Supporting Community-Driven Sustainable Bioenergy Projects

Dovetail Partners, Inc.

Final Report, Executive Summary

December 2012

This project was undertaken by 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.*

Executive Summary

The goals of the project are to: *Support community-driven transitions to alternative energy by (1) developing high-quality objective information about pertinent topics and options related to bio-energy systems; and (2) building strong communication structures to gather and disseminate information among project partners, stakeholders, and the larger public.* High quality information, open dialogue among stakeholders, and a creative, entrepreneurial spirit are essential ingredients in the complex task of transitioning to new energy systems.

To support the goals, the project was structured as an iterative and collaborative process between the study team and community steering committees to set direction, gather and analyze information, discuss results, identify new questions and options of greatest interest, and plan next steps accordingly. Collaborating organizations were the Cook County Local Energy Project (CCLEP); Ely's Alternative Energy Task Force (AETF); Dovetail Partners; the University of Minnesota; LHB Engineering; Wilson Engineering, BioBusiness Alliance of Minnesota and Svebio, the Swedish Bioenergy Association. Major funding for the project came from the Cook County Commissioners, USDA Wood Education and Resource Center, and the Minnesota Natural Resource and Environment Trust Fund, as advised by the Legislative Citizen Committee on Minnesota Resources.

This Executive Summary provides major findings from a series of background reports on key issues related to biomass energy: financial feasibility for biomass system development and available biomass supplies; life cycle impacts associated with biomass energy systems and associated emissions; local environmental considerations identified through community input; and supply chain logistics. Complete individual background reports and fact sheets summarizing results of assessments are available separately.

Pre-Feasibility Financial and Wood Supply Analysis

Major Findings:

- Over the past decade, technological innovations have improved biomass energy options ranging from small supplemental wood stoves for single family residences, furnaces for large public buildings, and community scale district heating and combined heat and power (CHP).
- Biomass energy systems that have been engineered to optimize energy use density and energy transport distance (i.e., heat demand per linear foot of buried pipe) excel in energy efficiency, financial performance, and overall environmental impacts.
- The most promising woody biomass options in each community have similar costs to fossil fuels per unit of energy ($/mmBtu), high net present value (NPV), short payback periods, and low annual operating expenses.
- Annual biomass demand for the relatively small community district heating systems under consideration in Grand Marais and Ely range from 390 dry tons (DT) for small and medium-sized systems to 7,858 DT for a community-wide CHP system in Ely.

- Current annual biomass estimates available from harvest residuals within 60-mile radii of Ely are 44,679 dry tons of hog fuel and 34,309 dry tons of clean chips. Within 60 miles of Grand Marais, estimates are11,450 DT of hogfuel and 9,246 DT of clean chips.
- Additional engineering services and financial evaluations (e.g., facility siting, business ownership and planning, etc.) will be necessary to go to the next step of pursuing biomass energy system development based on the findings of this project.
- A financial model developed for the project can be used to evaluate additional alternative community-scaled biomass systems.

Life Cycle Impacts and Environmental Considerations

Major Findings:

- Biomass and fossil fuels emit different levels of chemical compounds that affect air quality, human health, and climate. Air emission estimates of the largest district heating options are between 2 – 14% of State of Minnesota Option D emissions limits. In the future, regulation of compounds emitted by fossil fuels or biomass fuels could continue to tighten.
- Overall environmental impacts, including human health impacts, linked to wood fuels have been found to be significantly lower than the impacts linked to use of fossil fuels.
- Installing state-of-art pollution technology that would virtually eliminate most emissions is costly but appears to have strong community support.
- Because woody biomass is commonly a bi-product of timber harvest, local environmental impacts coincide with harvest levels, intensity, restrictions, etc. Local environmental considerations related to biomass utilization in northern Minnesota include concerns about impacts to native plant communities, wildlife, water quality, carbon storage, air quality, wildfire risks, recreation and economic opportunities and other issues.
- Long-term environmental impacts of woody biomass utilization are not well researched and pre-cautionary approaches can be useful in minimizing unknown impacts. Minnesota's use of third-party forest certification, biomass harvesting guidelines, logger training and certification programs, and other tools aid in addressing forest sustainability and biomass utilization concerns.
- Research done in Minnesota concluded that following the biomass harvesting guidelines established by the Minnesota Forest Resources Council (MFRC) should mitigate concerns about soil nutrients, structure and wildlife habitat.
- Given the critical importance of the biomass harvesting guidelines in addressing environmental concerns, it is important to maintain or enhance training and monitoring programs that help ensure their consistent application.

Supply Chain Discussions and the Socio-Economic Considerations of Biomass Energy

Major Findings:

- The existence of a healthy, active logging and forest management labor force is a critical factor in long-term viability of locally-sourced bioenergy. In the past decade, dwindling demand for forest projects has contributed to reduced forest management and declining numbers of operators.
- Numerous strategies are being discussed within logging industry for harvesting, handling, and processing bioenergy feedstocks. The high cost of equipment investment relative to the low demand for feedstocks indicates that some types of purchase agreements or other assurances may be necessary.
- In both Ely and Grand Marais, there is interest in expanding small public building district heating clusters into downtown areas. Numerous business owners in each community responded positively to a survey about near-term plans to replace current heating systems and interest in district heating. The financial viability of downtown extensions ultimately will be determined by how many of these businesses elect to join when additional information is available.

Introduction

In northern Minnesota, several communities are interested in the potential for biomass energy to address local concerns about energy costs, self-reliance and environmental stewardship. Among these communities are the cities of Ely and Grand Marais (Figure 1). In 2011, with support from the Legislative Citizen Commission on Minnesota Resources (LCCMR), these communities joined forces with Dovetail Partners and an extensive study team to explore biomass energy opportunities and answer questions about likely short and long term impacts. This collaborative effort over the next 18 months engaged community and government leaders and citizens along with experts from Dovetail Partners, the University of Minnesota, Wilson Engineering, the USDA Wood Education and Resource Center, and private industry in exploring economic, social and environmental aspects of biomass energy in northern Minnesota.

Figure 1. Project Area Map

Project Overview

In the past decade, Minnesota legislation has set ambitious goals to increase renewable energy in the state's energy portfolio. Many energy sources and implementation strategies could potentially play a role in reaching these goals. Ideally, diversification of the energy sector will both reduce carbon dioxide emissions from fossil fuel-based energy and contribute other economic, social, and environmental benefits to the state.

One approach of particular interest in forested regions is conversion to locally-sourced woody biomass energy. This approach would use a local resource – residual biomass from timber harvest, fire mitigation, and other tree or brush removal activities - that is currently unused or under-valued. As such, it has potential to support additional jobs in the forest sector, reduce buildup of fire-prone materials in forests, and provide an alternative to costly heating oil and propane used for heat. A first task in evaluating these opportunities is to determine whether a sustainable supply of woody biomass is available for bioenergy use within a reasonable distance of interested consumers.

In addition to renewable fuels, there is also the potential to increase efficiencies and lower energy costs by connecting major consumers into district energy systems. In northern Europe, and increasingly in northern US states, advances in community-scale district heating or combined heat and power (CHP) technologies are making them more practical, financially-viable, and environmentally-preferable to stand-alone furnaces. Determining how such systems could be expanded in Minnesota involves identifying building clusters where distributed energy is both technically and financially feasible, then working through supply chain logistics of getting woody biomass from forest to the energy production facility and to customers.

High quality information, open dialogue among stakeholders, and a creative, entrepreneurial spirit are essential ingredients in the complex task of transitioning to new energy systems. Below is a description of how project partners attempted to bring these ingredients together.

Project Structure

The goals of the project were: *Support community-driven transitions to alternative energy by (1) developing high-quality objective information about pertinent topics and options related to bio-energy systems; and (2) build strong communication structures to gather and disseminate information among project partners, stakeholders, and the larger public.*

To support these goals, the project was structured as an iterative and collaborative process between a study team and community steering committees to set direction, gather and analyze information, discuss results, identify new questions and options of greatest interest, and plan next steps accordingly. Background reports on all pertinent topics were developed, summarized into fact sheets and other presentations, and shared in small sector group discussions (e.g., with forest managers, loggers, customers) and in public meetings with citizens and stakeholders. The project was conducted in two phases, as described below.

Phase I focused on developing technological options for biomass energy systems (also referred to as configurations) at different scales of operation. Preliminary assessments were made of the biomass feedstock demand, system costs, and financial performance of alternative options. Options ranged from small, stand-alone residential wood-burning or pellet stoves, to medium-sized district heating systems for resorts or small business clusters, up to larger district heat or co-generation of heat and power (CHP) systems connecting government, business, and residential areas in each community. In Ely, several options developed prior to this project were also considered. At the conclusion of Phase I, community groups selected the most promising options for further study.

Phase II produced in-depth background reports on financial feasibility, biomass availability within 60-mile supply zones around each community, environmental impacts of forest biomass harvest, and estimated air emissions of biomass combustion systems (both direct (smoke-stack) and life cycle (cradle-to-grave)). Implementation issues throughout the supply chain from forest to consumer were discussed with public lands representatives, loggers and timber industry representatives, major customers, and environmental stakeholders. A tour of several comparable biomass district heating systems in the region was organized. Fact sheets on study findings were disseminated at meetings with different interest groups and in larger public meetings. Phase II concludes with a final report of all findings to each community.[1]

---

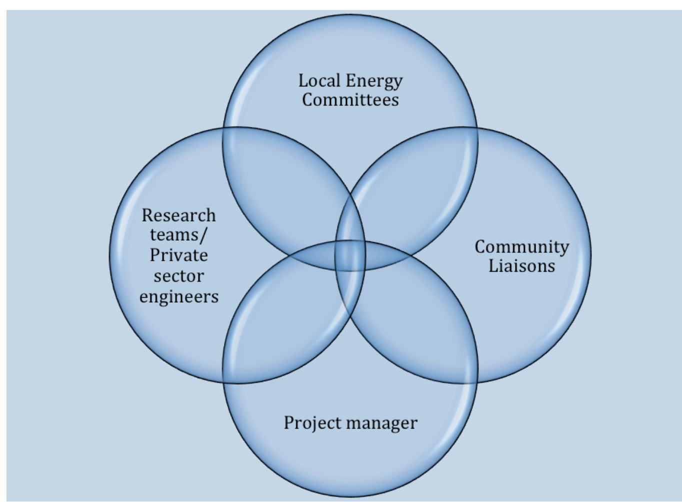
[1] Although not within the scope of this project, each community is engaged in discussions of potential third phases for more detailed engineering and business planning.

The community focus of the project dictated an operational structure that included a number of key partners. The Phase I and II community energy groups and experts from the private sector and academia that had major roles and responsibilities during the project were:

- *Project sponsor*, Dovetail Partners, a private nonprofit organization with expertise in forestry, economics, and public policy, provided overall administration, and conducted environmental and air quality assessments;
- *Project manager* developed plans, oversaw day-to-day progress, and maintained communication among collaborators.
- *Community Liaisons* in each community facilitated the flow of information among partners, stakeholders, and the public and liaisons in each community;
- *Local energy committees* - the Alternative Energy Task Force in Ely and the Cook County Local Energy Committee in Grand Marais – comprised of representatives of government, business, conservation, and other interests;
- *Research teams* at the University of Minnesota Departments of Forest Resources and Applied Economics analyzed biomass availablity and costs and financial aspects of optional systems;
- *Private sector engineers* – LHB, Inc., FVB Energy, Inc., and Wilson Engineering - were contracted separately through grants from Cook County and USDA Forest Service Wood Education and Resource Center (WERC) to provide technical information on design of small, medium, and large stand-alone or district energy systems.

The importance of the collaborative structure (Figure 2) that was used for this project cannot be overemphasized. In order to deliver on the goal of maintaining a community-driven focus, it was essential to have the local energy committees in place and adequate resources available to support a dedicated community liaison. Without these functional elements, it would not have been possible to make the necessary adjustments to the project to address the evolving and critical needs of the communities in addressing the complex considerations of energy system alternatives. In some ways, "it takes a village" to develop sustainable energy systems!

Figure 2. Community-Driven Project Structure



Summary of Project Results

The following sections summarize the major background reports that were completed to address the financial, wood supply, environmental, life cycle and supply chain aspects of the project.

Pre-Feasibility Financial and Wood Supply Analysis

Assessments conducted by experts from the University of Minnesota, LHB, Inc and Wilson Engineering included seven bioenergy options within the community of Ely and nine within Cook County and Grand Marais. Options range from supplying heat for small, single-building facilities to district heating that provides combined heat and power throughout a community's business or residential districts. The resulting prioritized system options, costs and modeled financial performance are summarized in the following tables (Tables 1-4). The overall results of the project illustrate the potential for responsible and sustainable development of biomass energy in northern Minnesota. There are a range of biomass energy system sizes and types that could be used in northern Minnesota, and district heating systems appear to make financial sense for many communities in this region. The research also found that from an energy-efficiency and environmental impact viewpoint, the largest systems aren't necessarily the best. Instead, it is important to "right-size" biomass energy systems to optimize energy use densities and other factors. A financial feasibility model developed for the project helps illustrate the potential costs and returns for systems of various scales. This model is available to other groups interested in assessing community biomass energy options.

In terms of available biomass supply, research shows that sufficient excess biomass is available from supply zones of less than 60 miles from the project areas. Available material includes residues from logging operations (in excess of that required to be retained on the harvest site in compliance with state guidelines) as well other fuel types. For example, just 50% of the tops and limbs from harvest residuals around Ely could provide nearly 60,000 dry tons per year, which is enough to meet the annual fuel demands for the largest potential system more than seven times over. In the Grand Marais supply zone, 50% of tops of limbs from annual harvesting could result in over 12,000 dry tons of biomass, which is about four times the annual fuel needs of the largest system evaluated. Both of these estimates are based on current harvest levels, which are generally lower than historic levels for most land ownerships and which are lower than what research has determined to be environmentally sustainable for the region. If harvest levels increase or materials other than tops and limbs are included in the biomass availability estimates, then the volume estimates are significantly increased.

Challenges related to the biomass supply include potential competition with other wood and biomass users as well as the need for sufficient infrastructure, including logging professionals, to harvest and deliver the material to a biomass facility. The background report completed by the University of Minnesota includes a discussion of biomass harvesting, handling and transportation costs. For a logger to justify moving equipment to a site to process biomass there needs to be enough throughputs to offset hourly costs. Small parcel sizes, long mobilization distances between harvest sites, and long transport distances to the biomass facility are disincentives. Where current biomass harvesting infrastructure is lacking, future investment in equipment will likely be predicated on sufficient volume demands and consistent market prices.

The background report "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." contains the full analysis of the biomass system options and the modeling of financial performance, including a discussion of assumptions and key metrics. It *is available from the project website or by contacting Dovetail Partners.*

Pre-feasibility financial and wood supply analysis for Ely (Tables 1 and 2)

Table 1. Modeled biomass systems and equipment specifications for Ely.

Configuration	Heat demand (non-peak) (MMBtu/yr)	Building connections	Fuel type	Annual biomass demand dry tons (wet tons)
Option 1: Vermilion Community College	7,680	0	Chips/Hog	527 (878)
Option 2: E-BCH, Sibley, ISD 696	16,235	3	Chips/Hog	1,754 (2,924)
Option 3A: Option 2 extension	21,381	18	Chips/Hog	2,559 (4,165)

[1] Assumes 55-60% of heat load with peaking backup for coldest days. [2] District heating portion of a CHP system; a stand-alone district heating system was not analyzed in the LHB report.

Table 2. Financial performance of proposed options for Ely.

	Option 1:	Option 2:	Option 3A:
Capital costs including hookup ($)	$1,934,318	$3,783,002	$5,459,348
Annual electricity sales ($)	$0	$0	$0
Net Present Value ($)	$64,767	$1,140,469	$4,560,259
Simple payback period (years)	12	0	13.5
Biomass cost of heat ($/mmBtu)	$32	$26	$30
Current fossil fuel price ($/mmBtu)	$30	$29	$29

[1] Including Power Purchase Agreement (PPA) for electricity sold.
[2] Cost of fossil fuel only; does not include the full cost of heating.

Pre-feasibility financial and wood supply analysis Cook County/Grand Marais (Tables 3 and 4)

Table 3. Modeled biomass systems and equipment specifications for Cook County.

Configuration	Heat demand (non-peak) (MMBtu/yr)	Building connections	Fuel type	Annual biomass demand dry tons (wet tons)
M1: Heat for main lodge and guest cabins at Lutsen Resort	5,200	12	Chips	390 (650)
L3: Public buildings north of 5th Street N and CC Courthouse	11,796	10	Chips/Hog	940 (1,567)
L6: District heat for downtown business district and L3	30,562	75	Chips/Hog	2,450 (4,083)
Hybrid: Combination of L3 and L6 scenarios for largest users	24,186	21	Clean chips Hog fuel	1,940 (3,233)

[1] Assumes 55-60% of heat load with peaking backup for coldest days.

Table 4. Financial performance of proposed options for Cook County.

	M1	L3	Hybrid	L6
Capital costs including hookup ($)	$994,700	$4,040,000	$7,330,000	$13,050,000
Annual electricity sales ($)	$0	$0	$0	$0
NPV project cost ($)	$1,303,533	$5,639,484	$10,586,839	$17,922,468
NPV savings (including PPA) ($)[1]	$2,316,000	$5,848,000	$11,894,000	$15,094,000
Net Present Value ($)	$1,012,158	$208,098	$1,306,862	$(2,828,098)
Simple payback period (years)	0	12	0	>20
Biomass cost of heat ($/mmBtu)	$23	$36	$33	$44
Current fossil fuel price ($/mmBtu)[2]	$34	$33	$33	$33
Maximum annual outlay ($)	$0	$33,453	$0	$342,679

[1]Including Power Purchase Agreement (PPA) for electricity sold.

[2]Cost of fossil fuel only; does not include the full cost of heating.

Life Cycle Impacts and Environmental Considerations

To evaluate potential life cycle impacts of converting to biomass energy, a background report was prepared using published studies of life cycle and at-combustion-site impacts of wood energy systems and comparisons to more conventional systems (natural gas, heating oil, and propane). Findings of various studies were reported and then interpreted in context of specific options under consideration in Cook County and Ely. Similarly, potential environmental impacts were drawn from published reports on Minnesota timber harvest, principally the *Generic Environmental Impact Study of Timber Harvest and Forest Management in Minnesota*, and its updates. In general, biomass energy has the potential to reduce total overall environmental impacts and emissions by avoiding many of the impacts associated with fossil energy sources (e.g., mining, long-distance transport, and international military conflict). However, the use of biomass energy can increase the types of impacts that are encountered locally. Locally-sourced woody biomass means that both negative and positive impacts occur in the local area. Per unit of energy, forest biomass energy generates lower emissions than fossil fuels of some air pollutants, and higher levels of others. The size of the biomass system that is developed, the type and amount of fuel that are used, and where the facility is located are all considerations that will influence the environmental and life cycle impacts of the system. The size of systems being considered by Ely and Grand Marais are relatively modest in size and impacts can be managed through appropriate design, installation, permitting and monitoring.

The ecological effects on soils, wildlife, fire regimes, and water quality of using biomass for bioenergy depend on the existing condition of the forest stand and the amount of biomass to be removed over a specific period. The results depend on such factors as the timing of removal, the volume removed, and the nature of the biomass (e.g., bolewood, fine or coarse woody debris, harvest residuals, etc). According to the *Journal of Forestry*[2] scientific evidence from sites across North America suggests that the productivity of most sites is largely resilient to removing harvesting residuals. Documentation of negative effects on site productivity due to biomass removal is rare (Malmsheimer et al. 2011). The project scenarios under consideration in Cook County and Ely are relatively small in terms of total biomass demand; however, their development still represents a potential change in forestry practices in the region and it is important to consider the impacts of that change.

Sustainable forest management practices are well-known and widely-practiced in Minnesota, as evidenced by the widespread participation in third-party forest certification, use of harvesting guidelines and best management practices, and continuing education programs for natural resource managers and harvesting professionals. These tools help protect the forests' environmental and ecological values. A recent meta-analysis of the scientific literature suggests the effects of biomass harvest on biodiversity can vary by harvesting practices and other factors. Biomass harvesting guidelines are recognized as an important tool for taking a precautionary approach to making use of this energy resource. With scientific evidence lacking for significant negative project level impacts, harvesting guidelines can allow managers the flexibility to tailor prescriptions to site conditions, address limiting factors and promote analysis of the impacts across a scale that includes numerous ownerships and projects (Malmsheimer et al. 2011).

---

[2] *Journal of Forestry*, October/November 2011, 109(7S):S24-S26.

In 2007, Minnesota established biomass harvesting guidelines to help address long-term biomass sustainability considerations. A study done in Minnesota concluded that following the biomass harvesting guidelines established by the Minnesota Forest Resources Council (MFRC) should mitigate concerns about soil nutrients, structure and wildlife habitat (Arnosti et al. 2008). An important area of focus is on ensuring the guidelines are well understood and being consistently implemented. The first year of biomass guideline monitoring indicates that there is still room for improvement and the need to ensure that the new guidelines are being incorporated into contracts and forest management practices. Training and monitoring programs are essentially to improving guideline implementation.

Community members expressed a number of concerns about biomass harvesting, including the potential impacts to soil resources, wildlife habitats, water quality, tourism and other factors. At the same time, there is strong support for its potential benefit : reduced wildfire risks, improved forest health, economic benefits, and local energy self-reliance. This analysis indicates that sufficient biomass material can be responsibly harvested as a bi-product of (not additional to) current timber harvests, which at present are significantly lower than what research has found to be sustainable. Based on this analysis, sufficient biomass material is currently available and can be responsibly harvested to support the community-scaled biomass energy projects being evaluated in Cook County and Ely. 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 (Table 8) and other environmental safeguards be continued and widely adopted.

Table 8. 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 • 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

The complete background reports "Local Environmental Considerations Associated with Potential Biomass Energy Projects in Cook County and Ely, Minnesota" and "Life Cycle Impacts of Heating with Wood in Scenarios Ranging from Home and Institutional Heating to Community Scale District Heating Systems" are available from the project website or by contacting Dovetail Partners.

Supply Chain Discussions and the Socio-Economic Considerations of Biomass Energy

Community district energy based on locally-grown biomass is a complex network of resources, activities, people, and technologies. Supply chain logistics begins in the forest, with long-term and short-term management plans and guidelines. Timber harvest, brush management, or other activities follow, and then the processing, hauling, and storage of woody biomass for energy production. The end user, the energy consumer, completes the chain. Throughout the entire process, different businesses come into play, often with competing interests and very limited knowledge of other links in the chain.

In mid-2012, exploratory discussions were held with potential participants in supplying and consuming biomass energy in Ely and Grand Marais. The objective was to improve practical understanding of key considerations in each segment of the chain, to promote whole-system thinking and partnering, and hopefully to find "win-win" strategies for cleaner energy, improved forest management, and stronger community economies. Over 75 people from different sectors of community were brought into these discussions. The results highlight diverse perspectives and opportunities related to biomass energy development in these communities, including the important role of land managers and professional loggers as well as the interests of the energy customers and local citizens. The results help frame up a continuing dialogue between the municipalities, timber operators, energy customers and other supply chain stakeholders about optional arrangements for supplying biomass energy feedstocks.

The complete background report "Supply Chain Logistics and Concerns" is available from the project website or by contacting Dovetail Partners.

Acknowledgements

Thanks to the project study team, including Dr. Dennis Becker, Dr. Steve Taff, David Wilson, Andrew Smale of the University of Minnesota; Dr. Jim Bowyer and Dr. Steve Bratkovich of Dovetail Partners; Cheryl Miller, Katie Fernholz, Matt Frank of Dovetail Partners; and Gary Atwood and Gloria Erickson, based in northern Minnesota. The research team specifically wishes to thank the citizens and citizen groups that provided input to the project, including the Cook County Local Energy Project (CCLEP) and Ely's Alternative Energy Task Force (AETF), and stakeholder advisory groups in each community which were key partners informing the development of the project and the focus of research efforts. Local community coordinators, Gary Atwood in Cook County and Gloria Erickson in Ely, served a critical service in facilitating community engagement through the design and completion of the project. Also, land managers, landowners and logging professionals in the project area provided invaluable insights into biomass opportunities and challenges. Special thanks to Cook County Commissioners, the USDA Wood Education and Resource Center, and the Minnesota Natural Resource and Environment Trust Fund, as advised by the Legislative Citizen Committee on Minnesota Resources for supporting this project and the exploration of community-driven renewable energy in northern Minnesota.

References

Arnosti, D., Abbas, D., Current, D., and M. Demchik. 2008. Harvesting fuel: Cutting costs and reducing forest fire hazards through biomass harvests. Institute for Agriculture and Trade Policy. Minneapolis, 80 pp. Available at: http://www.upwoodybiomass.org/downloads/harvesting_fuel_arnosti_et_al_2008.pdf.

Malmsheimer, R., Bowyer, J., Fried, J., Gee, E., Izlar, R., Miner, R., Munn, I., Oneil, E., and W. Stewart. 2011. Managing forests because carbon matters: Integrating energy, products, and land management policy. *Journal of Forestry*, 109(7S):S7-S50.

Minnesota Forest Resources Council. 2007. Biomass harvesting guidelines for forestlands, brushlands and open lands. 42 pp. Available at: http://files.dnr.state.mn.us/forestry/biomass/biomassHarvestingGuidelines.pdf.

Final Report prepared by:

Cheryl Miller and Kathryn Fernholz

Dovetail Partners
528 Hennepin Ave, Suite 703
Minneapolis, MN 55403
612-333-0430
www.dovetailinc.org
info@dovetailinc.org