2011 Project Abstract
For the Period Ending June 30, 2013

PROJECT TITLE: Supporting Community-Driven Sustainable Bioenergy Projects
PROJECT MANAGER: Kathryn Fernholz
AFFILIATION: Dovetail Partners Inc
MAILING ADDRESS: 528 Hennepin Ave, Ste 703
CITY/STATE/ZIP: Minneapolis, MN 55403
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WEBSITE: [If applicable] http://www.dovetailinc.org
FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2011, First Special Session, Chp. 2, Art.3, Sec. 2, Subd. 07

APPROPRIATION AMOUNT: $150,000

Overall Project Outcome and Results

This project helps guide development of sustainable community-scale forest bioenergy programs in Northeast Minnesota and provides examples from the region to assist communities statewide considering similar projects. Locally produced, community-based renewable energy systems hold significant promise for increasing energy security, reducing carbon emissions, and contributing to local economies. The goals of this project were to develop and share information and tools that address key questions about the viability of community bioenergy systems. During the first phase, existing models and planning tools were adapted to evaluate feasibility, impacts, and management needs for community-scale and other small bioenergy applications being proposed in Ely and Cook County. During the second phase of the project, the information and tools developed in Ely and Cook County were shared with communities, land managers, policymakers, investors, and others interested in the long-term prospects and viability of locally produced bioenergy. The results of the project indicate that there are abundant potential biomass supplies that could meet the needs of the community-scaled biomass energy projects being considered. The financial analysis illustrates that a number of the projects being considered have reasonable potential payback periods and other positive indications of financial feasibility. The environmental review reports summarize major considerations that were identified in interviews with local stakeholders and provide information about the mitigations that are in place to manage risk (e.g., Minnesota's use of biomass harvesting guidelines, third-party forest certification and ecological monitoring). At this time, the community of Ely is considering options for moving forward with a biomass system or systems that could serve the community college, hospital, school and/or other facilities. The community of Grand Marais has completed additional engineering analysis for a potential district heating system that could serve a number of public buildings and private businesses that represent the major potential customers for the system.

Project Results Use and Dissemination

The study team has prepared and made publicly available the final reports and fact sheets from the project that address the estimates of available fuel supplies for biomass facilities in Ely and Cook County and evaluations of potential environmental impacts and available mitigations. An additional report, "Community-Driven Biomass Energy Opportunities – A Northern Minnesota Case Study" has been prepared and made publicly available. The report highlights the findings from the projects and also describes the approach and community-driven structure of the project, conclusions and recommendations that can assist other communities facing similar

questions and decisions about renewable energy. The fact sheets, complete reports and the executive summary report are available at the project website (http://www.dovetailinc.org/content/lccmr-supporting-community-driven-sustainable-bioenergy-projects).

Community meetings were held in Grand Marais and Ely throughout the project to engage community input and present project findings to community members. Presentations about the project have been made to the Minnesota Forest Resources Council, Minnesota Forest Resources Partnership, and attendees of the Heating the Midwest Conference held in Carlton, Minnesota.

Project information, products and results have been shared through the webpages that have been maintained throughout the project. These pages have shared the fact sheets, reports, and materials distributed at public meetings (e.g., presentation slides). News releases have also been distributed during the project, including radio interviews and newspaper articles in Ely and Grand Marais as well as statewide media engagement (e.g., Midwest Energy News). The activities of the project also included meetings with diverse partner groups, including staff of CERTs, landowner and land managers, loggers and forest product industry representatives, environmental and conservation organizations, local residents and other Minnesota citizens.

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2011 Work Plan Final Report

Date of Status Update: 6/30/2013
Date of Next Status Update: Final Report
Date of Work Plan Approval: 6/23/2011
Project Completion Date: 6/30/2014 **Is this an amendment request?** __No___

Project Title: Supporting Community-Driven Sustainable Bioenergy Projects

Project Manager: Kathryn Fernholz
Affiliation: Dovetail Partners Inc
Address: 528 Hennepin Ave, Ste 703
City: Minneapolis **State:** MN **Zipcode:** 55403

Telephone Number: (612) 333-0430
Email Address: katie@dovetailinc.org
Web Address: http://www.dovetailinc.org

Location:

Counties Impacted: Statewide

Ecological Section Impacted: Lake Agassiz Aspen Parklands (223N), Minnesota and Northeast Iowa Morainal (222M), North Central Glaciated Plains (251B), Northern Minnesota and Ontario Peatlands (212M), Northern Minnesota Drift and lake Plains (212N), Northern Superior Uplands (212L), Paleozoic Plateau (222L), Red River Valley (251A), Southern Superior Uplands (212J), Western Superior Uplands (212K)

Total ENRTF Project Budget:		
	ENRTF Appropriation $:	150,000.00
	Amount Spent $:	150,000.00
	Balance $:	0

Legal Citation: M.L. 2011, First Special Session, Chp. 2, Art.3, Sec. 2, Subd. 07

Appropriation Language:
$75,000 the first year and $75,000 the second year are from the trust fund to the commissioner of natural resources for an agreement with Dovetail Partners, Inc., in cooperation with the University of Minnesota to assess feasibility, impacts, and management needs of community-scale forest bioenergy systems through pilot studies in Ely and Cook County and to disseminate findings to inform related efforts in other communities.

I. PROJECT TITLE: Supporting Community-Driven Sustainable Bioenergy Projects

II. FINAL PROJECT SUMMARY: This project helps guide development of sustainable community-scale forest bioenergy programs in Northeast Minnesota and provides examples from the region to assist communities statewide considering similar projects. Locally produced, community-based renewable energy systems hold significant promise for increasing energy security, reducing carbon emissions, and contributing to local economies. The goals of this project were to develop and share information and tools that address key questions about the viability of community bioenergy systems. During the first phase, existing models and planning tools were adapted to evaluate feasibility, impacts, and management needs for community-scale and other small bioenergy applications being proposed in Ely and Cook County. During the second phase of the project, the information and tools developed in Ely and Cook County were shared with communities, land managers, policymakers, investors, and others interested in the long-term prospects and viability of locally produced bioenergy. The results of the project indicate that there are abundant potential biomass supplies that could meet the needs of the community-scaled biomass energy projects being considered. The financial analysis illustrates that a number of the projects being considered have reasonable potential payback periods and other positive indications of financial feasibility. The environmental review reports summarize major considerations that were identified in interviews with local stakeholders and provide information about the mitigations that are in place to manage risk (e.g., Minnesota's use of biomass harvesting guidelines, third-party forest certification and ecological monitoring). At this time, the community of Ely is considering options for moving forward with a biomass system or systems that could serve the community college, hospital, school and/or other facilities. The community of Grand Marais has completed additional engineering analysis for a potential district heating system that could serve a number of public buildings and private businesses that represent the major potential customers for the system.

The study team has prepared and made publicly available the final reports and fact sheets from the project that address the estimates of available fuel supplies for biomass facilities in Ely and Cook County and evaluations of potential environmental impacts and available mitigations. An additional report, "Community-Driven Biomass Energy Opportunities – A Northern Minnesota Case Study" has been prepared and made publicly available. The report highlights the findings from the projects and also describes the approach and community-driven structure of the project, conclusions and recommendations that can assist other communities facing similar questions and decisions about renewable energy. The fact sheets, complete reports and the executive summary report are available at the project website (http://www.dovetailinc.org/content/lccmr-supporting-community-driven-sustainable-bioenergy-projects).

Community meetings were held in Grand Marais and Ely throughout the project to engage community input and present project findings to community members. Presentations about the project have been made to the Minnesota Forest Resources Council, Minnesota Forest Resources Partnership, and attendees of the Heating the Midwest Conference held in Carlton, Minnesota.

Project information, products and results have been shared through the webpages that have been maintained throughout the project. These pages have shared the fact sheets, reports, and materials distributed at public meetings (e.g., presentation slides). News releases have also been distributed during the project, including radio interviews and newspaper articles in Ely and Grand Marais as well as statewide media engagement (e.g., Midwest Energy News). The activities of the project also included meetings with diverse partner groups, including staff of CERTs, landowner and land managers, loggers and forest product industry representatives, environmental and conservation organizations, local residents and other Minnesota citizens.

III. PROJECT STATUS UPDATES:

Project Status as of January 10, 2012 (*First Status Update Report)*: Local coordinators have been contracted in Cook County (Gary Atwood) and Ely (Gloria Erickson) to support the project (Activity 1, Outcome 1). Local steering committees and stakeholder advisory groups have been organized in Ely and Cook County. Visits have been made to the study area in August, October and November 2011, including meetings with project stakeholders (Activity 1, Outcome 1). Research assistants have been hired to develop supply and financial models (Activity 1, Outcome 2).
Project related webpages (http://www.dovetailinc.org/content/lccmr-supporting-community-driven-sustainable-bioenergy-projects) have been established to support access to project information (Activity 2, Outcome 2). An update about the project was provided to the Minnesota Forest Resources Partnership (MFRP) on December 15, 2011 (Dissemination).

Project Status as of August 20, 2012 (Second Status Report): The project activities between January and August 2012 have focused on completing the estimates of available fuel supplies for biomass facilities in Ely and Cook County and evaluations of potential environmental impacts and available mitigations. Preliminary findings indicate that there are abundant potential biomass supplies that could meet the needs of the community-scaled biomass energy projects that are being considered. Preliminary financial analysis also illustrates that a number of the projects being considered have reasonable potential payback periods and other positive indications of financial feasibility. The project team has been involved with a number of meetings in the project area to support engagement with community members, various segments of the forest industry, and public land managers. Specific Activities and Outcomes during this period include:

- Community meetings were held in Ely on February 9, 2012 (Activity 1, Outcome 1). The Cook County local coordinator was involved with extensive outreach to community members in Cook County via Township meetings and other events in January 2012 (Activity 1, Outcome 1).
- The environmental review by Dovetail Partners (Activity 1, Outcome 4) and supply and financial modeling by U of MN (Activity 1, Outcome 2) are nearing completion.
- Meetings were held with land managers and harvest operators on June 6th and 7th in Duluth and Eveleth (Activity 1, Outcome 1) to review preliminary supply and demand analysis (Activity 1, Outcome 3).
- The environmental analysis component of the project includes review of available life cycle assessment research and data (Activity 1, Outcome 4) and the preliminary findings were included in a presentation at community meetings held in Ely and Grand Marias on July 9th and 10th (Activity 1, Outcome 1).
- A presentation about the project was made at a Minnesota Logger Education Program (MLEP) workshop on July 10th (Activity 1, Outcome 1).
- The project team collaborated with the Minnesota Forest Resources Council (MFRC) to develop a fact sheet that provides an overview of Minnesota's biomass harvesting guidelines (Activity 2, Outcome 1).
- The biomass harvesting guidelines factsheet is available at the project webpage and is being used to provide information about impacts of locally produced community bioenergy (Activity 2, Outcome 2). The factsheet can be downloaded at the Dovetail Partners website: http://www.dovetailinc.org/files/BiomassHarvestingFactSheet0412.pdf (Activity 2, Outcomes 2).
- The biomass harvesting guidelines factsheet has been promoted through the website, news release, newsletter, and land manager meetings (Dissemination). The news release about the fact sheet is available at: http://www.dovetailinc.org/content/protecting-minnesotas-forests-while-utilizing-biomass-resources (Dissemination).

Project Status as of January 23, 2013 *(Third Status Update Report)***:** The project activities between August 2012 and January 2013 have focused on preparing the final reports addressing the estimates of available fuel supplies for biomass facilities in Ely and Cook County and evaluations of potential environmental impacts and available mitigations. The reports indicate that there are abundant potential biomass supplies that could meet the needs of the community-scaled biomass energy projects that are being considered. The financial analysis illustrates that a number of the projects being considered have

reasonable potential payback periods and other positive indications of financial feasibility. The environmental review reports summarize major considerations that were identified in interviews with local stakeholders and provide information about the mitigations that are in place to manage risk (e.g., Minnesota's use of biomass harvesting guidelines, third-party forest certification and ecological monitoring). Fact sheets were prepared to summarize the major findings and help communicate the project outcomes to members of the community and other stakeholders. The fact sheets, complete reports and the executive summary report are available at the project website (http://www.dovetailinc.org/content/lccmr-supporting-community-driven-sustainable-bioenergy-projects). Community meetings were held in Grand Marais and Ely in December 2012 to present the report findings. Following the delivery of the final reports at the public meetings, the community of Ely is considering options for moving forward with a biomass system or systems that could serve the community college, hospital, school and/or other facilities. The community of Grand Marais has engaged in further engineering analysis for a potential district heating system that could serve a number of public buildings and private businesses that represent the major potential customers for the system. Specific Activities and Outcomes during this period include:

- Project update presented to the Minnesota Forest Resources Council on September 19th (Activity 1, Outcome 1 and Dissemination)
- Completion of the physical supply and financial models for assessing locally sourced biomass (Activity 1, Outcome 2)
- Completion of the report on results of model in Ely and Cook County, with identification of financial arrangements of alternative energy technologies in these communities (Activity 1, Outcome 3)
- Completion of the review and reporting of life cycle and environmental impacts of locally-sourced bioenergy systems (Activity 1, Outcome 4)
- Development of fact sheets summarizing the report findings addressing community bioenergy systems and impacts (Activity 2, Outcome 1)
- Delivery of the final reports at public meetings (Grand Marais – Dec. 11, 2012; Ely – Dec 12, 2012) (Activity 1, Outcome 1)
- Dissemination of the fact sheets, project reports and meeting presentation via posting online at the project website (http://www.dovetailinc.org/content/lccmr-supporting-community-driven-sustainable-bioenergy-projects) as well as posting by the City of Ely and the Cook County Local Energy Project at their website. (Activity 2, Outcome 2)
- Coverage of the project in a Midwest Energy News article on January 15, 2013 (Beyond the Reach of Natural Gas Boom, Minnesota Towns Look to Biomass, Midwest Energy News January 15, 2013, http://www.midwestenergynews.com/2013/01/15/beyond-the-reach-of-natural-gas-boom-minnesota-towns-look-to-biomass/) (Activity 2, Outcome 2)

Project Status as of June 30, 2013 *(Fourth Status Update Report)***:**
As of June 30, 2013, the work for the project is complete. The project activities between January 2013 and July 2013 have focused on sharing the results of the project beyond the participating communities (i.e., dissemination). The study team has also prepared and made publicly available the final reports and fact sheets (as described in the previous update) addressing the estimates of available fuel supplies for biomass facilities in Ely and Cook County and evaluations of potential environmental impacts and available mitigations. An additional report, "Community-Driven Biomass Energy Opportunities – A Northern Minnesota Case Study" has been prepared and made publicly available. The target audience for this report are interested parties, stakeholders and decision-makers outside of the participating communities (e.g., other Northern Minnesota communities). The report highlights the findings from the projects and also describes the approach and community-driven structure of the project, conclusions and recommendations that can assist other communities facing similar questions and decisions about renewable energy. This report is currently available at the Dovetail website. At this time, the community of Ely is considering options for moving forward with a biomass system or systems that could serve the community college, hospital, school and/or other facilities. The community of Grand Marais has completed additional engineering analysis for a potential district heating system that could serve a number of public buildings and private businesses that represent the major potential customers for the system. Specific Activities and Outcomes during this period include:

- Project News Release (2/20/13) “Northern Minnesota Project Offers Insights on Community-Driven Sustainable Bioenergy” http://www.dovetailinc.org/content/northern-minnesota-project-offers-insights-community-driven-sustainable-bioenergy (Activity 2, Outcome 2)
- Presentation of project results at “Heating the Midwest” conference in Carlton, MN on April 26th, 2013 (Activity 2, Outcome 2)
- Final Project results and reports posted at website June 2013 (Activity 2, Outcome 2) (http://www.dovetailinc.org/files/DovetailCommunityBioEnergy0613.pdf)
- Meeting with environmental organization representatives and stakeholders on June 5th, 2013 to share project results and outcomes (Activity 2, Outcome 2)
- Presentation of project outcomes to Minnesota Forest Resources Partnership (MFRP) on June 20th, 2013 (Activity 2, Outcome 2)

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Assess feasibility and impacts of forest biomass energy in Ely and Cook County

Description: The project will be initiated through community meetings to ensure strong teamwork and broad communication. The UMN research group will adapt existing models to localized fuelsheds to estimate current and future forest biomass feedstocks under a variety of forest management scenarios and supply targets and will be used to forecast changes in forest carbon stocks resulting from forest type restoration, firewise treatments, and other practices. Biomass supplies at specified price and policy levels will be estimated. Costs and financial arrangements needed to supply energy under a number of heat and power scenarios will be analyzed. Dovetail Partners will review available information regarding the life cycle impacts (i.e., harvest, use, disposal, transportation, etc.) of alternative energy systems and report on environmental impacts (i.e., carbon emissions, sequestration, air quality, water quality, biodiversity, wildfire) of different systems and management scenarios. Community coordinators and the project team will meet and communicate regularly with key community groups (residents, businesses, officials, timber industry, public forest managers, etc.) to address issues related to forest management, biomass feedstocks, spatial scale, and the supply chain. Activity 1 will be evaluated through interviews and surveys.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 133,375.00
Amount Spent: $ 133,375.00
Balance: $ 0

Activity Completion Date:

Outcome	Completion Date	Budget
1. Informed input gathered from community leadership and stakeholders on community bioenergy issues through meetings, surveys, and newsletters.	December 2012	$48,560
2. Physical supply and financial models for assessing locally sourced biomass.	September 2012	$33,000
3. Report on results of model in Ely and Cook County, with identification of financial arrangements of alternative energy technologies in these communities.	December 2012	$33,000
4. Review of life cycle and environmental impacts of locally-sourced bioenergy systems	January 2013	$18,815

Activity Status as of January 10, 2012 (*First Update Report)*: Local coordinators have been contracted in Cook County (Gary Atwood) and Ely (Gloria Erickson) to support the project (Activity 1,

Outcome 1). Local steering committees and stakeholder advisory groups have been organized in Ely and Cook County. Visits have been made to the study area in August, October and November 2011, including meetings with project stakeholders (Activity 1, Outcome 1). Research assistants have been hired to develop supply and financial models (Activity 1, Outcome 2).

Activity Status as of August 20, 2012 (Second Report): Specific Activities and Outcomes during this period include:

- Community meetings were held in Ely on February 9, 2012 (Activity 1, Outcome 1). The Cook County local coordinator was involved with extensive outreach to community members in Cook County via Township meetings and other events in January 2012 (Activity 1, Outcome 1).
- The environmental review by Dovetail Partners (Activity 1, Outcome 4) and supply and financial modeling by U of MN (Activity 1, Outcome 2) are nearing completion.
- Meetings were held with land managers and harvest operators on June 6th and 7th in Duluth and Eveleth (Activity 1, Outcome 1) to review preliminary supply and demand analysis (Activity 1, Outcome 3).
- The environmental analysis component of the project includes review of available life cycle assessment research and data (Activity 1, Outcome 4) and the preliminary findings were included in a presentation at community meetings held in Ely and Grand Marias on July 9th and 10th (Activity 1, Outcome 1).
- A presentation about the project was made at a Minnesota Logger Education Program (MLEP) workshop on July 10th (Activity 1, Outcome 1).

Activity Status as of January 23, 2013 *(Third Update Report)***:** Specific Activities and Outcomes during this period include:

- Project update presented to the Minnesota Forest Resources Council on September 19th (Activity 1, Outcome 1)
- Completion of the physical supply and financial models for assessing locally sourced biomass (Activity 1, Outcome 2)
- Completion of the report on results of model in Ely and Cook County, with identification of financial arrangements of alternative energy technologies in these communities (Activity 1, Outcome 3)
- Completion of the review and reporting of life cycle and environmental impacts of locally-sourced bioenergy systems (Activity 1, Outcome 4)
- Delivery of the final reports at public meetings (Grand Marais – Dec. 11, 2012; Ely – Dec 12, 2012) (Activity 1, Outcome 1)

Activity Status as of June 30, 2013 *(Fourth Update Report)***:**

- Final Project results and reports posted at website June 2013 (Activity 2, Outcome 2) (http://www.dovetailinc.org/files/DovetailCommunityBioEnergy0613.pdf)

Final Report Summary:

The final reports addressing the estimates of available fuel supplies for biomass facilities in Ely and Cook County and evaluations of potential environmental impacts and available mitigations indicate that there are abundant potential biomass supplies that could meet the needs of the community-scaled biomass energy projects that are being considered. The financial analysis illustrates that a number of the projects being considered have reasonable potential payback periods and other positive indications of financial feasibility. The environmental review reports summarize major considerations that were identified in interviews with local stakeholders and provide information about the mitigations that are in place to manage risk (e.g., Minnesota's use of biomass harvesting guidelines, third-party forest certification and ecological monitoring). At this time, the community of Ely is considering options for moving forward with a biomass system or systems that could serve the community college, hospital, school and/or other facilities. The community of Grand Marais has completed additional engineering analysis for a potential district heating system that could serve a number of public buildings and private businesses that represent the major potential customers for the system.

ACTIVITY 2: Broadly disseminate case studies and decision tools

Description: We will share the expertise, tools, and knowledge gained in this project to accelerate learning in other rural communities and among land managers and policymakers. Our team will produce useful information, including models, inventory protocols, analytical matrices, and fact sheets needed in assessing the physical and economic feasibility of locally produced community bioenergy systems and their impacts. We will make the results of the project and information about Ely and Cook County case studies available online and through a variety of outlets (e.g. community and/pr conference presentations). Evaluation by key groups at mid-point and conclusion.

Summary Budget Information for Activity 2:

ENRTF Budget: $ 16,625
Amount Spent: $ 16,625
Balance: $ 0

Activity Completion Date:

Outcome	Completion Date	Budget
1. User-friendly decision tools and fact sheets on community bioenergy systems and impacts	June 2013	$ 6,185
2. Dissemination online and presentations	June 2013	$ 10,440

Activity Status as of January 10, 2012 (*First Update Report)*: Project related webpages (http://www.dovetailinc.org/content/lccmr-supporting-community-driven-sustainable-bioenergy-projects) have been established to support access to project information (Activity 2, Outcome 2).

Activity Status as of August 20, 2012 (Second Report): Specific Activities and Outcomes during this period include:

- The project team collaborated with the Minnesota Forest Resources Council (MFRC) to develop a fact sheet that provides an overview of Minnesota's biomass harvesting guidelines (Activity 2, Outcome 1).
- The biomass harvesting guidelines factsheet is available at the project webpage and is being used to provide information about impacts of locally produced community bioenergy (Activity 2, Outcome 2). The factsheet can be downloaded at the Dovetail Partners website: http://www.dovetailinc.org/files/BiomassHarvestingFactSheet0412.pdf (Activity 2, Outcomes 2).

Activity Status as of January 23, 2013 *(Third Update Report)***:** Specific Activities and Outcomes during this period include:

- Development of fact sheets summarizing the report findings addressing community bioenergy systems and impacts (Activity 2, Outcome 1)
- Dissemination of the fact sheets, project reports and meeting presentations via posting online at the project website (http://www.dovetailinc.org/content/lccmr-supporting-community-driven-sustainable-bioenergy-projects) as well as posting by the City of Ely and the Cook County Local Energy Project at their website. (Activity 2, Outcome 2)
- Coverage of the project in a Midwest Energy News article on January 15, 2013 (Beyond the Reach of Natural Gas Boom, Minnesota Towns Look to Biomass, Midwest Energy News January 15, 2013, http://www.midwestenergynews.com/2013/01/15/beyond-the-reach-of-natural-gas-boom-minnesota-towns-look-to-biomass/) (Activity 2, Outcome 2)

Activity Status as of June 30, 2013 *(Fourth Update Report)*:

- Project News Release (2/20/13) "Northern Minnesota Project Offers Insights on Community-Driven Sustainable Bioenergy" http://www.dovetailinc.org/content/northern-minnesota-project-offers-insights-community-driven-sustainable-bioenergy (Activity 2, Outcome 2)
- Presentation of project results at "Heating the Midwest" conference in Carlton, MN on April 26th, 2013 (Activity 2, Outcome 2)
- Final Project results and reports posted at website June 2013 (Activity 2, Outcome 2) (http://www.dovetailinc.org/files/DovetailCommunityBioEnergy0613.pdf)
- Meeting with environmental organization representatives and stakeholders on June 5th, 2013 to share project results and outcomes (Activity 2, Outcome 2)
- Presentation of project outcomes to Minnesota Forest Resources Partnership (MFRP) on June 20th, 2013 (Activity 2, Outcome 2)

Final Report Summary:

Fact sheets were prepared to summarize the major findings and help communicate the project outcomes to members of the community and other stakeholders. The fact sheets, complete reports and the executive summary report are available at the project website (http://www.dovetailinc.org/content/lccmr-supporting-community-driven-sustainable-bioenergy-projects). Community meetings were held in Grand Marais and Ely in December 2012 to present the report findings. An additional report, "Community-Driven Biomass Energy Opportunities – A Northern Minnesota Case Study" has been prepared and made publicly available. The target audience for this report are interested parties, stakeholders and decision-makers outside of the participating communities (e.g., other Northern Minnesota communities). The report highlights the findings from the projects and also describes the approach and community-driven structure of the project, conclusions and recommendations that can assist other communities facing similar questions and decisions about renewable energy. This report is currently available at the Dovetail website. Presentations about the project have been made to the Minnesota Forest Resources Council, Minnesota Forest Resources Partnership, and attendees of the Heating the Midwest Conference held in Carlton, Minnesota. Meetings have also been held with environmental organizations and stakeholders to share the outcomes of the project.

V. DISSEMINATION:

Description: We will regularly disseminate project information, products, and results through a website (http://www.dovetailinc.org/). Products will include models and other tools for evaluating local biomass energy resources, costs, impacts, and social acceptance. We will make presentations and/or information available to partner groups (e.g., Firewise, Minnesota Forest Resource Council, Clean Energy Resource Teams (CERTs), and to other key sectors, including county land departments, forest products industry and logging contractors, environmental and conservation organizations, and public and private forest landowners. We will also report the outcome of this project to state policymakers and others interested in the role of community-scale bioenergy in reducing the state's greenhouse gas emissions.

Status as of January 10, 2012 (*First Update Report)*: Project related webpages (http://www.dovetailinc.org/content/lccmr-supporting-community-driven-sustainable-bioenergy-projects) have been established to support access to project information (Activity 2, Outcome 2). An update about the project was provided to the Minnesota Forest Resources Partnership (MFRP) on December 15, 2011 (Dissemination).

Status as of August 20, 2012 (Second Report): Specific Activities and Outcomes during this period include:

- The biomass harvesting guidelines factsheet has been promoted through the website, news release, newsletter, and land manager meetings (Dissemination). The news release about the fact

sheet is available at: http://www.dovetailinc.org/content/protecting-minnesotas-forests-while-utilizing-biomass-resources (Dissemination).

Status as of January 23, 2013 *(Third Update Report)***:** Specific Activities and Outcomes during this period include:

- Project update presented to the Minnesota Forest Resources Council on September 19th (Activity 1, Outcome 1 and Dissemination)
- Dissemination of the fact sheets, project reports and meeting presentations via posting online at the project website (http://www.dovetailinc.org/content/lccmr-supporting-community-driven-sustainable-bioenergy-projects) as well as posting by the City of Ely and the Cook County Local Energy Project at their website. (Dissemination)

Status as of June 30, 2013 *(Fourth Update Report)***:**

- Project News Release (2/20/13) "Northern Minnesota Project Offers Insights on Community-Driven Sustainable Bioenergy" http://www.dovetailinc.org/content/northern-minnesota-project-offers-insights-community-driven-sustainable-bioenergy (Activity 2, Outcome 2)
- Final Project results and reports posted at website June 2013 (Activity 2, Outcome 2) (http://www.dovetailinc.org/files/DovetailCommunityBioEnergy0613.pdf)

Final Report Summary:

Project information, products and results have been shared through the webpages that have been maintained throughout the project. These pages have shared the fact sheets, reports, and materials distributed at public meetings (e.g., presentation slides). News releases have also been distributed during the project, including radio interviews and newspaper articles in Ely and Grand Marais as well as statewide media engagement (e.g., Midwest Energy News). The activities of the project also included meetings with diverse partner groups, including staff of CERTs, landowner and land managers, loggers and forest product industry representatives, environmental and conservation organizations, local residents and other Minnesota citizens.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget:

Budget Category	$ Amount	Explanation
Personnel:	$ 6,500	Matt Frank, 15%FTE to provide technical support for online dissemination and project activities.
Professional/Technical Contracts:	$ 7,500	Jim Bowyer – Review life cycle impacts of identified bioenergy systems.
	$ 7,500	Steve Bratkovich – Summarize environmental impacts and guidance for biomass harvest.
	$ 25,000	Cheryl Miller - Provide overall project management, including coordinating and overseeing activities, timelines, and products. Produce materials and make presentations during dissemination phase.
	$ 60,000	University of Minnesota – Adapt statewide models for local biomass estimates and costs, conduct assessments. Dennis Becker, Steven Taff, and graduate students will conduct work in contract.
	$ 40,000	Local coordinators in Ely and Cook County to conduct outreach effort, gather and present local information on biomass energy issues. *Specific contractors to be determined.*
Travel Expenses in MN:	$ 3,500	To cover expenses of project team travel to Ely and Cook County over two year grant period
TOTAL ENRTF BUDGET:	**$ 150,000**	

Explanation of Use of Classified Staff: Not Applicable

Explanation of Capital Expenditures Greater Than $3,500: Not Applicable

Number of Full-time Equivalent (FTE) funded with this ENRTF appropriation: 1.25

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
Cook County	$ 113,500	$	To conduct preliminary feasibility of alternative bioenergy technologies from 2010-2012
State			
CURA/CAP Student Research Assistant	$4,440		Summer 2011 research assistance
TOTAL OTHER FUNDS:	**$ 117,900**	**$**	

VII. PROJECT STRATEGY:

A. Project Partners: The main partners in this project are the City of Ely and its Alternative Energy Taskforce (Kurt Soderberg) and Cook County and its Cook County Local Energy Project (George Wilkes). These partners will be providing in-kind support to the project including expenditures for room rental, volunteer time, and materials at quarterly meetings and reports estimated to total $6,800 per community for a total of $13,600 during the project. Dovetail Partners will also be providing in-kind support to the project, including staff time and office resources estimated to total at least $15,000. Other organizational partners are Firewise (Paul Nelson), Minnesota Forest Resources Council (Lindberg Ekola), CERTs (Bill Mittlefehldt), and the US Forest Service (Patricia Johnson). None of these partners will receive money from the appropriation.

B. Project Impact and Long-term Strategy:

C. Spending History:

Funding Source	**M.L. 2005 or FY 2006-07**	**M.L. 2007 or FY 2008**	**M.L. 2008 or FY 2009**	**M.L. 2009 or FY 2010**	**M.L. 2010 or FY 2011**
City of Ely			$1000		
Iron Range Resources			$4000		
Blandin Foundation			$5000		
CERTS				$5000	
MN Office of Energy Security (ARRA)				$50,000	
Cook County			$2500		
Cook County Hospital			$2500		
City of Grand Marais			$2500		

VIII. ACQUISITION/RESTORATION LIST: Not Applicable

IX. MAP(S): See Attached

X. RESEARCH ADDENDUM: Not Applicable

XI. REPORTING REQUIREMENTS:
Periodic work plan status update reports will be submitted not later than January 31, 2012, September 30, 2012, and January 31, 2013. A final report and associated products will be submitted between June 30 and August 1, 2013 as requested by the LCCMR.

Final Attachment A: Budget Detail for M.L. 2011 (FY 2012-13) Environment and Natural Resources Trust Fund Projects

Project Title: *Supporting Community-Driven Sustainable Bioenergy Projects*
Legal Citation: Article 4, Section 2, Subd. 7a
Project Manager: *Kathryn Fernholz*
M.L. 2011 (FY 2012-13) ENRTF Appropriation: $ *$150,000*
Project Length and Completion Date: 2 years, *June 30, 2013*
Date of Update: *June 24, 2013*

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Balance	Activity 2 Budget	Amount Spent	Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	***Assess biomass availability and costs***			***Life cycle analysis and environmental***				
Personnel (Wages and Benefits) Matt Frank, 15% FTE to provide technical services for online dissemination and project activities	$0.00	$0.00	$0.00	$6,500.00	$6,500.00	$0.00	$6,500.00	$0.00
Professional/Technical Contracts Jim Bowyer. Review life cycle impacts of identified bioenergy systems.	$7,500.00	$7,500.00	$0.00	$0.00	$0.00	$0.00	$7,500.00	$0.00
Steve Bratkovich. Summarize environmental impacts and guidance for biomass harvest.	$7,500.00	$7,500.00	$0.00	$0.00	$0.00	$0.00	$7,500.00	$0.00
Cheryl Miller. To provide overall project coordination and on-ground management of project activities, timelines, and products. To produce materials and make presentation for dissemination.	$15,815.00	$15,815.00	$0.00	$9,185.00	$9,185.00	$0.00	$25,000.00	$0.00
University of Minnesota. Adapt existing models for use in forecasting biomass availability and costs, conduct assessments in Ely and Cook County. Dennis Becker and Steven Taff and graduate students will conduct work under this contract.	$60,000.00	$60,000.00	$0.00	$0.00	$0.00	$0.00	$60,000.00	$0.00
Unspecified contractors. To conduct outreach activities in Ely and Cook County. Contractors to be seleted by the communities through an application and interview process.	$40,000.00	$40,000.00	$0.00	$0.00	$0.00	$0.00	$40,000.00	$0.00
Travel expenses in Minnesota Mileage, lodging, food	$2,560.00	$2,560.00	$0.00	$940.00	$940.00	$0.00	$3,500.00	$0.00
COLUMN TOTAL	$133,375.00	$133,375.00	$0.00	$16,625.00	$16,625.00	$0.00	$150,000.00	$0.00

Emissions and biomass energy in Northeast Minnesota

Air quality impacts of biomass energy

Using locally-grown forest biomass for energy is of growing interest in northern Minnesota because of its potential to increase energy independence, lower carbon dioxide in the atmosphere, and reduce buildup of fire-prone materials in forests. This fact sheet focuses on expected air emissions of bio-energy projects being considered in Ely, Minnesota. It is part of a larger study on the feasibility, impacts, and social support for converting from fossil fuels to forest biomass energy. Other fact sheets in this series describe technical and economic aspects of biomass combustion systems, their wood fuel demands and local supplies, and the environmental impact of biomass harvest. A full report of the study by Dovetail Partners will be available in December, 2012.

Air emissions of energy production

All energy production – whether from fossil fuel sources (petroleum, coal, and natural gas) or non-fossil sources (hydroelectric, nuclear, geothermal, solar, wind, wood, and waste) – impacts air and the larger environment. Air emissions can be categorized as direct (on-site emissions produced at the power station) or as indirect (covering all emissions generated throughout the entire life cycle of energy production and use). Sorting out the overall impact of a given energy system is challenging, involving different fuel types, equipment, pollution controls, and other factors. Per unit of energy, forest biomass energy generates lower emissions than fossil fuels of some air pollutants, and higher levels of others. Locally harvested wood energy does have an advantage in avoiding emissions and environmental impacts associated with activities like offshore drilling, fracking, oil-shale mining, and international transportation systems. Widespread air pollutants are produced by burning fuels are summarized in Table 1.

Direct Emissions

Combustion is the largest source of emissions in the energy production process. Direct, on-site emissions are determined by fuels used, production equipment, and pollution controls.

- **Fuels:** Clean, dry wood fuels deliver superior energy efficiency and are environmentally better than dirty, wet fuels. Emissions are especially dependent on moisture content and percentage of bark. Overall, uniformly-sized fuels provide greater heating value, more uniform burning, lower emissions, and less need for boiler maintenance than wet, dirty, non-uniform fuels[1].
- **Production equipment:** Modern, high-efficiency equipment and optimal size are crucial factors in controlling combustion emissions. For residential scale systems, EPA-certified wood stoves emit 70 percent less particle pollution and are approximately 50 percent more efficient than wood stoves manufactured before 1990[2]. Larger, district heating systems should focus on high-density areas (high energy demand and short piping distances) and use automatic rather than manually-fed boiler systems. Balancing all factors, the largest scale does not necessarily translate to lowest environmental impact. Instead, systems engineered to optimize energy use density and energy transport distance have been found to have the lowest overall impact.
- **Pollution control**: Technologies are available that significantly reduce hazardous emissions. For instance, electrostatic precipitators reduce particulate emissions from combustion of wet forest residue to 13% of uncontrolled emissions, significantly below other wood fuels. Similar devices used with dry fuels can likewise substantially reduce particulate emissions.

Stationary sources of air pollution are regulated by Minnesota Pollution Control Agency under the federal Clean Air Act. Major facilities with a potential to emit (PTE) more than certain threshold amounts of any regulated pollutant must obtain an individual air quality permit. Facilities with emissions below these standard thresh-

Published December 2012

Table 1. Air pollutants produced during the combustion of fuels.

Sulfur dioxide (SO_2)	Acidic gas formed primarily by coal, oil, and diesel combustion. Contributes to fine particulate pollution and acid rain, which can damage lakes, buildings, and plants. High concentrations can affect breathing, cause respiratory illnesses, and aggravate existing cardiovascular diseases.
Nitrogen oxides (NO_X)	Acidic gases (nitrogen dioxide, nitrous acid, and nitric acid) produced by burning fuels at high temperatures (motor vehicles and stationary combustion sources such as electric utilities and industrial boilers). Contributes to ozone and acid rain and adversely impacts respiratory system.
Particulate matter (PM)	Very fine particles, including dust and smoke formed when coal, wood, or oil are burned. Airborne particles can cause haze and lower visibility and the smallest sizes, including PM10, are considered harmful to respiratory health. Wood fuels produce significantly higher particulate matter than fuel oil and natural gas, however modern pollution equipment can all but eliminate PM from smokestacks.
Carbon monoxide (CO)	Colorless, odorless gas produced by incomplete burning of carbon-based fuels, including gasoline, oil, and wood. Approximately 87% of MN emissions are from on-road and off-road vehicle use; approximately 4.8% from residential wood burning. If inhaled, interferes with oxygen absorption in blood and can be harmful to people with heart, lung, and circulatory system diseases.
Methane (CH_4)	Chemical compound that is the main component of natural gas, and is burned as a fuel for electrical generation. A major source of methane is geological (coal) deposits. It is a potent greenhouse gas, with 25 times more global warming potential than CO2. Although it is not toxic, it is highly flammable.
Volatile organic compound (VOC)	A large variety of chemical compounds, including methane, benzene and formaldehyde, some occur naturally or are human-made (paints, protective coatings, fossil fuel combustion). VOCs are major contributors to ground-level ozone (smog) which damages trees and other vegetation and increases susceptibility to respiratory problems.
Polycyclic aromatic hydrocarbons (PAHs)	Emissions resulting from incomplete combustion of wood. Sources of PAHs include home heating fuels, tobacco smoke, and vehicle exhaust. High levels of PAHs increase risk of cancer and asthma, especially in children. EPA-certified stoves and pellet stoves have much lower emissions than conventional stoves built before 1990.
Carbon dioxide (CO_2)	A chemical compound occurring naturally throughout ecosystem. The rapid increase of CO2 in the atmosphere - produced by combustion of fossil fuels used in electricity production, transportation, and industry – is the major driver in climate warming. See below for discussion of biogenic and fossil carbon dioxide.

olds acquire an Option D registration air permit that requires less record-keeping. Table 2 shows direct, on-site emissions estimates of biomass energy options being considered in Ely. Estimates are based on a number of source studies[3] and are not specific to combustion equipment used or moisture content of fuels. Estimates do not include hauling and logging.

All options using automatic feeding systems are within Option D emissions limits. Emissions of PAH and PM could become problematic if emissions limits are tightened or should the number of people relying on wood stoves for heat increase significantly in the future. These emissions could increase when heating with individual wood stoves because of incomplete combustion, intermittent operation, and lack of emission controls. Generating heat through district energy systems lend themselves to installation of automatic feeding systems and pollution control equipment that increase efficiency and reduce or virtually eliminate emissions of a number of pollutants.

Table 3 compares emissions produced by Ely's largest option with emissions from producing equivalent heat from wood stoves or propane generators. To show scale of operation, total emissions from the coal-fired facility at Taconite Harbor are also shown.

Indirect, Life Cycle Analysis

Full life cycle analyses consider all aspects of energy systems, including the manufacture and installation of combustion and distribution equipment, mining, extraction and transport of energy raw materials, energy production, disposal of ash, and end of life issues. The so-called "cradle-to-grave" impacts of Ely bioenergy options have been calculated based on published studies of life cycle and at-combustion site impacts of wood energy systems compared to conventional fossil fuel systems.

For forest biomass energy, local timber harvest and hauling wood are an additional source of emissions. Diesel fuel and lubricant consumption for these activities would increase emissions of most compounds by less than 1% but of CO_2, SOx, and NOx by much larger percentages. Inefficiencies caused by transmission losses from aging or insufficiently insulated piping can also result in higher emissions in district energy systems.

In all scenarios considered, significant impacts for wood pellet and fossil fuel options would occur far outside the local area. The magnitude of these would depend upon a number of factors. For pellets, these would include hauling distance and the type of fuel

Table 2. Estimates of direct, on-site air emissions[1] of biomass energy options (short tons/year) based on reported emissions per MMBtu. *(Note: one short ton is equal to 2000 lbs.)*

Pollutant		SO_2	NO_X	PM_{10}	CO	CH_4	VOC	PAH	Fossil CO_2
Regulatory thresholds									
Standard permit (PTE)[2]		50	100	25	100	---	100	---	100,000
Option D permit[3]		50	50	50	50	---	50	---	100,000
Configurations									
Five hundred supplemental single-family stoves, each 35 MMBtu.[4]	Cordwood	0.36	1.81	13.59	127.29	14.95	62.93	0.69	---
	Pellets	0.36	1.81	2.49	22.66	0.14	3.97	0.00	---
Option 1: Vermillion Community College. Annual heat load 7,227 MMBtu.	Chips[5]	0.19	1.20	0.86	2.97	0.17	0.30	0.34	---
	Pellets	0.19	0.81	0.47	1.63	0.07	0.10	0.04	---
Option 2: District heat for E-B Community Hospital, Sibley Manor, ISD 696. Annual heat load 16,235 MMBtu.	Chips	0.43	2.71	1.93	6.67	0.38	0.67	0.75	---
	Pellets	0.43	1.82	1.06	3.67	0.16	0.22	0.10	---
Option 3A: District heat for E-BCH, SM, ISD 696 (above) plus approximately 15 businesses along Sheridan Street. Annual heat load 21,553 MMBtu	Chips	0.57	3.60	2.57	8.86	0.51	0.89	1.00	---
	Pellets	0.57	2.41	1.41	4.87	0.22	0.30	0.13	---

[1]*Data obtained from average of Johansson et al. (2004), USEPA (2005), and the European Environment Agency (2009) (Tables 7 and 16), with supplemental data from IPCC Guidelines for National Greenhouse Gas Inventories Reference Manual. Data for fossil fuels from USEPA Aggregated Emissions Factors. See discussion below on fossil versus biogenic carbon dioxide.*

[2]*Potential to emit*

[3]*Actual emissions*

[4]*Assumes EPA-certified stove*

[5]*All district heat options assume automatic feeding systems with either clean chips or hog fuel.*

used in drying wood in the pellet manufacturing process. Although wood pellets have substantially lower environmental impact at the local level, life cycle emissions cause them to have higher overall environmental impacts per unit of heat than other forms of wood fuels. When emissions of fossil fuels related to extraction, processing, and transportation are considered, total life cycle impacts increase by 30-50%[4].

Carbon dioxide emissions and sequestration

A major driver for replacing fossil fuels with forest biomass energy is the reduction of carbon dioxide (CO_2). Life cycle analyses of biomass energy typically separate "fossil CO_2" from "biogenic CO_2". Biogenic CO_2 refers to the gases absorbed and released by plants as they grow, leaf out, and die. On the other hand, fossil CO_2 is from carbon geologically stored for millions of years that is released when fossil fuels are burned. The addition of billions of tons of fossil CO_2 is considered the largest contributor to global warming. In contrast, burning wood instead of fossil fuels is often considered carbon-neutral because it avoids new releases of geologically-stored carbon. Carbon-neutrality is also based on the premise that forests are growing and storing more biogenic carbon than is being released through mortality or harvest. Annual growth of forest species of northern and northeastern Minnesota far exceeds annual removal.

Per unit of energy (mmBtu), biomass emits more carbon during combustion because it is a less concentrated fuel than coal, natural gas, or oil. When the full life cycle of

Table 3. Comparison of emissions of potential and existing facilities in region (short tons/year), including harvest and transportation.

Emission	21,553 MMBtu Annual Heat Demand					Taconite Harbor, Minnesota Power (2003-04 averages)
	Automatic Wood Boiler, using chips	Wood Boiler using pellets	Equivalent number of wood stoves using cordwood		Propane Generator	
			Worst case	Best case		
SO_2	0.78	0.71	0.85	0.85	0.01	5,538
NO_x	5.22	3.39	5.71	4.72	1.83	3,373
PM_{10}	2.75	1.55	40.83	19.89	0.07	291
CO	9.52	5.22	301.20	184.20	1.06	2,875
CH_4	0.49	0.21	82.93	21.51	0.03	17.0
VOC	1.34	0.35	152.40	90.69	0.14	--
PAH	0.99	0.14	0.99	0.99	< 0.001	0
CO_2 fossil	107.05	64.25	160.65	160.65	1859.32	1,752,752

energy production is considered (rather than emissions at power stations only), energy generated from wood results in very low GHG emissions compared to alternatives. For combined heat-and-power (CHP) systems, GHG emissions are lowest for wood in the high efficiency systems, and behind only wind, hydrogen, and biogas systems in the low efficiency systems. Comparing space heating systems, GHG emissions were found to be lowest for wood among all systems examined. Wood pellets produced from short rotation tree plantations have the highest GHG emissions of all wood-based fuels.

[1]*Bowyer, 2012*
[2]*http://www.dovetailinc.org/files/HomeHeatingWithWood.pdf*
[3]*Bowyer, 2012*
[4]*ibid*
[5]*MN DNR, 2012*

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Bowyer, J. 2012. "Life Cycle Impacts of Heating with Wood in Scenarios Ranging from Home and Institutional Heating to Community Scale District Heating Systems". Background report to Dovetail Partners, Inc.

"Minnesota Forest Resources 2010". 2011. MN Department of Natural Resources, St. Paul.

"Heating with Wood: Using wood to heat your northern Minnesota home". 2011. Dovetail Partners, Minneapolis MN. http://www.dovetailinc.org/files/HomeHeatingWithWood.pdf

For more information about the project:

Contact: Katie Fernholz
Email: katie@dovetailinc.org
Phone: 612-333-0430
www.dovetailinc.org

Project Community Liaison:

Gloria Erickson, 218-365-0878
gjerickson@frontiernet.net
City of Ely Alternative Energy Task Force (AETF)
http://www.ely.mn.us/

Supporting Community-Driven Sustainable Bioenergy Projects is a project of Dovetail Partners, Inc. with funding provided by the *Minnesota Environment and Natural Resources Trust Fund* as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR). The Trust Fund is a permanent fund constitutionally established by the citizens of Minnesota to assist in the *protection, conservation, preservation, and enhancement of the state's air, water, land, fish, wildlife, and other natural resources.*

Graphic design and layout: Gary Atwood *Published December 2012*

Environmental Impacts of Biomass Harvesting and Wood Energy Production in Northeastern Minnesota

Using locally-grown forest biomass in community energy systems in northern Minnesota has the potential to increase the region's energy independence, lower carbon dioxide in the atmosphere, and reduce buildup of fire-prone materials in forests. This fact sheet focuses on potential environmental impacts of biomass harvest and forest sustainability guidelines needed to address such impacts. It summarizes a study by Dovetail Partners, Inc. that reviews relevant literature and testimony from forestry experts and stakeholder groups. Other fact sheets in this series describe technical and economic aspects of biomass combustion systems, woody biomass fuel demands and local supplies, and air emissions from biomass combustion. A full report of the study will be available in December, 2012.

Northern forests ecosystem

Two communities in northern Minnesota, Ely and Grand Marais, are considering construction of district heat systems, fueled by locally-grown woody biomass, for public buildings and business districts. These communities lie in the Northern Superior Uplands, a landscape dominated by fire-dependent forests and woodlands. The red and white pine forests of the past were largely cut down by the early 1900s. Today, they have been replaced by jack pine forests on drier ridges and outwash areas, and sugar maple forests (mixed with some pine, birch and cedar) in the highlands along Lake Superior. The different forest types, their ages, and relative health determine forest management decisions, including timber and biomass harvest.

The *Generic Environmental Impact Statement on Timber Harvesting and Forest Management in Minnesota* (GEIS) is an in-depth analysis of potential environmental impacts on forest ecosystems. It and subsequent guidelines and updates provide the basis for this review of potential positive and negative impacts of woody biomass harvest on these forests.

Northern Superior Upland Section

Biomass harvest operations

Woody biomass is typically removed from a forest as part of a traditional harvesting operation and can include tree tops, limbs, bark, and tree trunks (bolewood). Biomass is rarely removed as a stand-alone product because it is generally not economically viable. Because of this, environmental impacts of biomass removal are evaluated within the context of overall timber harvest and forest sustainability. Other sources of woody biomass are wildfire risk reduction treatments, wood salvaged from windstorm events, wildfire, insect or disease outbreaks, and restoration efforts. This material is often piled or burned because it is not economical to haul to markets. Tree trunks, or bolewood, are currently used for firewood and pellets. As long as viable markets for roundwood (e.g., pulp and timber markets) exist in the region, it is likely to be economically limiting to chip quality roundwood for bioenergy systems.

The current rate of timber harvest in northeastern Minnesota is significantly lower than a baseline rate (4 million cords annually statewide) found to be biologically sustainable in the GEIS. Preliminary data suggest that harvest levels for 2010 and 2011 are within the 2.6 to 2.9 million cord range. Inventory data also show that forest growth greatly exceeds wood harvest in the state. Minnesota is experiencing annual net timber growth of approximately 5.6 million cords (approximately twice as

[1] Ecological Classification System used by MDNR and USFS for managing public lands.

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Table 1. Ely and Cook County district heating systems, annual heat demand, fuel types, and biomass demands

Ely Configurations	**Heat load** *(MMBtu)*	**Fuel Type**	**Annual Biomass Demand** ***dry tons (green tons)***
Option 1: Vermillion Community College	7227	Chips/Hog	527 (878)
Option 2: Hospital, residential building, ISD 696	16,235	Chips/Hog	1,754 (2,924)
Option 3A: Option 2 plus 15 downtown businesses	21,553	Chips/Hog	2,499 (4,165)
Cook County and Grand Marais Configurations			
Option 1: Resort or small business cluster	5,200	Chips	390 (650)
Option 2: Grand Marais public buildings (north of 5th St. N and Cook County Courthouse)	11,796	Chips/Hog	940 (1,567)
Option 3: Grand Marais business district and public buildings	30,562	Chips/Hog	2,450 (4,083)
Option 4: Grand Marais Option 3 for largest users only	24,186	Chips/Hog	1,940 (3,233)

much as the current annual harvest rate). Table 1 shows estimates of annual biomass demand of optional systems being considered in Ely and Grand Marais. In 60-mile radii zones around Ely and Grand Marais, 2011 biomass harvest (tops and limbs) is estimated at 59,856 and 12,576 dry tons respectively, assuming that 50% of biomass is left on site for conservation purposes[2].

Impacts of woody biomass harvest

Ecological impacts on soils, wildlife, fire regimes, and water quality of using biomass for bioenergy depends on existing forest conditions and the timing, methods, and amount of biomass removed over a specific period. Although options being considered in Cook County and Ely demand relatively small volumes of biomass, they could alter forestry practices in procurement areas.

Positive benefits of biomass harvest for local forests and communities are numerous. In addition to providing a local renewable energy source, responsible woody biomass harvest could support hazardous fuel reduction and forest (habitat) restoration efforts. It could increase the economic value of forested areas, which can lead to better wood markets and management. The use of community trees and local wood-debris could also positively benefit community natural resources and economies.

Potential negative impacts of timber harvest were identified based on information provided in the GEIS and during meetings with expert and stakeholder groups in northern Minnesota (see sidebar).

Soil resources: Research indicates that harvesting trees once every several decades generally does not impact soil nutrients beyond rates of replenishment by annual leaf fall and nutrient cycling. Harvest on less productive sites with poor soils could have greater impacts. Loss of calcium, magnesium, and potassium greater than rates of replenishment are associated with timber harvest on coarse-textured and organic soils. Full tree harvesting (removal of the main stem of the tree as well as large and small branches), can increase calcium losses slightly compared to merchantable bole harvest (traditional timber removals). Losses for magnesium and potassium are also significantly increased under these conditions. It is for these reasons that biomass harvesting is restricted or not allowed on sites with lower nutrient (poorer) soils.

Forest health: For most forest types, insect and disease problems are closely related to age class structure and overall tree vigor. In general, the forests of northeast Minnesota are dominated by mature tree stands, including many aspen forests that are over 50 years old. For example, in a supply zone of 60-miles around Grand Marais the aspen-birch forest type occupies 415,659 acres (51% of timberland) and spruce-fir occupies 200,027 acres (25% of timberland).

[2] Becker, 2012

Of those acres, 53% and 42%, respectively, are greater than 60 years old and are either at or beyond their target harvest rotation age and are experiencing health declines. Similar data is shown for the region around Ely.

Wildlife: Impacts to wildlife are predicted based on what is known about a species' habitat requirements. The GEIS baseline harvest level is expected to have no negative impacts on sensitive or government-listed wildlife species found in the study area (Osprey, Bald Eagle, Red-shouldered Hawk, Loggerhead Shrike, Pine Marten, Timber Wolf, Wood Turtle). The less sensitive populations of non-listed species of game and non-game wildlife are unlikely to be significantly affected either positively or negatively at the baseline level of harvest, as this level of activity does not significantly alter the overall distribution of habitat types. Monitoring the population trends of more sensitive wildlife species is an important way to evaluate long-term land use impacts.

Water quality and fisheries: Depending on scale of operation, timber harvest and associated road-building can impact the quantity and rate of run-off, and increase sedimentation and water temperature. Forest management guidelines that are mandatory on public lands in Minnesota include practices related to riparian areas, buffer strips, and soil erosion from access roads and skid trails. Timber harvest that complies with these guidelines will have significantly fewer local water resource impacts than timber harvest carried out in the absence of such practices.

Recreation, aesthetics, unique resources: The GEIS found that less than one-third of the primitive and semi-primitive non-motorized areas on timberland would be significantly impacted by the base level of harvest. Timberland is forestland that is available for harvest and does not include wilderness areas such as the Boundary Waters Canoe Area. Visual impacts can occur with timber harvesting and forest management activities, however use of visual management guidelines (covering road location, use of buffers, size and shape of cut, and slash and debris disposal) can significantly reduce these impacts. A statewide database is maintained by the State of Minnesota to record unique cultural and historic sites. Land managers utilize this database in management planning and contribute to its maintenance.

Management tools and environmental safeguards

Environmental safeguards in place in Minnesota that focus directly on the sustainability of the state's forests include third party forest certification, the Minnesota Forest Management Guidelines developed by the Minnesota Forest Resources Council (MFRC), and the Minnesota Master Logger Certification program. In addition to these "Big Three," numerous programs and activities strive for long-term forest sustainability, including the MFRC Landscape Planning Committee, active MN DNR field, monitoring, and the Minnesota Sustainable Forestry Incentive Act for private landowners.

The *Minnesota Biomass Harvesting Guidelines* are recognized as an important tool for taking a precautionary approach to making use of biomass energy resources. To ensure that biomass energy systems can be responsibly maintained over the long-term, it is important that programs to implement and monitor the effective use of harvesting guidelines and other environmental safeguards be continued and more widely adopted.

Concerns about increased biomass harvesting *were identified in meetings and interviews with natural resource professionals, land managers, and community officials and citizens. Discussion of potential impacts and mitigation strategies are contained in full environmental report available at:* www.dovetailinc.org.

- *Timber harvests at sensitive ecological sites*
- *Impact on structure of native plant community, related to timing of harvests, retention of woody debris, stand structure, direct impacts, and long-term impacts*
- *Negative impacts on specific wildlife species, including Canada Lynx, Snowshoe Hare, and Timber Wolf*
- *Water quality degradation*
- *Increased harvest of bolewood for bioenergy*
- *Forest carbon storage and sequestration*
- *Noise pollution in BWCAW*
- *Air pollution (see separate fact sheet on air emissions)*
- *Ash disposal*

Supporting Community-Driven Sustainable Bioenergy Projects is a project of Dovetail Partners, Inc. with funding provided by the *Minnesota Environment and Natural Resources Trust Fund* as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR). The Trust Fund is a permanent fund constitutionally established by the citizens of Minnesota to assist in the *protection, conservation, preservation, and enhancement of the state's air, water, land, fish, wildlife, and other natural resources.*

Table 2. Summary of Minnesota's biomass harvesting guidelines

DO'S	DON'TS
During Biomass Harvesting:	***Avoid Biomass Harvesting:***
• Plan roads, landings and stockpiles to occupy a minimized amount of the site • Ensure that landings are in a condition to regenerate native vegetation after use, including tree regeneration • Avoid site re-entry to collect biomass after harvesting *(this reduces potential for soil compaction and damage to regeneration)* • Install erosion control devices where appropriate to reduce sedimentation of stream, lakes and wetlands • Retain and scatter at least one third of the fine woody debris on the site (50% was used in this study) • Encourage native seed mixes and avoid introduction of invasive species • Retain slash piles that show evidence of use by wildlife • Leave all snags, retain stumps and limit disturbance of pre-existing coarse woody debris	• Within 25 feet of a dry wash bank, except for tops and limbs of trees • On nutrient-poor organic soils deeper than 24 inches *(These sites typically have sparse (25-75%) cover that is predominantly (>90%) black spruce and stunted (<30 feet high).)* • On aspen or hardwood cover types on shallow soils (8 inches or less) over bedrock • On erosion-prone sites (e.g. steep slopes of 35% or more) • In areas that impact sensitive native plant communities and where rare species are present • In riparian areas or leave tree retention clumps • In a manner that removes the forest floor, litter layer or root systems; these resources must be left within the forest

References

Dennis R. Becker, Steve Taff, and David Wilson. 2012. *Pre-Feasibility Financial and Wood Supply Analysis for Biomass District Heating in Ely and Cook County, MN: University of Minnesota Report to Dovetail Partners, Inc.*, www.dovetailinc.org

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Forestry and biomass energy in Northeast Minnesota

The feasibility and impacts of using locally-grown forest biomass for energy is being extensively studied because of its potential to lower energy costs, reduce buildup of fire-prone materials in forests, and lower net carbon dioxide and greenhouse gases in the atmosphere. This fact sheet describes the types of forest biomass used to produce energy and estimates amounts of biomass resources in forests surrounding two communities in NE Minnesota – Ely and Grand Marais. It also compares biomass supplies with demands of optional biomass energy systems being considered in those communities. Other fact sheets in this series describe biomass combustion systems, environmental and life cycle impacts, Minnesota's biomass harvesting guidelines, and the economics of biomass energy. A full report of the study, titled "Supporting Community-Driven Sustainable Bioenergy Projects," will be available in December, 2012.

Forest managers, the timber industry and local communities work together to satisfy the multiple demands placed on Minnesota's forests. (Photo courtesy of USFS-Gunflint District)

Minnesota timberlands and biomass energy fuels

Managing Minnesota's forests is a complex calculation involving forest conditions, desired land uses, timber markets, public opinion, and government policies. The state's forests are divided into timberland where wood is harvested, reserved land (such as designated wilderness areas) that cannot be harvested, and brush and other lands, also not commercially harvested. A comprehensive environmental assessment of timber harvest statewide reported that annual harvests of 4 million cords of timber could be continued indefinitely without harming key forest ecological

Forest Biomass Feedstock	Moisture % by Weight	Suitable Uses	Heat Value (mmBtu/ton)	2010 cost $ / dry ton
Cordwood	35%	Firewood in conventional fireplaces, wood-burning stoves, or boilers for home heating	9.4	$154 (+ $58 delivery)
Clean (bolewood) chips	40%	Residential and small industrial heating	8.8	$48 - $68
Field chips (hog fuel)	40%	District heating and industrial systems with mechanical feeding systems	8.8	$37 - $57
Wood pellets	10%	Residential and small industrial heating	16.8	$167 (+ $67 delivery)

Table 1. Biomass Feedstocks

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characteristics (soil productivity, water quality, wildlife habitat, and aesthetic values).

Since the early 2000s, declining demand for paper and construction materials and greater reliance on imported wood have resulted in current harvests approximately 30% below this base level. The current harvest rate is also well below net annual growth (5.6 million cords) and mortality (4 million cords). The notable aging of Minnesota's forests, while far below the proportion of old growth forests before European settlement, presents management concerns including increased risk of disease and insect damage, and increased fire danger from dead and downed trees. A decline in the health of trees directly impacts the health of the forest industry and can result in a loss of jobs and the management infrastructure needed to maintain healthy natural resources.

Biomass energy is a burgeoning sector of the wood products industry that, if done appropriately, could help address forest health and other energy-related concerns in Minnesota. Burning wood is a time-honored method of creating heat or electricity, and is now greatly improved through more efficient and practical technology. Biomass fuel stocks used for heat and electricity in the region include hog fuel, or the slash and waste wood from timber harvesting (tops and limbs of trees), hazardous fuels reduction (Firewise), storm clean-up, right-of-way clearings, pre-commercial thinnings and related vegetation management projects, and removal of diseased or dead trees. Whole trees can also be processed into high-quality clean chips or manufactured wood pellets. Additional sources of biomass that may be used include mill residues, brushland clearing, and dedicated energy crops. Table 1 describes principal feedstocks available within 60 miles of Ely and Grand Marais, technologies they are used in, amount of energy produced, and cost of procurement. Processed wood pellets that would be trucked in from outside the area are also included.

Biomass availability and demand for energy

The viability of biomass energy depends on availability of supply compared to the cost of demand. In the heavily-forested region of NE Minnesota, the availability of locally-sourced biomass is more than sufficient for all the options being evaluated. The current supply of just harvest residuals (tops and limbs of commercially harvested trees) within 60 miles of Grand Marais and Ely is estimated at 11,450 and 44,679 dry tons respectively. In comparison, the amount of biomass needed to produce heat only for the options under consideration range from approximately 390 dry tons/year to produce 5,200 mmBtu of annual heat load for a small resort, up to 2,450 dry tons/year to produce 30,562 mmBtu of annual heat load for a district heating system covering businesses, public buildings, and private residences. The amounts of biomass needed if multiple biomass energy systems are built in one area are estimated in the study report.

Biomass resource stewardship

The buildup or removal of trees and other vegetation from Minnesota forests is an important public issue. On the one hand, a lack of market demand for small dimension biomass has meant that timber residuals are disposed of by burning in the forest, raising concerns about air quality, water quality, and erosion. On the other hand, over-harvesting of biomass could reduce soil nutrients, wildlife habitat, site productivity, and cause increased water erosion. Federal and state forest plans restrict biomass removal in some forest stands, such as near river bottoms or with low-nutrient soils. In areas where residual harvest is allowed or encouraged, guidelines and best management practices developed by the Minnesota Forest Resources Council are critical components of sustainable forest management. Biomass removal is also encouraged as part of timber stand improvement programs in areas being managed for larger trees or being restored to native forest types. A fact sheet describing biomass harvest guidelines is available.

Community	GEIS base scenario (cords) [1]	2006 - 2010 Actual Bolewood harvest (cords)[2]	2006-2010 Clean chips[3] (green tons/dry tons)[4]	2006-2010 Field chips (hog fuel)[5] (green tons/dry tons)[4]
Ely	436,814	291,710	57,182 / 34,309	74,465 / 44,679
Grand Marais	219,719	79,572	15,410 / 9,246	19,083 / 11,450

Table 2. Biomass Supply under all ownerships, within 60-mile radii zones.

[1] GEIS Base Scenario of 4 million cords harvest rate statewide.
[2] 2006 – 2010 Average Annual Harvest Rate (FIA estimate)
[3] 10% of bolewood harvest available for wood chips
[4] Conversion factor: 1 green ton of wood = 0.60 dry tons of wood (40% moisture content).
[5] Field chips or hog fuel is the tops, limbs, small trees and needles as defined by the USDA Forest Service biomass attributes. A conservative estimate of 50% is retained on site to meet the MFRC Biomass Harvest Guidelines.

Biomass harvesting, transport and processing

Determining whether an adequate supply of biomass exists for energy options is only the first step. It then needs to be harvested or (in the case of logging slash) collected, transported and processed into its final form for introduction to a boiler. The nature of the raw material will dictate the end fuel type and the steps necessary to achieve the final product. Completing each of these steps involves a cost in labor, equipment, and fuel. In some locations, the necessary infrastructure may already exist. In locations where the infrastructure doesn't already exist, the limited fuel demands of a modest district heating facility could eliminate some fuels from practical consideration. This may be the case if expensive new equipment must be obtained or if costly and time-consuming materials handling and transport are required.

It is also generally true that a lower quality biomass fuel produces higher emissions and waste ash. This means that lower fuel costs may quickly be offset by the cost of additional emissions controls and ash removal. In the end, all of these factors need to be considered when weighing the benefits and costs of each biomass fuel type in a particular district heating configuration.

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Ely Biomass Energy Options

Configuration	Annual heat load (mmBtu)	Fuel type	Annual biomass demand	
			green tons	dry tons
Option 1 Vermillion Community College	7,227	Clean chips Hog fuel	878	523
Option 2 E-B Community Hospital, Sibley Manor, Independent School District 696	16,235	Clean chips Hog fuel	2,905	1,743
Option 3A District heat for E-B Community Hospital, ISD 696, and section of business district.	21,553	Chips/Hog fuel	4,165	2,499

Cook County/Grand Marais Biomass Energy Options

Configuration	Annual heat demand (mmBtu)	Fuel type	Annual biomass demand	
			green tons	dry tons
Typical single family dwelling, stand-alone stove	35	Cordwood Pellets	5.3 3.0	3.2 2.7
Option 1 Resort of small business cluster	5,200	Chips	650	390
Option 2 Heat for public buildings north of 5th Street N incl. courthouse and laundromat	11,796	Chips/Hog Fuel	1567	940
Option 3 District heat for business district and public buildings north of 5th Street N	30,562	Chips/Hog Fuel	4083	2450
Opton 4 "Hybrid" scenario Public buildings north of 5th St. N. and 10 principal users in downtown area	24,186	Chips/Hog Fuel	3233	1940

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Emissions and biomass energy in Northeast Minnesota

Air quality impacts of biomass energy

Using locally-grown forest biomass for energy is of growing interest in northern Minnesota because of its potential to increase energy independence, lower carbon dioxide in the atmosphere, and reduce buildup of fire-prone materials in forests. This fact sheet focuses on expected air emissions of bio-energy projects being considered in Cook County. It is part of a larger study on the feasibility, impacts, and social support for converting from fossil fuels to forest biomass energy. Other fact sheets in this series describe technical and economic aspects of biomass combustion systems, their wood fuel demands and local supplies, and the environmental impact of biomass harvest. A full report of the study by Dovetail Partners will be available in December, 2012.

Air emissions of energy production

All energy production – whether from fossil fuel sources (petroleum, coal, and natural gas) or non-fossil sources (hydroelectric, nuclear, geothermal, solar, wind, wood, and waste) – impacts air and the larger environment. Air emissions can be categorized as direct (on-site emissions produced at the power station) or as indirect (covering all emissions generated throughout the entire life cycle of energy production and use). Sorting out the overall impact of a given energy system is challenging, involving different fuel types, equipment, pollution controls, and other factors. Per unit of energy, forest biomass energy generates lower emissions than fossil fuels of some air pollutants, and higher levels of others. Locally harvested wood energy does have an advantage in avoiding emissions and environmental impacts associated with activities like offshore drilling, fracking, oil-shale mining, and international transportation systems. Widespread air pollutants are produced by burning fuels are summarized in Table 1.

Direct Emissions

Combustion is the largest source of emissions in the energy production process. Direct, on-site emissions are determined by fuels used, production equipment, and pollution controls.

- **Fuels:** Clean, dry wood fuels deliver superior energy efficiency and are environmentally better than dirty, wet fuels. Emissions are especially dependent on moisture content and percentage of bark. Overall, uniformly-sized fuels provide greater heating value, more uniform burning, lower emissions, and less need for boiler maintenance than wet, dirty, non-uniform fuels[1].
- **Production equipment:** Modern, high-efficiency equipment and optimal size are crucial factors in controlling combustion emissions. For residential scale systems, EPA-certified wood stoves emit 70 percent less particle pollution and are approximately 50 percent more efficient than wood stoves manufactured before 1990[2]. Larger, district heating systems should focus on high-density areas (high energy demand and short piping distances) and use automatic rather than manually-fed boiler systems. Balancing all factors, the largest scale does not necessarily translate to lowest environmental impact. Instead, systems engineered to optimize energy use density and energy transport distance have been found to have the lowest overall impact.
- **Pollution control**: Technologies are available that significantly reduce hazardous emissions. For instance, electrostatic precipitators reduce particulate emissions from combustion of wet forest residue to 13% of uncontrolled emissions, significantly below other wood fuels. Similar devices used with dry fuels can likewise substantially reduce particulate emissions.

Stationary sources of air pollution are regulated by Minnesota Pollution Control Agency under the federal Clean Air Act. Major facilities with a potential to emit (PTE) more than certain threshold amounts of any regulated pollutant must obtain an individual air quality permit. Facilities with emissions below these standard thresh-

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Table 1. Air pollutants produced during the combustion of fuels.

Sulfur dioxide (SO_2)	Acidic gas formed primarily by coal, oil, and diesel combustion. Contributes to fine particulate pollution and acid rain, which can damage lakes, buildings, and plants. High concentrations can affect breathing, cause respiratory illnesses, and aggravate existing cardiovascular diseases.
Nitrogen oxides (NO_X)	Acidic gases (nitrogen dioxide, nitrous acid, and nitric acid) produced by burning fuels at high temperatures (motor vehicles and stationary combustion sources such as electric utilities and industrial boilers). Contributes to ozone and acid rain and adversely impacts respiratory system.
Particulate matter (PM)	Very fine particles, including dust and smoke formed when coal, wood, or oil are burned. Airborne particles can cause haze and lower visibility and the smallest sizes, including PM10, are considered harmful to respiratory health. Wood fuels produce significantly higher particulate matter than fuel oil and natural gas, however modern pollution equipment can all but eliminate PM from smokestacks.
Carbon monoxide (CO)	Colorless, odorless gas produced by incomplete burning of carbon-based fuels, including gasoline, oil, and wood. Approximately 87% of MN emissions are from on-road and off-road vehicle use; approximately 4.8% from residential wood burning. If inhaled, interferes with oxygen absorption in blood and can be harmful to people with heart, lung, and circulatory system diseases.
Methane (CH_4)	Chemical compound that is the main component of natural gas, and is burned as a fuel for electrical generation. A major source of methane is geological (coal) deposits. It is a potent greenhouse gas, with 25 times more global warming potential than CO2. Although it is not toxic, it is highly flammable.
Volatile organic compound (VOC)	A large variety of chemical compounds, including methane, benzene and formaldehyde, some occur naturally or are human-made (paints, protective coatings, fossil fuel combustion). VOCs are major contributors to ground-level ozone (smog) which damages trees and other vegetation and increases susceptibility to respiratory problems.
Polycyclic aromatic hydrocarbons (PAHs)	Emissions resulting from incomplete combustion of wood. Sources of PAHs include home heating fuels, tobacco smoke, and vehicle exhaust. High levels of PAHs increase risk of cancer and asthma, especially in children. EPA-certified stoves and pellet stoves have much lower emissions than conventional stoves built before 1990.
Carbon dioxide (CO_2)	A chemical compound occurring naturally throughout ecosystem. The rapid increase of CO2 in the atmosphere - produced by combustion of fossil fuels used in electricity production, transportation, and industry – is the major driver in climate warming. See below for discussion of biogenic and fossil carbon dioxide.

olds acquire an Option D registration air permit that requires less record-keeping. Table 2 shows direct, on-site emissions estimates of biomass energy options being considered in Grand Marais. Estimates are based on a number of source studies[3] and are not specific to combustion equipment used or moisture content of fuels. Estimates do not include hauling and logging.

All options using automatic feeding systems are within Option D emissions limits. Emissions of PAH and PM could become problematic if emissions limits are tightened or should the number of people relying on wood stoves for heat increase significantly in the future. These emissions could increase when heating with individual wood stoves because of incomplete combustion, intermittent operation, and lack of emission controls. Generating heat through district energy systems lend themselves to installation of automatic feeding systems and pollution control equipment that increase efficiency and reduce or virtually eliminate emissions of a number of pollutants.

Table 3 compares emissions produced by Grand Marais' largest option with emissions from producing equivalent heat from wood stoves or propane generators. To show scale of operation, total emissions from the coal-fired facility at Taconite Harbor are also shown.

Indirect, Life Cycle Analysis

Full life cycle analyses consider all aspects of energy systems, including the manufacture and installation of combustion and distribution equipment, mining, extraction and transport of energy raw materials, energy production, disposal of ash, and end of life issues. The so-called "cradle-to-grave" impacts of Grand Marais bioenergy options have been calculated based on published studies of life cycle and at-combustion site impacts of wood energy systems compared to conventional fossil fuel systems.

For forest biomass energy, local timber harvest and hauling wood are an additional source of emissions. Diesel fuel and lubricant consumption for these activities would increase emissions of most compounds by less than 1% but of CO_2, SOx, and NOx by much larger percentages. Inefficiencies caused by transmission losses from aging or insufficiently insulated piping can also result in higher emissions in district energy systems.

In all scenarios considered, significant impacts for wood pellet and fossil fuel options would occur far outside the local area. The magnitude of these would depend upon a number of factors. For pellets, these would include hauling distance and the type of fuel

Table 2. Estimates of direct, on-site air emissions[1] of biomass energy options (short tons/year) based on reported emissions per MMBtu. *(Note: one short ton is equal to 2000 lbs.)*

Pollutant		SO_2	NO_X	PM_{10}	CO	CH_4	VOC	PAH	Fossil CO_2
Regulatory thresholds									
Standard permit (PTE)[2]		50	100	25	100	---	100	---	100,000
Option D permit[3]		50	50	50	50	---	50	---	100,000
Configurations									
Five hundred supplemental single-family stoves, each 35 MMBtu.[4]	Cordwood	0.36	1.81	13.59	127.29	14.95	62.93	0.69	---
	Pellets	0.36	1.81	2.49	22.66	0.14	3.97	0.00	---
Option 1 (M1): District heat for small resort or business cluster. Annual heat load 5,200 MMBtu.	Chips[5]	0.14	0.87	0.62	2.15	0.12	0.21	0.24	---
	Pellets	0.14	0.58	0.34	1.18	0.05	0.07	0.03	---
Option 2 (L3): District heat for Grand Marais public buildings north of 5th Street N plus courthouse. Annual heat load 11,796 MMBtu.	Chips	0.31	1.93	1.39	4.85	0.28	0.49	0.55	---
	Pellets	0.31	1.32	0.77	2.67	0.12	0.16	0.07	---
Option 3 (L6): District heat for Grand Marais public buildings (above) and business district. Annual heat load 30,562 MMBtu	Chips	0.81	5.10	3.64	12.57	0.72	1.26	1.42	---
	Pellets	0.81	3.42	2.00	6.91	0.31	0.42	0.18	---
Option 4 (Hybrid): Combination of Options 3 and 4 (largest users only). Annual heat load 24,186	Chips	0.64	4.04	2.88	9.95	0.57	1.00	1.12	---
	Pellets	0.64	2.71	1.58	5.47	0.25	0.34	0.14	---

[1]*Data obtained from average of Johansson et al. (2004), USEPA (2005), and the European Environment Agency (2009) (Tables 7 and 16), with supplemental data from IPCC Guidelines for National Greenhouse Gas Inventories Reference Manual. Data for fossil fuels from USEPA Aggregated Emissions Factors. See discussion below on fossil versus biogenic carbon dioxide.*

[2]*Potential to emit*

[3]*Actual emissions*

[4]*Assumes EPA-certified stove*

[5]*All district heat options assume automatic feeding systems with either clean chips or hog fuel.*

used in drying wood in the pellet manufacturing process. Although wood pellets have substantially lower environmental impact at the local level, life cycle emissions cause them to have higher overall environmental impacts per unit of heat than other forms of wood fuels. When emissions of fossil fuels related to extraction, processing, and transportation are considered, total life cycle impacts increase by 30-50%[4].

Carbon dioxide emissions and sequestration

A major driver for replacing fossil fuels with forest biomass energy is the reduction of carbon dioxide (CO_2). Life cycle analyses of biomass energy typically separate "fossil CO_2" from "biogenic CO_2". Biogenic CO_2 refers to the gases absorbed and released by plants as they grow, leaf out, and die. On the other hand, fossil CO_2 is from carbon geologically stored for millions of years that is released when fossil fuels are burned. The addition of billions of tons of fossil CO_2 is considered the largest contributor to global warming. In contrast, burning wood instead of fossil fuels is often considered carbon-neutral because it avoids new releases of geologically-stored carbon. Carbon-neutrality is also based on the premise that forests are growing and storing more biogenic carbon than is being released through mortality or harvest. Annual growth of forest species of northern and northeastern Minnesota far exceeds annual removal.

Per unit of energy (mmBtu), biomass emits more carbon during combustion because it is a less concentrated fuel than coal, natural gas, or oil. When the full life cycle of

Table 3. Comparison of emissions of potential and existing facilities in region (short tons/year), including harvest and transportation.

Emission	30,562 MMBtu Annual Heat Demand					Taconite Harbor, Minnesota Power (2003-04 averages)
	Automatic Wood Boiler, using chips	Wood Boiler using pellets	Equivalent number of wood stoves using cordwood		Propane Generator	
			Worst case	Best case		
SO_2	1.1	1.0	1.2	1.2	0.02	5,538
NO_x	7.4	4.8	8.1	6.7	2.6	3,373
PM_{10}	3.9	2.2	57.9	28.2	0.1	291
CO	13.5	7.4	427.1	261.2	1.5	2,875
CH_4	0.7	0.3	117.6	30.5	0.04	17.0
VOC	1.9	0.5	216.1	128.6	.20	--
PAH	1.4	0.2	1.4	1.4	<0.001	0
CO_2 fossil	151.8	91.1	227.8	227.8	2,636.5	1,752,752

energy production is considered (rather than emissions at power stations only), energy generated from wood results in very low GHG emissions compared to alternatives. For combined heat-and-power (CHP) systems, GHG emissions are lowest for wood in the high efficiency systems, and behind only wind, hydrogen, and biogas systems in the low efficiency systems. Comparing space heating systems, GHG emissions were found to be lowest for wood among all systems examined. Wood pellets produced from short rotation tree plantations have the highest GHG emissions of all wood-based fuels.

[1]*Bowyer, 2012*
[2]*http://www.dovetailinc.org/files/HomeHeatingWithWood.pdf*
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