duluth Energy Transition, Chapter 2: Investigating Zero-Energy Potential

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All graphic materials prepared by:

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<td>12</td>
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<td>8</td>
<td>Measure 3 Modeled Energy Savings</td>
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<td>9</td>
<td>Measure 4 Modeled Energy Savings</td>
<td>14</td>
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<tr>
<td>10</td>
<td>Measure 5 Modeled Energy Savings</td>
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<td>19</td>
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<tr>
<td>15</td>
<td>Relative Costs of Measures Analyzed</td>
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Executive Summary

As part of its research on Duluth’s Energy Future Planning, the University of Minnesota’s Energy Transition Lab collaborated with the Center for Sustainable Building Research (CSBR) to investigate the potential of a carbon-neutral or net-zero energy building within Duluth’s existing municipal buildings. The goal of this research was to provide actionable strategies for the city to significantly increase a target building’s energy efficiency. The Energy Transition Lab managed the project, coordinated with city staff and stakeholders, and drafted and edited this report, while the CSBR research team did all of the technical and analytical work, contributed to editing and writing, and created all graphics and data found in this report.

The CSBR research team systematically assessed and identified opportunities within Duluth’s municipal facilities. Taken as a group Duluth’s Fire Halls were underperforming compared to national building performance data. Together with key city stakeholders, the research team identified Fire Hall 4 as a representative facility to proceed with an in-depth analysis.

The CSBR research team gathered information about the facility from existing drawings and site walkthroughs and utilized a combination of computer software to generate an energy model. Through iterative simulation the model was tuned and calibrated to within a reasonable tolerance of known energy usage and utility data. Once calibrated, the energy model was utilized to measure the potential effect of different energy conservation measures on total energy consumption in the building. These energy conservation measures included adjustments to operations, mechanical systems, and architectural retrofits, and collectively simulated energy usage reductions from 44%-62%. Based on current rates, these improvements would save an estimated $4,700 - $7,600 annually on utility expenditures. Some, but not all, of the measures projected to achieve significant reductions required relatively easy and inexpensive changes to building operations and maintenance.

In addition to the complex tasks of developing a calibrated energy model and analyzing the impact of energy conservation measures, the research team identified the amount of renewable energy output that Fire Hall 4 would require in order to achieve carbon neutral or net-zero energy designations. The on-site renewable system needed for carbon-neutral ranged from 63MWh – 93MWh; a net-zero energy system was much harder to attain with systems ranging from 126 MWh – 186MWh.¹ We will describe in detail the differences between net zero and carbon neutral below.

Potential actions and drawbacks of each energy conservation measure, renewable energy systems, and additional considerations are listed in conclusion.

¹ Note that these numbers refer to energy production of a renewable system (megawatt hours), not the size of the system (kilowatts or megawatts).
Introduction

In February 2015 Duluth community stakeholders participated in an Energy Future Charrette and identified key priorities for future research. The McKnight Foundation awarded the Energy Transition Lab grant funding to study and report on key aspects of Duluth’s energy future planning. The project brought together University and industry experts in bioenergy, solar, law, economics, sustainable building design, combined heat and power, and other disciplines to analyze forward-looking energy scenarios for Northeastern Minnesota.

One of the key outcomes of the Duluth Charrette was to understand how realistic it is to reach high levels of energy reductions in existing buildings. To set a high bar for this inquiry, the project scope was set as a goal of providing actionable, cost-effective models for Net-Zero Energy building retrofits. This research focuses upon retrofits rather than new construction because of the opportunities that exist within the state’s current building stock. The Energy Transition Lab asked the University of Minnesota’s Center for Sustainable Building Research (CSBR) to assist in the energy modeling.

The team hoped to analyze a public building that could be a significant and replicable model for future energy efficiency projects. The Center for Sustainable Building Research (CSBR) approaches buildings as architects and designers, and our open approach allowed us to explore multiple scenarios and pathways to achieve energy efficiency. While these may represent stretch goals for buildings, they are grounded in economic reality. The analysis involved five distinct goals:

1. Identify a civic building in Duluth, MN with the potential to reach net-zero energy consumption and to provide replicable learning and results.
2. Develop an energy model of the facility and its operations, and calibrate it to the building’s known energy demands.
3. Evaluate energy efficiency strategies and retrofits to reduce the building’s total energy consumption.
4. Size a renewable energy system to supply the remaining building energy load.
5. Quantify potential savings and environmental impacts of selected outcomes.

Duluth’s Fire Hall #4 was chosen as a representative facility. Simulated architectural and operations changes aimed to result in the building’s on-site energy production being equal to its on-site energy consumption, and its total CO₂ emissions equal to total CO₂ reductions. This allowed us to analyze the measures that would be necessary to retrofit Fire hall #4 to achieve a net zero energy profile, including both electricity and natural gas inputs. As a result of this exercise, the CSBR demonstrated how to transform an existing public building to Net-Zero Energy/Carbon Neutral facility and maximize emissions reductions.

The following sections detail the methods utilized in each phase of this project, the results, and recommendations for future action.
Phase 1: Identify a civic building in Duluth, MN with the potential to reach net-zero energy consumption.

CSBR conducted an analysis of the existing building stock in Duluth to identify potential demonstration sites. The potential sites also focused upon buildings in the district energy central city footprint\(^2\) that have the potential of reaching net zero energy consumption. Several buildings that were higher than a national median in energy use and carbon outputs were targeted.

As seen in Figure 1, a standard metric for assessing buildings is Energy Use Intensity (EUI), or all of the building’s energy usage divided by the gross building area in square footage. Figure 2 (page 6) shows a range of potential energy cost savings for several different Duluth public buildings. The percent reduction in operating energy costs is shown, rather than percent reduction in actual energy use. Energy use reductions for each potential level is shown in BTUs as well as Greenhouse Gas emissions reductions.

\(^2\) The siting of this project within the district energy central footprint was done to support the planned retrofits to the Duluth Steam Plant. The Duluth Steam Plant’s planned conversion to a more efficient district energy system should be paired with a focus on central city buildings, to maximize the efficiency of the entire system, expand the customer base, and create cost-effective opportunities for building improvements. A map of Duluth Steam’s Current System is included in Appendix A of this report.
## Figure 2: Comparison of Savings Potential

<table>
<thead>
<tr>
<th>Location</th>
<th>Current EUI kBTU/ft²/yr</th>
<th>National Median EUI kBTU/ft²/yr</th>
<th>Utilities Expenditures (2012 cal. yr.)</th>
<th>15% Reduction in Operating Cost</th>
<th>Reduction to Median EUI</th>
<th>50% Reduction in Operating Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>City Hall</td>
<td>55.64</td>
<td>67.3</td>
<td>$92,593.19</td>
<td>-$13,889/yr</td>
<td>-3,559,958 kBTU</td>
<td>-$46,297/yr</td>
</tr>
<tr>
<td>127,964 ft²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firehalls</td>
<td>Hall 1 = 61.19</td>
<td>88.3</td>
<td>$54,914.56</td>
<td>-$8,237/yr</td>
<td>-1,193,744 kBTU</td>
<td>-$27,457/yr</td>
</tr>
<tr>
<td>53,300 ft²</td>
<td>Hall 2 = 128.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hall 4 = 170.61</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hall 6 = 203.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hall 7 = 123.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>City Center West</td>
<td>106.83</td>
<td>88.3</td>
<td>$39,384.81</td>
<td>-$5,907/yr</td>
<td>-1,201,143 kBTU</td>
<td>-$19,692/yr</td>
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<tr>
<td>22,487 ft²</td>
<td></td>
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</table>
Building options for the modeling exercise included: Duluth City Hall, City Center West, and Fire halls #1, #2, #4, #6 and #7. CSBR determined the Energy Use Intensity (EUI) for each building, the national median EUI for buildings of the same type (Figure 3), and the recent utility expenditures for each building analyzed; and quantified the economic impact of theoretical energy reduction targets on the facility’s annual utility costs.

The full research team met with key city stakeholders, including city managers and facility operations staff, in July 2015 and all of the options were presented. Fire Hall #4 was identified as the ideal site for the Net-Zero analysis. The Fire Hall was deemed to be the ideal site for this analysis for several reasons:

- Duluth’s fire halls operate well above the Commercial Buildings Energy Consumption Survey (CBECS) Fire Station / Police Station EUI of 88.3.
- It was assumed that a successful net-zero energy retrofit / renovation program for this building would have the potential for replication at other fire stations within the municipality, a total representation of 65,000ft² of built area.
- The fire halls are distributed throughout residential areas; successful projects would increase exposure and awareness of net-zero energy strategies to the general public.
- Public order and safety buildings, which include fire and police stations, by nature of their 24/7 operations, have high energy demands.
- The 2013-2017 Capital Improvements Plan presents opportunity to influence facility efficiencies through an established investment schedule.

---

3 EUI includes energy spent on space heating, cooling, ventilation, water heating, lighting, refrigeration, office equipment, computers etc.
4 The U.S. Energy Information Administration (EIA) defines the CBECS as “a national sample survey that collects information on the stock of U.S. commercial buildings including their energy related building characteristics and energy usage data (consumption and expenditures).” EIA: [https://www.eia.gov/consumption/commercial/about.cfm](https://www.eia.gov/consumption/commercial/about.cfm)
The mechanical system in Fire hall 4 had recently been upgraded to a high-efficiency condensing boiler, which presented additional opportunities for retrofits.

Some of the existing buildings are dated and have not been remodeled. Upgrades to the stations could focus on improving quality of service as well as operational efficiency.

**Phase 2: Develop and calibrate an energy model of the facility**

The research team gathered information about the facility from existing drawings and site walkthroughs, and then utilized a combination of computer software to generate the building energy model. The basic building geometry, siting, and orientation were created in the modeling program Sketchup. A plug-in for OpenStudio, an energy modeling and analysis program, allowed thermal zones and preliminary material assembly properties to be assigned from within Sketchup. More detailed definitions of information relating to mechanical, electrical, and hot water systems, material assemblies and envelope performance, building occupancy and scheduling, and inputs for metered utility data, were entered within OpenStudio’s stand-alone program. Through iterative simulation and adjustment of the facility parameters, the model was calibrated to within a reasonable tolerance of known conditions.

![Figure 5: Energy Model Calibration](image-url)
Phase 3: Evaluate energy conservation measures and architectural retrofits

Several concerns about the condition of the facility at Fire Hall 4 were identified during the development and calibration of the energy model. In many respects, the facility was not in compliance with current building codes. The thermal envelope was inadequately insulated. It was found that both thermal zones of the building were over ventilated, and air leakage and infiltration through the envelope was a significant problem. As a result, temperatures in the building’s two thermal zones were rarely within acceptable tolerances- too cold in the winter, and too hot in the summer- causing mechanical equipment to cycle on/off excessively. These concerns are generally supported by known utility expenditures. The facility utilizes a large amount of gas in the winter and this increased usage is reflected by significant increases in utility bills during cold winter months.

Once calibrated, the energy model was utilized to measure the potential effect of different energy conservation measures on total energy consumption in the building. These energy conservation measures included adjustments to operations, mechanical systems, and architectural retrofits. The measures modeled, and their effects, are described in the following section.
Measure 1: Reduced Building Exhaust Rate

The first energy conservation measure (ECM) that was modeled reduced the building’s exhaust flow and outdoor air supply rates to ANSI / ASHRAE 62.1 recommended values. By scheduling the building exhaust fan to run at intervals rather than constantly, outdoor air changes through the mechanical system were reduced from 3 ACH (air changes per hour) to the code recommended 0.3 ACH. The result of the measure is drastic reduction of heating and cooling energy, including natural gas during heating months, and a combined 44.1% reduction in the overall energy consumption of the building. With the measure the EUI in the model went from 191.09 kBTU/ft² to 106.96kBTU/ft². This was the most surprising finding and was eye-opening for Duluth city staff.
Measure 2: Increased Roof Insulation to R-35

The second energy conservation measure (ECM) modeled increased the building’s roof insulation to R-35. This amount of above-deck roof insulation complies with ASHRAE 90.1 - 2010. The result of the measure is additional savings on natural gas during heating months, and combined with the previous measure results in a 45.8% reduction in the overall energy consumption of the building, bringing the building’s EUI to 103.62.

Figure 7: Measure 2 Modeled Energy Savings
Measure 3: Increased Wall Insulation to R-15.2

The third energy conservation measure that was modeled increased the building’s wall insulation to R-15.2. This insulation value complies with ASHRAE 90.1 - 2010. The result of the measure stabilized thermal zone temperature swings, and created additional savings on natural gas during heating months. Combined with the previous measures, the result is a 48.7% reduction in the overall energy consumption of the building, bringing the building’s EUI to 98.04.

Figure 8: Measure 3 Modeled Energy Savings
Measure 4: Air Infiltration Rates in the Apparatus Bay

The fourth energy conservation measure that was modeled addresses air infiltration rates in the Apparatus Bay. The baseline model simulates an infiltration rate of 1 ACH in the Apparatus Bay. This measure applies a theoretical reduction of the Apparatus Bay ACH value by 50%. The result of the measure is substantial savings on natural gas during heating months, and a combined 58.5% reduction in the overall energy consumption of the building, bringing the building’s EUI to 79.22.

Figure 9: Measure 4 Modeled Energy Savings
Measure 5: Refrigerator Replacement

Fire hall 4 runs three separate shifts per week, and each shift has their own refrigerator. The three refrigerators account for approximately 1800 kWh per year. The fifth energy conservation measure modeled replaces the existing refrigerators with an Energy Star rated unit that consumes approximately 400 kWh per year. The result of the measure saves approximately 1400 kWh per year, for a yearly savings of $126. This measure, combined with the previous measures, reduces energy use by 58.9% which brings the EUI down to 78.56 kBTU/ft$^2$.

Figure 10: Measure 5 Modeled Energy Savings
Measure 6: Address Fire Hall 4’s Internal Equipment Load

The final energy conservation measure that was modeled addresses Firehall 4’s internal equipment load. The baseline model miscellaneous plug load input is occupancy scheduled 1 W/ft², consistent with ASHRAE 90.1. The measure reduces the miscellaneous plug load input to 0.5 W/ft². A plug load analysis is recommended to further understand how best to achieve this measure. The combined result of this and the previous measures is a 62% reduction of the baseline model energy demand and reduces EUI to 72.66 kBTU/ft².

![Figure 11: Measure 6 Modeled Energy Savings](image-url)
Total Energy Reduction

As the table below shows, by implementing all of the above energy conservation measures, it may be possible for Fire Hall 4 to reduce its energy load by 62%, decreasing the building's EUI to 72.66. Based on current rates, the modeled energy reduction could save up to $7,600 annually on utility expenditures.

<table>
<thead>
<tr>
<th>Energy Conservation Measure</th>
<th>Energy Load Reduction</th>
<th>Building EUI</th>
<th>Anticipated Yearly Utility Savings (approx.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced Exhaust Flow</td>
<td>44.1%</td>
<td>106.96</td>
<td>$4,700</td>
</tr>
<tr>
<td>Increased Roof Insulation</td>
<td>45.8%</td>
<td>103.62</td>
<td>$4,900</td>
</tr>
<tr>
<td>Increased Wall Insulation</td>
<td>48.7%</td>
<td>98.04</td>
<td>$5,200</td>
</tr>
<tr>
<td>Reduced Infiltration</td>
<td>58.5%</td>
<td>79.22</td>
<td>$6,400</td>
</tr>
<tr>
<td>Updated Refrigeration</td>
<td>58.9%</td>
<td>78.56</td>
<td>$6,500</td>
</tr>
<tr>
<td>50% Reduced Plug Load</td>
<td>62%</td>
<td>72.66</td>
<td>$7,600</td>
</tr>
</tbody>
</table>

*Figure 12: Summary of Energy Conservation Measures*
Phase 4: Size a renewable energy system to supply remaining building energy load

In addition to the complex tasks of developing a calibrated energy model and analyzing the impact of energy conservation measures, we identified the size of renewable energy output that Fire Hall 4 will require in order to achieve carbon neutral or net-zero energy designations. The two scenarios presented below draw from existing information regarding CO₂ output from the production of 1 kBTU of electricity or natural gas.⁶⁷

Carbon-Neutral

To achieve the designation carbon-neutral, a building must produce an amount of renewable energy such that the amount of CO₂ required to produce it through renewable means, subtracted from the amount of CO₂ required to produce it by conventional means, would generate a CO₂ savings equal to the CO₂ output of the building’s current energy consumption. Because natural gas and electricity production produce a different amount of CO₂, a renewable energy system required to attain carbon-neutral designation need not supply all of a building’s required energy. The table below shows the amount of CO₂ produced annually based on Fire Hall 4’s electricity and gas consumption after the applied energy conservation measures. The final column is the electricity output required from an on-site solar array in order for Fire Hall 4 to achieve carbon-neutral designation.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced Exhaust Flow</td>
<td>56,040 lb</td>
<td>55,300 lb</td>
<td>92.7 MWh</td>
</tr>
<tr>
<td>Increased Roof Insulation</td>
<td>56,110 lb</td>
<td>52,900 lb</td>
<td>90.7 MWh</td>
</tr>
<tr>
<td>Increased Wall Insulation</td>
<td>56,200 lb</td>
<td>49,000 lb</td>
<td>87.6 MWh</td>
</tr>
<tr>
<td>Reduced Infiltration</td>
<td>55,500 lb</td>
<td>36,200 lb</td>
<td>76.4 MWh</td>
</tr>
<tr>
<td>Updated Refrigeration</td>
<td>53,800 lb</td>
<td>36,400 lb</td>
<td>75.1 MWh</td>
</tr>
<tr>
<td>50% Reduced Plug Load</td>
<td>37,400 lb</td>
<td>37,800 lb</td>
<td>62.6 MWh</td>
</tr>
</tbody>
</table>

Figure 13: Size of Solar Panel Necessary to Reach Carbon Neutrality.

⁷ Environmental Protection Agency: [https://www.epa.gov/energy/ghg-equivalencies-calculator-calculations-and-references](https://www.epa.gov/energy/ghg-equivalencies-calculator-calculations-and-references)
**Net-Zero Energy**

To achieve the designation *net-zero energy*, a building must produce annually, an amount of renewable energy equal to the building’s annual energy consumption. Simply put, the energy produced by the building must be equal to the energy consumed by the building. The table below shows the Fire Hall 4’s kBTU equivalency for its electricity and natural gas consumption after the applied energy conservation measures. The final column is the electricity output required from an on-site solar array in order for Fire Hall 4 to achieve net-zero energy designation.

<table>
<thead>
<tr>
<th>Energy Conservation Measure</th>
<th>Electricity kBTU</th>
<th>Gas kBTU</th>
<th>Solar Panel Output Required for Net-Zero Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced Exhaust Flow</td>
<td>159,200</td>
<td>474,400</td>
<td>185.7 MWh</td>
</tr>
<tr>
<td>Increased Roof Insulation</td>
<td>159,400</td>
<td>452,500</td>
<td>179.3 MWh</td>
</tr>
<tr>
<td>Increased Wall Insulation</td>
<td>159,700</td>
<td>419,200</td>
<td>169.7 MWh</td>
</tr>
<tr>
<td>Reduced Infiltration</td>
<td>157,700</td>
<td>310,100</td>
<td>137.1 MWh</td>
</tr>
<tr>
<td>Updated Refrigeration</td>
<td>152,800</td>
<td>311,100</td>
<td>135.9 MWh</td>
</tr>
<tr>
<td>50% Reduced Plug Load</td>
<td>106,200</td>
<td>322,900</td>
<td>125.7 MWh</td>
</tr>
</tbody>
</table>

*Figure 14: Size of Solar Panel Necessary to Receive the Designation of Being Net-Zero Energy*
Recommendations

The work presented in this report is the result of a complex process of analysis that demands a significant amount of time and expertise that is unavailable generally. As such, while this process could be replicated with the appropriate software expertise, the specific process undertaken by the authors does not translate easily into a replicable model or a simplified list of best practices. However, what this work does do well is expose the need to work to develop a holistic understanding of facilities’ construction, systems, and operations when addressing issues of energy efficiency. It also illustrates the importance of equipment operation to the energy use of a building. By understanding how a building runs, it is possible to make cost and energy savings adjustments even without a complicated energy model such as the one presented in this analysis.

The energy conservation measures presented above include adjustments to building operations and architectural retrofits. Implementation of these measures may not be cost effective, and in some cases may be prohibitively expensive. The table below provides a rough estimate of the typical costs of reach measures relative to one another.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Very little to no cost</th>
<th>Low cost</th>
<th>Moderate cost</th>
<th>High cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjusting exhaust fan</td>
<td>Replacing electronics</td>
<td>Increase roof insulation</td>
<td>Wall insulation</td>
<td></td>
</tr>
<tr>
<td>Adjusting Air Infiltration Rates in the Apparatus Bay</td>
<td>Refrigerator replacement</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

More detailed economic analysis and recommendations as to how best to enact certain courses of action would be required should the stakeholders choose to do so. However, it is the CSBR research team’s opinion that some changes could be implemented immediately, for low cost, and high impact.

Potential actions and drawbacks of energy conservation measures:

- **Measure 1**
  - Decouple the building exhaust fan from other ventilation requirements
  - Use humidity sensors or other controls for wet-area ventilation to limit ventilation fan operation
  - Use carbon monoxide sensors or other controls for fresh-air requirements to limit ventilation rate
  - Use a percentage timer for the building exhaust
  - Make the fan customizable for occupant comfort

---

8 This assumes a reduction in hose dryer fan operation.
• Make controls for the fan automatic rather than dependent on a maintenance person’s check
  • Additional analysis recommended

Measure 2
• Increase above-deck roof insulation to code as possible
  • As identified, structure may be unable to accommodate additional load
  • Additional analysis recommended

Measure 3
• Due to the brick veneer, additional wall insulation may be difficult, expensive, ineffective, or create additional problems
  • Additional analysis recommended

Measure 4
• Consider an air-curtain to reduce air leakage when apparatus bay doors are open during heating months
  • Fan in hose-drying tower may contribute to excessive ventilation rates – consider using a timer or humidity sensor to reduce fan runtime

Measure 5
• Refrigerators are numerous and dated – consider replacing with Energy Star or other energy efficiency rated equipment

Measure 6
• Replace old or inefficient electronics
  • Consider switches that completely power-down equipment like set-top boxes, DVD players, etc. These trickle charges can be significant in aggregate.

Renewable Energy System
• The first step towards an effective renewable energy system is to have an efficient facility with which to pair it. After reducing the building’s energy load and a carbon output, then a renewable energy system can be coupled to reach the desired goal of carbon-neutral or net-zero energy.
• Renewable energy systems in Public Order and Safety buildings may contribute to a community’s resiliency and disaster response.

Additional Considerations
• Do not discount behavioral changes. Often operations and maintenance practices have a higher impact than physical structural factors. Other factors like maintenance—behavior may be significant drivers of energy usage
• Make one change at a time to evaluate results.
• Consider the input of industry experts working on net-zero energy building typology prototypes when evaluating cost-effectiveness of retrofit/remodel vs. new construction.

Duluth city facilities staff welcomed this analysis and the somewhat surprising results. While they had the benefit of CSBR expert software modeling and analysis, the results showed them that some relatively simple measures related to building operations could make a tremendous impact on energy usage. In discussion with the research team, city staff discussed how they could measure and monitor these
operational changes. At this time the City of Duluth has begun to implement some of the no/low cost energy solutions suggested by this analysis.
Appendix A: Duluth Steam Current System\(^9\)

Appendix B: Assumptions

$CO_2$ - 1201 Lb/MWh
$N_2O$ = 1.5 Lb/MWh
$SO_2$ = 1.4 lb/MWh

Electricity 2014 Average Rate = $0.0463/kBTU

Natural Gas 2014 Average Rate = $0.010127/kBTU
Bibliography


Capital Improvement and Budget Five Year Plan. (2012). City of Duluth. Retrieved from:  

Retrieved from: https://www.eia.gov/consumption/commercial/about.cfm
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**Acknowledgements**

We thank those who contributed to this research including Ken Smith and Jim Green, Evergreen Energy; Mindy Granley, University of Minnesota-Duluth; John Rice, St. Mary’s Medical Center; Marianne Bohren, Western Lake Superior Sanitary District (WLSSD); Jerome Malmquist, University of Minnesota-Twin Cities; Adam Zoet, Minnesota Department of Commerce; and Jodi Slick and Bret Pence, Ecolibrium3.
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Executive Summary

On February 19, 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. 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 the policy, regulatory and policy barriers and opportunities in the region for combined heat and power or cogeneration plants. The Energy Transition Lab prepared this report to provide a high level summary of existing work on CHP along with Duluth-specific information and comparative case studies.

Combined Heat and Power (CHP), also known as cogeneration, is the simultaneous production of electricity and useful thermal energy from a single fuel source. CHP can be “Topping Cycle”--a power plant that generates electricity, and in the process captures the waste heat to use it productively or “Bottoming Cycle”--a process that uses thermal energy like steam or hot water for heating, cooling, or industrial process and captures some of the excess to generate electricity. Combining heat and power production from one fuel input is much more efficient than conventional electricity generation, which wastes an average of roughly 2/3 of the Btu value of the energy input. Separate centralized electricity generation and on-site heat generation has a combined efficiency of roughly 45%; cogeneration or CHP can reach efficiency levels of up to 80%.

Over the past year the Energy Transition Lab has been working with stakeholders from Duluth and other experts to identify policy, regulatory and legal barriers to CHP in the region. Research was conducted through site visits to Duluth, a review of dozens of expert reports, and interviews with organizations in Duluth, the surrounding region, and the state that have considered CHP in the past or have projects in process. From those interviews, we created case studies of Duluth Energy Systems, Western Lake Superior Sanitary District (WLSSD), University of Minnesota-Duluth (UMD), St. Mary’s Hospital in Duluth, University of Minnesota-Twin Cities campus, and St. Paul District Energy.

Some of the barriers identified include financing capital costs of projects, environmental permitting, utility tariffs, and regulatory and policy obstacles. Based upon barriers identified in existing reports and through interviews, the Energy Transition Lab identified and analyzed possible solutions. Solutions analyzed include: reforming standby rates to make CHP more financially attractive, making CHP projects eligible for Minnesota’s Conservation Improvement Program (CIP) incentives, developing new state portfolio standards for CHP, expanding financial incentives and introducing new financing models that reduce the upfront capital costs involved in CHP plant installation, providing education, assistance and

1 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.
2 U.S. DOE definition of CHP: http://energy.gov/eere/amo/combined-heat-and-power-basics
technical training; mapping opportunities for CHP in the state, addressing additional barriers in Minnesota law, and reforming regulatory practices. The report concludes with several case studies that illustrate the complexities involved in navigating and overcoming multiple roadblocks, but also highlight the work underway to improve the prospects for CHP and to capture its potential contribution to a more efficient, modern, and clean energy system.
Combined Heat and Power (CHP) in Duluth: Barriers and Opportunities

Introduction

On February 19, 2015 an Energy Future Charrette for Duluth was led by Ecolibrium3 in partnership with the city of Duluth. The Charrette was facilitated by the Great Plains Institute and the Rocky Mountain Institute and included representatives of Duluth’s city government, local businesses, Minnesota Power, the University of Minnesota-Duluth, and other community members, as well as key Minnesota partners the Environmental Quality Board (EQB) and the Energy Transition Lab. The goal of the Charrette was to determine the Energy Future Vision for the city by capturing the “ambitions and concerns” of key stakeholders with relevant economic, social, environmental, [and] sustainability aspects. The group focused on 3-4 key topic areas, including locally produced biomass, solar, and energy efficiency, with a strong economic development lens. One of the outcomes was a priority list of three topics for future research and analysis, including understanding the regulatory, policy, and legal barriers to deploying Combined Heat and Power (CHP) in Duluth.

The goal of this report is to address those questions with accurate and detailed information that is accessible to non-experts. The Minnesota Department of Commerce-Division of Energy Resources (DOC) and many stakeholders and experts have analyzed CHP barriers and opportunities in depth, in dozens of documents in total constituting thousands of pages. This report is a relatively short, high level, and non-technical summary of that extensive body of work, along with some Duluth-specific information and case studies.

What is Combined Heat and Power?

Combined Heat and Power (CHP), also known as co-generation, is the simultaneous production of electricity and useful thermal energy from a single fuel source. CHP can refer to a power plant that generates electricity, and in the process captures the waste heat to use it productively (Topping Cycle CHP). It can also describe a process that uses thermal energy like steam or hot water for heating, cooling, or industrial process and uses some of the excess to generate electricity (Bottoming Cycle CHP). Either way, CHP is a highly efficient way to use one unit of energy for multiple purposes.

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6 Ecolibrium 3 is a local nonprofit based in Duluth Minnesota. Ecolibrium 3 Website: [http://www.ecolibrium3.org/](http://www.ecolibrium3.org/)
7 See the Great Plains Institute: [http://www.betterenergy.org/](http://www.betterenergy.org/)
8 See the Rocky Mountain Institute: [http://www.rmi.org/](http://www.rmi.org/)
10 The other two topics make up the other main chapters of this report: analyzing the economic impact of bioenergy and solar and investigating the potential for Net Zero energy building retrofits.
11 See Glossary, page 57 of this report.
12 See Minnesota Department of Commerce’s CHP Stakeholder Engagement webpage: [http://mn.gov/commerce/industries/energy/distributed-energy/combined-heat-power.jsp](http://mn.gov/commerce/industries/energy/distributed-energy/combined-heat-power.jsp)
CHP plants can use a variety of fuels, including natural gas, coal, and biomass. Its most common uses in Minnesota are in chemical and paper manufacturing and processing, district energy systems, metals mining, food processing, and institutions like hospitals and universities.

**Why is CHP important?**

When CHP systems are properly sized and installed, they can reduce energy costs, improve power reliability, power quality, and environmental quality, as well as increase energy efficiency.\(^{15}\) Combining heat and power production from one fuel input is much more efficient than conventional electricity generation, which wastes an average of roughly 2/3 of the Btu value of the energy input.\(^{16}\) Separate centralized electricity generation and on-site heat generation has a combined efficiency of roughly 45%; cogeneration or CHP can reach efficiency levels of up to 80%.\(^{17}^{18}\)

\(^{14}\) Source: Center for Sustainable Energy [https://energycenter.org/self-generation-incentive-program/business/technologies/chp](https://energycenter.org/self-generation-incentive-program/business/technologies/chp), (used with permission).


Figure 2: Wasted Energy

19 Lawrence Livermore Labs: https://flowcharts.llnl.gov/
In the generation of electricity from power plants, Minnesota average efficiency is less than 33 percent, accounting for Btu losses in electricity generation, transmission, and distribution. While somewhat better than the national average, Minnesota is only 43% efficient in converting all fuel sources (including petroleum, gasoline, etc. in Figure 2) to useful energy. Wasted energy means wasted energy dollars. CHP which generates both electricity and thermal energy from the same fuel can save 35% of energy used.

![Image: Energy-Efficiency Comparisons]

For example, as the image above from the International District Energy Association shows, 60% of the energy produced by conventional power plants is lost as waste heat while only 20% of energy produced by district energy/combined heat and power plants are lost as waste heat. CHP plants' ability to capture heat and utilize it helps to significantly increase the efficiency of the system.

Most of the loss from conventional power plants is in the form of waste heat. In 2012, Minnesota power plants consumed 520 Trillion (TBtu) of fuel, and 340 TBtu of that fuel input was lost as waste heat. Compare that with the total demand for heat in Minnesota buildings and industry: 408 TBtu. In other words, the amount of wasted heat could meet over 80% of Minnesota’s heat and thermal energy needs.

As indicated, the strongest value proposition for CHP is its ability to save up to 35% of the energy required for a given purpose, cutting energy costs and reducing CO2 and other pollutants. Thus, CHP can

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22 *CHP in Minnesota: Baseline and Value Proposition Factsheet*, Microgrid Institute for the Minnesota Department of Commerce, Division of Energy Resources (August 2014).


24 FVB, *Policies and Potential*, at p. xiii
save money, especially for commercial, industrial, and institutional customers. Utility-owned CHP plants can also be an attractive investment.\textsuperscript{25}

Additionally, CHP can help Minnesota achieve state and federal energy requirements. Minnesota state law mandates increased annual energy efficiency in electricity and natural gas and also set goals for economy-wide greenhouse gas reduction.\textsuperscript{26} The legislature has stated in law that “energy savings are an energy resource, and that cost-effective energy savings are preferred over all other energy resources.”\textsuperscript{27}

In addition, state laws promote the growth of renewable energy resources, including biomass.\textsuperscript{28} CHP is highly suitable for renewable resources such as biomass. It’s also a good fit with district energy systems.\textsuperscript{29} Finally, on-site CHP systems can also allow hospitals, universities, and other important facilities to provide resilient backup power, maintaining electricity and heating supplies during extreme weather emergencies.\textsuperscript{30,31}

Other state policies support CHP and co-generation. According to the recent Minnesota Public Utilities Commission Grid Modernization report, the Cogeneration and Small Power Production statute is intended “to give the maximum possible encouragement to cogeneration and small power production consistent with protection of the ratepayers and the public.”\textsuperscript{32} And finally, federal rules proposed under the Clean

\textsuperscript{25} DOC CHP Final Action Plan, Abridged Report (October 2015), at 2
\textsuperscript{26} Minnesota Statute 216B.241; 216H.
\textsuperscript{27} Ibid, 216B.2401.
\textsuperscript{28} Minnesota Statutes 3.8852, 41A.11, 216B.1691 (Renewable Energy Objectives and Standards), etc.
\textsuperscript{29} Ken Smith, President and CEO, St. Paul District Energy. Interview, 2016.
\textsuperscript{31} For more information see the following Oak Ridge National Laboratory 2013 report:
\url{http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_critical_facilities.pdf}
\textsuperscript{32} MPUC staff report on Grid Modernization, quoting Minn. Stat. Sec. 216B.164:
Air Act (the Clean Power Plan) will potentially require a 32% reduction in power plant emissions by 2030, thereby further incenting CHP efficiency savings.33

“CHP can potentially help support key policy goals by increasing the average efficiency of Minnesota’s electric and thermal generation systems, reducing aggregate greenhouse gas emissions, and improving the energy security and resilience of local energy systems”

-Minnesota Department of Commerce-Division of Energy Resources

Although there are significant benefits to CHP, many barriers limit its use in Minnesota. This report specifically focuses on Duluth, but will provide statewide information on barriers to CHP that will put Duluth into a broader context. The report will:

a. Summarize current CHP deployment in Minnesota
b. Review the identified barriers and solutions to CHP in Minnesota
c. Describe two case studies of successful CHP projects in Minnesota
d. Compare those with two case studies of past Duluth proposals
e. Evaluate the opportunity for two current Duluth-area CHP projects
f. Based on the case studies and the statewide analysis, discuss regulatory, policy, and legal barriers, opportunities, and solutions for CHP in Duluth

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33 Clean Power Plan implementation has been stayed by the U.S. Supreme Court. For Minnesota’s proposed specific targets, see EPA.gov at https://www3.epa.gov/airquality/cpptoolbox/minnesota.pdf
Combined Heat and Power in Minnesota

Existing Facilities

The Minnesota Combined Heat and Power Policies and Potential study by FVB Energy\textsuperscript{34}, completed in August 2014, was commissioned by the Minnesota Department of Commerce- Division of Energy Resources (DOC). According this study, there are:

- 961.5 Megawatts of CHP operating in Minnesota
- 52 sites
- 83% in large systems, greater than 20 Megawatts

The largest CHP plants are chemical and paper processing. The FVB study identified the technical potential for new natural gas-fired CHP plants in Minnesota as 3049 Megawatts and for biomass CHP, 230 Megawatts.\textsuperscript{35} The economic potential, those with estimated payback of less than 10 years, is 984 MW. The report identifies CHP economic potential by utility service territory; most of the potential is located in high load factor markets in Minnesota Power and Xcel Energy territories. High load factor, the ratio of the average load divided by the peak load, means that energy usage is relatively constant rather than “peaky”. These estimates do not include the potential for converting existing power plants to recover currently wasted heat to use for heat and industrial processing and for reducing statewide greenhouse gas emissions.

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\textit{The economic potential for new CHP plants with an estimated payback period of 10 year or less is 984 megawatts}

---


Identifying CHP Barriers in Minnesota

Combined heat and power projects face a range of economic, regulatory, and institutional challenges in Minnesota. In this section we review and summarize the significant amount of recent policy analysis, research, and stakeholder engagement on the issue of policy and regulatory barriers to combined heat and power in Minnesota.

Energy Savings Goal Study

In 2013 The Minnesota Legislature established the Energy Savings Goal Study (ESG), which required a study of energy efficiency generally, including CHP in Minnesota. The DOC conducted stakeholder meetings in late 2013 and its ESG Study report and findings were presented to the Legislature in 2014. One key recommendation was for continued evaluation of combined heat and power:

Commerce recommends that the legislature explore and define a more specific policy objective behind CHP development in the state. Commerce recommends continued engagement of stakeholders in 2014 to clarify policy regarding the incorporation of CHP into existing policy frameworks and, more specifically, its inclusion in CIP [the Conservation Improvement Program].

The study concluded that any program or policy to promote CHP should “reduce risk for customers and for utilities,” and “have long-term achievement objectives that focus on system reliability and utility/operator relationships.” The key barrier to CHP identified was Standby Rates, which are charges by utilities to customers with on-site, non-emergency generation, including CHP, for the service of providing grid backup power when on-site generation is not available.

The DOC received a grant from the U.S. Department of Energy (DOE) to carry out a strategic stakeholder engagement process and develop an Action Plan for CHP deployment in Minnesota in 2014-2015. The process included:

- Informing stakeholders of current activity
- Discussing barriers and opportunities
- Soliciting solutions
- Developing an action plan with detailed steps necessary to increase deployment of CHP in Minnesota

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38 Ibid., 1.
39 Ibid., 12.
40 Ironically, each utility in Minnesota has only a small number of customers paying standby tariffs; they appear to have a disproportionate impact on CHP projects.
Throughout the period of the DOE grant, the DOC conducted a series of stakeholder meetings which included multiple expert reports and presentations, facilitated discussions, and stakeholder surveys and written comments. All of this detailed information is collected on DOC’s website.\textsuperscript{41} We summarize the results of this work into two parts, the expert reports and recommendations and the stakeholder input.

Note that these analyses include two models of CHP ownership, 1) customer-sited and financed by customer and/or third party and 2) utility-owned or financed projects.

**Expert Studies**

Several expert studies analyzed the effects of Minnesota’s standby rates and net metering rules on CHP development in the state and recommended policy changes to rate structures.\textsuperscript{42, 43} The Energy Resources Center (ERC) report recommended a number of best practices for designing standby rates, grouped by functional criteria.\textsuperscript{44} ERC used three functional categories of criteria to evaluate standby rates:

- **Transparent rates** provide customers with clear signals on the cost of electric service and help customers operate in a cost-effective manner that lessens their burden to the utility.
- **Flexible rates** are those which allow the customer to avoid charges when not using service.
- **Electric rates that promote economically efficient consumption** should be designed to discourage the wasteful use of utility services while promoting all that is economically justified in terms of private and social costs incurred and benefits received.\textsuperscript{45}

The report provides recommendations related to each of these categories:

<table>
<thead>
<tr>
<th>Principle</th>
<th>Analysis and Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transparency</strong></td>
<td><em>Standby rates should be transparent, concise and easily understandable.</em> Potential CHP customers should be able to accurately predict future standby charges in order to assesse their financial impacts on CHP feasibility.</td>
</tr>
<tr>
<td></td>
<td><em>Standby usage fees for both demand and energy should reflect time-of-use cost drivers.</em> Time-of-use energy rates send clear price signals as to the cost for the utility to generate needed energy. This would further incentivize the use of off-peak standby services.</td>
</tr>
</tbody>
</table>

\textsuperscript{41} Combined Heat and Power Stakeholder Engagement, Minnesota Department of Commerce: [https://mn.gov/commerce/industries/energy/distributed-energy/combined-heat-power.jsp](https://mn.gov/commerce/industries/energy/distributed-energy/combined-heat-power.jsp)


\textsuperscript{44} ERC, 10-12.

\textsuperscript{45} Ibid.
<table>
<thead>
<tr>
<th>Flexibility</th>
<th>The Forced Outage Rate should be used in the calculation of a customer’s reservation charge. The inclusion of a customer’s forced outage rate directly incentivizes standby customers to limit their use of backup service. This further links the use of standby to the price paid to reserve such service creating a strong price signal for customers to run most efficiently. This would also involve the removal of the grace period. The standby demand usage fees should only apply during on-peak hours and be charged on a daily basis. This rate design would encourage [distributed generation] DG customers to shift their use of standby service to off-peak periods when the marginal cost to provide service is generally much lower. Furthermore, this design would allow customers to save money by reducing the duration of outages.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economically Efficient Consumption</td>
<td>Grace periods exempting demand usage fees should be removed where they exist and standby rates should be priced to reflect usage. Exempting an arbitrary number of hours against demand usage charges sends inaccurate prices signals about the cost to provide this service. The monthly reservation cost providing the grace periods charges for 964 hours of usage no matter if a customer needs that level of service. Standby demand usage should be priced as-used on a daily and preferably an on-peak basis. This method directly ties the standby customer to the costs associated with proving standby service and allows customers to avoid monthly reservation charges by increasing reliability.</td>
</tr>
</tbody>
</table>

The FVB Policies and Potential study analyzed regulatory issues and policy barriers and potential solutions and identified a range of economic, regulatory, and institutional challenges:

- Relatively low electricity prices in Minnesota make CHP economic viability more challenging in comparison with other states.
- Most potential industrial or commercial entities require a very short payback on efficiency investments including CHP.
- Most industrial and commercial entities do not have the experience, skills and time for the difficult task of developing a CHP project.
- Decades of energy supply and price volatility inhibits CHP investment.
- There is no market value established for the GHG, power grid resiliency or other benefits of CHP.

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46 Reservation Charge refers to a “monthly charge per kW of the customer’s needed standby capacity and cannot be avoided when standby is not taken. The reservation charge generally ensures that standby service will be available when needed by the customer during unscheduled and scheduled outages.” ERC, 22.
47 Forced Outage Rate (FOR): the FOR “of a generating unit for a given time span is defined as the number of hours the unit is forced out of service for emergency reasons divided by the number of total hours that the generating unit is available for service during that time interval (plus the number of hours during a forced outage). The FOR measures the probability that the unit will not be available for service when required.” ERC, 23.
48 ERC, 11-12.
49 FVB, Policies and Potential, xiv.
• Historically, CHP projects have been discouraged by unfavorable interconnection requirements and standby rates.

Other reports documented barriers to CHP and recommendations for improvement.\(^{50}\)

**Stakeholder Views: Barriers to Development of CHP**

Stakeholders, mostly from Minnesota, have weighed in on barriers to CHP based on their own real-life experiences. It’s important to note that stakeholders include utilities, customers, third party developers, and others, who may have divergent views on barriers. Stakeholder perspectives on CHP barriers vary depending on whether they reflect an energy customer or third party developer interested in deploying CHP on-site, or a utility company which is considering investing in a CHP facility that is customer-sited or at an existing power plant.

General stakeholder perspectives:

- CHP economics are considered mixed for commercial financing
- Existing incentive programs are viewed as inadequate to support CHP financing in Minnesota
- The biggest gaps in knowledge and talent involve business, finance, and legal expertise\(^{51}\)

From the perspective of developers, customers, or other third parties, barriers to investment and deployment include:

- Current policies and standards complicate projects and inflate costs
- Policies focus too much on utility investment in onsite power systems
- Lack of price signals for environmental, social, and system attributes
- State goals of conservation and clean energy should better overcome challenges
- Standby changes aren’t flexible or transparent
- Standby power tariffs and net metering are not considered fair toward third-party-owned CHP
- Utility strategy/business conflicts are seen as hindrances to CHP
- Statutory size limits (Minn. Stat. 216H and PURPA) constrain potential for economic CHP development.
- Limitations and restrictions reduce the ability to transport power and integrate generation resources.
- Non-utility companies are restricted in power and heat sales.\(^{52}\)

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From the perspective of utilities, regulatory and legal issues affecting their ability to finance, own, and operate CHP projects include the following. Utilities generally:

- Support policy changes that would clarify cost-recovery for CHP investment at customer sites where appropriate, but utilities generally oppose new regulatory requirements
- Question assumptions of market potential and comparative costs/benefits
- Are concerned about potential ratepayer cross subsidization, and community burdens without commensurate benefits
- Are concerned about preferential treatment of gas companies over electric companies

Other specific issues affecting utilities:

- Risk of holding stranded assets if a CHP customer could go out of business or significantly reduce their energy load.
- Responsibility for reliability, grid integration, and risk-mitigation costs.
- Requirement to meet service obligations and restrictions, and limitations in investments by least-cost planning requirements and cost-calculation, apportionment, and recovery provisions.
- Potential fuel-switching regulations and considerations

Issues utilities share with customers and third parties:

- There are a lack of mechanisms to attach a value to thermal output.
- Statutes create size limitations; Minn. Stat. 216H prevents baseload plants larger than fifty Megawatts.

The Brattle Group evaluated utility approaches across the U.S. and found that they range from trying to block CHP, to accommodating it, to capitalizing on CHP as an opportunity to meet efficiency and renewable energy goals and support customer preferences.

For both utilities, customers, and third parties, many of the barriers identified relate to costs and benefits—who pays and who benefits, and payback and investment options. Others relate to system issues such as reliability, stranded assets, and siloed regulatory treatment of electricity and thermal energy systems. Other policy and regulatory questions are significant—the lack of incentives or alternative avoided cost formulas for more efficient energy facilities that help meet state renewable energy and greenhouse gas reduction goals. Other barriers include gaps in knowledge and expertise. There is not one simple answer to the question “given all the benefits of combined heat and power, why doesn’t Minnesota use it more?”

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54 Ibid.
Potential Solutions

The long litany of barriers gives rise to a wide array of possible solutions, but not every barrier has a clearly defined antidote. In this section, we summarize and evaluate a number of potential policy and regulatory and other solutions to CHP challenges. First we list the priority steps selected in DOC’s Final CHP Action Plan, then we categorize the most important recommendations made by DOC, experts, and stakeholders into our own summary list of solutions. Then, we analyze and assess progress for each solution category.

The DOC established a Final Action Plan with a variety of recommendations. In it DOC established six Priority Areas:

1. Establish CHP Evaluation Methodology and Criteria, to provide regulatory certainty regarding how CHP projects could be evaluated within CIP. Specifically, in the near term, DOC proposes establishing a CHP energy savings attribution model and project evaluation criteria
2. Map CHP Opportunities including public facilities like wastewater treatment plants
3. Education and Training Needs and Options
4. CHP Ownership Problems and Solutions—making funding streams and financing opportunities available, including access to on-bill repayment for utility investments in customer-sited CHP.
5. CIP CHP Supply-Side Investments—considering utility investment in new infrastructure to capture waste heat from power plants as EUI-CIP
6. Standby Rates

Including DOC’s priorities and other expert and stakeholder input, we categorize all of the solution options into the following primary areas:

- Reform Standby Rates
- Use Conservation Improvement Program as incentive mechanism
- Pass new legislation creating procurement targets
- Create or expand financial incentives or ease of financing for CHP
- Remove specific barriers in existing law
- Change regulatory practices in pricing, billing, and cost analysis
- Advance education, technical assistance, and training
- Map Opportunities

Below, we summarize each area and give a status update, if any.

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57 This list represents an amalgam of different reports and stakeholder input. See DOC’s CHP webpage, including Microgrid Institute, CHP Post-Engagement Stakeholder Survey, for the most effective policy initiatives preferred by participants:

1. Introduce transparent, unbundled pricing for standby rates (forty-three percent of respondents)
2. Establish CHP project evaluation methodologies and criteria (thirty-nine percent of respondents)
3. Introduce transparent, unbundled pricing for standby rates (forty-three percent of respondents)
4. Establish CHP project evaluation methodologies and criteria (thirty-nine percent of respondents)
Analysis of Solutions

1. Standby Rates

As stated above, standby rates are charges by utilities to customers with on-site, non-emergency generation, including CHP, for the service of providing grid backup power when on-site generation is not available. Many experts and stakeholders believe that reforming standby rates could enable many more CHP projects to be cost effective.

“If the economic barrier that standby rates currently impose on CHP projects were completely eliminated, the ERC’s analysis indicates that the potential for new CHP capacity with a less than a ten-year payback would increase from 779 MW to 1,116 MW within Minnesota’s IOU service territories”

-DOC CHP Final Action Plan, page 52

The most common recommendations for reforming standby rates, from both experts and stakeholders, include the following criteria:58

- Rates should be transparent and easily understandable.
- Pricing should be “unbundled,” meaning that rather than a flat rate, each driver of cost should be charged separately, for “dedicated distribution, shared distribution, transmission, and generation capacity.”59 That is, the specific costs attributable to the specific customer should be differentiated from the larger costs to the grid that are shared by many customers.
- Tariffs should give a clear customer price signal based on costs and reward customers for shifting their back-up usage away from expensive peak demand hours. Charges for both demand and energy60 should reflect time of use differences. ERC recommends that standby demand usage fees should only apply during on-peak hours and be charged on a daily basis. According to ERC’s review of Minnesota Power’s standby tariff, “[i]f outages can be controlled and minimized the CHP system operator can save a great deal of money” on their rates.61
- Rates should be flexible, so customers can avoid charges when not using backup service.62

58 ERC, Analysis of Standby Rates; DOC Final Action Plan, (2015) 52. See the ERC report for more detail on how standby rates work in Minnesota, and other recommendations on Forced Outage Rate, Grace Periods, and interaction with Net Metering.
59 Ibid., 24.
60 In a typical monthly billing period, “demand” refers to the maximum amount of energy (kw) used in a given period during that month (peak) and energy refers to how many kwh used during the entire period. For a helpful example, see Understanding Demand and Consumption: http://www.think-energy.net/KWvsKWH.htm.
Status Update on Standby Charges

In 2013, the Legislature passed legislation prohibiting utilities from imposing standby charges on net-metered or other qualifying facilities of 100 kW capacity or less.\(^{63}\) Prior to the legislation, Minnesota Public Utilities Commission (PUC) order had exempted facilities of 60 kW or less from standby charges. Several investor-owned utilities filed proposed tariff modifications. In related dockets, some advocates recommended that the exemption to standby charges should be extended to net metered facilities under 1,000 kW (1 Megawatt) as allowed by the 2013 statute.

In January 2014 the Minnesota Public Utilities Commission (PUC) approved the utilities’ proposed tariff changes prohibiting standby charges for net-metered or qualifying facilities of 100 kW or less.\(^{64}\) Other than that change, the order stated the 2004 rules for allowable costs for standby charges remained in force.\(^{65}\) The PUC also required investor-owned utilities in Minnesota\(^{66}\) to confer with other stakeholders and the Minnesota Department of Commerce—Division of Energy Resources “on the need and potential scope for a generic proceeding to address standby rates.” In January 2015 the DOC recommended that the Commission undertake a generic proceeding to review standby charges and develop a generic approach and framework for standby service that meets goals for transparency, economic efficiency, flexibility, accuracy, fairness, and other principles and best practices.\(^{67}\) Through the following months, the PUC received comments from approximately 20 different entities, and on November 19, 2015 ordered all rate-regulated utilities to file updated standby service tariffs by May 19, 2016.\(^{68}\) These tariffs have been filed and the next step is for the PUC to take comments from interested parties. Several parties have requested an extension in the comment period to August 19, 2016 to allow for adequate review and analysis.

2. CHP in the Conservation Improvement Program (CIP)

Stakeholders, consulting experts, and the DOC considered two main approaches relating to CHP becoming eligible for Conservation Improvement Program (CIP) incentives. The Conservation Improvement Program or CIP, established in Minnesota law in the 1980s, requires MN utilities to achieve 1-1.5% energy savings goals annually in both electricity and gas sales, through customer (demand-side) conservation.\(^{69}\) As stated in the final CHP Action Plan, “CHP systems do not fit neatly into the standard definition of supply-side or demand-side efficiency resources as CHP systems address system efficiency improvements.

\(^{63}\) MN Public Utilities Commission Order, Docket No. E-017/M-13-609 and other related dockets.


\(^{65}\) Ibid.

\(^{66}\) Otter Tail Power Company, Northern States Power Company (Xcel Energy), Interstate Power and Light, Minnesota Power.

\(^{67}\) DOC, MPUC Comments to E002/M-13-315 et al, Need for Generic Proceeding.

\(^{68}\) MN PUC Order, Docket No. E-999/CI-15-115.

\(^{69}\) Minn. Stat. Sec. 216B.241.
Consequently, CHP does not clearly fit into utility Conservation Improvement Programs, which focus on demand-side efficiency to meet the 1.5% energy savings goal.70

Nevertheless, many stakeholders supported exploring two CHP approaches71 including 1) targeting CIP end-user incentives towards CHP energy customers’ energy savings (demand side) and 2) allowing CIP incentives to be used to reward utilities that invest in CHP infrastructure (supply side).72

**Demand Side Efficiency Approach**

The first approach would allow customers to increase efficiency by producing electricity from excess thermal energy or bottom-cycle waste-heat recovery systems. This would be consistent with CIP’s mission of reducing electricity demand by customers.73 The demand-side bottom cycle approach could utilize a new tier of natural gas and electric utility Conservation Improvement Program (CIP) incentives targeted at end-users.74 FBV’s study modeled these with either capital incentives, operating incentives, or a combination of both capital and operating incentives to customers or third parties.75 The study also suggests utilities could leverage their low cost of capital to finance CHP retrofits and recover it in their rate base.76

To enable including CHP in demand-side CIP, DOC’s Action Plan prioritizes establishing an attribution model and project evaluation criteria for CHP energy savings.77 Discussions with stakeholders suggest there is a need to provide regulatory certainty regarding how CHP projects could be evaluated within CIP and how to measure energy savings. DOC is currently moving forward on this Action Item to establish a CHP Energy Savings Attribution Model and Project Evaluation Criteria.

One point to consider, especially in Minnesota Power’s territory, is that many large industrial customers have opted out of CIP and evaluate their own efficiency actions. This decreases transparency and may decrease the opportunities for CHP energy savings possible at these facilities.

**Status Update on Demand-Side CIP for CHP**

The U.S. Department of Energy is finalizing a CHP energy savings measurement and evaluation protocol with a national group of stakeholders. At the state level, DOC is responsible for developing and maintaining standard energy-savings assumptions for use under utility energy efficiency programs. The

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73 The FVB report suggests this is consistent with state statutes, FVB, *CHP Policies and Potential*, 59-61.
74 FVB, *CHP Policies and Potential*, 61-64.
75 Ibid.
76 Ibid., 63.
DOC has developed a Technical Reference Manual (TRM) to serve as a reference for standard algorithms and assumptions for calculating savings from a wide array of energy efficiency measures. DOC also established a Technical Reference Manual Advisory Committee (TRMAC) in 2013, which acts as a forum for Minnesota utilities and other stakeholders to provide ongoing feedback and recommendations regarding the content of the Minnesota TRM. The protocol is expected to use utility-specific algorithms for evaluating CIP-eligible savings. Assuming stakeholder support, DOC anticipates these changes will be incorporated into the yearly TRM update.

CHP Supply Side Efficiency Approach

The second approach to using CIP would include CHP as a supply-side opportunity, in which a utility invests in a new CHP plant which will generate both electricity and thermal energy. It is considered a supply-side resource because its function is to produce additional energy rather than reduce waste from existing energy production. Credit for this type of utility-owned CHP would utilize the Electric Utility Infrastructure EUI provision in CIP. This approach is more controversial among stakeholders, as a supply-side option. As Minnesota Power commented, “[r]educing energy usage is always more cost-effective than adding efficiencies to energy production.” Others suggested that new topping-cycle CHP systems (power plants that capture waste heat) are new generation and should therefore be considered in Integrated Resource Plans rather than being considered as a conservation measure. Thirty-eight percent of respondents who participated in the post-engagement CHP stakeholder survey indicated that including CHP as an eligible supply-side resource under electric utility infrastructure (EUI) investments in CIP would be an effective policy initiative to explore and facilitate CHP deployment in Minnesota.

Existing Minnesota law is ambiguous or even contradictory in its treatment of EUI investments in CIP. On the one hand, the law allows a utility or association to include in its CIP plan energy savings from EUI improvements projects “approved by the Minnesota Public Utilities Commission under 216B.1636 or waste heat recovery converted into electricity projects that may count as energy savings in addition to a minimum energy-savings goals of at least one percent for energy conservation improvements.” The EUI projects must “result in increased energy efficiency greater than that which would have occurred through normal maintenance activity.” This statute suggests that investor-owned utilities can seek cost recovery for these investments.

However, the definitions section of the same statute states:

Energy conservation improvement “means a project that results in energy efficiency or energy conservation. Energy conservation improvement may include waste heat that is recovered and converted into electricity, but does not include electric utility infrastructure projects approved by

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78 Conversation with Adam Zoet, DOC CHP Project Manager, (2016).
79 Ibid.
80 Ibid.
81 “CHP CHP Supply-Side Investments” is priority area V. in the DOC Final Action Plan.
83 DOC, Final Action Plan Unabridged, 47.
84 Ibid., 46.
85 Minnesota Statute 216B.241 subd. 1c (d)
86 Minnesota Statute 216B.1636.
the commission under section 216B.1636. Energy conservation improvement also includes waste heat recovered and used as thermal energy."\(^8\)

\(^8\) Minnesota Statute 216B.241, Subd. 1 (e).
Status Update on Supply-Side CIP for CHP

There are a number of uncertainties that would need clarification to move forward with EUI-CHP in CIP. DOC is seeking grant funding to advance the policy discussion with stakeholders, and to address questions related to program design, administration, regulatory treatment, and measuring project benefits. Additionally, the Legislature would need to clarify the laws.

3. Legislation Creating New Portfolio Standards for CHP

FVB’s Policies and Potential Report included a variety of policy options that could help drive adoption of CHP.88 Policy option group 4 and 5 include new or expanded renewable portfolio standards, or procurement targets for utilities. The current Renewable Energy Standard requires all Minnesota utilities to procure or generate 30% renewable electricity by 2030 (Xcel Energy) or 25% by 2025 (all other utilities).89 The first set of options would amend this requirement and add biomass-fired CHP as an eligible renewable technology. This would be a “carve-out” of the existing requirement, or could be part of an expanded RPS with higher numerical goals. The second option would create a new alternative portfolio standard (APS) for CHP requiring electric utilities to obtain a given percentage of sales from CHP (regardless of fuel) by a given year.

Other policy options that would support CHP development would include Clean Power plan compliance mechanisms or carbon pricing that creates an incentive for lower carbon energy sources and greater efficiency in electricity generation.90 The state Environmental Quality Board’s Climate Solutions and Economic Opportunity (CSEO) process included an analysis of CHP to help meet Minnesota’s greenhouse gas reduction goals.91

Besides portfolio standards, FVB’s report contains specific legislative language suggestions for amending a variety of Minnesota energy planning statutes. For example, the Integrated Resource Planning law existing preference for renewable energy facilities could be expanded to explicitly disallow a new plant that only produces electricity, unless the utility has demonstrated it to be in the public interest.92

88 FVB, CHP Policies and Potential, 64.
89 Minnesota Statute 216B.1691.
90 FVB, CHP Policies and Potential, 56.
91 DOC, Final Action Plan, 10: https://www.eqb.state.mn.us/content/climate-change
Status Update on Portfolio Standards

DOC did not make portfolio standards an explicit Action Item, but noted under Action Item V. that they could be a good alternative to the CIP supply-side approach:

[If] CIP EUI provisions are deemed inappropriate or ineffective to support CHP investments, Commerce recommends continued discussion with stakeholders regarding alternative policies such as a new APS that could increase CHP deployment, where appropriate, in Minnesota. 94

This new portfolio standard could potentially increase Minnesota’s CHP deployment by as much as 1,000 MW of new CHP by 2030, approximately doubling existing CHP capacity. 95 Action Item V. was listed as a long term goal, so this alternative might not come into play until 2017 or later.

93 FVB, Policies and Potential, xvii.
94 Ibid., 51.
95 Ibid.
4. Expand Financing and Financial Incentives

A consistent theme throughout all the Minnesota CHP discussions is the need for incentives to reduce up-front capital costs, direct support for the infrastructure investment, and financing programs to reduce costs of capital. As in Connecticut and New York state, a Green Bank or similar financing entity that focuses on clean energy investment and provides tools like gap financing or loan loss reserves would significantly expand access to capital for CHP and other projects. Some private firms are working to establish community-scale green banks or “clean energy financing hubs” that can help finance local energy projects. Additionally, procurement targets such as renewable energy standards and alternative portfolio standards, discussed in section 3 above, create a significant financial incentive for utilities to support CHP deployment, without requiring use of taxpayer funds.

Status Update on Financing

96 See the Coalition for Green Capital for information and resources on developing state-level green banks: www.coalitionforgreencapital.com.
97 For a Minnesota-based company, see Eutectics: http://eutecticsllc.com/clean-energy-financing-hubs/.
DOC established as Action Item IV “Leverage Existing Financing Programs Applicable to CHP.” The DOC approach in the near term is to explore ways to improve its existing financing program offerings. The table, below, is part of this DOC’s effort to coordinate this information on their website.

<table>
<thead>
<tr>
<th>Eligibility (recipient)</th>
<th>Guaranteed Energy Savings Program</th>
<th>Local Energy Efficiency Program</th>
<th>Energy Savings Partnership</th>
<th>Trillion Btu Program</th>
<th>Commercial - Property Assessed Clean Energy Program</th>
<th>Rev It Up Program</th>
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<td>Site Agencies, Higher Ed, Local Governmental Units, K-2</td>
<td>Local Governmental Units, K-12</td>
<td>LEEP Program participants</td>
<td>Commercial and Industrial Businesses, 501 (c)(3) organizations</td>
<td>Commercial and Industrial Businesses, 501 (c)(3) organizations</td>
<td>Local Governmental Units, Commercial and Industrial Businesses, Small Businesses (&lt; 50 employees), Health Care Facilities, MHFA</td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Site Administered Energy Savings Performance Contracting (ESPQ) Program</td>
<td>State Administered Design-Bid-Build (DDB) Program for local governmental entities</td>
<td>Revolving Loan Fund</td>
<td>Special Assessment (against property)</td>
<td>Revenue Bonds – tax-exempt or taxable</td>
<td>(project dependent)</td>
</tr>
<tr>
<td>Project Size</td>
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<td>Min. $50k - Max. $350k</td>
<td>Min. $50k - Max. none</td>
<td>Min. 10k - Max. $1M</td>
<td>Max. 20% of Assessed Property Value</td>
<td>Min. $1M - Max. $2M</td>
</tr>
<tr>
<td>Term (years)</td>
<td>Up to 25</td>
<td>Up to 15</td>
<td>Up to 15</td>
<td>Up to 5</td>
<td>Up to 20</td>
<td>Up to 25</td>
</tr>
<tr>
<td>Interest Rate</td>
<td>n/a</td>
<td>n/a</td>
<td>3 - 6%</td>
<td>4.5 - 6%</td>
<td>4 - 6%</td>
<td>Dependent upon issuance (4 - 6%)</td>
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<td>Commerce</td>
<td>Commerce</td>
<td>St. Paul Port Authority</td>
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<td>Contact</td>
<td>Peter Berger 651-539-1850 <a href="mailto:peter.berger@state.mn.us">peter.berger@state.mn.us</a></td>
<td>Alex Cecchini 651-539-1707 <a href="mailto:alex.ceccini@state.mn.us">alex.ceccini@state.mn.us</a></td>
<td>Peter Klein 651-204-6211 <a href="mailto:pmk@sppa.com">pmk@sppa.com</a></td>
<td>Peter Klein 651-204-6211 <a href="mailto:pmk@sppa.com">pmk@sppa.com</a></td>
<td>St. Paul Port Authority: Peter Klein 651-204-6211 <a href="mailto:pmk@sppa.com">pmk@sppa.com</a></td>
<td>Eric Rehm 651-539-1853 <a href="mailto:Eric.Rehm@state.mn.us">Eric.Rehm@state.mn.us</a></td>
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</tr>
</tbody>
</table>

![Figure 7: Financing Programs Chart. Source: Final CHP Action Plan](image)

5. Address Barriers in Existing Law

Stakeholders have pointed out that part of Minnesota’s Next Generation Energy Act that is intended to reduce greenhouse gas emissions from new baseload fossil fuel generation could have the impact of capping any new CHP plants at under 50 Megawatts. Under this interpretation, the state law could also run afoul of federal Public Utilities Regulatory Policies Act of 1978 (PURPA) encouragement for small power production and cogeneration up to 80 Megawatts. The Minnesota Chamber of Commerce comments state:

Without adding cogeneration and combined heat and power to the specific exclusions found in §216H.03 subd. 1, the current statute will continue to contradict Minnesota’s nation leading energy conservation policies and the federal Public Utility Regulatory Policies Act of 1978

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98 DOC, Final Action Plan, 44.
99 DOC, Final Action Plan, 45
Moreover, leaving §216H.03 subd. 1 as it currently reads results in an illogical cap of 49.99 Megawatts for any new CHP facility in Minnesota, even when a larger facility could produce greater economic and environmental benefits. Correcting this is essential to greater CHP penetration in Minnesota.  

Status Update

The DOC’s Final Action Plan adopts the stakeholder suggestion of potential 216H waiver process or alternative treatment for CHP facilities that achieve certain benefit thresholds—e.g., high efficiency, pointing out that this affects ability of third parties and customers to finance, own and operate CHP projects. Flint Hills Resources’ Pine Bend Refinery in Rosemount received an exemption from the law in the 2016 Legislative Session, allowing it to move forward with its CHP project.

6. Reform Regulatory Practices

Some recommendations for CHP policy changes could be addressed either through legislation or at the Public Utilities Commission. For example, some have suggested a way to overcome barriers is “flexible rate treatment including on-bill repayment for utility investments in customer-side CHP.”

A theme expressed by many stakeholders is that the value of CHP is not accurately captured by the current economic cost-benefit analysis, and that a more complete accounting of those values should be incorporated into regulatory decisions. There are many analyses of best practices in capturing the full value of energy efficiency, solar, and CHP.

Several stakeholders, including the Western Lake Superior Sanitary District (WLSSD), have pointed out that many Minnesota laws establish a strong preference for high efficiency and renewable resources energy production, but that renewably-fueled CHP receives no greater benefit under rates or regulations than a fossil-fueled, lower efficiency project. For example, see the list of statutes requiring increasing percentages of renewable energy usage and goals requiring increasing reductions in greenhouse gasses.

Additionally the Certificate of Need statute states that no proposed large energy facility shall be approved “unless the applicant can show that demand for electricity cannot be met more cost effectively through energy conservation and load-management measures” and a nonrenewable energy generating plant shall not be approved without showing “an assessment of the risk of environmental costs and regulation” over

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105 DOC Final CHP Action Plan, 43.
the life of the plant and that it is less expensive than a renewable plant.\textsuperscript{111} While this statute indicates a strong preference for more efficient and renewable resources, a renewably-fueled CHP plant would likely be found more expensive than a conventional power plant, given traditional avoided cost calculations.

The Midwest Cogeneration Association takes the position that conventional avoided cost calculations don’t account for the true value of CHP projects, thus creating a negative financial incentive to cut the size of projects.

Minnesota utility power buyback tariffs are often based on marginal generation costs. This does not reflect the true higher avoided costs of future generation. Rates that are improperly based on marginal costs are insufficient to incentivize distributed generation projects of the future. As a result of low avoided cost rates of payment, CHP projects are often sized only to offset a facility’s own electricity consumption without sales back to the grid. In some instances, this is a less cost effective and less efficient use of a valuable distributed generation resource.\textsuperscript{112}

The Blue Green Alliance states that “[s]ocietal and broader economic benefits (such as avoided costs of transmission) of CHP need to be captured in the economic decisions to install a CHP system.”\textsuperscript{113}

Minnesota Power has expressed concern that CHP projects will cost all of their customers more than conventional generation.\textsuperscript{114} However, Minnesota Power has indicated that their utility-owned biomass CHP plant at their Rapids Energy Center co-located with the UPM-Blandin Paper Company has favorable economics. In its filing to the PUC, Minnesota Power stated that the plant “provides Minnesota Power and its ratepayers with considerable revenue stability and provides Blandin with competitive electric rates and operational flexibility.”\textsuperscript{115}

Public Utilities Commissioners are often reluctant to step outside the boundaries of traditional regulatory interpretation of concepts like “avoided cost” and “least cost” options, unless they feel they have explicit legal authority to do so. Legislative action that specifically authorizes the PUC to consider energy system, long-term, and environmental and social benefits in cost determinations would accelerate these reforms.

7. \textbf{Advance education, technical assistance, and training}

Analysis of stakeholder discussions show three main gaps in market knowledge and workforce resources: CHP options and opportunities information, regulatory, finance and development issues, and onsite energy staffing.\textsuperscript{116}

\textbf{Status Update}

\textsuperscript{111} Minnesota Statute §216B.243, Subd. 3, 3a.
\textsuperscript{112} Midwest Cogeneration Association Comments on CHP Stakeholder meetings, (Oct. 10, 2014), 2.
\textsuperscript{113} Blue Green Alliance Comments to DOC Stakeholder Process, (Oct. 10, 2014), 2.
\textsuperscript{114} Minnesota Power Comments to DOC, (Oct, 10, 2014).
\textsuperscript{115} Minnesota Power filing In the Matter of a Petition for Approval of an Amended and Restated Electric Service Agreement Between Blandin Paper Company and Minnesota Power, Docket No. E015/M-12-1348, (Dec. 19, 2012).
\textsuperscript{116} DOC Final Action Plan, 40-41.
DOC has taken on this priority by updating its website with resources, including information on where to get technical assistance in assessing potential CHP projects. Ideally this resource will help bridge knowledge gaps across Minnesota.

8. Map CHP Opportunities

While there is significant economic potential for CHP in Minnesota, stakeholders in the DOC process indicated that identifying viable CHP opportunities would most likely come from individual feasibility studies or limited utility studies. Stakeholders were largely positive about mapping potential at public facilities, because they can be good candidates for CHP given that “many have significant and concurrent electrical and thermal demands” and are “better able to accept longer paybacks and have access to lower cost financing.” DOC adopted mapping of CHP opportunities as its second Priority Area in the Final Action Plan, and is focusing on wastewater treatment facilities in 2016-2017.

Mapping opportunities for CHP is an important step for a community interested in maximizing local assets for a more efficient, integrated, and clean energy system. This can start with heat mapping, identifying “hot spots” for waste heat. In St. Paul, a model study of this type was done along the Central Corridor line, which is a key commercial and Green Line transit “spine” along University Avenue, connecting downtown St. Paul, the University of Minnesota, and Minneapolis. This study was focused on identifying “Energy Island Clusters” which are defined as areas with producers of excess energy (waste heat or excess energy/physical capacity), significant energy consumption, and relatively compact energy-use pattern or energy density.

The study goals included:

- work with multiple public data sets to evaluate stranded energy opportunities, including industrial waste heat and excess facility heat capacity, with an eye towards “thermal smart grids”
- evaluate components of the energy system including production, distribution, consumption, and renewable energy and assess the most likely technical, financial, and market scenarios for adoption
- inventory energy production facilities and heat recovery opportunities in the study area
- assess energy user potential based on load density and patterns
- create a distribution system analysis
- assess the potential to convert fossil fuel users to renewable energy
- study the feasibility of system integration

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117 Ibid.
118 Ibid at 34.
119 Ibid.
121 Ibid at 15. This study was focused on identifying opportunities for district energy systems, with a focus on integrating electricity and thermal energy. District energy is a thermal delivery system that connects energy users with a central or shared production facility. Ibid. page 6.
122 Ibid, p. 11-13
While this study was in part aimed at use of district energy systems, the analysis was focused on identifying combined heating and electricity energy optimization opportunities. This kind of “thermal” mapping with an overlay of economic development and building owner information would be a valuable way for a city to analyze its CHP potential.

**Status Update**

DOC has narrowed its initial focus for high CHP potential on wastewater treatment facilities given the public facility advantages mentioned, as well as the fact that they are large energy users. Water and wastewater systems consume an estimated 3-4% of total U.S. electricity consumption and are often one of the larger energy users in municipalities. DOC points out that electricity consumption can be reduced at wastewater facilities by using “anaerobic digestion to produce digester gas and then use the digester gas as a fuel for the combined production and beneficial use of heat and electrical power.” This is the type of system planned by the Western Lake Superior Sanitary District, described in the Case Study section, below.

DOC received a DOE grant to map Wastewater Treatment Plant opportunities for CHP, focused on decreasing energy use and scoping opportunities for renewable energy generation. DOC believes this strategy could identify and spur implementation of some 100 Megawatts of CHP in the near term.

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124 DOC, Final Action Plan, 34.
125 Conversation with Adam Zoet, DOC. (2016).
126 DOC, Final Action Plan, 36.
CHP Case Studies

For the following case studies, we interviewed individuals who championed CHP projects. Those interviewed include Ken Smith and Jim Green, Evergreen Energy; Jerome Malmquist, University of Minnesota-Twin Cities; John Rice, St. Mary’s Hospital (Duluth); Mindy Granley, University of Minnesota-Duluth, and Marianne Bohren, Western Lake Superior Sanitary District (WLSSD). The case studies are intended to represent the perspective of proponents for customer-sited CHP projects to better understand the barriers they face. We did not interview other stakeholders, such as utility companies, involved in each of the projects.

Current Combined Heat and Power Projects in Minnesota

St. Paul Cogeneration

St. Paul’s original downtown coal-fired plant was built in the early 1900s, serving the street cars in the city as well as some steam customers. As far back as the 1970’s, documents mention transitioning the system to alternative fuel sources so renewable energy was always part of the long-term vision. St. Paul Cogeneration was established in the 1990s in order to improve the St. Paul district heating system’s fuel efficiency and to provide an environmentally sound source of electric and heating.

As seen in the cartoon, former St. Paul Mayor George Latimer is widely credited for his visionary leadership in pushing the project forward. In 1993 District Energy St. Paul’s new CEO Anders Rydaker started focusing upon integrating combined heat and power into the district energy system. Several factors helped to facilitate the establishment of the plant. New corporate entities were created to implement the project. Market Street Energy (now Ever-Green Energy) was formed to develop the project, and began to seriously and strategically plan for implementing CHP. Cinergy joined as a partner on the project and put up the financial capital, District Energy put up the opportunity, and state biomass legislation facilitated the development of the project. It took a decade for the new CHP plant, known as St. Paul Cogeneration, to become operational in 2003.

To make the project work, Northern States Power (now Xcel Energy) had to agree to purchase the electricity produced by the plant to meet the obligations of the state’s biomass legislation. It took approximately three years to complete the process to formalize the power purchase agreement (PPA)

enabling the project to move forward. In the PPA, the utility agreed to pay a certain price for the electricity produced.\textsuperscript{128}

The new CHP plant was built adjacent to the district energy plant, enabling the use of the waste heat from electricity production to produce hot water for the district heating system.\textsuperscript{129} Waste wood is the primary source of fuel for St. Paul Cogeneration. The plant receives about 40 truckloads of material daily from municipal and private brush sites, storm-damaged trees, tree trimmings, diseased trees, land clearing, clean construction residues, habitat restoration projects, and other activities that produce wood waste. A majority of the biomass for the plant is acquired from within the Twin Cities metropolitan area within 60 miles of the plant.\textsuperscript{130} The CHP plant is able to produce 65 megawatts of heat and 33 megawatts of electricity simultaneously which makes it about twice as efficient as a conventional electricity plant. The plant provides thermal energy for heating approximately 32 million square feet of building space in downtown St. Paul. Customers include higher education institutions, hospitals, Fortune 500 companies, commercial buildings, apartments, hotels, entertainment venues, historic buildings, and even the Minnesota State Capitol. The electricity produced is supplied to the local electric utility, Xcel Energy, in accordance with the power purchase agreement (PPA).\textsuperscript{131} District Energy St. Paul is the largest and most integrated hot water district energy system in North America.

**The Opportunity for CHP: What Worked**

*Financial Partners*

To finance the original CHP project, District Energy needed an external financial partner which led to the formation of Market Street Energy and a partnership with Trigen/Cinergy from Cincinnati, Ohio.\textsuperscript{132}

*Supportive Legislation*

In 1994, the state Legislature debated the future of nuclear energy in Minnesota. The final “compromise” legislation that passed was named after the Prairie Island nuclear plant and created the state’s first mandates for renewable electricity including wind and biomass.\textsuperscript{133} 134 The biomass mandate originally required NSP to procure 125 Megawatts of biomass-fueled electricity. It is unlikely that either the St. Paul Cogeneration Project or other resulting biomass projects would have been completed without the Minnesota Legislature passing renewable electricity legislation that included the biomass mandate.

\textsuperscript{128} St. Paul Cogeneration has a Power Purchase Agreement with Xcel Energy to buy the electricity, and District Energy St. Paul buys thermal energy from St. Paul Cogeneration.

\textsuperscript{129} Evergreen Energy Website: http://www.ever-greenenergy.com/operations/st-paul-cogeneration/

\textsuperscript{130} Ibid.

\textsuperscript{131} Ibid.

\textsuperscript{132} The plant is now owned by Evergreen Energy and DTE.

\textsuperscript{133} The original law, Minn. Stat. §216B.2424 Subd. 5 (1994), required Xcel Energy to “construct and operate, purchase, or contract to construct and operate” 50 megawatts of electricity from biomass to be operational by 2001, and an additional 75 megawatts to be operational by 2002: https://www.revisor.mn.gov/statutes/?id=116c.779

\textsuperscript{134} Minn. Stat. §216B.2424: https://www.revisor.mn.gov/statutes/?id=216b.2424
Local Leadership

At the same time the cities of Minneapolis and St. Paul were jointly producing climate action plans. Several items within the action plans focused upon energy, buildings and transport including the development of biomass CHP in the region. As a result, Minneapolis and St. Paul passed a joint resolution which was pivotal at building support at the Capitol for the biomass mandate. This was an example of the importance of cities influencing state action. As Ken Smith, Ever-Green Energy CEO says “Local governments demonstrate leadership by putting forward clear goals and establishing pathways to achieve them. It is a critical element to advancing action that leads to meaningful change.”  

Biomass Availability

At the same time, tree cuttings and slash in the Twin Cities were being landfilled, and there was a surplus of wood waste. Using this tree waste as a source of biomass instead of landfilling was an environmental solution with multiple benefits. The consistent supply of tree cuttings, logging slash, and other woody biomass for use as biomass at the CHP plant has also been an economic solution. In recent years, many communities have come to depend on their partnership with St. Paul Cogeneration and its affiliate Environmental Wood Supply, to dispose of the excess tree material from storm and emerald ash borer damage. It would actually cost communities more to dispose of the material in a different manner.

Favorable Carbon Footprint

The carbon neutrality of biomass depends greatly upon the source of the biomass and the distance it is transported. Whole trees are not cut down to burn as fuel for St. Paul Cogeneration. Rather it utilizes clean waste wood that otherwise would have to be open burned or landfilled where it would decompose and release the carbon. The waste wood consumed by St. Paul Cogeneration is normally trucked. For a project with the Minnesota DNR that disposed of waste wood resulting from the removal of invasive species, analysis by Ever-Green Energy concluded that the BTU value of the diesel fuel consumed to deliver a truckload of the biomass from the project site to St. Paul Cogeneration (round trip) was approximately 2% of the BTU content contained in each truckload of biomass.  

Barriers

CEO Ken Smith’s perspective is that “it is understandable why utilities may resist CHP: depending upon the project, it can result in a loss of sales if a large organization or institution starts producing its own electricity.” However, Smith says,  

If we are going to be serious about carbon reduction, the use of CHP offers great opportunities to increase efficiencies and cut carbon emissions. It is also an important strategy that is being deployed in many locations to support the increased integration of wind and solar resources and

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135 Ken Smith, President and CEO, Evergreen Energy. Interview, 2016.
136 Ibid.
increase resiliency. Those are reasons why CHP is being deployed as important part of energy and climate strategies in many locations around the globe.\textsuperscript{137}

**Future Opportunities**

Looking to the future, Smith believes CHP can provide responsive power generation that will be needed to support a grid more dependent upon variable renewable resources, such as wind and solar, particularly if thermal storage is added to CHP, as St. Paul is already initiating.\textsuperscript{138} Germany and other European countries are deploying a strategy called “Power to Heat” in communities.\textsuperscript{139} The strategy, a kind of energy storage, integrates hot water thermal storage tanks together with district heating systems. The process uses excess wind and solar power from the grid, which otherwise would be curtailed, to generate heat (thermal energy) that is distributed to buildings connected to the district heating network as needed.

\textsuperscript{137} Ibid.

\textsuperscript{138} Ken Smith, President and CEO, Evergreen Energy. Interview, 2016.

University of Minnesota Twin Cities

The University of Minnesota’s (UMN) Twin Cities campus is in the process of completing construction on its new natural gas cogeneration plant. The plant, which utilizes a combustion turbine-driven CHP system, will be complete and operational by the end of 2016 and will provide thermal energy and electricity; Xcel energy will provide the University with backup power if needed.140

Capturing the Opportunity for CHP

Several factors helped to facilitate the approval and construction of the University of Minnesota’s Cogeneration Plant, which is housed on the Minneapolis campus’ 1912 Old Main Utility Building, a legacy coal-fired heating plant.141

The need for additional heating resources on campus

The major catalyst for the University of Minnesota’s investment in its energy system was the need for additional thermal energy.142 The University’s boilers were installed in the 1940s and reaching the end of their service life. At the same time, campus expansion resulted in an increased demand for thermal energy which was projected to exceed the existing systems’ ability to produce steam in 2014/2015.143

As the University identified options producing additional heat for campus, CHP became an obvious solution. The University of Minnesota’s Director of Energy Management Jerome Malmquist points out that a cogeneration system is only feasible for systems with thermal load. If a system cannot utilize the heat generated through electricity production then it is not possible to justify investing in an expensive CHP system. If electricity production creates waste heat, that thermal energy will be lost if it is not captured and utilized. By capturing and utilizing waste heat, the system’s overall energy efficiency is increased dramatically.144 Malmquist estimates the campus CHP plant will be 80%-83% efficient.

While the need for thermal energy ultimately drove UMN to install an additional power plant, the cost and efficiency savings obtainable through CHP systems are the factors that ultimately encouraged the University’s Board of Regents to invest in its 22.8 Megawatt turbine cogeneration system.

The University of Minnesota’s Commitment to Sustainability

In 2008, the University of Minnesota signed on to the American College and University Presidents’ Climate Commitment.145 The Twin Cities campus has established a plan to reduce greenhouse gas emissions 50% by the end of 2020 and is developing plans for 100% reduction, or carbon neutrality, by 2050.146 The University of Minnesota’s Master Plan identifies energy efficiency and the use of renewable energy as

140 Jerome Malmquist, Director, Energy Management University of Minnesota. Interview, 2016
141 See University of Minnesota website, http://govrelations.umn.edu/capital/power-plant.html
142 Jerome Malmquist, Director, Energy Management University of Minnesota. Interview, 2016
144 Jerome Malmquist, Director, Energy Management University of Minnesota. Interview, 2016
necessary tools for reducing the campus’ greenhouse gas emissions and UMN Energy Management has proposed developing a new Utility Master Plan to commence within the next 18 months.\textsuperscript{147} The Board of Regents Policy on sustainability and energy efficiency outlined in the 2009 document \textit{University of Minnesota Systematic Sustainability}\textsuperscript{148} also states that “the University shall undertake a process to increase energy efficiency, reduce dependence on nonrenewable energy, and encourage the development of energy alternatives through research and innovation.”\textsuperscript{149} While Malmquist maintains that the CHP plant was approved as a “good solid business decision,” University leadership may also have been influenced by students and others in the surrounding community who for several years have advocated for the University to move “beyond coal.” CHP represents an opportunity to significantly increase the efficiency of energy production, and therefore reduce greenhouse gas emissions, on campus. For the University, the ability to cut the institution’s utility footprint by 30% was a major factor that contributed to the adoption of CHP.\textsuperscript{150}

\textit{Resilience}

Additionally, the plant makes the University resilient in the event of unanticipated outages. The plant will be capable of “black starting” with auxiliary generation in case of a transmission grid power failure. Energy managers will have the ability to “island” the plant and provide heat and power to University hospitals, labs, and other critical parts of the University’s energy load, protecting people as well as hundreds of millions of dollars of University research activities.\textsuperscript{151} The current practice of depending upon one plant for 100% of the campus’ heat has been cited as a top property insurance risk.

\textit{Space Availability}

The University of Minnesota’s ability to invest in CHP was also facilitated by the available space on campus to put in the system. The University had foresight in sizing the previous system, recognizing that future demand could grow. Otherwise, space could have been a significant hurdle, and space constraints typically require more planning and stricter design requirements.\textsuperscript{152}

\textit{Biomass}

While currently the University of Minnesota is not planning on utilizing biomass as a fuel source for the CHP plant, it is possible that will be considered in the future. However, right now all extra scrap wood in the region is already used by St. Paul District Energy’s biomass cogeneration plant. The University of

\textsuperscript{148} University of Minnesota System-wide Sustainability (2009): \url{https://italladdsup.umn.edu/assets/pdf/UM_Systemwide_Sustainability_Final_Report.pdf}
\textsuperscript{149} Board of Regents Sustainability and Energy Efficiency Policy: \url{http://regents.umn.edu/sites/regents.umn.edu/files/policies/Sustain_Energy_Efficiency.pdf}
\textsuperscript{150} Jerome Malmquist, Director, Energy Management University of Minnesota. Interview, 2016
\textsuperscript{151} UMN website: \url{http://govrelations.umn.edu/capital/power-plant.html}.
\textsuperscript{152} Ibid.
Minnesota has been considering purchasing oat hulls from Saskatchewan, Canada and has been talking with NRRI about torrefied material\textsuperscript{153,} \textsuperscript{154} but the major barrier is the cost of transportation.\textsuperscript{155}

**Barriers**

*Tariffs, Rules, and Statutes*

The Public Utility Regulatory Policies Act (PURPA)\textsuperscript{156} allows a CHP project such as the one at the University of Minnesota to connect to the grid. However, Malmquist’s perspective is that the biggest hurdle for the University of Minnesota has been Minnesota tariffs and laws.\textsuperscript{157} In addition to the standard tariffs it was necessary to establish an Interconnect Agreement (IA) and Power Purchase Agreement. Malmquist says “existing regulations have not been developed with the opportunity for cogeneration in mind. Many of these regulations do not facilitate CHP but rather favor existing utilities as the sole energy producers of energy.” In addition, the University faced several other unforeseen barriers relating to layers of regulation.

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**Lesson Learned**

“The lessons learned from this experience is that before any organization begins a CHP project, it is necessary to be aware of existing rules and regulations that relate to distributed energy production, its use, its possible export to the grid, and the backup power needed if the system fails.”

-Jerome Malmquist, UMN-Twin Cities Energy Manager

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\textsuperscript{153} The University of Minnesota Duluth’s Natural Resources Research Institute (NRRI) is currently working on a project to produce torrefied pellets. For more information about this project see: http://www.nrri.umn.edu/default/pt.asp?id=1771


\textsuperscript{155} Jerome Malmquist, Director, Energy Management University of Minnesota. Interview, 2016

\textsuperscript{156} U.S. Code Chapter 46; see http://www.ferc.gov/industries/electric/gen-info/qual-fac/what-is.asp as well as http://www.ucsusa.org/clean_energy/smart-energy-solutions/strengthen-policy/public-utility-regulatory.html#V184GeR1p40

\textsuperscript{157} Jerome Malmquist, Director, Energy Management University of Minnesota. Interview, 2016

\textsuperscript{Ibid.}
on cogeneration including federal FERC and NERC rules and regulations\textsuperscript{158} and the Midcontinent Independent System Operator (MISO)\textsuperscript{159} rules.

Environmental permitting can be a very large hurdle especially in urban areas. It is necessary to show that emissions will be reduced as a result of the project.\textsuperscript{160} The Center for Climate and Energy Solutions explains that installing cogeneration can increase a facility’s onsite air emissions even if the improvement reduces total emissions associated with the facility due to the more efficient generation of both heat and electricity on site. Some environmental permitting regulations do not always take this into account.\textsuperscript{161}

\textit{Costs Associated with Connecting to the Grid}

While the new cogeneration plant will serve about 60\% of the electrical energy needed on an annual basis for the University of Minnesota’s East Bank campus, it will still be necessary for the University’s system to be connected to the power grid in order to ensure the reliability of energy to campus in the case of a campus system outage and to sell any excess electricity into the grid. This means that the University needed to negotiate a Power Purchase Agreement (PPA) and Interconnection Agreement (IA) with the local utility, Xcel Energy.\textsuperscript{162} A PPA is a contract between a party that generates electricity (in this context, the University of Minnesota) and one that will purchase electricity (in this context, Xcel Energy).\textsuperscript{163}

In many ways, the University of Minnesota’s cogeneration project is setting a precedent. In Minnesota, the standard interconnection agreement terms apply to systems up to 10 MW, but this project includes a 22.8 MW generator. In addition, typical PPAs assume that 100\% of the power being produced will be sold to the grid. This is not the case with UMN’s cogeneration project. Rather, the university will be producing 20 Megawatts of electricity and plans on utilizing nearly all of the power being produced. The value proposition for the University requires them to use most of the electricity to offset their electric bill retail costs, rather than selling it to Xcel for a lower price. As a result, negotiations with Xcel are taking more time and some rules on energy production and grid connection are being reinvented and redefined, breaking new ground in the interconnection agreement.\textsuperscript{164}

The University of Minnesota will need to pay for interconnection to the grid as well as standby rates for backup power from Xcel in the case of an emergency. While the CHP plant is extremely reliable, the campus depends on consistent energy. If this system fails it would have some very negative consequences for research on campus.\textsuperscript{165}

Another barrier in this negotiation process is the fact that by self-generating electricity, the University of Minnesota will cut about $8 million out of Xcel’s net annual revenue, according to Malmquist. Flint Hills

\begin{footnotesize}
\textsuperscript{158} North American Electric Reliability Corporation (NERC) establishes technical standards for grid operators: \url{www.nerc.com/}; the Federal Energy Regulatory Commission (FERC) regulates, monitors, and investigates wholesale interstate energy activity: \url{www.ferc.gov/}.
\textsuperscript{159} MISO is the regional bulk transmission operator: \url{www.misoenergy.org}.
\textsuperscript{160} Jerome Malmquist, Director, Energy Management University of Minnesota. Interview, 2016
\textsuperscript{161} C2ES: \url{http://www.c2es.org/technology/factsheet/CogenerationCHP}.
\textsuperscript{162} Jerome Malmquest, Director, Energy Management University of Minnesota. Interview, 2016.
\textsuperscript{164} Jerome Malmquist, Director, Energy Management University of Minnesota. Interview, 2016.
\textsuperscript{165} Ibid.
\end{footnotesize}
Resources in Rosemount is also building a CHP plant meaning that Xcel stands to lose large quantities or revenue from several different sources. This precedent-setting case will continue to have an economic effect on Xcel, which could affect the viability of other CHP projects in the region. Malmquist, the University champion for the project, believes that is why the negotiation process between the University of Minnesota and Xcel has been difficult and lengthy.

Malmquist suggests that it is important to know and understand all of the energy costs and charges required by the local utility prior to beginning a CHP project. Utility tariffs can be very detailed and complicated. Besides standby rates there may be other additional supplemental costs that will be added to the bill to cover the back-up power provided by the local utility. Ultimately, the rates established between the University of Minnesota and Xcel will have a direct impact on the economic viability of the University’s CHP project.

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The economic viability of cogeneration systems depends on their ability to safely, reliably and economically interconnect with the existing grid. Interconnection standards, including technical specifications as well as application processes and fees, between utilities and cogeneration systems are often state mandated and vary regionally.

- Center for Climate and Energy Solutions

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**Infrastructure/Technological Barriers**

Malmquist points out that the siting of a CHP project is a very important factor that contributes to the project’s overall feasibility and success. A good locale with good infrastructure is very important. While the University of Minnesota benefited from an existing location that was compatible with the transition to CHP, the project also encountered barriers related to CHP infrastructure. For example, the existing water piping on site was not adequate for CHP and had to be re-constructed.

Other unforeseen technical hurdles the University faced included:

- Natural gas pressure: natural gas has to be compressed to 500psi for this type of CHP plant to function. However, gas purchased from Centerpoint Energy is only at 90psi. The University needed to purchase a gas compressor to speed up the gas. These compressors can be very loud and require sound insulation enclosures.

- Duel fuel: The University is an “interruptible rate” customer. This provides the University with a lower natural gas rate. This means that the University can be curtailed off of natural gas on very cold days when the energy needs of the area distribution system is greatest. For reliability

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166 For more information about the Flint Hills project see: [https://www.pca.state.mn.us/news/flint-hills-resources-proposed-refinery-changes-are-open-public-review](https://www.pca.state.mn.us/news/flint-hills-resources-proposed-refinery-changes-are-open-public-review)

167 Jerome Malmquist, Director, Energy Management University of Minnesota. Interview, 2016

168 Ibid.

169 Ibid.
purposes this requires the University to have a dual-fuel CHP system meaning it can operate on either natural gas or fuel oil. During these peak periods of gas usage, backup fuel oil is used. It is significantly more expensive than natural gas. However, the lower gas rates significantly contribute to the CHP project being cost effective.\textsuperscript{170}

\textit{Financing}

One barrier to adopting CHP, as well as other carbon-cutting technologies, is financial return on investment and payback periods. Renewable energy and energy efficiency technology often have high up-front costs; the necessary modifications to the electric distribution system on campus for UMN’s CHP project cost about $8 million. The University’s payback on investment is expected to be 8-9 years, depending on the price of natural gas and electricity. For most industry capital investments, a 1-2 payback period is ideal. Longer payback periods indicate a higher level of uncertainty and risk, making investments look less attractive even if the project will bring huge financial gains, environmental benefits, and a hedge against electric price volatility in the future.

\textit{Future Opportunities}

Malmquist suggests that there needs to be an incentive for investors to accept longer paybacks, and that businesses need to be guaranteed a market for long-term investments such as CHP.\textsuperscript{171} He believes electric utilities and state policies need to evolve to better support the ability of customers to supply their own generation in distributed energy systems, without facing crippling tariffs.\textsuperscript{172} Like Ken Smith, he points to northern European countries where policies support the use of highly efficient, distributed heating systems.

The University’s CHP plant is now successfully moving forward. On May 24, 2016 Xcel Energy filed a petition seeking PUC approval of the two Power Purchase Agreements (PPAs) and the Interconnection Agreement sought by the University of Minnesota.\textsuperscript{173} The first PPA would be for a limited amount of test energy beginning in fall 2016 and up to the date of commercial operation. The second PPA is for 5 years, starting once the CHP system has reached commercial operation. The University self-certified with FERC as a Qualifying Facility (QF) under PURPA, as a small power production facility under 80 Megawatts. Normally under PURPA and Minnesota law, utilities are required to purchase all energy and capacity made available by QFs. However, Xcel has received an exemption for plants over 20 MW. Nevertheless, Xcel states that they agreed to move ahead with this project because the University is a “state constitutional corporation,” formed before statehood in 1958, which gives the project a unique public interest component.\textsuperscript{174}

\textsuperscript{170} Ibid.
\textsuperscript{171} Jerome Malmquist, Director, Energy Management University of Minnesota. Interview, 2016
\textsuperscript{172} This points to the need for new utility business models, to remove the disincentive for distributed generation which reduces utility revenue. Xcel Energy, the Energy Transition Lab, and many other Minnesota stakeholders are participating in an innovative process, the e21 Initiative, which will release consensus white papers in 2016 regarding these issues. See \url{http://www.betterenergy.org/projects/e21-initiative}
\textsuperscript{173} See PUC Docket 16-445.
\textsuperscript{174} Ibid, Xcel \textit{Energy Petition for Approval of PPA and Interconnection,} 2.
St. Mary’s Medical Center Duluth

As Northeast Minnesota’s largest hospital, St. Mary’s Medical Center serves patients from across Northern Minnesota, Wisconsin and Michigan. The Medical Center was identified by an evaluation conducted in 2001 by the Minnesota Environmental Quality Board as having good potential for a cogeneration project. The Medical Center leadership considered investing in CHP in the past, and although the decision was made to put their investment into another sector within the Medical Center, it is likely that CHP will be brought up again in the future.

St. Mary’s energy system provides thermal energy for heat and hot water for half of the Essentia Duluth Campus and is also connected to downtown Duluth’s district energy system. St. Mary’s system’s primary fuel source is natural gas but it also has the ability to burn fuel oil as a backup. With this system, St. Mary’s Medical Center has the ability to alter its source of energy based upon relative fuel prices. When prices for natural gas were high several years ago, St. Mary’s began purchasing more energy from Duluth Energy Systems. Similarly, as prices for natural gas decrease, St. Mary’s is able to produce more energy internally. St. Mary’s also provides backup steam services to Duluth for when the district energy system goes down.

The Opportunity for CHP

St. Mary’s was considering CHP several years ago because the center was in the process of replacing old equipment. The equipment replacement provided St. Mary’s with the opportunity to evaluate its options related to energy generation and consider investing in technologies such as CHP.

Barriers

Ultimately St. Mary’s did not invest in a CHP System for several reasons.

Space

The Essentia Duluth Campus is composed of what was originally four separate businesses. St. Mary’s Medical Center accounts for approximately 50% of the campus square footage. Over the past 20 years, the businesses merged to form what is now the Essentia Duluth Campus. As a result, the campus space is an amalgamation of buildings with individual entrances and parking lots connected by skywalks. The result is a convoluted campus layout that never would have been designed this way. The available space in St. Mary’s buildings and the surroundings buildings is limited and unoccupied property is currently used for parking.

175 For more information see: http://www.essentiahealth.org/stmarysmedicalcenter/find-a-clinic/essentia-healthst-marys-medical-center-duluth-46.aspx
177 John T. Rice (2016). Director of Maintenance, St. Mary’s Medical Center Duluth Clinic. Interview, 2016
178 The current steam energy system in Duluth is quite inefficient and in the process of trying to upgrade to a more efficient hot water system. See the Duluth Energy Systems Case Study for more information.
179 John T Rice, Director of Maintenance, St. Mary’s Medical Center Duluth Clinic. Interview, 2016
180 Ibid
181 Ibid
Director of Maintenance John T. Rice points out that up front construction capital is the largest barrier to investing in CHP, even though the efficiency improvements would ultimately save money. As Mr. Rice explained, CHP should be “no brainer” for St. Mary’s. He continued “[i]f we look at life cycle costs, it would be an attractive project but the initial capital costs are the most expensive which can be a barrier.” The high initial capital costs involved in CHP were also a barrier because of competing priorities. St. Mary’s Medical Center was investing in several technology upgrades at the same time CHP was being considered. For example, the electronic medical record system was a very big investment in materials, training and personnel for the organization. For a time, “all available capital was being devoted to IT and adding more buildings and CHP was put on the backburner.”

According to Rice, in the last decade Minnesota Power told St. Mary’s that if the medical center were ever interested in investing in cogeneration, they would be glad to partner with them. Mr. Rice thinks that Minnesota Power is more interested in keeping St. Mary’s as a customer and partnering with cogeneration would be one means of staying involved. However, no serious discussions ever occurred. If St. Mary’s ever did continue to move forward with cogeneration, they would likely seek out Duluth Energy Systems and Minnesota Power as partners. Rice believes these relationships would be beneficial, but they could also act as a barrier to slow down the conversion process.

While CHP is not currently being considered, it is possible that the option will be put on the table again in the future. St. Mary’s is considering expansion and if the medical center moves some facilities or undergoes expansion CHP will inevitably come up.

182 John T Rice, Director of Maintenance, St. Mary’s Medical Center Duluth Clinic. Interview, 2016
183 Ibid.
University of Minnesota Duluth

University of Minnesota’s Duluth (UMD) Campus, serving a total of 10,878 students, overlooks Lake Superior in northeastern Minnesota. UMD consistently ranks among the top Midwestern regional Universities in rankings published by U.S News and Report. UMD’s Office of Sustainability coordinates events, activities and efforts across campus, shares information, and tracks information related to energy use, carbon emissions, and waste production in order to promote and evaluate sustainability on the UMD campus.

“\textit{The Office of Sustainability and the UMD Campus are committed to communicating, educating and inspiring action to integrate sustainability into all aspects of campus life}”

-Office of Sustainability Mission Statement

The Opportunity for CHP

In 2011, UMD published its Energy Action Plan (EAP) which outlined specific goals and actions that the campus would take to reduce greenhouse gas emissions. The EAP outlines specific targets that UMD will work towards achieving including:

- A 15% reduction in greenhouse gas emissions by 2020
- Complete carbon neutrality by 2050

UMD’s central heating plant is responsible for about 32% of the campus’ total carbon emissions. The central heating plant primarily burns natural gas. Prior to 2005 the plant also burned Fuel Oils #2 and #6 but the campus curtailed this practice in 2005, and plans to avoid using fuel oil in the future, in order to prevent an increase in greenhouse gas emissions. In 2011 UMD contracted for distribution system studies for the campus steam plant in order to identify and prioritize recommendations for improving the emissions profile of the plant and its distribution system. The studies also provided recommendations regarding the opportunity for CHP on campus.

The Full Steam Study conducted by Stanly Consultants in 2011 for UMD’s central heating plant considered the feasibility and cost effectiveness of installing a small steam microturbine CHP system. The system would produce between 50 and 275 kW of electricity for use on the UMD campus. The study considered

\textsuperscript{184} UMD Website: \url{http://www.d.umn.edu/facts/}
\textsuperscript{185} Office of Sustainability: \url{https://umdsustain.wp.d.umn.edu/about-us/}
\textsuperscript{187} Ibid.
\textsuperscript{188} Ibid.
options for replacing an existing pressure reduction station with a steam microturbine either in the heating plant or in one of the other larger buildings on campus.\textsuperscript{189}

**Barriers**

Ultimately the feasibility study concluded that although installing the CHP system on campus was technically feasible, “the combination of low electrical rates from Minnesota Power (MP), additional electrical standby service riders required by MP if such a system were installed and the low cost of steam generation”\textsuperscript{190} did not make the project cost-effective. As a result investing in a steam micro-turbine system was not seen as an attractive option for UMD.

While CHP was not recommended for UMD with existing standby rates and gas prices, Stanly Consultants also pointed out that further consideration of cogeneration opportunities may become warranted in the future if:

- Electrical supply agreements can be re-negotiated
- Green technology incentives/grants become available
- Larger additional coincident steam and electrical loads become necessary to serve future campus growth\textsuperscript{191}
- The prices of natural gas and grid-supplied electricity increases\textsuperscript{192}

\textsuperscript{189} Stanley Consultants Steam Study Phase I & II (2011).
\textsuperscript{190} Ibid.
\textsuperscript{191} Ibid.
High potential CHP projects in the Duluth area

Western Lake Superior Sanitary District (WLSSD)

Western Lake Superior Sanitary District (WLSSD) provides wastewater and solid waste services and oversight to communities throughout Northeast Minnesota. Unlike many wastewater treatment facilities, WLSSD isn’t associated with a specific city or county but is rather a regional utility managed by a nine member board. WLSSD is a special political subdivision which covers 17 different communities spread out over 530 square miles including four major industrial customers and the cities of Duluth, Cloquet, Hermantown, Proctor, Carlton, Scanlon, Thomson and Wrenshall as well as nine surrounding townships. WLSSD’s wastewater treatment plant located in Duluth treats 40 million gallons of wastewater daily. Approximately half of the wastewater treated by WLSSD comes from local industries while the other comes from homes and businesses.

“To Plan and Provide for the Effective and Economical Collecting and Treatment of Wastewater and to Ensure Responsible Solid Waste Management through Effective Planning, Oversight, Education and Customer Services…. thereby protecting the St. Louis River basin and Lake Superior.”

-WLSSD Mission

The Opportunity for CHP

In 2000-2001 WLSSD invested in four, 1 million gallon digesters for treating the solid material remaining following the treatment of wastewater. The digester processes this material into a high quality soil supplement product that is applied to agricultural and mine lands and also produces a methane-based biogas which is collected and used for heat. While this system is extremely efficient year round, the district cannot fully utilize the biogas produced during the warm summer months resulting in this valuable commodity being flared four months of the year. In order to utilize all of the biogas produced by the facility, WLSSD has proposed installing generators to convert the gas produced during digestion into electricity. At the current level of gas production WLSSD would be able to produce about 35% of its own electricity.

WLSSD recently evaluated their system for the facility’s long-term energy plan and identified several additional opportunities that would increase WLSSD’s ability to invest in a CHP system.

193 WLSSD Website: http://wlssd.com/about-us/
194 Marianne Bohren, Executive Director, WLSSD. Interview, April, 2016.
195 WLSSD Website: http://wlssd.com/about-us/
197 WLSSD Website: http://wlssd.com
198 Marianne Bohren, Executive Director, WLSSD. Interview, April, 2016.
Integrating Additional Waste Products into the System:

WLSSD is currently only utilizing half of the digester capacity. WLSSD also has a food waste composting program and recently evaluated the additional gas-production potential if food waste were integrated into the digesters.\textsuperscript{199}

Infrastructure Updates

Biogas is used by WLSSD in boilers to produce process and facility heat. In 2015, WLSSD replaced old steam boilers that were at the end of their useful life with nine modern modular boilers as well as a biogas conditioning facility.\textsuperscript{200} The new boilers can use biogas or natural gas to produce hot water heat. This, along with other upgrades, will increase WLSSD’s energy efficiency.\textsuperscript{201}

By building upon the improvements in the plant heating system, taking advantage of the additional capacity available in the digesters for direct introduction of agricultural waste such as food scraps and fats, oils and grease, and installing engine generators to convert this biogas into electricity WLSSD could become energy self-sufficient. WLSSD would be able to fully utilize all of the heat and electricity produced by the CHP system. Currently, WLSSD purchases $3 million in electricity annually.\textsuperscript{202} It is estimated that the annual savings associated with installing engine generators at the current rate of biogas production would save about $750,000 in purchased electricity. With the added incorporation of agricultural waste into the digester to increase biogas production the WLSSD could eliminate the need to purchase electricity for use at the waste treatment plant.\textsuperscript{203}

Barriers:

Finances

The largest barrier to implementing this project is funding. WLSSD has submitted a bonding proposal that is under consideration at the Minnesota Legislature to help fund 35% of the cost for installation of engine generators and other efficiency upgrades.\textsuperscript{204} While the Senate bonding bills included $8.1 million\textsuperscript{205} for this project the House bill did not. Unfortunately, the Legislature adjourned \textit{sine die} in May 2016 without passing a bonding bill. Partial state funding for this project will not move forward in 2016 unless the Governor calls a Special Legislative Session and the House and Senate agree on a final bill that includes funding for WLSSD’s CHP project.

\textsuperscript{199} Marianne Bohren, Executive Director, WLSSD. Interview, April, 2016.
\textsuperscript{201} Marianne Bohren, Executive Director, WLSSD. Interview, April, 2016.
\textsuperscript{202} This amounts to about a third of all of WLSSD’s non payroll operating costs. Source: Harnessing Energy From Wastewater, (2015): \url{http://wlssd.com/news/biogas-harnessing-energy-from-wastewater/}
\textsuperscript{203} Marianne Bohren, Executive Director, WLSSD. Interview, April, 2016.
\textsuperscript{204} Ibid.
\textsuperscript{205} Bonding 2016 Draft: \url{https://drive.google.com/file/d/0B2VVRCbxQP6sLUp3OHFiNFB6Rms/view}
Standby Rates

When WLSSD installs a CHP system, the organization will initially produce about 35% of the electricity needed to operate the wastewater treatment plant.\(^{206}\) WLSSD’s influent, or incoming waste, also varies based on industrial operations which can cause variability in gas production and fluctuating electricity needs.\(^{207}\) This also may lead to varying levels of electrical generation. For these reasons, there will still be the need to purchase a portion of the facility’s electrical needs. This will require a standby power agreement with Minnesota Power. The current standby rates and procedures are currently under review by the Minnesota Public Utilities Commission. It is difficult to determine the impact of standby rates on overall electrical savings until they are approved.

Standby rate uncertainty was cited by WLSSD as a barrier that could derail its investment in CHP. WLSSD noted this concern in comments for the DOC’s stakeholder process identifying barriers to CHP deployment in Minnesota.\(^{208}\) WLSSD has discussed their plans with Minnesota Power, their local electric utility, which is in the process of revising its standby tariff. As mentioned above, the Minnesota Public Utilities Commission recently required all investor-owned utilities, including Minnesota Power, to file new standby tariffs, and the DOC has targeted wastewater treatment plants as a priority for CHP development.\(^{209}\)

According to WLSSD Executive Director Marianne Bohren, this is new regulatory territory for utilities in terms of having entities on the grid producing their own power; she is hopeful that they can move forward with Minnesota Power’s support.\(^{210}\)

Environmental Regulations

WLSSD recently updated the air permit to encompass both generators operating at 100%.\(^{211}\)

\(^{206}\) If WLSSD is able to invest in additional upgrades beyond CHP such as replacing steam boilers with hot water boilers and improving the facility’s ability to process additional biomass waste products then the facility may be able to become entirely energy self-sufficient producing 100% of the facility’s energy needs in-house.

\(^{207}\) Marianne Bohren, Executive Director, WLSSD. Interview, April, 2016.


\(^{209}\) See the section on CHP Barriers and Solutions in this report.

\(^{210}\) Marianne Bohren, Executive Director, WLSSD. Interview, April, 2016.

\(^{211}\) Ibid.
Duluth Energy Systems

Duluth Energy Systems, a city-owned heating and cooling system operated and managed by Ever-Green Energy\(^{212}\), provides thermal energy to 165 buildings in Canal Park and the central business district of Downtown Duluth. The current district energy system is currently 83 years old and the city of Duluth is hoping to renovate and modernize the steam system in 2017 while Superior Street and local utility infrastructure are undergoing renovation.\(^{213}\) \(^{214}\)

> “We take 90 million gallons of water from Lake Superior in a year, treat it, heat it to 365 degrees and then we send it one way through pipes until it literally runs out of steam... When it runs out of steam, it’s actually really hot water. We then treat that and we send it back into Lake Superior and start all over again with 40 degree water.”

-Jodi Slick, CEO Ecolibrium3

The Opportunity for CHP

The Duluth Energy Systems Conversion from Steam to Hot Water

The City of Duluth’s plan is to upgrade a major section of this aging and inefficient steam district energy system to a hot water system in 2017. The eventual conversion of the entire distribution system from steam to hot water is expected to increase system efficiency by approximately 40%.\(^{215}\) There is currently an opportunity to conduct a major portion of this conversion at a reduced cost by scheduling it to coincide with scheduled street and utility renovations on Superior Street in the central business district.\(^{216}\) The city has a pending bonding proposal in the Minnesota Legislature, for $21 Million for the infrastructure project.\(^{217}\)\(^{218}\) If Duluth Energy Systems is able to move forward with its conversion from steam to hot water, this would result in a hot water system meeting 30% of the system’s load, along the north side of the freeway on a mile-long stretch along Lake Superior.\(^{219}\)


\(^{213}\) Duluth Energy Systems: [http://www.duluthenergysystems.com/about/](http://www.duluthenergysystems.com/about/)


\(^{218}\) As noted above, the Legislature adjourned *sine die* in May 2016 without passing a bonding bill, so the funding will not move forward in 2016 unless the Governor calls a Special Legislative Session and the House and Senate agree on a final bill. Governor Dayton has indicated support for the bonding proposal.

\(^{219}\) Jim Green, General Manger, Duluth Energy Systems. Interview, 2016
Incorporation of Biomass into the Energy Mix

In conjunction with the hot water project, Duluth Energy Systems is planning to convert to biomass to offset coal consumption. The company will install equipment to allow locally derived woody biomass (wood chips) from waste wood such as logging slash to be included into the energy mix. After this conversion about 25% of the system’s fuel requirements would be met with locally derived woody biomass. Even if funding is not approved for the conversion from steam to hot water, it is likely that Duluth Energy Systems would attempt to move forward with a small biomass system.

Minnesota Power’s Incorporation of More Renewable Fuels into the Energy Mix

Often investment in CHP is triggered by a catalyzing event. Besides the synergy with the city’s street infrastructure renovations, another key factor will be significant to the project’s success. According to Duluth Energy System’s General Manager Jim Green, this event in Duluth was Minnesota Power’s decision to transition some of their generation from coal to natural gas and renewables. Minnesota Power’s most economic plan will likely involve taking advantage of pre-existing assets and infrastructure.

Ken Smith suggests this is the ideal time “to identify opportunities for other types of investments in other forms of energy generation. The opportunity for CHP comes up when you begin to install new generation. If you are going to install new forms of generation, why not invest in generation near the city in areas where the thermal load produced can be re-integrated into the system.”

An Ideal Location

There is an ideal partner for the updated Duluth Energy Systems operation, an old industrial building that has opened up in Duluth on the waterfront. The old Georgia Pacific Plant, located to the west of Duluth Energy Systems’ current location, was recently bought by an entrepreneur who is interested in bringing a new business to the site. The location is ideal for several reasons:

20 Jim Green, General Manger, Duluth Energy Systems. Interview, 2016
23 Jim Green, General Manger, Duluth Energy Systems. Interview, 2016
24 Ken Smith, President and CEO, Evergreen Energy. Interview, 2016.
• It’s located within a multi-modal transportation hub—on Lake Superior for water transport, and also very close to the railroad and the freeway.

• It is directly across the freeway from a Minnesota Power substation.

• Use of this location would improve Duluth Energy Systems’ ability to incorporate biomass into its fuel mix. Prior to closing down during the great recession, Georgia Pacific used the location to produce “super-wood.” The building already has all the biomass handling and processing facilities on site which would facilitate the use of biomass as a fuel source. In addition, at Duluth Energy System’s current location in Duluth, there is not sufficient space to store the quantity of biomass that would be needed to offset coal as a fuel source. The Georgia Pacific site would provide more space and flexibility to incorporate more biomass into the fuel mix.

• The location has significantly more space compared to Duluth Energy System’s current facility. It has sufficient space to install a cogeneration facility that is at least the size of the St. Paul district energy system in the Twin Cities.

• Duluth Energy System’s current location is very close to Canal Park, the city’s tourist district, and could be repurposed to better service the city’s growing tourism industry. From a public planning perspective, this is a great opportunity to move the generation of thermal energy outside of Canal Park to a location that is better suited for that use.

Duluth Energy Systems envisions the ideal scenario for CHP at the Georgia Pacific site to be a thermal energy user or tenant in the building to utilize the heat resource produced. In 2015 an investor was interested in constructing a biochemical plant in the area which would require steam. Unfortunately, the investors went to another state but the opportunity remains.

**Torrefaction**

Another factor that would help to facilitate the adoption of CHP for Duluth Energy Systems is the commercial development of torrefaction technology. The University of Minnesota Duluth’s Natural Resources Research Institute (NRRI) is currently working on a project to produce torrefied pellets. Torrefied material is produced from woody biomass but has many of the same properties as coal which makes it more compatible with Duluth Energy System’s current boilers. Duluth Energy Systems had initially planned on using sawdust as a biomass source, but it turned out not to be compatible with Duluth

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225 Jim Green, General Manager, Duluth Energy Systems. Interview, 2016
227 Jim Green, General Manager, Duluth Energy Systems. Interview, 2016
228 Ibid
229 Ibid
Energy System’s boilers. If torrefied material was available at an affordable price, it would be possible to convert the plant to biomass without needing to invest in expensive changes to the facility. \(^{232}\)

Duluth Steam pays $2.50 per million Btu for coal and about $4 per million Btu for natural gas. While natural gas is more expensive, burning it requires running less of the plant machinery so the overall costs of burning coal and natural gas turn out to be fairly similar. Wood pellets currently cost about three times the cost of coal, in part because many of the pellets are produced elsewhere and would need to be transported to the site. Locally produced biomass such as torrefied wood material would provide an excellent pathway for Duluth Energy Systems to convert to biomass. In addition, because the plant is older and produces more CO\(_2\) compared to some more efficient plants, it would be also offset coal usage and related carbon emissions.\(^{233}\)

**A Healthy Logging Sector**

Ever-Green Energy does not advocate for cutting down whole trees for fuel. However, if the region’s logging industry is healthy enough it would provide sufficient logging slash and waste wood to provide a carbon neutral source of biomass.\(^{234}\) In this way, projects that would support the logging sector would also support the adoption of biomass-fueled projects.\(^{235}\)

**Barriers**

**Negotiations with local utilities**

According to Jim Green of Duluth Energy Systems, a significant barrier to deploying combined heat and power is working through the variety of technical and regulatory hurdles to add a new source of power generation to the grid, regardless of the interest level of the local electric utility. Overcoming these barriers will require the involvement of a variety of state agencies including Commerce (DOC) and MPCA. One factor in favor for the utility is that producing energy through biomass cogeneration would provide Minnesota Power another renewable source of energy to add to their portfolio.\(^{236}\)

**Costs of Biomass vs. Natural Gas**

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 conventional fuels, such as coal, natural gas, and propane.\(^{237}\) 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.\(^{238}\) With

\(^{232}\) Jim Green, General Manager, Duluth Energy Systems. Interview, 2016  
^{233} Jim Green, General Manager, Duluth Energy Systems. Interview, 2016  
^{234} Ken Smith, President and CEO, Evergreen Energy. Interview, 2016.  
^{235} Read more about proposed projects that could positively affect the region’s logging sector: *Duluth’s Energy Future: Economic Modeling of Proposed Biomass and Solar Initiatives* (2016):  
^{236} Jim Green. Interview 2016.  
^{237} Kent Jacobsen, MN DNR. Email exchange, 2016.  
^{238} Ibid.
natural gas prices now at historic lows, biomass is currently more expensive. However, biomass prices are more stable.\textsuperscript{239} 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.\textsuperscript{240}

\textbf{“Not all renewables are created equal”}

- Ken Smith, President and CEO, Evergreen Energy

Ken Smith points out that Minnesota Power has tried to expand the use of biomass generated power but has run into difficulties due to the cost of biomass power compared to the cost of other renewables such as wind. Smith says that when comparing sources of renewable energy, the benefits of wind, for example, seem much greater if you are only analyzing the price of electricity generated at the source, and not recognizing the total cost of the energy source. Power generated great distances from load centers in communities requires transmission to deliver it to where it is needed.

Smith maintains that it is beneficial to the grid to incorporate a mixture of different sources of energy. Power generated by variable sources also requires other generation sources to support the stability and reliability of the grid, but biomass energy is dispatchable as needed. This kind of comparison of alternatives also does not recognize the benefits of generating power near a central business district where the thermal energy can also be used.\textsuperscript{241} 242 As Smith points out, “It’s not an apples-to-apples comparison but that’s what is happening.”\textsuperscript{243}

\begin{thebibliography}{99}
\bibitem{bib239} Ken Smith, President and CEO, Evergreen Energy. Interview, 2016.
\bibitem{bib240} Miller, 2013: \url{http://www.dovetailinc.org/land_use_pdfs/lccmr_resources/community_bioenergy.pdf}
\bibitem{bib241} Ken Smith, Evergreen Energy
\bibitem{bib243} Ken Smith, President and CEO, Evergreen Energy. Interview, 2016.
\end{thebibliography}
Conclusions for Duluth

Duluth stakeholders asked the Energy Transition Lab to identify the barriers, opportunities, and solutions for CHP in Duluth and our region. This report has summarized those and provided some specific examples of projects in other parts of the state that have been successful—despite the barriers. We show in the chart below how the two successful CHP projects, St. Paul Cogeneration and the University of Minnesota-Twin Cities compare with the two Duluth case study projects that did not go forward.

Figure 8. CHP Projects-Comparing Barriers & Opportunities

<table>
<thead>
<tr>
<th>Barriers</th>
<th>St. Paul Cogeneration</th>
<th>UMN-Twin Cities</th>
<th>St. Mary’s</th>
<th>UMN-Duluth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial capital cost</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Low electricity rates so not cost-effective</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Environmental permitting</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to financing</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Interconnection issues</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utility negotiations</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Standby Charges</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>NERC, FERC and MISO rules</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upgrades needed for existing infrastructure, adding cost</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Space Availability</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Regional competition for biomass</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Project too small for economies of scale</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Opportunities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supportive legislation</td>
<td></td>
<td>X</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Visionary leadership/“Champion”</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ability to attract investors</td>
<td></td>
<td>X</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Public entity with ability to self-finance</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Low cost fuel source</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ability to accept longer payback period</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Cost effective over life cycle</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Potential for integrated energy system</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
While the University of Minnesota-Duluth project and St. Mary’s project had some advantages, it is clear from the list above that the CHP projects that moved forward had a long list of “opportunity” attributes that helped the project succeed. The two new CHP projects in Duluth and the surrounding region currently under consideration, Duluth Energy Systems and WLSSD, have almost all of the positive assets listed above:

**Figure 9. High-Potential CHP Projects in Duluth Region**

<table>
<thead>
<tr>
<th>Opportunities/Assets</th>
<th>Duluth Energy Systems</th>
<th>WLSSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supportive legislation</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Visionary leadership/“Champion”</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Potential to attract investors</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Public entity with ability to self-finance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low cost fuel source</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ability to accept longer payback period</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cost effective over life cycle</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Potential for integrated energy system</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Timing of infrastructure replacement</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Need for additional thermal energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to use all energy produced</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ability to use existing infrastructure</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sufficient space available</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Commitments to carbon reduction</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Compatibility with renewable fuels</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Favorable carbon footprint</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Access to easy transport</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Agreement with utility</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Unique public interest component</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Need for resilient back-up power</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>

Both projects are depending upon supportive legislation to help them move forward. WLSSD needs a direct bonding appropriation. The city of Duluth needs state bonding to complete the major street and utility infrastructure that will help to make the Duluth Energy Systems upgrades more cost-effective. However, the majority of CHP plants in Minnesota were built without state funding (see map, figure 7 page 27) so that should not be taken as a prerequisite for success.

In conclusion, identifying opportunities and overcoming barriers to CHP will require potential projects to “stack” a multitude of attributes that are able to overcome obstacles. There is not one “silver bullet” but rather “silver buckshot.” In addition, much work remains to remove barriers and reform laws and policies if Minnesota wants to accelerate deployment of CHP projects.

**Looking to the Future**

For those interested in exploring CHP potential in their communities, there are useful resources and ways to help advance CHP in Minnesota. See Appendix 1 for a screening tool checklist and other technical assistance. The DOC CHP website is another key resource that is frequently updated. The DOC’s effort to support the broader deployment of CHP is ongoing and Duluth stakeholders should be an active part of those activities. Energy customers, cities, and other interested in CHP should follow and if possible, participate in the DOC’s CHP stakeholder process and updates, and in the relevant PUC dockets related to standby rates and other key issues discussed above.

The city of Duluth could consider undertaking “thermal” mapping with an overlay of economic development and building owner information. As discussed above (page 27-28), this would be a valuable way for any city to analyze its CHP potential.

The recently-released EQB state project called Climate Solutions and Economic Opportunities (CSEO) analyzed a number of policy options to evaluate their effectiveness both in meeting Minnesota’s carbon reduction goals and in creating positive economic impact. The analysis shows that increasing combined heat and power in Minnesota would cut 10% of the greenhouse gas emissions needed to meet the state’s 2030 goal, save money, and create 2,330 jobs. These policy options may be considered in the 2017 Legislative Session. Cities, campus energy managers, and CHP proponents can provide input to Legislators to help craft laws that better support the development of highly efficient energy systems like combined

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244 Minnesota Environmental Quality Board, *Climate Strategies Report* (2016), 40, accessed at [https://www.eqb.state.mn.us/content/climate-change](https://www.eqb.state.mn.us/content/climate-change). The assumption for these results is adding 800 megawatts of gas-fired CHP and 300 megawatts of biomass-fired CHP by 2030. See full analysis at Center for Climate Strategies, *Minnesota Climate Strategies and Economic Opportunities* (March 29, 2016), IV-37.
heat and power. Overcoming these obstacles will help move Minnesota forward towards modern, integrated, and highly efficient energy systems that advance our state's policy goals.

Appendix

Appendix A: Checklist for Evaluating Potential CHP Projects

The U.S. Department of Energy CHP Technical Assistance Partnerships provides an excellent resource. Their screening tool includes this checklist:

- Do you pay more than $.06/kWh on average for electricity (including generation, transmission and distribution)?
- Are you concerned about the impact of current or future energy costs on your business?
- Are you concerned about power reliability? Is there a substantial financial impact to your business if the power goes out for 1 hour? For 5 minutes?
- Does your facility operate for more than 3000 hours per year?
- Do you have thermal loads throughout the year (including steam, hot water, chilled water, hot air, etc.)?
- Does your facility have an existing central plant?
- Do you expect to replace, upgrade, or retrofit central plant equipment within the next 3-5 years?
- Do you anticipate a facility expansion or new construction project within the next 3-5 years?
- Have you already implemented energy efficiency measures and still have high energy costs?
- Are you interested in reducing your facility's impact on the environment?
- Do you have access to on-site or nearby biomass resources (i.e. landfill gas, farm manure, food processing waste, etc.)?

The Technical Assistance Partnership advises that if your proposed project can answer yes to three or more of the questions, it may be a good candidate for CHP, and the U.S. DOE Midwest CHP Technical Assistance Partnership can offer a free site screening and technical assistance for evaluating feasibility of CHP at your site.

Another important factor to consider is the need for resilient, reliable power in emergency situations. For critical infrastructure like hospitals, water treatment plants, and community centers, self-generation with the ability to “island” and provide power and heat when there is a grid failure can offer security and safety.

An older report, but still providing useful guidance, was published by Minnesota Planning. It lists several factors that are important in ensuring cogeneration will be cost effective:

245 US Department of Energy CHP Technical Assistance Partnerships: http://midwestchptap.org/support/
246 Ibid.
1) Size of thermal and power loads. The size of the load will dictate the type of technology that can be used. Remember, it is most cost effective to supply electric capacity at less than your peak demand so that your system is able to operate as much as possible at full capacity. Of course, if you are able to sell back to the grid at sufficient price, you can plan your capacity to exceed or meet your peak demand because the system will still be able to function at full capacity even if your facility does not need all of the electricity produced.

2) Thermal and Electric load factors. Equivalent Full Load Hours (EFLH) is the ratio of annual energy compared to the peak demand times 8760 (the number of hours in a year); high electric and thermal EFLH increases the feasibility of cogeneration.

3) Relatively high cost electric power resources. If other power resources (i.e., fossil fuels) are expensive, it will make alternative resources, including renewables, more cost competitive.

4) Cost-effective back up electric supply. Sometimes cogeneration may not meet all of your electric supply needs. It is important to have a cost-effective back up just in case.

5) Planned new construction or upgrades. It is best to plan cogeneration projects for new construction sites or sites in need of upgrades. These technologies are easier to incorporate with newer facilities that are likely to be more reliable and require less maintenance.

6) Relatively high-value market for excess power generation. If excess power can be sold at a sufficient price, it becomes more economical. [This section also references the federal Investment Tax Credit (ITC) and Production Tax Credits (PTC)][248]

7) Opportunity to re-dedicate cost of replacing existing thermal resources to the cost of a new cogeneration project. If the avoided costs for upgrades or replacements can be put back into the cogeneration project, the project becomes more cost effective.

8) Available and affordable fuel supply. If there is an opportunity to use lower-cost, easily accessible fuels with cogeneration as compared to current fuels used for thermal production, cogeneration presents an option to avoid higher costs.

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Glossary of Key Terms

**Topping Cycle CHP:** This is the most common type of cogeneration. Fuel is used to generate electricity or mechanical energy and a portion of the waste heat from power generation is then used to provide thermal energy. ²⁴⁹

**Bottom Cycle CHP:** During this process, waste heat from an existing process is used to produce electricity. ²⁵⁰

**Standby Charges:** “Standby rates are charged by utilities to customers with on-site, non-emergency generation (including CHP) for the service of providing backup power when on-site generation is not available. Net metering is a policy that allows customers with on-site generation to receive a bill credit for unused electricity exported to the grid during times when their generation exceeds their on-site consumption”. ²⁵¹

**Forced Outage Rate:** A measure of the probability that a generating unit will not be available due to forced outages. ²⁵²

**Reservation Charge:** A monthly charge per kW of the customer’s needed standby capacity, which cannot be avoided when standby is not taken. It ensures that standby service will be available when needed by the customer during unscheduled and scheduled outages. ²⁵³

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²⁴⁹ Center for Climate and Energy Solutions: [http://www.c2es.org/technology/factsheet/CogenerationCHP](http://www.c2es.org/technology/factsheet/CogenerationCHP)

²⁵⁰ Ibid

²⁵¹ DOC Final Action Plan at 6


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