Madelia Bio-Based Eco-Industrial Assessment

Rural Advantage

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Executive Summary


Madelia Chamber Photo

The Madelia Bio-Based Eco-Industrial Resource Assessment project involved the gathering and analysis of data to develop a basic renewable energy and materials flow analysis [Renewable Resources Profile] for the community of Madelia, Minnesota. The scope of this project included the region within a 25 mile radius of Madelia. The project team identified, inventoried and assessed the sources of biomass material flows from the major processors, energy users, and agricultural sectors within the project area. A Renewable Resources Profile has been developed to inform the community about the amounts, characteristics, and methods of utilizing local agricultural and industrial biomass feedstocks for energy and/or bio-based industrial development.

The first task of this project was to inventory the biomass supply from the region. Agricultural related biomass supply was determined using local and USDA Agricultural Census data. A survey was developed and sent to 164 area industries and businesses. The goal was to identify potential major biomass generators. Other smaller generators were not included since the focus was on primary sources of biomass supply. Results of the inventory estimate over 20 million tons of biomass available annually in the region with a potential of producing over 38 trillion BTU's of energy.

The second task identified the energy demand from the region. Energy demand was divided into four sectors for tabulation: residential, industrial, commercial, and agricultural. For each sector we calculated the demand for thermal energy [from natural gas, LP gas, fuel oil, wood]; electricity and transportation fuels [diesel, gasoline, ethanol, biodiesel]. Information was collected from our survey responses and a variety of public data resources. Results show an estimated total energy demand from the region of over 47 trillion BTU's with thermal demand at 17.588 trillion BTU's; electrical demand at 14.95 trillion BTU's; and transportation fuels at 14.651 trillion BTU's.

Key findings from this assessment are 1) on a net basis, there is more energy demand than could be supplied from biomass sources under the current cropping system and 2) it is unrealistic to expect that 100% of the energy demand for the region to be supplied from within the 25 mile radius area due

to site specific energy demands and distribution limitations with existing infrastructure.

The final task identified emerging technologies the community could consider in a new community-based renewable energy facility that could be fed by the vast productive agricultural land resource in the region. Technologies considered include anaerobic digestion, gasification, pyrolysis, electricity, and wind.

Key objectives in pursuing this kind of facility include:

- energy security from locally grown energy production
- increased economic and environmental sustainability of family farms
- improved ecological health - including water quality
- a more vibrant community and sense of place

The results of this project, captured in this report, can assist Madelia community leaders in planning how the city could further develop the concept of a renewable energy facility as an anchor for an eco-industrial park that would advance positive community growth in the region. Following these methods could give the community a distinct competitive advantage over rural communities that are considering a more traditional path of economic development.

The Watonwan River Tim Nolan

Introduction

Eco-industrial development offers an alternative approach to current economic development models by integrating sustainable development principles as a primary driver. A key component is the creation of a network of businesses that cooperate with one another and with local communities to improve resource productivity, restore the local environment, and eliminate pollution and associated costs. The aim is for higher environmental performance and economic value creation.

The Madelia Model is intended to apply an eco-industrial development approach by providing a concept for how a community can capitalize on agricultural production in the region to create renewable energy and bio-based processing that enhances rural wealth economically, socially and environmentally. This report focuses on the renewable energy piece of this concept, which will be closely integrated with bio-based processing.

The model is centered on Madelia, Minnesota and includes an area of approximately a 25 mile radius as the 'community'. The concept being that within a 25 mile radius of a rural community you can grow, or collect from natural or industrial sources, enough biomass to 'fuel' your community and bio-based processing. Capitalizing on the synergies between agriculture, environment and community to bring renewable energy processing into a community gives it a distinct competitive advantage.

The Rural Economic Development Concept, diagramed on page 7 is the premise of this concept. This concept supports rural communities who have a longer term, sustainable vision that advances agriculture, quality of life, and business opportunity. The framework for this concept includes a bio-based eco-industrial park, with a sustainability theme, that includes small community sub zones for pre- processing, consolidation, processing and identity preserved storage of agricultural products. Local farmers, growing a diverse range of crops, would be the backbone to supply the raw product.

A strong agricultural framework is critical to revitalizing rural Minnesota. This concept enhances our base agricultural system by promoting crop diversity; develops new local market opportunities; and provides local processing to add value to locally grown crops.

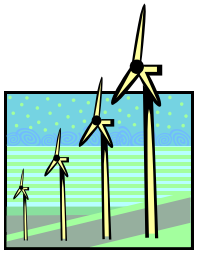
The bio-based eco-industrial park would process, manufacture and package agricultural crops raised in the region. The energy supply would be a locally grown renewable energy source that might include bio-fuels, wind, methane, synthetic natural gas, solar or hydrogen. A processing company would be the main anchor of the industrial park and would transform agricultural products into higher value commodities such as derivatives, medicines, or cellulose to plastics. Other companies within the industrial park would process their own agricultural commodities, utilize the value added products for further processing or utilize co-products for additional value added products.

The sub zones would be other communities in the surrounding area. These sites would provide a location for collection, consolidation, pre processing or manufacturing that is physically close to the growers. An example might include storage bins for crops other than corn or soybeans where identity can be preserved. It also could be a collection point for crops going to the industrial park for load efficiencies.

With biomass technologies, a huge issue is the transportation costs associated with getting the biomass to the energy facility. Imagine that a small community could have a facility that would take bales of hay [biomass] and convert them to a bio-oil. They would do this by densifying the material through pyrolysis [described later in this document]. Instead of transporting a few large bales per semi load to a refinery, you could transport one bio- oil tanker [replaces seven semi loads of biomass].

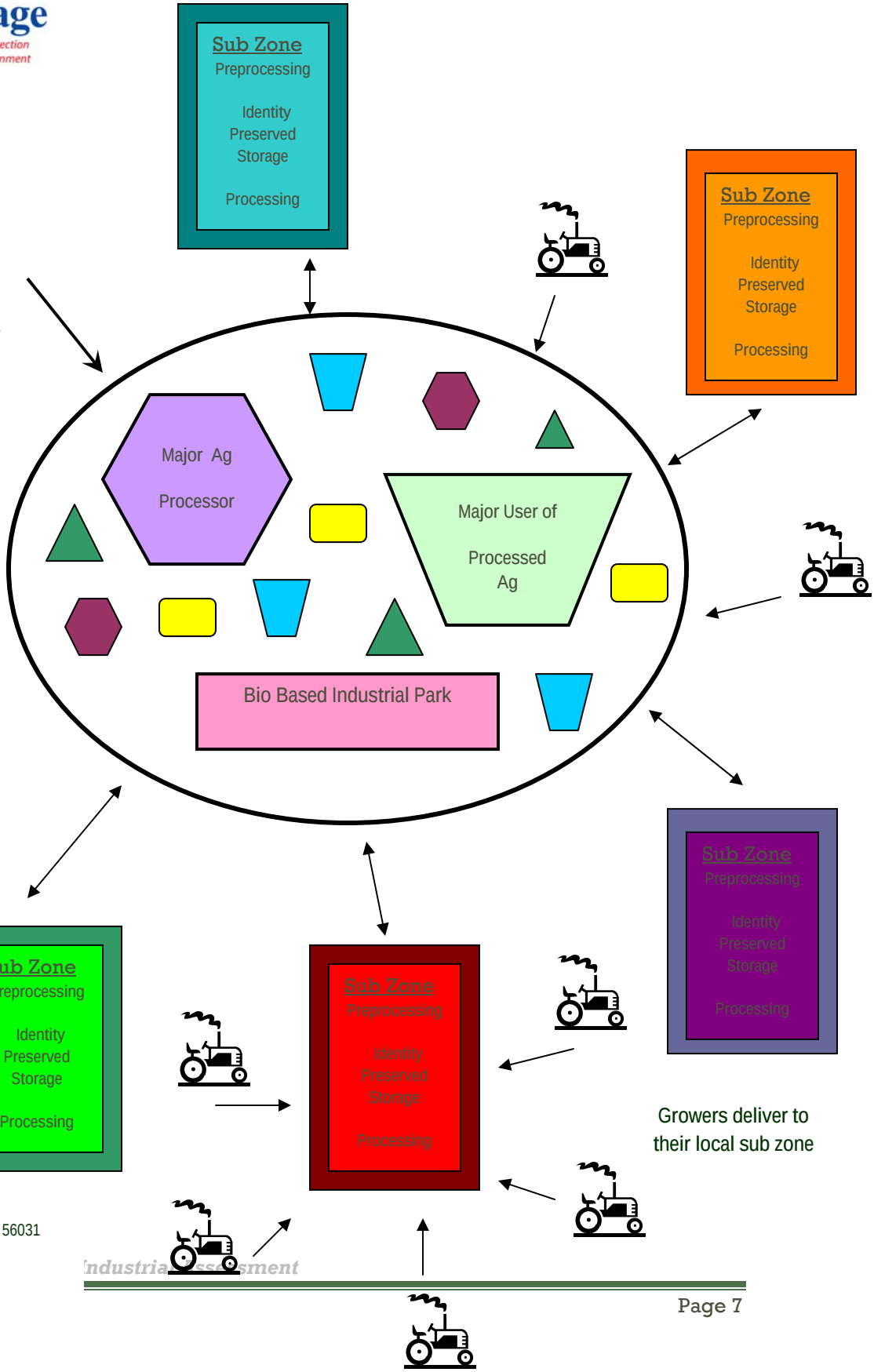
This model carries through an underlying theme of sustainability. Farmers would receive a premium for crops grown in a sustainable way; manufactures would be committed to low emissions to air and water and there would be a commitment to living wage jobs. In addition to jobs, this concept supports the development of viable rural communities that are less dependent on government; provide additional ecological services; and promote a positive social atmosphere of community. This would be WIN- WIN- WIN for the region economically, socially and environmentally.

Rural Economic Development Concept



Renewable Energy

[Wind, Thermo, Solar, Methane, Bio Fuels, Hydrogen, Etc.]



Growers deliver to their local sub zone

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An Eco-Industrial Park is "a community or network of companies and other organizations in [a physical park] who choose to interact by exchanging and making use of byproducts and/or energy in a way that provides one or more benefits over traditional, non-linked operations" These benefits include: reduction in natural resources use for inputs, reduction in pollution, reduction in energy use, reduction in disposal of wastes, and increase in value of non-product outputs. (Gertler 1995, 16).

The Madelia Model is intended to be a working document or a roadmap toward development of a sustainable renewable energy and bio-based eco-industrial park model that showcases the multiple benefits of a sustainable community development mindset that can be replicated across the landscape. The Madelia Model leverages the combination of local agricultural land resources, regional environmental advantage and rural community power to elevate a rural community's position toward positive growth, sustainability and being the pride of the prairie.

Madelia City Park Tim Nolan

To capture the multiple benefits the Madelia Model can bring to a community, the community should consider adopting a set of principles that define the type of development they desire. These principles should be the result of

inclusive community dialogue around these issues. Basic principles considered may include:

1. Create and utilize sustainable, locally grown, renewable energy.
2. Utilize local agricultural products for value-added processing.
3. Support landscape diversification that provides multiple benefits.
4. Nurture industries that provide living wage jobs.
5. Desire industries with clean air and water emissions.

The area targeted for this project is the area within a 25 mile radius of Madelia, Minnesota. This distance was selected because the team felt it was a large enough area to adequately supply biomass to support renewable energy processing with a goal of up to 20% of the landscape converted to non row crops or perennial biomass energy crops such as native prairie mixes.

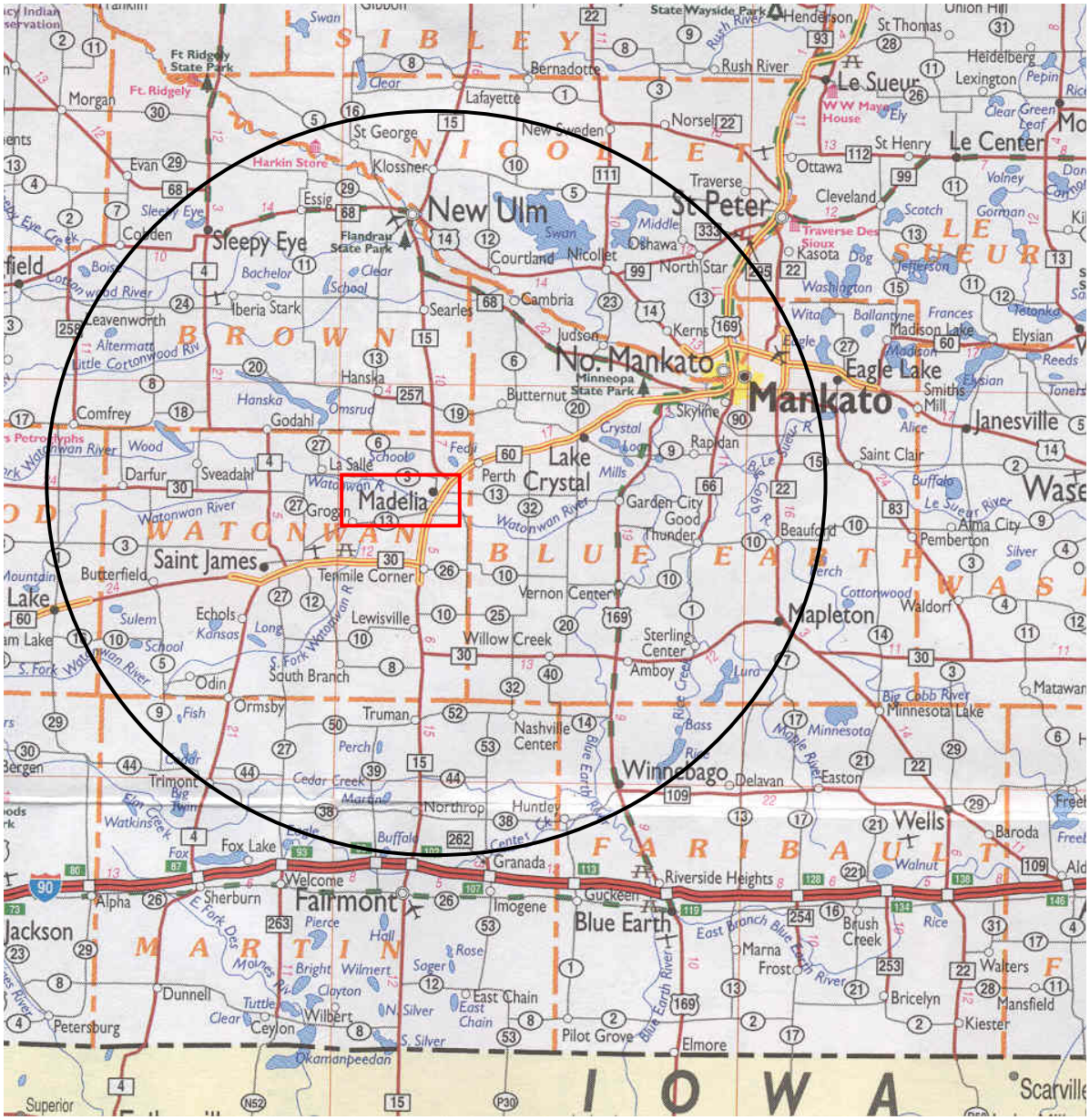
Within the 25 mile radius there are 1.9 million acres currently in annual row crop [corn/ soybean] cultivation. Conversion of 20 percent of the row crop acres, or 380,000 acres, can be accomplished by utilizing precision conservation methods and targeting the converted acres to the most environmentally sensitive areas. Corn and soybeans could then be grown on the lands with highest productivity for corn and soybeans and the more marginal lands growing bio-energy crops.

Precision conservation is a term that was adopted to mean higher level BMP's that are applied to strategically targeted environmentally sensitive areas. Of these 380,000 acres, we should estimate one half [190,000 acres] of the acres being planted to long term perennials, preferably native prairie mixes.

The other one half of the acres could be short term perennials [alfalfa, switchgrass, hay crops, etc.], small grains, and cover crops. These acres could then be rotated as part of the overall farm system to build soil health and productivity throughout the farm. As additional bio-energy markets develop, along with bio-based processing, these acres could transition to

long term perennial plantings. This would allow maximum synergy between agriculture and environment.

Area Within A 25 Mile Radius of Madelia, Mn



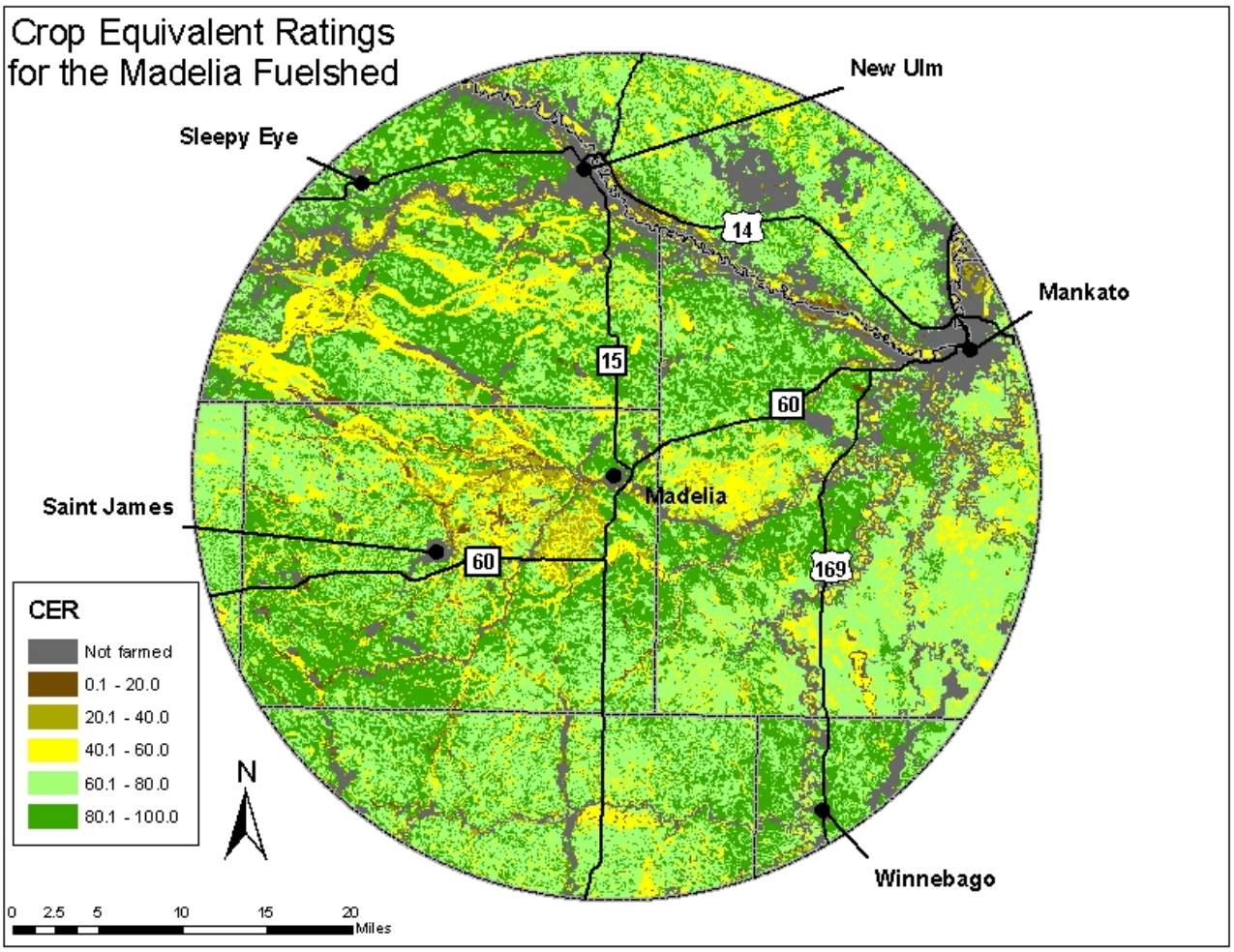
The Watonwan River, which flows through Madelia, is listed on the 2006 Minnesota impaired waters list for impairments of fecal coliform, turbidity, mercury and fish IBI. These impairments affect aquatic recreation, fish consumption, and aquatic life in the Watonwan River. These impairments also affect potential economic development in the region. Federal and state laws prohibit additional pollutant discharges to waters that are listed as impaired. Any industry/ business desiring to come to the area would not be permitted unless they met the water quality criteria.

The Watonwan River Tim Nolan

Agricultural nonpoint source pollution is a contributor to these impairments in our intense row crop production area here in south central Minnesota and throughout the Midwest. Being able to take advantage of perennial bio-energy crops, such as native prairie mixes, could help agriculture address the water quality concerns and increase profitability through payments for

biomass and ecological services. If the Madelia Model would get built, and 20 percent of the landscape would be in bio-energy plantings, it would resolve the water quality problems. The result: a huge win for agriculture; a huge win for the environment; and a huge win for community and society.

The following map was prepared by Dr. Michael Russelle, ARS- St. Paul and Adam Birr, Graduate Student, University of Minnesota- St. Paul. The map is a GIS analysis of the crop equivalency ratings for the Madelia fuelshed [25 mile radius area]. Crop equivalency ratings are an index of soil productivity. The



index ranges from 1 to 100 with 100 indicating the most agriculturally productive soils. On this map, the most productive soils are darker green. As you move to the yellows and brown tones you find your lower productive soils. We might call this our "Opportunity Map" because there are plenty of

'opportunities' for a bio-energy cropping system in this landscape. Preliminary estimates indicate that about 23% of the landscape would meet the environmentally sensitive criteria that consider soil type, slope, proximity to water, and drainage factors.

Madelia Skyline Tim Nolan

Study Methodology

The Madelia Bio-Based Eco-Industrial Resource Assessment project involved the gathering and analysis of data to develop a basic renewable energy and materials flow analysis [Renewable Resources Profile] for the community of Madelia, Minnesota. For the purposes of this project we are interested in the region within a 25 mile radius of Madelia. The project team has identified, inventoried and assessed the major biomass material flows from the major processors, energy users, and agricultural sectors within the project area. A profile has been developed to help the community assess the amounts, characteristics, and methods of utilizing local agricultural and industrial biomass feedstocks for energy and/or bio-based industrial development.

This report is divided into four major sections: biomass supply, energy demand, emerging technologies and recommendations. Throughout the project we tried to keep focused on the bigger picture and net energy quantities. Actual numbers may be higher. In addition, data is not categorized by "within a 25 mile radius of Madelia" so we have used county data as the base where needed.

In the technologies section we chose not to include corn grain to ethanol as one of the technologies. The corn grain to ethanol conversion is well developed and does not need to be discussed here. One objective of this report is to expand our thinking on renewable energies and it's role in providing more profitable farms, cleaner air and water and vibrant rural communities.

The Madelia community leaders can utilize this report to assist in planning how the city could further develop the concept of a renewable energy facility as an anchor for an eco-industrial park that would advance positive community growth in the region. Following these methods could give the community a distinct competitive advantage over rural communities that are considering a more traditional path of economic development.

Biomass Supply

USDA-NRCS Photo

The first step of the study was to conduct an inventory of the types, amounts, sources, & characteristics of the biomass materials and energy demand in the project area. A survey was developed and sent to 164 industries, businesses, schools, government and other entities. Survey responses were limited, even with telephone call follow up, with only 18 returned. Low response was due to the inability to understand what was being requested and desire to not disclose the information.

Key information needed for the study is available from public sources and was extrapolated for use in this report to complement the survey responses. For example, if you have an ethanol plant of a certain size it will use XX amount of energy and water. This information can then be adjusted to the size of ethanol plants within the region to determine energy demand and output from these sources. Through the Harris Directory we were able to identify major businesses and industries in the region. Using US Department of Commerce data we were able to determine energy and other values necessary to complete the report.

One of the problems with this data is that it is available by county and not as a '25 mile radius around a community'. To accommodate this we utilized the data from the following counties to represent the area: Watonwan, Martin, Blue Earth, Brown, Faribault, and Nicollet. These counties are representative of the area. For the Madelia area, biomass supply is a function of:

- Land in Annual Tillage

- Livestock [manure]
- Land in Natural or Conservation Use
- Industrial Supply

The following four sections identify the biomass supply that would have potential for bio- energy use from each of these sectors. As a community you would not choose to utilize all of these sources for energy, but rather you would select the most feasible supplies based on several factors. It should be noted that all of the biomass supply is currently being used for other purposes such as livestock feed, bedding, ethanol, fertilizer or energy. A small portion is disposed of as waste.

A. Land in Annual Tillage

According to the 2004 Minnesota Department of Agriculture Ag Census 1,917,662 acres were in crop production in the six county region. Corn and soybeans dominate the crop mix and comprise the bulk of what is available as a potential renewable energy resource. Sweet corn and green peas are grown exclusively for processing at local facilities to enter the human food market. The silage that results from these industries has potential as an energy feedstock but is high in moisture; limited in quantity; and is available only seasonally. Hay crops are grown as a forage crop to feed the beef and dairy industries. Hay crops do have potential as a renewable energy feedstock while providing significant ecological services. Straw from small grain crops could contribute to the overall biomass supply but under the current farm system are only available in limited numbers.

USDA-NRCS Photo

Table 1: Land in Annual Tillage

Crop	Acres	Biomass Yield	Total	M BTU's/ Ton	Total BTU's
Oats	4,800	1 ton/acre (straw)	4800 tons	16.484	79,123 M
Winter Wheat	1,600	1.8 tons/acre (straw)	2880 tons	14.75	42,480 M
Spring Wheat	9,486	1.8 tons/acre (straw)	17,359 tons	14.75	256,045 M
All Hay	17,800	4 tons/acre	71,200 tons	15.458	1,100,609.6 M
Sweet Corn	19,500	4 tons/acre [22.4% DM]	17,550 tons	15.536	272,656.8 M
Corn Silage	20,900	7 tons/acre [28.5% DM]	41,800 tons	15.536	649,404.8 M
Soybeans	848,300	45 bushels/acre	1,145,205 tons	20.46	23,430,894 M
Corn (stover)	991,000	4 tons/acre	3,964,000 tons	15.536	61,584,704 M
Corn (grain)		150 bushels/acre	4,162,200 tons	16.2	67,427,640 M
DM = Dry Matter		**Total**	**9,577,944 tons**		**154,843,557 M**

Note: The yield estimates in this table were developed by Rural Advantage from a variety of sources. Fifteen million BTU's per ton of biomass was used to calculate total BTU's. Source: http://www.nass.usda.gov/QuickStats/Pull Data_US_CNTY.jsp

B. Livestock – [Manure]

Many agricultural producers in the region add value to their corn crop by feeding it to livestock. Swine, in confinement, is the specie most dominant with a small compliment of the beef and dairy industries. Approximately 42 million bushels of corn is used to feed livestock annually in the Madelia region. The USDA Ag Statistics Service publishes the livestock inventory by county annually. The inventory for swine, beef and dairy are shown in the table below. Swine make up the largest numbers

MN Pork Website Photo

followed by dairy and beef. Note that these are inventory numbers and not animal unit numbers.

Table 2: Livestock Numbers

Date of Inventory	December 1, 2004	January 1, 2005	January 1, 2005
County	**Swine**	**Beef**	**Dairy**
Blue Earth	416,000	1,300	1,000
Brown	275,000	3,100	6,500
Faribault	203,000	1,200	2,400
Martin	692,000	1,500	1,200
Nicollet	265,000	800	6,800
Watonwan	205,000	500	800
Total	2,056,000	8,400	18,700

Source: Personal Correspondence & http://www.nass.usda.gov/QuickStats/PullData_US_CNTY.jsp

Table 3: Manure Produced

Animal Type	# of Animal Units	Tons/Year/AU	Tons/year
Swine	822,400	11.5	9,457,600
Beef	8,400	10.8	90,720
Dairy	26,180	14.6	382,228
Total	856,980		9,930,548

Source: University of Minnesota

Table 4: Energy Value of Manure

Animal Type	Gas Produced Ft3/ Day	Gas/ Yr	BTU's/ft3	BTU's/Yr/AU	# AU	BTU's T/ Year
Swine	17.0	6232	600	3,739,200	822,400	3.075
Beef	31	11,315	600	6,789,000	8,400	0.057
Dairy*	65	23,725	600	14,235,000	26,180	0.373
Total						3.505

http://muextension.missouri.edu/xplor/agguides/agengin/g01881.htm

* Private Correspondence [Five Star Dairy Study]

C. Land in Natural or Conservation Use

Throughout the region there are approximately 204,322 acres in natural or conservation use that potentially could be harvested for bio-energy use. These areas are currently in perennial systems and include prairie, wetlands, pastures, forests, and the riparian area along creeks and streams. These areas may be in either public [such as parks or wildlife management areas] or private ownership. Currently, 52,843 of these acres are enrolled in the Conservation Reserve Program [CRP] or the Conservation Reserve Enhancement Program [CREP]. The balance or approximately 151,479 acres, are in a natural or conservation use. For program [CRP & CREP] acres, public policy would need to change to allow harvest from these acres for bio-energy. There is interest in this, especially as a management tool to mimic fire, control invasive species, and limit tree invasion into prairie landscapes. When we look at the non program acres, not all of these acres would be available to harvest for bio-energy use. It is estimated that about 37,870 acres or 25% could be harvested. These areas include native plantings, non natives such as cattails or reed canarygrass, and woody plants such as willows and cottonwoods. The potential biomass supply estimate from these acres takes into account a harvest once every three years to minimize negative impacts from these sites.

A conservative estimate of biomass yield is two tons per acre. A dry ton of biomass yields about 15 million BTU's resulting in the following potential energy supply from these areas.

Table 5 : Biomass Supply From Natural or Conservation Areas

Type	Acres Available	Annual Acres Harvested	Yield T/Acre	Total Yield	BTU's Per Ton	Total BTU's
CRP/ CREP	52,843	17,614	2 T	35,228	15 M	528,420 M
Natural/ Cons. Acres	37,870	12,623	2 T	25,246	15 M	378,690 M
Total	90,713	30,237		60,474		907,110 M

Source: USDA, Local Resource Managers

D. Industrial Supply

A multitude of industries are present in the region which have waste or by-products that could be used in energy production. The survey sent to businesses and industries included questions about types and quantities of waste streams/by-products that could potentially be used for bio-energy. Examples of biomass materials from industrial sources that could be converted to energy include paper waste, grease, oils, dried distillers grains, solid waste, bio-solids, food processing silages, screenings, and soybean hulls. Potentially, companies with larger volumes of biomass waste streams could convert it to energy on their own and reduce the amount of energy they need to purchase from outside sources.

A good example of this is Corn Plus ethanol plant at Winnebago, Minnesota where they recently started converting low value by-products from the ethanol process into synthetic natural gas. Preliminary results indicate replacement of at least one half of their natural gas demand. The limited survey responses hindered our ability to get a collective number of industrial by-products that could be converted to energy but we were able to consider the major ones. Several industries have a volume that is too small to

economically consider individually. Industrial streams that could be considered include dried distillers grains, soybean hulls, food processing wastes, compost and refuse derived fuel from Prairieland Compost Facility at Truman, Minnesota, grease and oils. Food processing waste [ie. sweet corn silage] is listed in the Land in Annual Tillage section. The 21.454 trillion BTU's of potential energy is a very conservative number for this sector. The rest are summarized in the following tables.

Dried Distillers Grains

Dried distillers grains, also referred to as DDG's, is a by-product in the production of ethanol. DDG's are actually a combination of two separate waste streams in the ethanol process, syrup solids and wet cake solids, collectively having a BTU content of 8,500 per lb.

Two ethanol plants are currently in operation in the study area, Corn Plus at Winnebago and North Star Ethanol at Lake Crystal. Two additional plants are being built, Buffalo Lake Energy at Fairmont and Vera Sun at Welcome. The amount of by-products and energy potential are listed in the following table.

Table 6 : DDG Energy Potential

Facility Annual Capacity	**Corn Plus (Winnebago)**	**Northstar (Lake Crystal)**	**Buffalo Lake (Fairmont)**	**Vera Sun (Welcome)**
Bushels (million)	16	19	41	41
Ethanol (million/gallons)	44	52	110	110
DDGs [1] (million/pounds)	272	323	697	697
Energy Potential[2] (trillion BTU's)	2.312	2.745	5.924	5.924
Total	**16.905 Trillion BTU's**			

Note: These estimates were developed by Rural Advantage from a variety of sources
Sources: [1] 17 lbs of DDG's are generated for every bushel of corn converted to ethanol - Personal Correspondence [2] Energy Content per lb of DDG is 8,500 BTU's - http://www.auri.org/research/fuels/pdfs/fuels.pdf

Soybean Hulls

Soybean hulls are a by-product of the soybean crush process. Three soybean oil crush facilities are in operation within the region. CHS operates plants in Mankato and Fairmont, while Archer Daniels Midland (ADM) operates a facility in Mankato.

Table 7: Soybean Hulls

Facility	ADM	CHS-Mankato	CHS- Fairmont
Annual Capacity			
Bushels (million)	24.75	36.3	36.3
Hulls Produced[1] (million lbs)	148.5	217.8	217.8
Energy Potential[2] (trillion BTU's)	1.124	1.648	1.648
Total BTU potential (trillion BTU's)	4.42		

Note: These estimates were developed by Rural Advantage from a variety of sources
[1] Soybean hulls are approximately %10 of total - Personal Correspondence
[2] Hulls contain 7570 BTU's /lb - http://www.auri.org/research/fuels/pdfs/fuels.pdf

Table 8: Selected Industrial Supply Summary

Biomass Material	Supply	Energy Content	Total Energy Value
Compost [Municipal Waste]	1,800 T/ Yr	10 M BTU's/ T	.018 T BTU's
Refuse Derived Fuel	6,250 T/ Yr	15 M BTU's/ T	.094 T BTU's
Grease [Food Processing]	576.38 T/ Yr	17 M BTU's/ T	.010 T BTU's
Bio-Solids	1,095 T/ Yr	5 M BTU's/ T	.005 T BTU's
Dried Distillers Grain	298,197 T/ Yr	17 M BTU's/ T	16.905 T BTU's
Soybean Hulls	292,050 T/ Yr	15,140,000 BTU's/ T	4.422 T BTU's
Total	**599,968.38 T/Yr**		**21.454 T BTU's/ Yr**

Source: Rural Advantage Survey

Table 9: Summary of Biomass Supply

Source	Volume	Energy Value
Land In Annual Tillage	9,577,944 Tons	154,843,557 M BTU's
Livestock [Manure]	9,930,548 Tons	373,000 M BTU's
Land in Natural/ Conservation Use	60,474Tons	907,110 M BTU's
Industrial	599,968.38 Tons	21.454 T BTU's
Total	**20,168,934 Tons**	**38.218,465 Trillion BTU's**

Energy Demand

Everyone is an energy user of multiple energy forms. We use electricity to light our homes and run our computers; gasoline runs our cars and we heat our homes, offices, and businesses with natural gas. For this report we classified energy users in the region into the following groups: residential, industrial, commercial, and agricultural to determine energy demand from the region.

Energy demand within the region consists of thermal fuels [natural gas, LP gas, fuel oil, wood], electricity, and transportation fuels [diesel, gasoline, ethanol, biodiesel]. On a larger scale these three make up the bulk of energy demand for the rest of the state and country. In order to replace what we use locally and even export renewable energy statewide or nationally, it is important to produce the form of renewable energy that can utilize the existing infrastructure for delivering the energy to the sectors and users that need it.

Electricity, natural gas, & bio-diesel are forms of energy that can already use the current infrastructure for distribution. Virtually every house, business, factory, and farm already use electricity, thermal fuels and transportation fuels. Bio-diesel is already being blended in varying quantities and ratios with petro-diesel so that increasing the quantity would not pose a large challenge to the distribution system. Every effort should be made to focus on producing forms of energy that could fit into the existing infrastructure so the expense of building a whole new infrastructure does not have to be incurred.

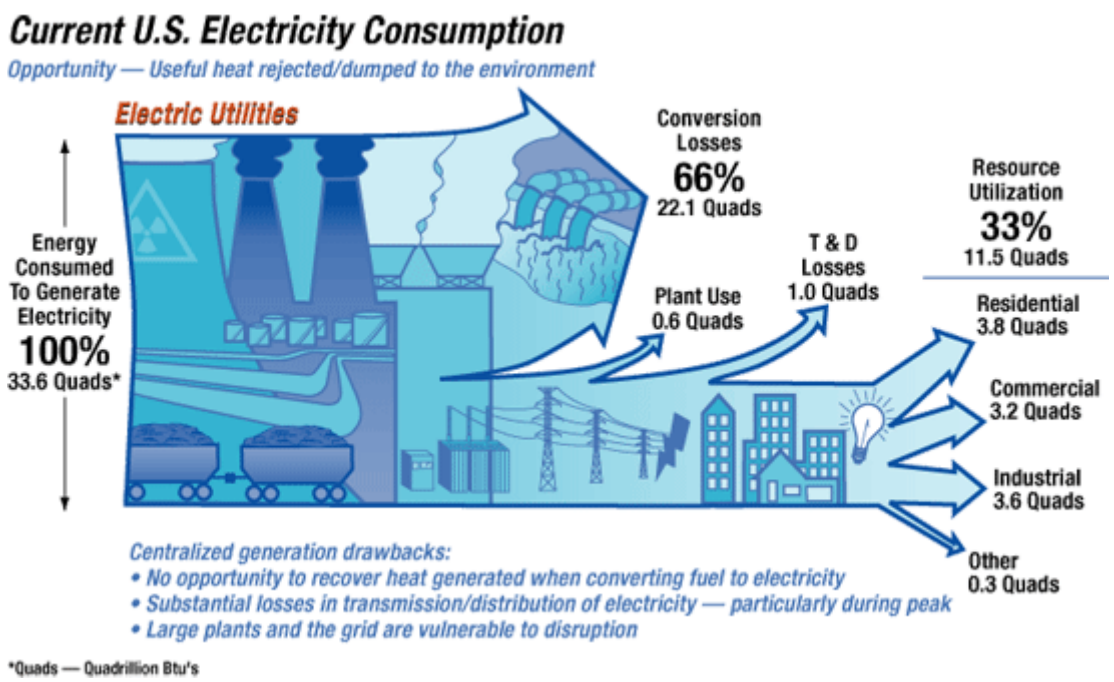
Production of synthetic natural gas can be achieved via anaerobic digestion, gasification or pyrolysis. Production of bio-diesel from either vegetable oil or animal fats is commercially viable and could be examined further. Technologies are being researched on using pyrolysis to create a bio-oil which may be usable for bio-diesel.

Bio-diesel demand is driven by the agricultural sector which uses large quantities of petro-diesel for field operations. The net energy balance of bio-

diesel is more favorable than petro-diesel or even ethanol. The crop, livestock and processing industries in the region could provide feedstocks for bio-diesel production.

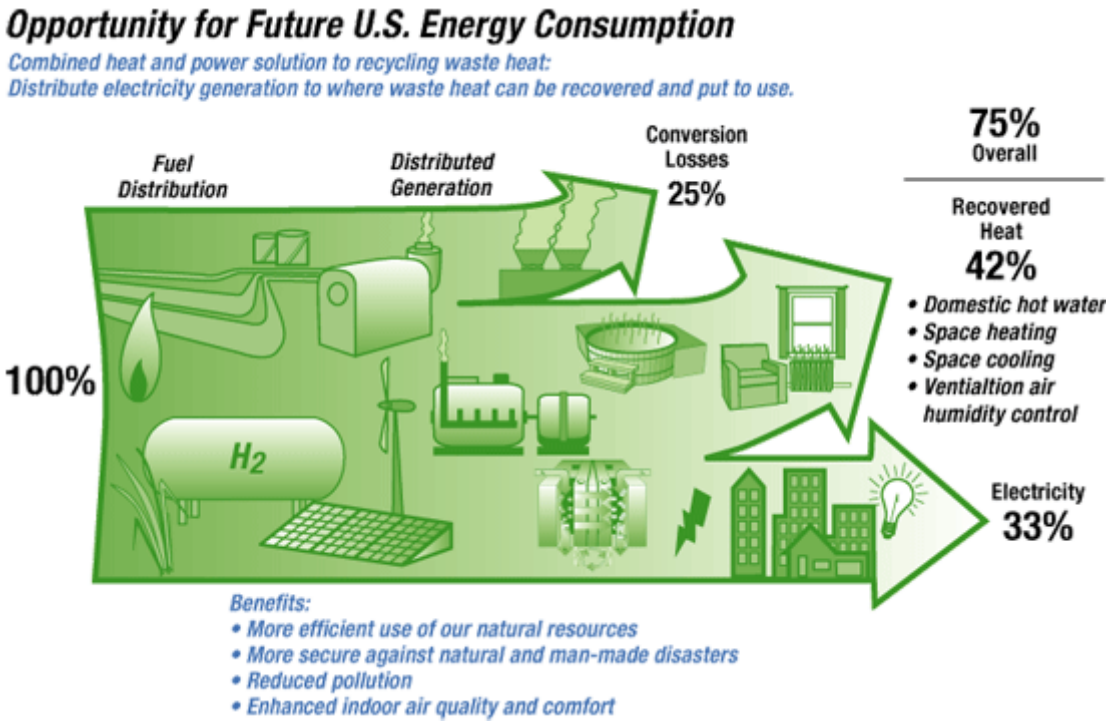
Current electricity production, transmission, and distribution are very inefficient, utilizing only about 1/3 of the total energy that enters the system. Conventional power plants produce electricity and emit heat as a by-product. This "waste" heat is sent through cooling towers to the outside environment. This represents a loss of almost 2/3 of the total energy available. Transmission and distribution also contribute to losses of energy because of the long distances electricity typically travels.

The diagram below depicts current U.S. electricity consumption. The energy consumed to generate electricity nationally is 33.6 Quads. However the amount actually utilized by residential, commercial, and industrial sectors is only 33% (11.5 Quads) of the total amount entering the system. Over 60% is lost during conversion of the feedstock to electricity.



Combined heat and power (CHP) also known as co-generation is a much more efficient way of producing electricity because the "waste heat" typically produced in the conventional system is captured and utilized and provides a revenue stream. A very basic example of this is a vehicle engine producing excess heat that is sent to the outside environment during summer but captured and used to heat passengers during winter months. In this way a typical internal combustion engine becomes a combined heat and power unit heating the vehicle while still powering it forward during winter.

The diagram below depicts how CHP can improve the overall efficiency of electricity production. The recovered heat that leaves the current system through cooling towers is captured and put to use in a number of diverse applications. Domestic hot water, space heating and cooling, humidity control, as well as process steam for industrial use are a few of the uses for the recovered heat. CHP can boost the efficiency of the system to 75% or better.



The benefits of CHP go beyond merely boosting efficiency and reducing fuel needs. In addition, the very nature of CHP is that it will be de-centralized, thus leading to even greater efficiencies by reducing the distance electricity has to travel before being used. Other benefits include:

The difference between primary electricity and on site electricity is the loss associated with producing and transmitting electricity from the centralized power plant to electrical end users.
This means we use 111.5 million BTU's of energy per year for us to actually use 37.3 million BTU's of electricity.
About two-thirds of the 111.5 million BTU's are lost that could be captured and utilized in various applications if produced locally.

- Rural, living wage, job growth to build and maintain facilities as well as grow, collect, and process biomass feedstocks.
- Reduced energy costs for industries doing business in the region. Ability to take control of energy production and attain a level of energy self sufficiency.
- Opportunity to attract businesses and industries by providing cost-competitive, consistent, reliable, clean energy.

Coupling the process of combined heat and power with thermo-chemical conversion of biomass to energy can provide additional benefits that include:

- Ability to use a wide range of multiple feedstocks and industrial wastes.
- Utilization of locally grown or produced feedstocks.
- Reduction of green house gases by using renewable feedstocks instead of fossil fuels.

A. Residential Energy Demand

The Energy Information Administration of the Department of Energy has compiled energy consumption per household organized by Census Region. The Madelia area is located in the West North Central Region. The energy consumption by type per household is shown in the table below. The Clean Energy Resource Teams (CERT's) compiled the number, type, and estimated fuel consumption of registered vehicles in each county using data available from the Dept. of Motor Vehicles. Transportation fuel energy demand is for passenger cars, pick-up trucks, SUV's, etc from the 6 county region.

The population of counties included in the study area are shown in the table below.

Table 11: County Population [2000 Census]

County	Population
Blue Earth	55,941
Brown	26,911
Faribault	16,614
Martin	22,849
Nicollet	29,721
Watonwan	11,750
Total	**113,786**

Note: Information compiled from U.S. Census Bureau, State & County Quickfacts
Source: http://quickfacts.census.gov/qfd/states

Table 12: Annual Household Energy Demand

Energy Type	% of HH Using This Fuel Type	Per Household Demand Million BTU's per year	Total Energy Demand Trillion BTU's per year
Electricity – Primary** [On Site Electric Use is 37.3 M BTU's per HH]	100%	111.5	5.035
Thermal			
Natural gas 29,801 HH's	66%	85.0	2.533
LP Gas 2,258 HH's	5%	63.9	0.144
Fuel Oil 6,773 HH's	15%	75.4	0.511
Wood 6,321 HH's	14%	29.3	0.185
Transportation Fuels [1] [Gasoline & Ethanol]	100%		9.561
Total			**17.969 T** BTU's

Estimates in this table were developed by Rural Advantage from a variety of sources.
Source: Energy Information Administration 2001 Residential Energy Consumption Survey: Household Energy Consumption and Expenditures Tables, Table CE1-10c
[1] Clean Energy Resource Teams (CERT's) Regional Strategic Energy Plan.
www.cleanenergyresourceteams.org

A Note about Trillions:

Parts of this study summarize energy demand and production in Trillions of BTU's. When you consider the cost of energy, you look at the cost per Million BTU's. For the numbers we are working with for this project we have Million Million BTU's. To minimize confusion, we choose to use Trillion instead of Million Million for this report. This is done because the number of zeros involved in talking in terms of millions of BTU's becomes daunting and confusing. For example, the total residential energy demand in the Madelia study area is 17.969 trillion BTU's. Nationally, energy consumption is considered in terms of quadrillions or a thousand trillions. As a nation we use about 100 quadrillion BTU's in all forms to power the nation.

B. Industrial Energy Demand

A survey was sent to 164 industrial and commercial energy users in the study area with 18 responses. In completing follow up calls, it became clear that either the surveyed entities did not understand what was being requested or did not want to disclose the information. Therefore, the methodology for estimating industrial and commercial demand in the region was modified to make use of publicly available data.

Identifying Industrial Users

Industrial energy users in the study area were identified from the 2005 Harris Minnesota Directory of Manufacturers. In addition to basic name, address and contact information this directory lists the total number of employees and the SIC* code for the business.

*SIC means Standardized Industrial Classification

Table 13: Industrial Energy Demand

Company	SIC Code	Employees	Energy Intensity 1000 BTU per $	Labor Weighted Energy Intensity
ConAgra Foods	2011	386	2.57	992.02
Tony Downs	2013	300	2.57	771
Fairmont Foods	2038	280	2.57	719.6
Nuvex Ingredients	2043	250	2.57	642.5

AMPI	2023	212	2.57	544.84
Butterfield Foods	2015	150	2.57	385.5
House of Print	2752	130	0.77	100.1
ADM Mankato	2075	105	2.57	269.85
WFS	2048	97	2.57	249.29
Del Monte Corporation	2033	70	2.57	179.9
Tony Downs St. James	2015	60	2.57	154.2
Seneca Foods	2033	50	2.57	128.5
Schmidt's Meat Market	2011	40	2.57	102.8
Darling International	2048	40	2.57	102.8
CHS Inc	2075	40	2.57	102.8
Continental Carbonic	2813	40	9.69	387.6
Corn Plus Ethanol	2869	40	9.69	387.6
Anderson Custom Processing	2023	35	2.57	89.95
August Schell Brewing	2083	35	2.57	89.95
Crystal Valley Coop	2875	30	9.69	290.7
LaSalle Coop	2875	30	9.69	290.7
Central Graphics	2752	24	0.77	18.48
Protein Sources LLP	2048	22	2.57	56.54
Davisco Foods	2026	20	2.57	51.4
Tony Downs PA	2015	18	2.57	46.26
RH News Service	2711	18	0.77	13.86
HRW marketing PA	2048	15	2.57	38.55
St. James Publishing	2711	15	0.77	11.55
Stimpert Enterprises	2452	13	2.46	31.98
Sleepy Eye Herald	2711	12	0.77	9.24
Preferred Printing	2752	12	0.77	9.24
LaSalle Food Processing	2013	10	2.57	25.7
Minnesota Hardwoods	2426	10	2.46	24.6
Watonwan Enterprises	2434	10	2.46	24.6
Conestega Furniture	2512	10	1	10
HRW marketing	2048	9	2.57	23.13
Ogden Newspapers	2711	9	0.77	6.93
Master Graphics	2752	8	0.77	6.16
Mountain Lake Observer	2711	7	0.77	5.39

Madelia Media	2711	6	0.77	4.62
Butterfield Mfg	3563	6	0.84	5.04
GEF	2099	5	2.57	12.85
Midwest Getaway Mag.	2721	5	0.77	3.85
Blue Earth Graphics	2752	5	0.77	3.85
W T Printery	2759	5	0.77	3.85
Alwyn Co	2844	5	9.69	48.45
Georges City Meat	2011	4	2.57	10.28
Herald Publishing	2711	4	0.77	3.08
Soldier Creek Press	2731	4	0.77	3.08
Anderson Custom Processing	2819	4	9.69	38.76
Dicks Locker	2013	3	2.57	7.71
Hanska Meats	2013	3		0
Olson Locker	2015	3	2.57	7.71
Crystal Lake Tribune	2711	3	0.77	2.31
Umbreits Locker	2011	2	2.57	5.14
Bartsch Cabinet	2434	1	2.46	2.46
Sleepy Eye Cabinets	2434	1	2.46	2.46
Total		2711		7509.91
Energy Intensity Weight Ave.			2.77	

Source: Energy Information Administration, Manufacturing Consumption of Energy 1994, DOE/EIA-0512, Washington, DC 1997 www.eia.doe.gov/emeu/mecs/mecs94/e/ei_1.html

Energy intensity is a measure of the energy use per dollar of product produced. This unit of measurement is used to compare energy intensity across the entire spectrum of products. No coherent comparison per unit could be constructed to compare all the diverse products and services in the economy so using the value of the product produced is a simplifying and unifying measure. The energy intensity for each industry in the study region is tabulated in the previous table.

Industry specific data for dollars of manufacturing was not available. However, the table below is sorted by number of employees and the top six employers account for 55% of the employment in the region and have the

same energy intensity. Assuming that the number of employees is a surrogate for the manufacturing value, the number of employees was multiplied by the energy intensity to obtain a labor weighted energy intensity. This value was then used to calculate the average labor weighted energy intensity for the region.

Not surprisingly, the labor weighted energy intensity is slightly above the intensity of the primary food processing industries in the region. Given the dominance of one industry type, it seems reasonable to use this measure to estimate the regions industrial energy consumption.

Manufacturing Output in the Madelia Region

The census bureau maintains county level statistics on manufacturer's shipments. These data are available on the internet at http://quickfacts.census.gov/qfd/states. The data for the counties in the study region are shown in the table below.

Table 14: Manufacturing Outputs in Dollars by County

County	Manufacturers Shipments
Blue Earth	$1,160,809,000
Brown	$1,580,773,000
Faribault	$ 322,282,000
Martin	$ 294,146,000
Nicollet	$ 604,553,000
Watonwan	$ 139,256,000
Total	$4,101,819,000

Source: http://quickfacts.census.gov/qfd/states

The value of all manufacturing output in the study region was $4.1 billion and the estimated energy intensity of this manufacturing was 2,700 BTU per dollar of output. This puts the estimated regional energy consumption at 11,074,911 million BTU per year or 11.0 Trillion BTU. This compares to an estimated total industrial energy use in Minnesota industrial sector of 656.8 trillion in 1997.

It should be noted that the average energy intensity for US manufacturing is 5,490 BTU per dollar of output so the energy intensity for the region is well below the national average.

Operating experience with the food industries that make up the bulk of the study area activity suggests the energy consumption for this sector will be largely divided into electrical and thermal loads. The Energy Information Administration has tabulated the energy consumption by industry and type. The energy consumption of the food industry as a whole and fruit and vegetable canning are shown in the following table.

Table 15: Composition of Energy Use in Food Industry Sector

Industry Type	All Food	Fruit & Vegetable Canning
	Trillion BTU	Trillion BTU
Energy Type		
Total	1,123	47
Net Electricity	231	11
Residual Fuel Oil	12	
Distillate Fuel Oil	17	
Natural Gas	567	35
LPG	6	
Coal	160	
other	89	1
		47
Thermal Demand as %	76%	77%

The industrial energy consumption just described will be divided, largely, into electrical and thermal loads. Since the study looks at the overall energy demand of the region, the exact distribution of electrical and thermal demand is not so important at this time. It is estimated, however, that the thermal demand would be approximately 60% of the total; and electric demand (primary) would be approximately 40%. Thus of the 11 Trillion BTU total 6.6

Trillion is for thermal demand and 4.4 Trillion is for primary electricity demand.

The Clean Energy Resource Teams (CERT's) compiled the number, type, and estimated fuel consumption of registered vehicles in each county using data available from the Dept. of Motor Vehicles. Total demand for transportation fuels in the industrial and commercial sectors is approximately 2.590 trillion BTU's. For this study industrial demand was estimated to be 2/3 of the total (1.736 trillion BTU's).

Table 14: Industrial Energy Use Distribution by Type in Minnesota

Energy Demand Type	Trillion BTU
Electric	
Primary Electricity	4.315
Thermal	
Natural Gas, Fuel Oil, Coal, Biomass	6.685
Transportation [1]	
Gasoline, Diesel, Ethanol, Biodiesel	1.736
Total	12.736

Note: Estimates in this table were developed by Rural Advantage from a variety of sources.

Source: [1] Clean Energy Resource Teams (CERT's) Regional Strategic Energy Plan. www.cleanenergyresourceteams.org

Since this study looks at the overall energy demand the exact distribution of electrical and thermal is not so important at this time but becomes important as we plan electrical generation to meet specific demand.

Total transportation fuel demand for the commercial and industrial sectors is 2.590 trillion BTU's according to CERT's data. This is split approximately 2/3 for industrial demand (1.736 Trillion BTU's) and 1/3 for commercial demand (0.854 trillion BTU's).

C. Commercial Energy Demand

Commercial building energy use includes the full range of office buildings, retail space, hospitals and other public buildings. As in the industrial sector, the absence of meaningful survey responses has forced this study back on to public data.

According to the 2002 summary of energy consumption, the total commercial energy consumption in Minnesota was 341.7 trillion BTU. The population of Minnesota is approximately 5.1 million people. If we make the assumption that the distribution of commercial buildings is approximately proportional to population, then the commercial energy consumption per capita is about 67 million BTU per year.

With a total population in the survey range of 113,786 people, the total commercial energy consumption for thermal fuels and electricity is estimated to be 7.6 trillion BTU per year.

Total transportation fuel demand for the commercial and industrial sectors is 2.590 trillion BTU's. This is split approximately 2/3 for industrial demand (1.736 Trillion BTU's) and 1/3 for commercial demand (0.854 trillion BTU's). The distribution of this energy demand between thermal and electricity generation is shown in the table below.

Madelia Main Street

Tim Nolan

Table 16: Commercial Energy Use Distribution by Type in Minnesota

Thermal Fuel Demand	Trillion BTU	% of Total
Coal	1.6	0.5
Natural Gas	105.4	30.8
Petroleum (fuel oil)	9	2.7
Biomass	2.1	0.6
Electrical Demand		
Primary Electricity	223.3	65.4
Total	**341.7**	**100**

Source: www.eia.doe.gov/emeu/states/sep_sum/html/sum_btu_com.html and Clean Energy Resource Teams Regional Strategic Energy Plan at www.cleanenergyresourceteams.org

D. Agricultural Energy Demand

Energy used in the agricultural sector is skewed towards diesel fuel for farm equipment and natural gas for the production of synthetic fertilizers. These two forms of energy comprise over 75% of the total on farm energy demand. Dr. Douglas Tiffany, University of Minnesota economist has estimated the on farm energy demand for corn, soybeans, alfalfa, and wheat. Alfalfa was expanded to include all hay crops since field operations are very similar. Similarly, wheat was expanded to include all small grains for the same reasons. Diesel, gasoline, & natural gas figures for sweet corn and corn silage are the same as for corn grain. LP gas is used primarily for drying corn grain. Sweet corn and corn silage do not have this requirement.

Major energy efficiencies can be gained by transitioning the current, corn dominant, cropping system to a cropping system that utilizes perennials on up to twenty percent of the most environmentally sensitive areas. This step would increase the energy efficiency of the cropping system; decrease

energy demand; and increase the biomass supply for a renewable energy facility.

In general, perennial crops are more efficient at capturing solar energy for conversion to biomass than corn and soybeans. The net balance of energy is also greater when perennials are included in the system because of the reduction of inputs and eliminated trips across the field for maintenance operations associated with annual crop production.

For example, the data analyzed in the agricultural energy consumption section of this report illustrates that we use about 3.9 trillion BTU's for just the production of anhydrous ammonia used in the current cropping system. Converting 20% of the landscape to perennial crops that would not require anhydrous ammonia fertilizer represents a reduction of 780,000 million BTU's.

In addition, the benefits of converting to a cropping system that includes perennials go beyond the issues previously mentioned to include benefits such as improved air and water quality, impaired waters delisting, carbon payments, Conservation Security Program eligibility, nutrient [nitrogen and phosphorous] payments, groundwater recharge payments, decreased greenhouse gases, improved quality and quantity of wildlife habitat, and increased opportunity to add higher value revenue streams to the farm family with increased agro-tourism opportunities and attracting bio-based processing to the region. Development of the Madelia Model can attract funding for these programs to our region. These programs currently exist and are being used in other regions of the country.

NRCS Photos

Table 17: Agricultural Production Energy Consumption

Crop Fuel Use	Corn (grain) 991,000 A	Sw. Corn & Silage 40,400 A	Soybeans 848,300 A	All Hay 17,800 A	Small Grains 15,5886 A	Total 1,913,386 A
Diesel G/A **Total Usage**	9.37 9,285,670	9.37 378,548	7.43 6,302,869	9.80 174,440	7.24 115,014	16,256,541 Gal
Gasoline G/A **Total Usage**	1.15 1,139,650	1.15 46,460	0.91 771,953	0.81 14,418	0.89 14,138	1,986,619 Gal
LP G/A **Total Usage**	9.58 9,493,780	-0- -0-	0.75 636,225	-0- -0-	0.82 13,026	10,143,031 Gal
Electric Khr/A **Total Usage**	35.63 105,927,990	-0- -0-	27.50 69,984,750	37.23 1,988,082	29.88 1,424,019	179,324,841Khr
Natural Gas mm BTU/acre **Total Usage**	3.95 3,909,495	3.95 159,378	0.20 168,811	0.72 12,798	1.74 27,784	4,278,266

Tiffany, Douglas. "Agricultural Energy: Understanding Usage, Anticipating Policy Directions" presented at Windy River Energy Fair, August 17, 2002

Source: http://www.misa.umn.edu/vd/endowed.htm

Table 18: Total Agricultural Energy Demand

Fuel Type	Unit Totals	BTU per Unit	Total Energy	Total in Trillions
Diesel	16,256,541 gal.	138,700 BTU/gal	2,254,782,236,700	2.25
Gasoline	1,986,619 gal.	124,800 BTU/gal	247,930,051,200	.25
L.P.	10,143,031 gal	91,300 BTU/gal	926,058,730,300	.93
Electricity	179,324,841	3414 BTU/kw-hr	612,215,007,174	.60
N.G.	4,278,266	1,000,000 BTU	4,278,266,000,000	4.3
			Total	**8.33**

Source: University of Minnesota

Summary of All Energy Demand

The total study area energy consumption is estimated to be nearly 50 trillion BTU when the primary energy needed to generate electricity is taken into account.

Table19: Summary of Energy Types by Sector

Energy Type / Energy User	Thermal	Primary Energy for Electricity	Transportation Fuels	Total
Residential	**3.373**	**5.035**	**9.561**	**17.969**
Industrial	**6.685**	**4.315**	**1.736**	**12.736**
Commercial	**2.3**	**5**	**0.854**	**8.154**
Agriculture	**5.23**	**0.60**	**2.5**	**8.33**
Totals	**17.588**	**14.95**	**14.651**	**47.189**

All units in trillion BTU's

This summary shows the baseline energy needs for the region. As we look to convert biomass to usable energy forms, the total energy input requirement will increase because additional energy will be needed to carry out the conversion. Overall the conversion processes range from 60 to 80% efficient so as much as an additional 30 trillion BTU's will need to be found for a total of 77 trillion BTU's demand. This calculation is discussed and explained further in the emerging technologies section of this report.

Emerging Technologies

Interest, research and development in renewable energy is growing at an unprecedented pace. Much of the discussion is around corn grain for ethanol, biodiesel from soybeans, or ethanol from corn stover. For the discussion here, we want to suggest that the reader think beyond where the current discussions are and look at what might be next. Think about renewable energy beyond the context of fermentation, ethanol, and biodiesel.

There are several emerging technologies for converting biomass feedstocks to energy. Most of us are familiar with coal used to generate electricity, corn grain to ethanol, and soybeans to biodiesel. As we look forward to an emerging renewable energy movement in the United States we have an opportunity to define the direction renewable energy will go in the future. If we think about it, and work to evolve it, we can capitalize on not only using renewable energy in our rural communities but enhance family farm profitability, improve air and water, and generate vibrant rural communities. Rural communities can have a competitive advantage for growth by working toward this end. For this report we will discuss anaerobic digestion, gasification, pyrolysis, electricity, and wind and how they could fit into the Madelia Model.

Anaerobic Digestion

Anaerobic digestion is a natural process that converts biomass to energy. Anaerobic digestion has been used for over 100 years to stabilize municipal sewage and a wide variety of industrial wastes. Anaerobic digestion is the breakdown of organic material by a microbial population that lives in an oxygen free environment. Anaerobic means literally "without air". When organic material is decomposed in an anaerobic environment the bacteria produce a mixture of methane and carbon dioxide gas.

Anaerobic digestion treats waste by converting putrid organic materials to carbon dioxide and methane gas. This gas is referred to as biogas. The biogas can be used to produce both electrical power and heat. The conversion of solids to biogas results in a much smaller quantity of solids that must be disposed.

During the anaerobic treatment process, organic nitrogen compounds are converted to ammonia, sulfur compounds are converted to hydrogen sulfide, phosphorous to orthophosphates, and calcium, magnesium, and sodium are converted to a variety of salts. Through proper operation, the inorganic constituents can be converted to a variety of beneficial products. The end products of anaerobic digestion are natural gas [methane] for energy production, heat produced from energy production, a nutrient rich organic slurry, and other marketable inorganic products.

With over two million swine [ie. manure] in the region, anaerobic digestion should be a consideration as a potential renewable energy supply to make methane. Currently, livestock producers in the region are utilizing the manure from their livestock operations as a fertilizer for their cropping system. Farmers in the region recognize a yield bump of 15 to 20 bushels per acre by using manure as a fertilizer source rather than using an equivalent amount of commercial fertilizer. Interest in expanding corn acreage in the region will only increase the demand and value of manure as a fertilizer.

Because of the value of manure as a fertilizer, there may be limited interest in using manure, converted to energy via anaerobic digestion, as a feedstock for renewable energy. Operations with limited liquid manure storage or limited land availability for manure application at agronomic rates may have interest in supplying an anaerobic digestion facility.

Liquid swine manure tends to be low in carbon content. In order to make methane you need a significant amount of carbon. This shortage can be resolved by blending a cellulosic feedstock with the manure to provide adequate levels of carbon. Corn stover is a cellulosic material that is high in carbon, readily available, and fairly easy to handle that could be blended with manure to generate methane. Corn stover is the part of the corn plant that remains following grain harvest. Generally, it consists of the stalks, leaves and cob of the corn plant. There is value to stover as a soil enhancement to replenish nutrients and organic matter to the soil following the corn crop. Research at the University of Minnesota estimates that one half of the stover could be removed and still maintain soil health.

Corn stover in south central Minnesota would yield about four tons per acre total. Estimates for use as a bio-energy feedstock should not exceed two tons per acre.

An opportunity for Madelia would be to utilize municipal sewage sludge from the wastewater treatment process as the 'manure'. Municipal sewage sludge is a little higher in carbon than liquid swine manure but could still need additional cellulosic feedstock. Local biomass feedstocks could supply the additional carbon needs. Additional products to consider include beef and dairy manure, which would be limited but might have some availability.

In addition, consideration should be given to industrial feedstocks available such as compost, dried distillers grains, chicken fat, grease, screenings, and paper as potential cellulose supplies. Studies of co-digestion are underway now in labs in Minneapolis with results looking very good at this stage.

Mixtures of liquid swine manure and corn stover are being studied with funding from the Legislative Commission on Minnesota Resources. Methane production efficiencies appear to be quite favorable.

The photo on the right is an anaerobic digestion system at Five Star Dairy in Elk Mound, WI built by Microgy, Inc.

Anaerobic digestion technology is proven with an 8 million gallon digester complex under construction by Microgy in Huckabay, Texas. In addition, Agri Waste Energy has constructed digesters and a gas refinery at Baldwin, Wisconsin.

Gasification

Gasification is the process where you can take biomass feedstocks [cellulosic material], gasify them by burning under a low oxygen condition, and creating synthetic natural gas, heat/steam and ash. The synthetic natural gas could be used locally by a larger natural gas user, the steam could be converted to electricity or used for heat. The resulting ash could be spread back on the fields as a fertilizer product.

Gasification requires a feedstock that is generally lower than 30% moisture. The gasification process is a low water consumption process which is an important consideration for areas with limited water supply. In addition, gasification can use multiple feedstocks. As various renewable energy projects move forward and get adopted in rural communities, the ability to use multiple feedstocks will be a distinct advantage. For the Madelia area, feedstocks might include prairie grasses, corn stover, paper waste, compost, wood waste and dried distillers grains. Each community should consider what materials are available to them and then evaluate how they could best achieve a reliable biomass feedstock supply.

Fischer Tropsch Technology

Gasification and producing liquid fuels by the Fischer Tropsch process is the highest risk but also has the highest potential as liquid fuels technologies continue to evolve.

The application of this technology is not really new. Fischer Tropsch technology was developed during WWII in Germany when fuel supplies were low and hard to come by. Virtually all the methanol produced in the world is produced from synthesis gas by catalytic conversions. The technology has been available to produce ethanol for at least 30 years but has not been commercially competitive against fossil fuels or corn ethanol until recently.

The technology combines gasification of almost any biomass feedstock with catalytic conversion to create synthetic natural gas. Ethanol, methanol, butenol or proponol can then be made relatively easily from the syngas [synthetic natural gas]. The syngas could be used directly without further conversion by a customer with a natural gas energy demand. Locating this technology next to a high demand natural gas user, such as an industry, school or hospital, with a commitment from them to purchase the resulting renewable energy, could provide a key piece of the financial packaging necessary to ensure the project is built.

Fischer Tropsch technology combines steam reforming gasification with catalytic processes. Steam reforming gasification differs in that the oxygen source in the gasification step is water vapor, which undergoes decomposition to form carbon monoxide and hydrogen. This gas, which contains little or no nitrogen, is suitable for further processing by catalytic conversion to liquid fuels. Pearson Technologies, Inc. have been using this process to convert sugar cane to ethanol quite successfully in Mississippi.

Wind power has a potential key role in the Fischer Tropsch process as well. The conversion of biomass to liquid fuels is hydrogen limited. The potential exists to increase the ethanol yield by 100 gallons per ton if additional hydrogen could be put into the reactors. Hydrogen could be created from water by electrolysis using wind power. Adding additional hydrogen to the process could significantly enhance the ratio of energy in to energy out.

The pursuit of utilizing enzymatic processes for cellulose to ethanol [ie: cellulosic ethanol] is limited and by some estimations, is not technically feasible at the scope and scale needed to be a viable renewable energy player. Despite millions of dollars and decades of research, no enzymatic process has been identified to process a broad spectrum of lignocellulosics for conversion to ethanol. By contrast, steam reforming gasification has been shown to be able to gasify everything from feedlot manure to wood to crop residues including rice straw and corn stalks. As we move forward with the effort to utilize locally grown feedstocks, it will be important to be able to use multiple feedstocks.

The first generation of renewable gasification technologies in Minnesota is now in start up at Little Falls in the Central MN Ethanol Coop. At this facility, wood wastes from the surrounding logging industries is gasified in an air fed updraft gasifier to produce a synthesis gas comprised of nitrogen, hydrogen and carbon monoxide. Upon mixing with the exhaust from the distillers dried grain dryer, the synthesis gas burns completely producing a high temperature gas comprised of nitrogen, water vapor and carbon dioxide. This hot gas is then directed to a heat recovery boiler to produce high pressure, superheated steam. Steam is directed through a back pressure turbine producing approximately 1 megawatt of the 4 megawatt electric power demand of the plant. The reduced pressure steam is then used in the process for mash preparation, distillation and evaporation.

Central MN Ethanol Plant Linda Meschke

An alternate to gasification for steam production in ethanol plants is direct combustion of the syrup and/ or dried distillers grains to produce synthetic natural gas. This process, now in operation at Corn Plus in Winnebago, Minnesota, has displaced about one half of the natural gas consumption by this plant.

Opportunities for similar facilities exist in the region of this study. The soybean crushing plants in the region would be in a great position to capitalize on this. Calculations show that the soybean hull co-product of bean crushing contains sufficient thermal energy to replace the use of natural gas and coal at these facilities.

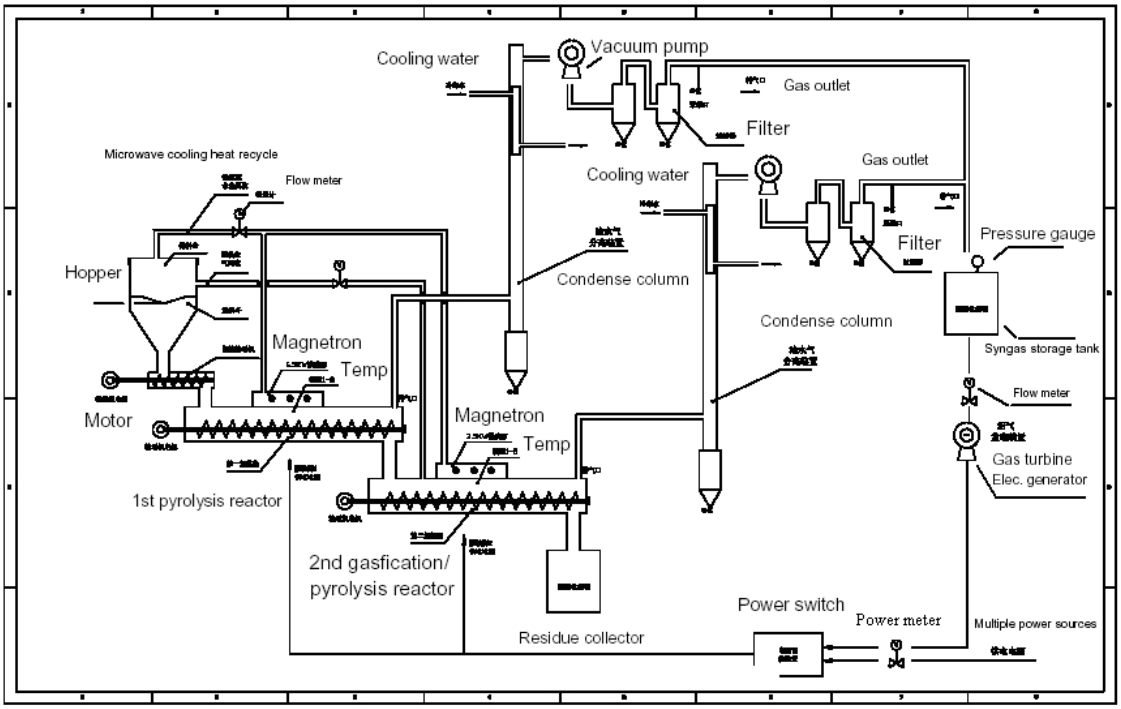
Pyrolysis

Pyrolysis is the chemical decomposition of organic materials by heating in the absence of oxygen or any other reagents, except possibly steam. Pyrolysis is usually understood to be anhydrous (without water). This phenomenon commonly occurs whenever solid organic material is heated strongly in absence of oxygen, e.g. when frying, roasting, baking, toasting. Even though such processes are carried out in a normal atmosphere, the outer layers of the material keep its interior oxygen-free. (Which is why the outer layer oxidizes (burns) but not the inside.) An ancient industrial use of anhydrous pyrolysis is the production of charcoal through the pyrolysis of wood. More recently, pyrolysis has been used on a massive scale to turn coal into coke for metallurgy, especially steelmaking. In many industrial applications the process is done under pressure and at operating temperatures above 430°C (806°F). Anhydrous pyrolysis can also be used to produce liquid fuel similar to diesel from solid biomass or plastics . The most common technique uses very low residence times (<2 seconds) and high heating rates using a temperature between 350-500 °C and is called either fast or flash pyrolysis.

Pyrolysis yields about 40% bio-oil, 40% syngas, and 20% ash. The emissions enter a condensing column where the bio-oil condenses out. Syngas coming off the top can be captured and utilized. There is a residual ash that can be reapplied to the fields as fertilizer.

Pyrolysis is a low water use technology. Water is used in the cooling towers but is not used in the conversion process. This technology also can readily use multiple biomass feedstocks, the advantages which were discussed earlier. Research is being conducted at the University of Minnesota Diesel Lab on usage of this bio-oil as bio-diesel for engines.

Dr. Roger Ruan, University of Minnesota has developed a Microwave-Assisted Pyrolysis System in the lab at the University. This system would take biomass feedstocks, use microwaves to heat them, and then capture the bio-oil, syngas and ash.



Microwave-Assisted Pyrolysis System – Dr. Roger Ruan, University of Minnesota

Electricity

Most of us utilize electricity that is generated from coal or nuclear sources. The efficiency of this system is about 35%. This means that for every unit of electricity you consume, two additional units are used to manufacture it and get the energy to you. To take renewable biomass feedstocks grown in the Madelia region and convert it to electricity – as your primary objective- is probably not feasible. In order to provide a renewable source of electricity that is feasible, the community should consider generating electricity as a secondary energy objective by utilizing steam/ heat via co-generation of gasification, pyrolysis, anaerobic digestion or wind.

Co-Generation

In most energy conversion processes you have two outputs. One is the energy or power you are creating and the second is the heat that is released from the conversion process. Those who are able to utilize both the heat and the power have the potential to dramatically increase the overall efficiency of their energy production.

The application of combined heat and power [CHP] is limited, however, to those locations where there is substantial continuous demand for thermal [natural gas] energy and a simultaneous demand for electricity. Owing to the economics of scale, these plants must often be very large to justify the capital investment. Processing plants are likely candidates for this application.

Development of CHP projects is handicapped by the need to assure an economic feedstock to the CHP process. Across the nation, this technology has gained application where there is simultaneously a low-value co-product, a high thermal demand, and a simultaneous electrical demand. The rice processing industry, for example, has used rice hulls to produce both heat and power for over twenty years.

Wind

Wind is a desirable form of renewable energy [electricity] but is available only 35 to 40% of the time. In addition, on the hottest and coldest days of the year the wind generally does not blow. These are peak electrical demand days and when you want to be selling electricity. A solution for community wind projects is not in the turbine but in power storage and recovery.

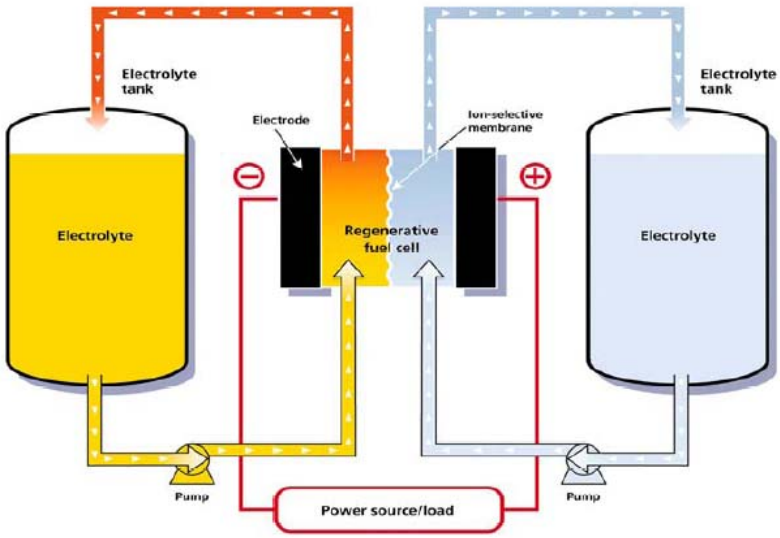

USDA – NRCS Photo

Until recently, wind power production of up to 10% of total electric generation was considered a practical upper limit. Newer technologies, however, are raising the limit, potentially as high as 40%. These technologies include various options for collecting and storing wind energy. Demonstration projects are now under construction for up to 12 megawatt-hour capacity of wind generated electricity stored in a VRB, Inc. power system.

This promising technology uses large capacity flow batteries to store and stabilize the flow of electricity from a wind field. The VRB, Inc. power system

is currently in use to store electricity generated by wind and to distribute it during calm times. On islands and other remote, isolated power grids these units are supplying power on a continuous basis. The concept is that the positive and negative electrolyte is stored separately until needed and then they are combined utilizing a flow through membrane. In a traditional battery, the two electrolytes are stored together.

VRB, Inc. Power System



Concept of the VRB-ESS

A wind field could be developed in the community in combination with the VRB, Inc. Power System to provide a continuous supply of local renewable electricity to the region to compliment electricity supplied by the grid or other generation methods.

As the economics and actual performance of wind farms and power systems become better understood, communities may choose to use local investors, perhaps in combination with the bonding capacity of a local governmental unit, to build a wind field to produce local grown renewable energy to meet at least a portion of the local demand. Nearly 60% of the cost of wind power is capital recovery and interest. Numerous studies have shown the potential of these local financing structures to help drive down the cost of wind power production.

RECOMMENDATIONS

The objective of this report was to determine the potential biomass supply, assess the energy demand and then discuss what type of renewable energy could be produced and by what process to best serve the 25 mile radius "community" around Madelia, MN. In our evaluation we wanted to consider solutions that would not only produce local renewable energy for the Madelia community but provide it in a way that enhanced the economic, ecological, and social wealth of the community resulting in a distinct competitive advantage for economic growth. Viable solutions must provide valuable secondary benefits that include clean air and water, economically stable family farms and a vibrant community.

In summary, the available renewable resources in the region are not capable of supporting the regional energy demand- even if you used 100% of them.

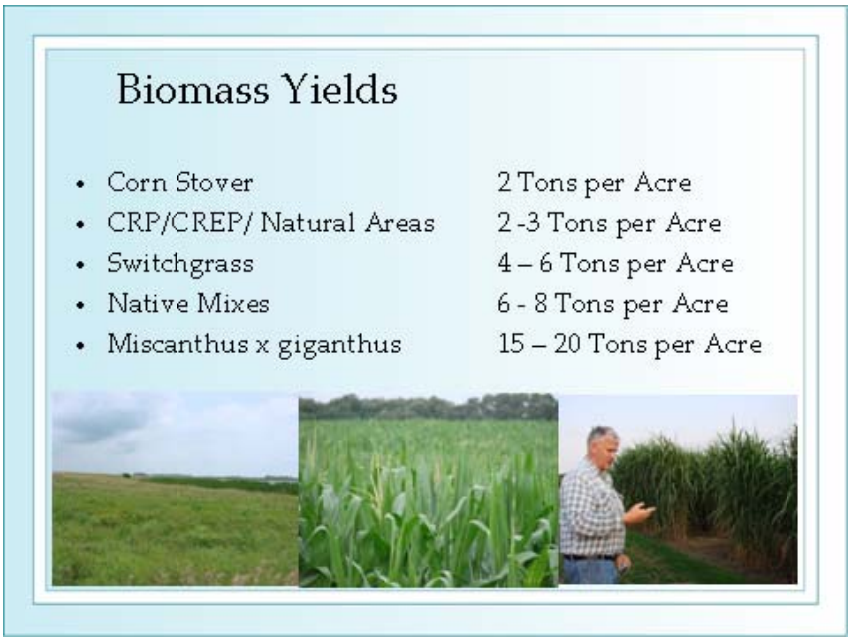
Item	Supply	Energy Supply
Total Biomass Supply Available	20 Million Tons	38 Trillion BTU's
Total Energy Demand	All Sources	47 Trillion BTU's
	Difference	**9 Trillion BTU's [short]**

Considering the low population density and the large available agricultural land resources this is not necessarily what we would expect. Also, consideration has to be given to the type of energy that is being used and where it is used. There are infrastructure limitations that will prevent the distribution of some energy types to the entire region. For example, if you create synthetic natural gas in Madelia, some could be used right in Madelia but, how do you get it to New Ulm, Mankato or St. James? There is the option to process it one step further and make the synthetic natural gas pipeline grade. It could then go in the natural gas pipeline and be available, literally to all natural gas users.

The community could consider becoming a portal community to supply 'green' energy to a broader market. This would entail converting biomass feedstocks to energy by what would be considered 'green' methods. They would create energy for themselves plus extra to be sold [at a premium] to other users. This concept needs to be further developed but is another concept that can give rural communities a competitive advantage.

As we look forward and consider what our energy picture might be – or not be- in the future there are three considerations that all communities should evaluate to put themselves in the best position to have an adequate renewable, affordable, and secure energy supply that sustains rural communities into the future. These include:

1) Increase Biomass Supply –Biomass supply can be increased by growing crops that yield more biomass per acre, such as perennials, to compliment available industrial sources of biomass. Conversion of approximately 20 % of the landscape to perennial bio-energy crops would supply the necessary feedstock plus provide the much needed water and air quality benefits to get the Watonwan River off the impaired waters list. This also could support and supply new bio-processing in the community.



2) Increase Efficiency –

Increased efficiency can refer to many things. It is increasing the efficiency of crops grown. For example, corn is a very energy intense crop. Corn requires significant energy to till, plant, manage and harvest. It requires significant amounts of nitrogen fertilizer and water, both which are energy intense. The manufacturing of nitrogen fertilizer is extremely energy intense. Compare the numbers in Table 17 for natural gas consumption by corn versus other crops. Converting to a cropping system with up to 20% perennials would reduce the energy demand in the region from crop production significantly.

Producing electricity on site as opposed to large centralized facilities, such as we have now, greatly improves efficiency because far less is lost in the distribution system. For every one unit of electricity used, two units are used getting it here. This is very inefficient and we need to figure out how to do it better.

3) Decrease Demand –

Americans are known throughout the world for our abnormal consumption attitude [ie. consume all you want with limited consequences]. Energy consumption included. By decreasing consumption of energy we can bring the overall energy balance for our region to a more sustainable level. Developing a more sustainable level can help maintain costs, provide adequate supply and reduce homeland security risks.

The Madelia community should consider having a community dialogue about these issues and develop a strategy to move forward with the pieces that fit best with their goals and objectives.

Next Steps

We would recommend that the community evaluate the information presented in this report and have a community dialogue on how the community might move forward. This document is not the end-all. It is meant to get the conversation started on how a community could move forward with a competitive advantage by incorporating renewable energy initiatives in their planning.

As part of the community dialogue, we would suggest that a set of principles be developed that the community can support and that will set the stage for the type of tenant you want to attract. These principles should set the bar and support where your community wants to go. Suggestions include:

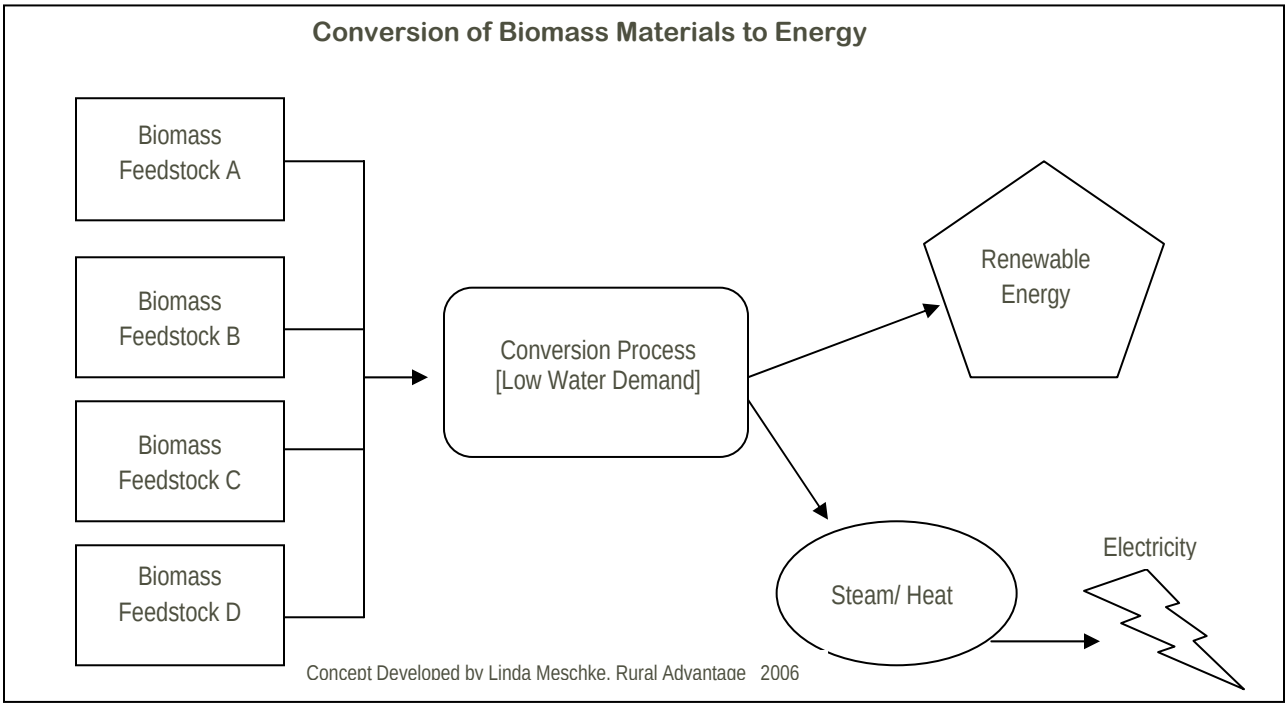
- Support Landscape Diversification That Provides Multiple Benefits
- Create & Utilize Sustainable Renewable Energy
- Utilize Local Agricultural Products For Value- Added Processing
- Nurture Industries That Provide Living Wage Jobs
- Desire Industries With Clean Air & Water Emissions
- Local Ownership

In addition, the community could ask for assistance in identifying general strategies on how to further develop candidate ventures as anchor tenants for a future eco-industrial park. Screening Criteria [in the form of technical and economic metrics], bench marked against existing technologies that can be used to assess potential ventures for commercialization can be part of this effort.

As decisions are further defined, development of an economic analysis model that will enable the community to determine how they can advance the development of local bio-based energy production or consolidate locally produced biomass materials as feedstocks for industrial production.

As the community considers a renewable energy facility that processes locally grown crops it should consider the additional value they can have by going with a process that can use native prairie mixes or other perennials as a feedstock. In addition to having a distinct competitive advantage for economic growth they will have multiple agricultural, environmental and community benefits that will result in increased rural wealth. These plantings could also support new bio-based processing for an eco-industrial park in the community.

Below is an illustration of a model process communities could benefit from to create renewable energy. This model has two key elements that will distinguish it from the status quo. The first one is that it uses multiple biomass feedstocks. As the renewable energy industry develops, this will become a key for long term sustainablity. The ability for a region to capitalize on the biomass feedstocks available in their region results in efficiencies and adoptability. It also assures a diverse landscape to minimize risk to farmers from weather, insects, weeds and market variability.



The second key element is low water demand from the conversion process. Low water demand technology is currently available to convert biomass to energy. As these technologies get more refined they will begin to be built. Many regions do not have the water resources that are available in south central Minnesota. Also, there are many demands on our water resources in addition to energy production so there needs to be a balance between water consumption and prevention of water use conflicts.

To move a renewable energy project forward, there are three items that must be in place:

1. An adequate biomass supply.
2. The conversion facility/ plant.
3. A demand/ buyer for the energy produced.

If the community can provide two of these three, they should be able to get financing for the third piece. Madelia has two of the three pieces needed. To make it work, *and gain the fullest benefit to the community*, the basic strategy could be as follows.

1) Consider the existing larger energy consumers in the community, the opportunity to be a green energy community portal, and existing infrastructure decide which type of energy the community might want to manufacture. This would meet the demand piece.

2) Consider using corn stover as the biomass supply for the short term, with a strong community commitment to go to perennial feedstocks [on up to 20% of the landscape] in the long term. Corn stover is readily available but the tonnage per acre is low compared with perennial plantings. Perennial plantings could be phased in over the next five or ten years. It would take two to three years, once perennials are established, to the first harvest. Also, the environmental gains needed to get delisted on the impaired waters list would not be accomplished with stover. Commitment to

perennials is a critical piece. Without it, you loose your distinct competitive advantage. This would meet the supply piece.

3) Having the first two elements makes financing the third piece feasible but not automatic. Size and scale would be important discussion points. Being a green energy portal community might need to be a piece of the project to make the economics work. Some type of local ownership should be the goal. Developing a system to utilize both the power [energy] and the heat from the processing [example: hydroponics greenhouse] can improve the economics. The Madelia Model establishes a renewable energy scenario that sets Madelia apart from traditional development and provides an achievable platform for new investment in the community.

We look forward to working with the Madelia community to have a dialogue about how to move forward with these recommendations.

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