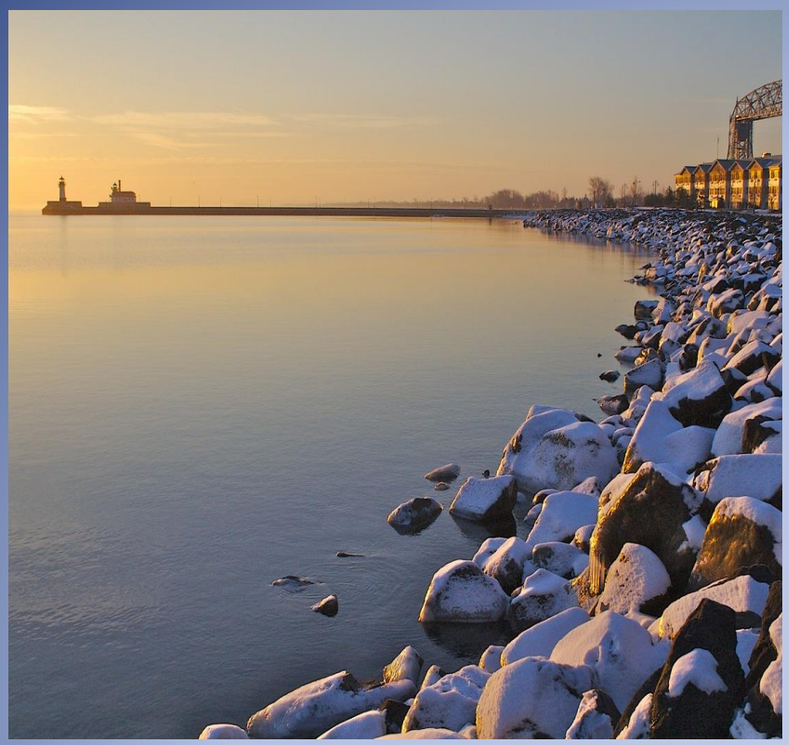

Duluth's Energy Future

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.

Energy Transition Lab

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Acknowledgements

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

We would like to thank the McKnight Foundation for their support and guidance. We would also like to thank our project research partners and co-authors:

Chapter 1: Monica Haynes, Gina Chiodi Grensing, Travis Eisenbacher, and Karen Haedtke, Bureau of Business and Economic Research, University of Minnesota-Duluth (UMD) Labovitz School of Business and Economics

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We thank our many project stakeholders and organizations who contributed data to the reports including the City of Duluth, Western Lake Superior Sanitary District, St. Mary's Hospital, University of Minnesota Duluth, Evergreen Energy, the University of Minnesota department of Energy Management, Duluth Energy Systems, Ecolibrium 3, the Great Plains Institute, Innovative Power Systems (IPS), and the Natural Resources Research Institute (NRRI).

We would also like to thank those who reviewed the reports and provided valuable comments including: Anna Dirkswager, Clean Energy Economy Minnesota; Kathryn Fernholz, Dovetail Partners; Jodi Slick and Bret Pence, Ecolibrium3; Brendan Jordan, Great Plains Institute; Pamela Kramer, Local Initiatives Support Corporation (LISC); Brendon Slotterback, McKnight Foundation; Neal Young and Kari Howe, Minnesota Department of Employment and Economic Development (MN DEED; Ken Jacobson, Minnesota Department of Natural Resources (MN DNR) Division of Forestry; Ben Bagdon, Minnesota Forest Industries (MFI); Kristopher J. Spenningsby, Minnesota Power; Jerome Malmquist, University of Minnesota, Twin Cities; Mindy Granley, University of Minnesota-Duluth; Ken Smith and Jim Green, Evergreen Energy; Marianne Bohren, WLSSD; John Rice, St. Mary's Hospital; Adam Zoet and Lise Trudeau, Minnesota Department of Commerce (DOC).

Executive Summary

On February 19, 2015 an Energy Future Charrette was led by Ecolibrium3[1] in partnership with the city of Duluth, Minnesota. The Charrette was facilitated by the Great Plains Institute[2] and the Rocky Mountain Institute[3] 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)[4] and the Energy Transition Lab (ETL).[5] 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."[6] 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.[7] 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.

ECONOMIC IMPACTS

- 1000 new jobs in the eight-county study area
- $407 million in combined economic activity in the eight-county region during construction of four biomass projects
- $54 million in additional wages, benefits, and proprietor income as well as $80 million contribution to regional GDP annually from the operation of the four biomass projects
- $2 million in additional wages and benefits, $2.2 million towards the state's GDP, and $3 million in gross during construction of the solar project in Duluth.

[8]Lifescience 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%20BioIndustrial%20Processing%20Roadmap%20-%20FULL%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.[9] Coal production emits several harmful pollutants detrimental to human health, in addition to carbon dioxide (CO_2). 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.

Chapter 2: Investigating Net-Zero Energy Potential

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

[9] Minnesota Power, *Your Electricity Your Choice*, (2016): http://www.mnpower.com/CustomerService/CostDisclosure?TargetFrame=_blank

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.[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.[11] Its economic potential in Minnesota is 948 megawatts according to a recent study. CHP works well with biomass fuel and it creates jobs.[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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[10] International Energy Agency (IEA) Information Paper, *Energy Efficiency Indicators for Public Electricity Production from Fossil Fuels*, (2008), 5.

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

[12] *Minnesota Combined Heat and Power Policies and Potential, CARD Final Report*, FVB Energy Inc., prepared for Minnesota Department of Commerce Division of Energy Resources at page xvi; also see *Assessment of the Technical and Economic Potential for CHP in Minnesota*. (2014). FVB Energy, 2, 47: http://mn.gov/commerce-stat/pdfs/chp-technical-economic-potential.pdf. For jobs data, *see* Minnesota Environmental Quality Board, *Climate Strategies Report* (2016), 40: 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* (2016), IV-37.

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 economy[14]and spur sustainable

[13] This will be included in a supplemental version of the report.

[14] Minnesota Clean Energy Profile (2014): http://www.mn.gov/deed/assets/mn_cleanenergy-economy-profile-fullreport_tcm1045-133120.pdf

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[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.[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.[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.[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.
[18] Duluth Steam Master Plan (2013): http://www.ever-greenenergy.com/wp-content/uploads/2012/10/Duluth-Master-Plan-Final_web.pdf

Bibliography

CHP in Minnesota: Baseline and Value Proposition Factsheet. (2014). Prepared by the Microgrid Institute for the Minnesota Department of Commerce Division of Energy Resources.

Duluth Steam Master Plan. (2015). Duluth Energy Systems. Retrieved from: http://www.duluthenergysystems.com/wp-content/uploads/2013/01/Duluth-Master-Plan-Final_December2013.pdf

Minnesota Clean Energy Economy Profile: How Industry Sectors are Advancing Economic Growth. (2014). Collaborative Economics Inc. Report Prepared for the Minnesota Department of Employment and Economic Development, Department of Commerce, Department of Agriculture, and Environmental Quality Board. Retrieved from: http://www.mn.gov/deed/images/mn_cleanenergy-economy-profile-fullreport.pdf

Minnesota and Climate Change: Our Tomorrow Starts Today. (2016). Minnesota Environmental Quality Board. Retrieved from: https://www.eqb.state.mn.us/sites/default/files/documents/EQB%20Climate%20Change%20Communications.pdf

Minnesota Climate Strategies and Economic Opportunities. (2016). Center for Climate Strategies. Retrieved from. http://www.climatestrategies.us/library/library/view/1186

Spurr, Mark. (2014). *Minnesota Combined Heat and Power Policies and Potential.* Prepared by FVB Energy Inc for Minnesota Department of Commerce (DOC) Division of Energy Resources. Retrieved from: http://mn.gov/commerce-stat/pdfs/CHP%20pdfs/CHPRegulatoryIssuesandPolicyEvaluation.pdf

Spurr, Mark; Anne Sampson and James Wang. (2014). Assessment of the Technical and Economic Potential for CHP in Minnesota. Prepared by FVB Energy Inc. and ICF International for the Minnesota Department of Commerce Division of Energy Resources. Retrieved from: http://mn.gov/commerce-stat/pdfs/chp-technical-economic-potential.pdf

Taylor, Peter, Olivier Lavagne d' Ortigue, Nathalie Trudeau, and Michel Francoeur. *Energy Efficiency Indicators for Public Electricity Production from Fossil Fuels.* (2008). International Energy Agency (IEA) Information Paper. Retrieved from: https://www.iea.org/publications/freepublications/publication/En_Efficiency_Indicators.pdf