Minnesota Biomass Heating Feasibility Guide

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1 Introduction

In 2011, the Agricultural Utilization Research Institute (AURI) solicited proposals to develop a Biomass Heating Feasibility Guide “for the replacement of high-cost heating fuels, such as propane and fuel oil, with biomass combustion heating systems.” The contract, awarded to DLF Consulting, resulted in this report, which will assist turkey producers and greenhouse operators in rural areas to understand the feasibility of using biomass for heating. The report provides an overview of the elements involved in a biomass heating system – fuels and technologies – and provides information regarding what is required to set up and operate such a system.

Objectives

The study analyzed the following:

- Energy use at several greenhouse and turkey producer locations
- Technical feasibility: fuel and technology
- Economic feasibility

Acknowledgements and Thanks

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- Southwest Clean Energy Resource Team
- Southern Minnesota Initiative Foundation
- Southwest Minnesota Initiative Foundation
- Eric Bibeau, Ph.D., P.Eng. (University of Manitoba - Mechanical Engineering Department; Alternative Energy Chair, Manitoba Hydro)
- Eugene Gala P.Eng. (E-mission Free Inc.)
- Jennifer Lukovich (University of Manitoba)
- Erik Nickel (Mechanical Engineer)

In addition, more than 30 people were interviewed and/or provided information on biomass fuels, combustion technologies, greenhouse operators, poultry producers and heating system companies.

Disclaimer:

2 Executive Summary

The *Minnesota Biomass Heating Feasibility Guide* focuses on the feasibility of replacing fuels such as propane and fuel oil with biomass-fueled heating systems in the poultry production and greenhouse industries. Biomass for the purposes of this report refers to any agricultural or forestry derived product which can be fed into a combustor and burned to generate heat. Biomass can be in bulk form (e.g., straw bales, agricultural processing byproducts, wood chips, hog fuel, sawdust, turkey litter) or densified form (e.g. pucks, pellets, cubes).

Many of the poultry producers and greenhouse operators in Minnesota currently use propane or fuel oil to heat their buildings. Most are located in rural areas where they do not have access to lower cost fuels such as natural gas. Heating costs for these operations are a significant portion of their operating expenses, and more cost effective heating systems are needed for these industries to stay competitive and grow in Minnesota. Propane and fuel oil are some of the most expensive heating fuels available, and an opportunity exists for the replacement of these high cost fuels with biomass.

Minnesota has a tremendous wealth of biomass, amounting to around 25 million tons available per year. The state also has suppliers of biomass who are supplying large power plants as well as smaller users of biomass; growth in this industry will be a function of a growth in demand. The use of biomass as a heating fuel not only has an extensive history in the European Union but also in Minnesota where resourceful farmers and city planners have made the decision to use local biomass. Examples include a greenhouse/livestock operation that produces, processes, sells and uses its own biomass to provide the majority of heat required, and the City of Saint Paul, which uses local tree residues and other fuels to provide heat and power.

This guide is a resource on the following topics:

- Biomass resources – agricultural and forestry
- Biomass fuel suppliers in Minnesota
- Biomass fuel handling examples
- Biomass heating system suppliers and products
- Biomass heating system components (Balance of System)
- Biomass heating system costs and financial implications
- Financial sensitivity analysis

Each of the above topics is explored in this report, with conclusions provided for each section. The following table provides a summary that captures the issues related to and the implications of the factors listed above.

Table 2-1: Summary of Biomass Heating Systems[1]

	Facility: Greenhouse @ 22K ft2 or Turkey Barn @ 50K ft2 Combustor Size: 2 MMBtu/h					
	Fuel Form	**Pellet**	**Pellet**	**Woodchip**	**Bale**	**Bulk**
	Combustor	**Indoor Air Heater**	**Outdoor Water Heater**	**Outdoor Water Heater**	**Indoor Water Heater**	**Indoor Water Heater**
1	**Fuel Type**	Wood Pellet	Wood Pellet	Woodchip	Baled Straw / Stover	Woodchips / Hogfuel / Biomass (loose stover)
2	**$ / Ton**	$ 175	$ 175	$ 75	$ 60	$ 60
3	**Moisture**	6%	6%	30%	15%	15 - 45%
4	**System Type**	Hot Air	Hot Water	Hot Water	Hot Water	Hot Water
5	**Combustor Cost**	$ 120,000	$ 165,000	$ 165,000	$ 165,000	$ 165,000
6	**Balance of System Cost**	$ 120,000	$ 105,000	$ 105,000	$ 320,000	$ 350,000
7	**Initial Costs**	$ 258,000	$ 290,000	$ 305,000	$ 532,000	$ 564,000
8	**Annual Costs**	$ 47,000	$ 47,000	$ 25,000	$ 28,000	$ 27,000
9	**Annual Savings**	$ 84,000	$ 84,000	$ 84,000	$ 84,000	$ 84,000
10	**Annual Debt**	$ 31,000	$ 35,000	$ 32,000	$ 55,000	$ 57,000
11	**Pre-tax Internal Rate of Return (equity)**	17.1%	13.0%	42.0%	11.1%	11.9%
12	**Net Present Value**	$ 95,000	$ 67,000	$ 280,000	$ 91,000	$ 112,000
13	**Simple Payback (Yr)**	8.2	9.1	5.2	9.6	9.3
	NOTES					
1	The fuels listed cover the gamut of feedstocks reviewed in the report					
2	Prices vary, however, those listed are based on supplier data from Minnesota in response to the request for proposal					
3	Moisture is a key factor of any biomass fuel impacting storage, handling and boiler efficiency.					
4	Heat generated can be used in a number of ways, e.g. Air heat can be converted, with efficiency losses to water heat, and vice					
5	Costs based on an aggregated review of combustor information provided in response to the request for proposal					
6	Costs cover what the rest of the system requires e.g. Pumps, controls, pipes, concrete, buildings etc.					
7	Total of the lines 5 and 6 in addition to other expenses (such as 5% contingency cost). IMPORTANT: the bulk and bale systems require manual loading equipment which is not included in this price.					
8	Includes fuel, operations and maintenance. For transportation add $2-3 per mile.					
9	Calculated based on what will be saved by NOT using propane @ $1.50 per gallon					
10	Based on 75% of the project financed @ 6% over 10 years					
11	Based on 2% inflation, 2% cost of fuel increase, 6% discount rate, 15 year project life					
12	Present value of future discounted cash flows - if NPV is positive, the investment is worth examining					
13	Amount of time for the project to pay for itself based on savings paying off the investment					

Based on the results shown above (using NRCAN RETScreen software), biomass heating systems exist for virtually any biomass feedstock available – including wood pellets, woodchips, hogfuel, corn stover bales and more. These systems require different handling systems and involve different levels of investment; however, they all have positive Net Present Value, a simple payback under 10 years and internal rates of return over 11%.

Heating with biomass is a technically and economically viable option in Minnesota – for users of propane – as the supply of the biomass; the equipment necessary for its storage, processing and combustion, the capital, expertise, and experience (globally and nationally) are all available and present in the state.

[1] Results derived using NRCAN RETScreen: http://www.retscreen.net/ang/home.php

3 Guide Overview

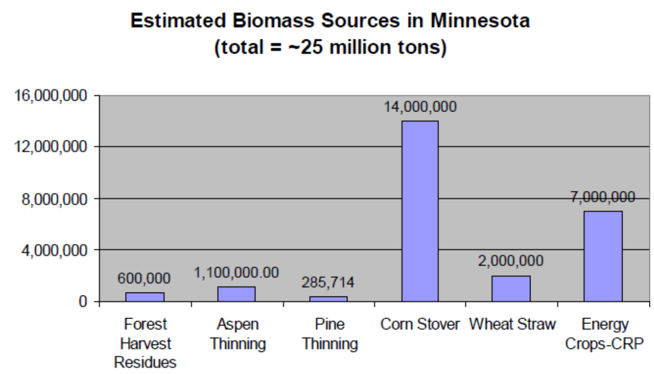
This guide provides a wide perspective on the feasibility of using biomass as a heating fuel for greenhouses and poultry farms in Minnesota. The methodology applied includes:

- Research on greenhouses and poultry farms interested in being involved in this guide
- Visits to Minnesota poultry and greenhouse facilities in February 2012 including other facilities of interest for the guide: biomass fuel developers, potential biomass heating sites and alternatives to the conventional greenhouse and poultry farm paradigms
- Preparation of three separate Requests for Proposal sent to suppliers of equipment:
  - Biomass heating combustors
  - Biomass fuels available in Minnesota for commercial applications
  - Balance of system components (engineering, buildings and system design)
- Analysis of proposals received and summation of the information
- Additional research of biomass heating studies from Minnesota and nearby regions
- Modeling of the results using different system configurations to determine economic feasibility relevant to poultry and greenhouse operators in Minnesota
- Sensitivity analyses to system parameters assumed as actual systems installed will differ
- Development of recommendations for various sizes of systems and types of applications
- Presentation of results to stakeholders in April 2012
- Final report summarizing findings

4 Minnesota Biomass Overview

The biomass potential in Minnesota is significant, with an estimated 25 million tons of forestry and agricultural biomass available (see figure below). In addition, more than 5 million tons of corn cobs are available, and there is potential for 5.6 million tons from energy crops such as hybrid poplar[2]. The point of this guide is not to investigate this total, nor to expand upon what its total potential use or impact could be; however, it is important to understand the extensive biomass resources and to use them in sustainable ways.

Figure 4-1: Biomass in Minnesota[3]



The use of biomass for energy production depends not only on the material being available, but on the biomass being economically feasible to use to generate heat and/or power. While Minnesota has large forest resources, the location of a portion of these will render them unusable for energy due to the distance and energy/expense it would take to gather and transport them. Likewise agriculture biomass resources, whether crop or animal related, are certainly available; however, if prices for competing fuels are less, then the utilization of these resources will remain low. The following table provides insight into the quantity of biomass that would be used in Minnesota based on certain pricing windows being available.

[2] University of Minnesota Extension – "Biomass Energy Potential in Minnesota" (2009) http://www.extension.umn.edu/agroforestry/components/Biomass-Energy-Potential-Minnesota.pdf

[3] University of Minnesota Extension – "Biomass Energy Potential in Minnesota" (2009) http://www.extension.umn.edu/agroforestry/components/Biomass-Energy-Potential-Minnesota.pdf

Table 4-1: Minnesota Biomass for Energy[4]

Availability of Biomass for Energy Production in Minnesota, Based on ONRL 1999 Study*

Resource	Quantity Available (000 dry tons/year)			Quantity Available Without Ag. Residues (000 dry tons/year)		
	<$30/t	<$40/t	<$50/t	<$30/t	<$40/t	<$50/t
Forest residues	468	682	875	468	682	875
Mill residues (wd)	71	916	1,121	71	916	1,121
Ag. residues	0	11,936	11,936			
Energy crop pot.	0	427	5,783	0	427	5,783
Urban wd waste	1,533	1,533	1,533	1,533	1,533	1,533
Total	2,072	15,494	21,248	2,072	3,558	9,312

*Walsh et al. 1999.

This chart demonstrates that biomass availability is governed by price with a variance of 19,000 tons based on a price increase from $30/ton to $50/ton. In summary, the millions of tons of biomass represent a huge energy resource, something Minnesota is already using for both power and/or heat generation, with potential for greater use in the future.

4.1 Soil Conservation

A significant consideration of the use of biomass for energy is related to the impact of biomass removed from the land and the direct effect on what the soil is now using to rejuvenate itself with on an annual basis to produce crops or trees. According to Minnesota's Agricultural Utilization Research Institute (AURI), unless the land is highly erodible, up to one third of the available biomass can be harvested on an annual basis without impacting the yield of the subsequent crop. Based on this information the land could sustainably yield (for instance) up to one third ton of stover/straw per acre per year, which could derived either by harvesting one third of the crop residue available, or by harvesting all the biomass every three years. In either case, the stover/straw that can sustainably be taken from the land is around one third ton of straw per acre per year, unless additional nutrients were added to supplement what was removed.

A different approach has been taken by Denmark (based on conversations with LINKA representatives) where a majority of straw is taken most years, and the ash is deposited back onto the fields from where the straw was cut. In this way they replenish the land's nutrients every year. Although this involves an additional step in the process, it has provided Denmark with a system that has provided straw for heating for the past nearly 30 years.

Whatever the approach, it is critical to examine a sustainable approach to the harvesting and use of biomass whatever the source based on a combination of soil chemistry, drainage, tilth and crops being grown.

[4] Dovetail.org presentation: http://www.slideshare.net/Beckyll/woody-biomass-for-energy-in-minnesota-consumption-and-availability

5 Existing Heating System Survey

In order to better understand how biomass could be used to assist owners of greenhouse and poultry farms to potentially lower their heating costs, visits were scheduled to visit a number of these as an initial step of this guide in order to obtain information on the energy demands of these operations. Over the period of a few days in mid February 2012, the following sites were visited:

- Pork and Plants Greenhouse – Eric Kreidermacher, Altura
- AURI – pelleting and R&D facility – Alan Doering , Waseca
- Drummers Garden Center – Bryden Jones, Mankato
- Turkey Producer – Gene Brownfield, Redwood Falls
- MinnWest Technology Campus and Greenhouse – Steve Salzer, Willmar
- Heartland Energy Systems – David J. Fiebelkorn, Willmar
- Turkey Producer - unnamed in this Guide

A survey form was developed for these interviews (Appendix B), the results of which have been aggregated and compiled into the sections below.

5.1 Greenhouses

The greenhouses visited were: Pork and Plants in Altura; Drummers Garden Center in Mankato; and the Willmar High School greenhouse. Additional research included Tom Marten's greenhouse in Grasstown, a facility in Wisconsin, larger commercial greenhouses (Minnesota and Manitoba), a straw bale heated facility in Canada (Prince Edward Island) and a solar greenhouse in Lake City, Minnesota.

In order to understand the energy issues of heating greenhouses, it is important to understand that operations and structures vary considerably in this industry:

- Size of operations: 1,000 to 1,000,000 square feet (ft^2) in facilities researched
- Type of structures: Glass, multi-layered rigid plastic, and multi-layered poly
- Type of insulation: None, moveable, shades, and bubble walls
- Ventilation: Mechanical, passive, automated and non-automated roof panels
- Heating methods: In floor, forced air convection, under plant beds, and radiant fin/tubes
- Heating fuels: Solar – passive and active, natural gas, propane, biomass – loose, baled, pellets
- Mode of operation: Partial and year-round
- Heat storage: None, walls, floors, and water
- Type of crops grown

Example:

To provide sample greenhouse energy requirements and costs, the following table provides these for a 2,880 ft^2 year-round use facility in Minnesota, covered with 2 layers of poly, heated with natural gas. The solar component is passive and costs are based on $0.45/kWh and $6.00 per MMBtu natural gas. Over 35% of the heat is provided by the sun, and 63% of the heating costs are natural gas. Only one greenhouse viewed in February incorporated passive and active solar heating as well as passively heated mass thermal storage[5].

Table 5-1: Sample 2,880 **ft²** Greenhouse Energy and Costs[6]

Energy Source and Cost	MMBtu	kWh	Cost
Solar	349		$ -
Heating	467		$ 4,310
Ventilation	89		$ 826
Lights	49	14,424	$ 1,308
People	1		$ -
Motors	17	5,001	$ 385
TOTAL	**972**	**19,425**	**$ 6,829**

Description of the greenhouse facilities visited and researched:

1. Pork and Plants Greenhouse – Altura, MN[7]

Located outside of Altura, this facility measures around 65,000 ft^2 and is heated with a combination of biomass pellets and propane (see figure below). Growing a variety of plants for household and commercial use, the greenhouses are a combination of glass and plastic, using mechanized and natural ventilation. The majority of the heat is provided by the burning of biomass pellets to heat water, which is circulated throughout the facility. To reduce costs, pellets are made onsite in a pellet mill and consist of a mixture of straw, wood waste and grasses – and are an additional revenue source for the farm when sold on the open market. Fuel costs are listed in the summary table at the end of this section. In this particular case only, the fuel cost is adjusted to account for the sales of the pellets. In addition rain water is stored and used, and water from the trays is recycled. Plants are heated directly under the roots as each support table contains radiant water tubes.

[5] Hazelnut Valley Farm: http://www.cleanenergyresourceteams.org/publication/going-nuts-clean-energy-solar-heated-greenhouse-and-biodiesel-hazelnuts
[6] Eugene Scales and Associates for the Minnesota Department of Commerce: http://www.state.mn.us/mn/externalDocs/Commerce/Energy_Conservation_for_Greenhouses_120503035439_EnergyConservationforGreenhouses.pdf 2003
[7] Pork and Plants Greenhouse: http://www.porkandplants.com/index.html

Figure 5-1: Pork and Plants Greenhouse

2. Drummers Garden Center – Mankato, MN[8]

This facility with a total of 36,000 ft^2 of covered greenhouse space is used part of the year for growing a variety of plants for home and commercial use. There are several greenhouses ranging from glass to multi-layer plexiglass to multi-layer poly as shown in figure below. The heating for these buildings is provided by the sun and natural gas, the latter of which heats water for in-floor heating as well heating the air through direct fired fan convection units.

Figure 5-2: Drummers Garden Center

[8] Drummers Garden Center: http://drummersgardencenter.com/

3. Willmar High School Greenhouse, Willmar MN[9]

Located on the campus of Minnesota West Technology in Willmar, this small greenhouse provides students with the opportunity to grow plants and learn about renewable energy (Figure below). The facility is heated with a combination of active (and passive) solar collection and biomass pellets. Heat is stored in a tank and distributed using a floor heating system. More detailed information was not available; however, this project is an example of how a small greenhouse can provide food, potentially income as well as opportunities for education and involvement for young people. Note the bin behind the solar collectors, which stores the biomass pellets.

Figure 5-3: Willmar High School Greenhouse

4. Hazelnut Valley Farms, Lake City MN[10]

This greenhouse is unique in a number of ways, in that it is constructed in such a way to maximize the sunlight it receives – otherwise known as a "solar greenhouse." Hazelnut bushes are grown in the facility. An energy storage system consists of water-filled drums heated with circulated solar heated air. More information was unavailable at the time of this writing, but this greenhouse provides a good example of using renewable heat.

Figure 5-4: Hazelnut Valley Farms

5. VANCO Farms Greenhouse: Prince Edward Island, Canada

[9] Willmar High School Greenhouse: http://www.cleanenergyresourceteams.org/publication/students-growing-renewable-veggies-willmar-high-school-greenhouse-project
[10] Hazelnut Valley Farm: http://www.cleanenergyresourceteams.org/blog/going-nuts-greenhouses-solar-energy-hazelnut-farm

This facility is featured in this guide due to the fact that it uses baled straw as its heating source. Located in Eastern Canada, Prince Edward Island (PEI) is a province with average winter temperatures of 19^{o}F. With 40,000 ft^2 of greenhouse space growing mostly flowers, VANCO was using fuel oil as its heating fuel. Energy prices in PEI are higher than many places in North America, and to counter that, VANCO farms installed a Danish straw burning water heating system.

Figure 5-5: VANCO Farms, PEI, Canada

Summary:

The following table summarizes information gathered from the visits and research listed above, and provides data for facilities from 1,000 to 80,000 ft^2. (The scale of "small" to "large" is for the scale of this guide only – clearly there are much larger greenhouse facilities in the region as well.) The data has been gathered from a number of facilities and represents an aggregated approach except where noted otherwise. Greenhouses operate across the state, using a variety of fuels with a wide variety of costs depending upon the energy efficiency measures used, type of glazing, heating systems and heat requirements of different types of plants being grown. Heating costs vary from \$0.75 to \$3.00 per ft^2.

Table 5-2: Combined Data for Selected Greenhouse Facilities

	Large	Medium	Medium	Small
Total Greenhouse Area (ft2)	65,000 - 80,000	30,000 - 40,000	30,000 - 40,000	1,000 - 3,000
Fuel Production	On-site	Purchased	On-site	Purchased
Heat Storage	Yes	No	No	Yes
Type of Heating System	Fin/tube, under plant beds	Floor Heating, convection direct fire unit	Fin/tube, under plant beds, water/air fan convection	In-floor
Full/Part year Operation	Full Year	Part Year	Full Year	Part year
Heating Fuel (see note)	Biomass Pellets	Natural Gas / Propane	Straw bales	Biomass Pellet
Unit	Ton	Therm / Gal	Ton	Ton
Cost / Unit	$150 - $180	$0.65 / $1.50	$80 - $100	$150 - $200
Heating Cost / yr	$50,000 - $65,000	$30,000 / $100,000	$35,000 - $45,000	$3,000 - $5,000
Cost / ft2	$0.75 - $0.85	$0.65 / $3.00	$1.10 - $1.20	$1.70 - $2.00
MMBtu / yr	8,000 - 9,000	3,500 / 8,000	7,500 - 8,500	800 - 1,200
MMBtu / hr Heating Capacity	4 - 6	3 - 5	3 - 5	.4 - 1

Note: Heating Fuels listed do not include solar contribution.

5.2 Turkey Farms

The turkey farmers visited and/or interviewed in February were: Gene Brownfield (Redwood Falls), Paul Kvistad (Wood Lake) and a producer whose name cannot be used in this guide. A summary of this information as well as other data gathered is presented in the table at the end of this section.

Poultry operations vary less than greenhouse operations; however, there are differing approaches to note:

- Size of operations: Turkey farms vary considerably in terms of size, ranging from 20,000 ft^2 to many hundreds of thousands of square feet
- Type of operations: Brooders (up to 5 weeks), Hens (up to 15 weeks), Toms (up to 25 weeks); each have different heating requirements (more heat needed when younger)
- Type of structures: Typically metal clad post and beam structures with dirt floors
- Ventilation: Mechanical, passive, automated and non-automated
- Heating methods: Forced air convection, radiant fin/tubes, radiant heaters, attic/solar ventilation air pre-heat
- Heating fuels: Solar – passive, natural gas, propane, (biomass – loose, baled, pellets possible)
- Mode of operation: Year-round
- Heat storage: None

1. Gene Brownfield – Redwood Falls, MN

This turkey farmer has a large operation with a total of eight barns, each measuring 52,000 ft^2. Each barn has a combination of brooders and hens with a brooder cycle of 4-5 weeks and a hen cycle of 7-8 weeks. The barns are oriented east to west and are all heated with propane. Heating needs for the older birds are considerably less than for the brooders due to the fact that they generate their own heat.

Figure 5-6: Gene Brownfield Turkey Barns

2. Paul Kvistad – Wood Lake

Paul has a total of three barns measuring 82,000 ft^2 in total, also raising brooders and hens. This farm, like many in Minnesota uses propane for a heating fuel in a combination of radiant and forced air convection units. Ventilation is provided from openings in the sides and tops of the barns. Paul uses a unique solar pre-heating concept by drawing in outside air through a solar heated attic prior to blowing it into the barns.

3. Unnamed participant

This farmer heats with natural gas and raises brooders in barns measuring a total of 50,000 ft^2. The cycles for raising turkeys are roughly the same, and this farmer keeps the young birds for 4-5 weeks prior to shipping them off to grow into birds ready for sale.

Examples of the types of heating equipment used in many turkey farms are shown in the figure below.

Figure 5-7: Examples of Radiant Forced Air Heaters Used in Turkey Farming

Summary

The information gathered from the three producers above and data from additional farmers has been combined in the table below. As noted above, the total barn size varies between different operations, and propane is the most widely used fuel, although some producers are able to access natural gas depending on their location. The heating requirements for brooders are higher than the larger birds given that the animals are not producing much of their own heat, and the larger birds require less heat. Heating costs vary from \$0.70 to \$0.95 per ft^2.

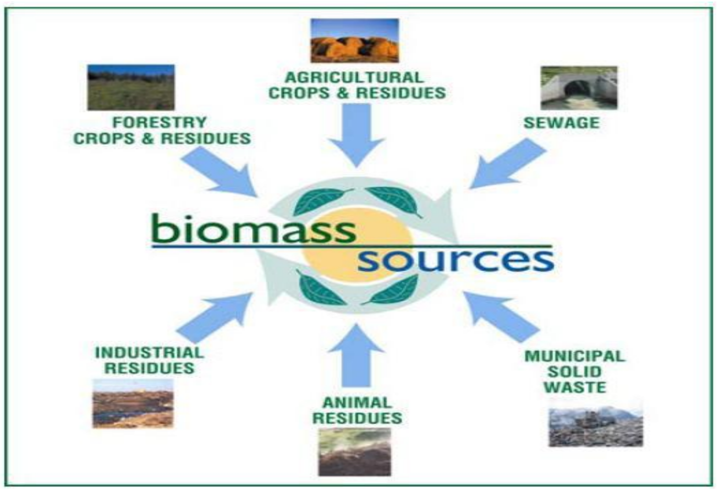
Table 5-3: Turkey Producer Information

	Large	Medium	Small
Farm Size	175,000 - 225,000	75,000 - 100,000	30,000 - 50,000
No. Barns	4 - 5	3 - 4	1 - 2
Ave Size ea	45,000 - 55,000	35,000 - 40,000	20,000 - 25,000
No. Turkeys per barn	25,000 - 30,000	20,000 - 25,000	20,000 - 25,000
Operation	Brooders, Hens, Tom	Brooders, Hens	Brooders
Heating Fuel	Propane	Propane	Natural Gas
Unit	Gallon	Gallon	Therm
Cost/Unit	$ 1.50	$ 1.75	$ 0.65
Heating Cost/yr	$150,000 - 175,000	$60,000 - 85,000	$25,000 - 35,000
Cost / ft2	$0.75 - $0.85	$0.80 - $0.95	$0.70 - $0.80
MMBtu / yr	8,000 - 8,500	4,000 - 5,500	1,500 - 3,000
MMBtu/hr Heating Capa	24 - 28	6 - 10	2 - 4

6 Biomass Fuel

Biomass fuel is carbon neutral, and sources examined in this guide range from agricultural crops and residues to forestry products. Other types of biomass include industrial by-products, animal (and human) waste, and municipal solid waste, as well as energy crops such as cereals and oilseeds (see figure below). For the purposes of this guide, only the categories of forestry and agricultural crops and residues, and related industrial process products (sawdust, woodchips, and agricultural by-products) will be considered.

Figure 6-1: Biomass Overview[11]



The types of biomass covered in this guide include the agricultural and forestry examples included in the figure below.

Figure 6-2: Agricultural and Forestry Biomass Examples

[11] NRCAN: http://www.nrcan.gc.ca/eneene/sources/index-eng.php



The energy value of each of these different types of biomass, and energy values of other fuels (renewable and non-renewable) are included in the table below, which covers a wider range of fuels from fossil to wood to agriculture to animal waste, crop residues, herbaceous and woody crops as well as urban waste.

Table 6-1: Fuel Characteristics

	Average	Unit	Moisture	Sources
	Fossil Fuels			
Fuel Oil	18,015	Btu/lb	-	2
Coal	10,749	Btu/lb	-	2
Oil	18,355	Btu/lb	-	1
Natural Gas	100,000	Btu/therm	-	1
Propane	91,600	Btu/gal	-	1
Lignite coal	6,578	Btu/lb	-	1
	Wood			
Pellets	7,524	Btu/lb	8	2
Pile Wood	4,084	Btu/lb	-	2
Hardwood wood	8,469	Btu/lb	-	14,18
Softwood wood	8,560	Btu/lb	-	12,13,14,15,16,17
Softwood Chips	4,084	Btu/lb	50	2
Softwood Chips	6,535	Btu/lb	20	2
Forest S. Chips	5,718	Btu/lb	30	2
Forest H. Chips	5,718	Btu/lb	30	2
Sawdust Dry	8,000	Btu/lb	0	3,4
Sawdust Green	4,500	Btu/lb	50	5
	Animal Waste			
Manure	8,500	Btu/lb	0	6
Manure	4,200	Btu/lb	50	6
Poultry Litter	5,000	Btu/lb	25	7,8

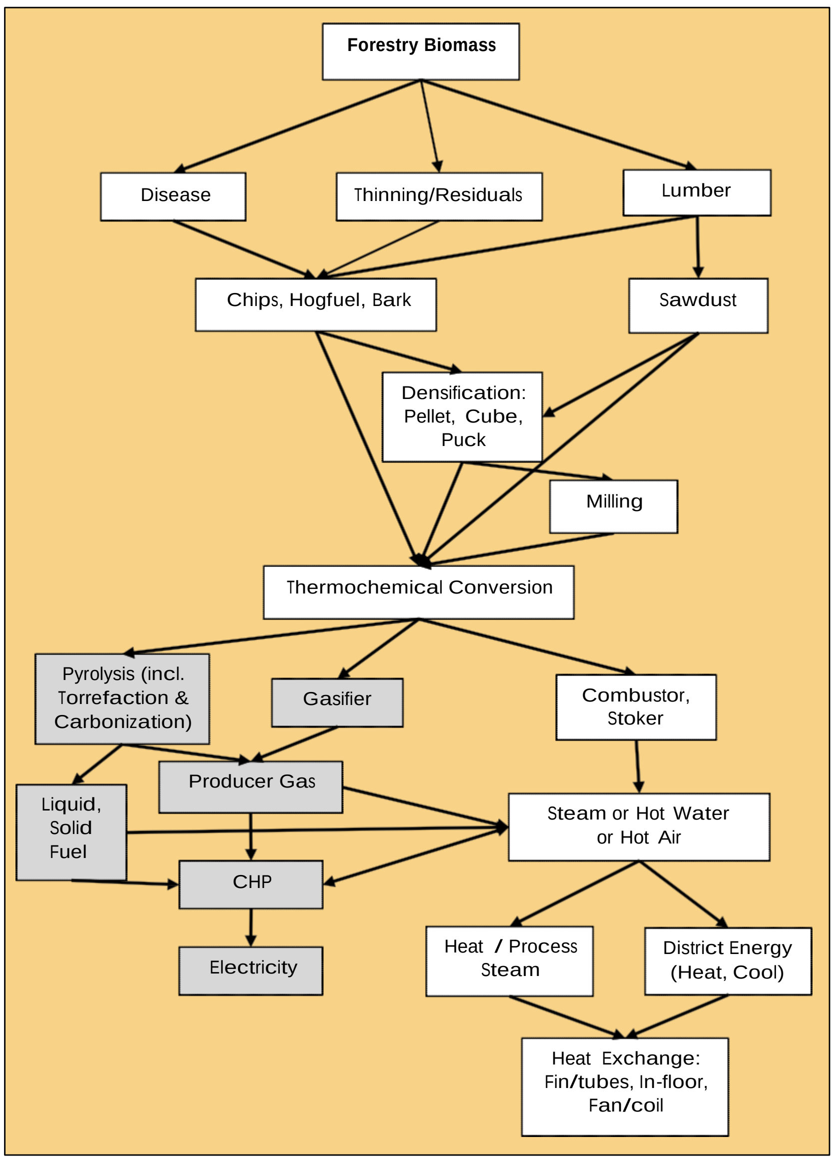
	Average	Unit	Moisture	Sources
	Ag Crop Waste			
Straw Chopped	6,234	Btu/lb	15	2
Straw Big Bales	6,234	Btu/lb	15	2
Grass Pellets	6,879	Btu/lb	8	10,11
Corn stalks/stover	7,777	Btu/lb	-	12,13,17
Sugarcane bagasse	7,900	Btu/lb	-	12,13,17
Wheat straw	7,556	Btu/lb	-	12,13,17
Hulls, shells, pruning	7,825	Btu/lb	-	13,14
Fruit pits	9,475	Btu/lb	-	13,14
	Herbaceous Crops			
Miscanthus	8,100	Btu/lb	-	17
Switchgrass	7,994	Btu/lb	-	12,13,17
Switchgrass dry	7,750	Btu/lb	-	9
Other grasses	7,901	Btu/lb	-	17
Bamboo	8,330	Btu/lb	-	17
	Woody Crops			
Black locust	8,496	Btu/lb	-	12,17
Eucalyptus	8,303	Btu/lb	-	12,13,17
Hybrid poplar	8,337	Btu/lb	-	12,14,17
Willow	8,240	Btu/lb	-	13,14,17
	Urban Residues			
MSW	7,093	Btu/lb	-	13,17
Newspaper	9,014	Btu/lb	-	13,17
Corrugated paper	7,684	Btu/lb	-	13,17
Waxed cartons	11,732	Btu/lb	-	13

Ref #	Reference
2	http://www.eubia.org/115.0.html
3	http://obitet.gazi.edu.tr/makale/makale/internalcombustionengines/053.pdf
4	http://www.hrt.msu.edu/energy/pdf/heating%20value%20of%20common%20fuels.pdf
5	http://www.hrt.msu.edu/energy/pdf/heating%20value%20of%20common%20fuels.pdf
6	http://www.extension.org/pages/38755/what-are-typical-values-for-the-higher-heating-value-of-manure-scraped-from-cattle-feedyard-surfaces
7	http://www.energy.sc.gov/publications/Poultry%20Litter%20Final%20Report.pdf
8	http://www.lfpdc.lsu.edu/publications/working_papers/wp88.pdf
9	http://www.fpl.fs.fed.us/documnts/techline/fuel-value-calculator.pdf
10	http://biomassmagazine.com/articles/6179/biomass-energy-lab-tests-giant-king-grass-pellets
11	http://stockgurucanada.com/2011/07/26/viaspace-inc-otcbb-vspc-giant-king-grass-pellets-consistent-testing-results-provide-credibility-for-market/
12	http://www1.eere.energy.gov/biomass/feedstock_databases.html
13	Jenkins, B., *Properties of Biomass*, Appendix to *Biomass Energy Fundamentals*, EPRI Report TR-102107, January, 1993.
14	Jenkins, B., Baxter, L., Miles, T. Jr., and Miles, T., *Combustion Properties of Biomass*, Fuel Processing Technology 54, pg. 17-46, 1998.
15	Tillman, David, *Wood as an Energy Resource*, Academic Press, New York, 1978
16	Bushnell, D., *Biomass Fuel Characterization: Testing and Evaluating the Combustion Characteristics of Selected Biomass Fuels*, BPA report, 1989
17	http://www.ecn.nl/phyllis

6.1 Forestry Biomass

Fuels in this sector consist of sawdust, woodchips, hogfuel (roughly chopped and ground wood), trimmings, cut logs and other industrial wood processing by-products (e.g., waste from a window factory). Other forestry biomass can be derived from fuel crops, or stands of trees grown only for fuel use such as willows and other fast growing trees. Much of the forestry resource is far from areas that can easily access it, making wider use of this resource less likely, particularly with fossil fuel heating prices dropping. The suitability of any one of these feedstocks for biomass heating depends on the type of heat technology chosen, how it is designed and what types of fuel it can handle. Forestry resources in Minnesota can and are also being used for power generation (see grayed boxes in the figure below); however, this guide's focus is on heat only. The biomass pathways in the figure examine how the biomass from various sources can be processed into fuels to be used for fuel.

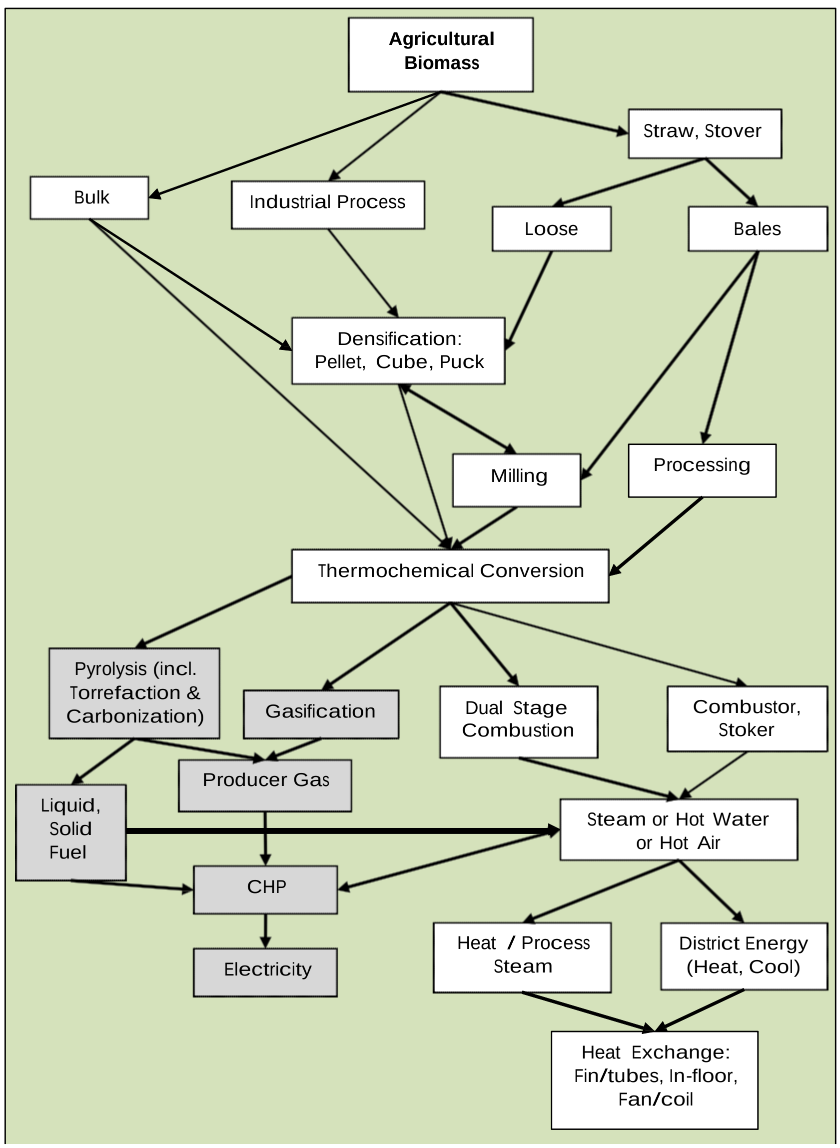
Figure 6-3: Forestry Biomass Pathways



6.2 Agricultural Biomass

Fuels in this sector consist of agricultural residues of all types grown in Minnesota including: corn, wheat, canola, beans, sunflowers, oats and flax. Each of these resources has unique characteristics, production amounts per acre, and differing collection, processing, storage and combustion dynamics. Work is being done to develop crops like miscanthus and switch grass as fuel crops, which may augment future biomass fuel supplies. As above the figure below provides an idea of how agricultural biomass moves from the field to being a fuel to provide heat and/or power. As this guide deals only with heat, the grayed boxes (power production) will not be further developed. Other agricultural biomass that exists and which will not be covered in this guide includes animal by-products, animal waste (biogas) as well as cereal and oilseeds.

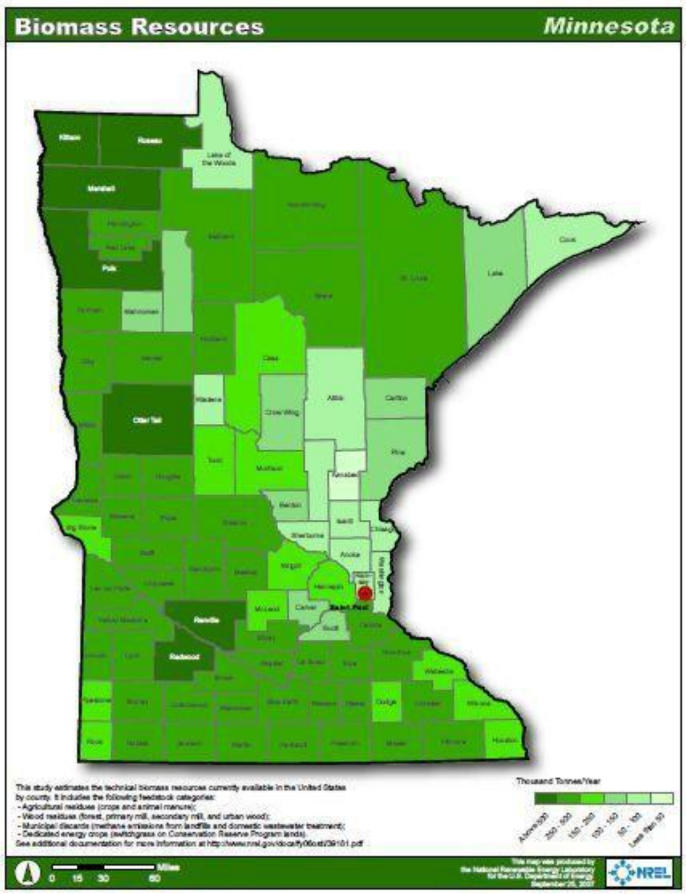
Figure 6-4: Agricultural Biomass Pathways



6.3 Quantifying Biomass Supply

In order to develop an idea of what level of biomass resources exist within a certain area, the National Renewable Energy Laboratory (NREL) has developed a Biomass Resources Tool, which provides overall information regarding the biomass grown across the country. In the figure below, all the counties of Minnesota are displayed each with a color code depicting approximately how much biomass is grown per year. In the counties around the south central and southwest portion of the state, between 250 and 500,000 tons of biomass are available. This amount includes agricultural and forest residues, energy crops and MSW – the majority, however, are agricultural and forest residues. To give perspective, a small- to medium-sized turkey farm would consume around 500 tons of biomass per year.

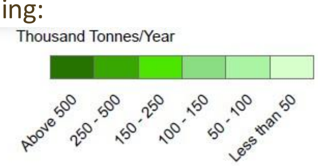
Figure 6-5: Minnesota Biomass[12]



The lower section of the figure above has been expanded below for easier reading:

This study estimates the technical biomass resources currently available in the United States by county. It includes the following feedstock categories:
- Agricultural residues (crops and animal manure);
- Wood residues (forest, primary mill, secondary mill, and urban wood);
- Municipal discards (methane emissions from landfills and domestic wastewater treatment);
- Dedicated energy crops (switchgrass on Conservation Reserve Program lands).

See additional documentation for more information at http://www.nrel.gov/docs/fy06osti/39181.pdf



[12] NREL: http://en.openei.org/wiki/File:NREL-eere-biomass-h-minnesota.pdf

6.4 Fuel Handling

As shown in the above diagrams, biomass fuels can come in a very wide variety of shapes and sizes, in addition to a wider array of energy content, density, moisture content and transportation requirements. In this section the topic of fuel handling will be developed, using as categories the following:

- Pelleted or densified biomass
- Bulk biomass
- Baled biomass

Each of these categories comes with its advantages and disadvantages, unique costs and factors as well as a number of shared characteristics (see table below).

Table 6-2: Densified or Processed Biomass Fuels Minnesota

Biomass Heating Fuels	Type of Feedstock	Processing	Handling Equip	Storage	Feed mechanism to Combustor
Pelletted or densified biomass	Forestry and Crop residues, Industrial byproducts	Grinding, Densification	Auger, Conveyor	Bin / Silo	Auger, Conveyor
Bulk biomass feedstock	Wood chips, Flax shives, Sunflower Hulls, Other		Loader	Enclosed barn/shed with loader access	Walking floor, Auger
Baled Feedstock	Corn Stover, Wheat Straw, Bean Straw, Canola Straw, Grasses	Bale Grinder / Slicer	Fork lift/crane	Barn/Shed	Walking floor, Bale conveyor

Pelleted, or densified, biomass

Made from many different feedstocks (agriculture and forestry based), densified biomass also can be made from fuel crops (e.g., willow and switch grass). Typically, however, pelleted fuel is usually made when there is a supply of suitable material available from another process already in place and profitable on its own (e.g., sawdust from a sawmill or oat hulls from a food processing facility). Due to the processing requirements, which include bulk biomass grinding, foreign material separation, hammermilling, mixing, pelletizing, cooling, storing and transportation, the cost of pellets typically runs from $150-$200 per ton. Densified biomass has many forms including pellets, pucks, cubes and logs. This type of biomass fuel is typically made by a supplier who themselves can use the fuel, and due to the large capital requirements is not usually a fuel made on a farm. Storage involves a bin or grain-type silo.

- Advantages: Ease of storage, transportation and handling, small storage footprint. If wood based, very small ash output.
- Disadvantages: Transportation, if far from a source, will push costs up. Higher per ton costs than other biomass fuels. High capital costs to set up a mill.

Bulk biomass

In the form of hogfuel, woodchips, sunflower hulls, flax shives or other feedstocks, this type of biomass requires less capital up front than pellets, but more in terms of pre-combustion handling. Costs for this category of biomass will range from $40 to $80 per ton, but will require the construction of a barn to store and keep the biomass dry, a fuel movement mechanism designed for this type of fuel (e.g., walking floor) and potentially a drying facility to reduce moisture and increase the energy per ton value of the biomass.

- Advantages: Can be available nearby with wood residues or a processing facility; low per ton fuel cost; if wood, very small ash output.
- Disadvantages: Transportation. if far from a source, will push costs up; variable moisture content and quality of feedstock; capital required for on-farm infrastructure including a front-end loader.

Baled biomass

Limited to primarily an agriculture-based feedstock, this type of biomass is straw and stover bales from corn, wheat, oats, and flax. In addition to these common crops, less common baled material like grasses and canola straw can be used. Costs for this type of biomass fuel range from $40 to $80 per ton depending on location and quality. Combustors using this type of fuel are not common in North America; however, they are very common in the EU where heating systems for farms, as well as whole towns and cities, are based on this type of technology. Like the bulk biomass, the baled feedstock must be stored out of the weather, and requires the use of a forklift or crane to move it. Once on the bale conveyor, the bale is either ground or sliced and fed into the combustor.

- Advantages: If farm- or rural town-based, this type of biomass can be easily available, with many farmers already owning or having access to baling equipment. Cost is low, and a farm-based operation using this technology can provide all of its own fuel and heat.
- Disadvantages: Transportation, if far from a source, will push costs up; variable moisture content and quality of feedstock; capital required for on-farm infrastructure including a fork lift, or if a larger operation, crane.

Biomass pricing and availability:

As part of this guide a Request for Proposals (Appendix C) was sent out to a number of biomass suppliers and the following information was gathered. This is not meant to represent a comprehensive list of Minnesota biomass fuel suppliers.

Table 6-3: Biomass Fuel Supply Information

Fuel Supplier	Location	Type of Fuel	Price per ton
Ever-Green Energy	Minneapolis	Woodchips	Sold only to St. Paul Dist Energy
MARTH	Marathon	Wood Pellets	$135 - 145
		Debarked woodchips	$55 - 65
Great Lakes Renewable Energy	Hayward	Wood Pellets	$145
Pork and Plants	Altura	Biomass Pellets	$150
Hedstrom Lumber	Grand Marais	Woodchips	$50
		Hogfuel	$20
Kotter & Smith	Deer River	Pellets	$165
		Woodchips - wet	$30-40
		Woodchips - dry	$50
		Hogfuel - wet	$25
Farmer supplied		Corn Stover bales	$60-80

Examples of biomass fuel processing and handling:

1. AURI – Waseca. This facility has a test unit that can be used to run small batches of feedstock through and to experiment with different pellet recipes, representing a valuable resource for businesses interested in examining biomass fuels.

Figure 6-6: Biomass Pelletize - AURI

2. Eric Kreidermacher – Altura. As part of his Pork and Plants farm/greenhouse operation, Eric has a pellet mill that uses a mixture of straw, grass and sawdust with the capability of producing 15,000 tons/year.

Figure 6-7: Biomass Pelletizing Operation

3. LINKA – Danish company with some systems in North America: Whole Bale Straw Burning Systems whereby the bales are stored in a covered barn, moved onto a conveyor using a ceiling mounted crane or forklift, and then sliced or ground and fed into the combustor. Systems that use straw to generate heat – without mixing it with other fuels like manure, or woodchips – require a unique feed system, which will deal with a combination of factors:
   - Lower energy density requiring more biomass material
   - Large bales that require pre-combustion processing (shredding, grinding)
   - Foreign objects (stones, metal pieces) that can foul up the transportation process to the boiler

   The LIN-KA system (below) uses a conveyor to feed the straw bales into a grinder that leads to a vacuum pressurized air system, which transports the biomass to the boiler. This method addresses the issue of biomass processing and eliminates the presence of rocks or metal, which are taken out of the biomass by the vacuum system.

Figure 6-8: LINKA Straw Conveyor System[13]

4. LINKA – walking floor mechanism that moves the bulk biomass into the combustor.

Figure 6-9: LINKA Walking floor mechanism[14]

5. Woodchip/Sawdust storage barn: Revelstoke, BC District Heating System

[13] Biomass Briquette Systems, LINKA Energy: http://www.biomassbriquettesystems.com/
[14] Biomass Briquette Systems, LINKA Energy: http://www.biomassbriquettesystems.com/

Figure 6-10: Bulk biomass storage barn

6. Bulk Biomass handling system: AFAB-USA

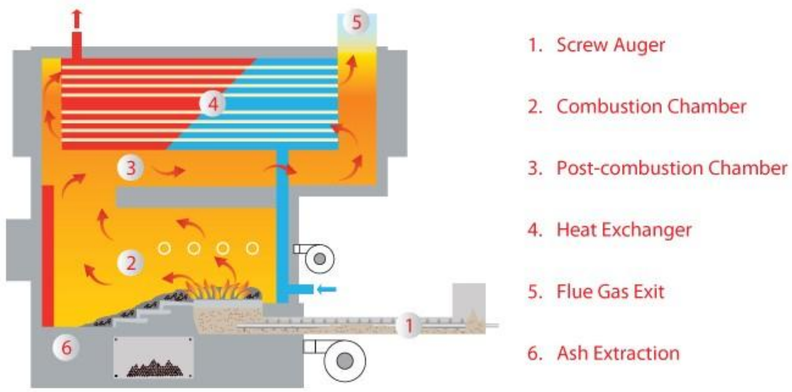
Figure 6-11: Containerized storage and handling for bulk biomass[15]

[15] AFAB-USA: http://www.afabusa.org/index.php

7 Biomass Heating Technologies

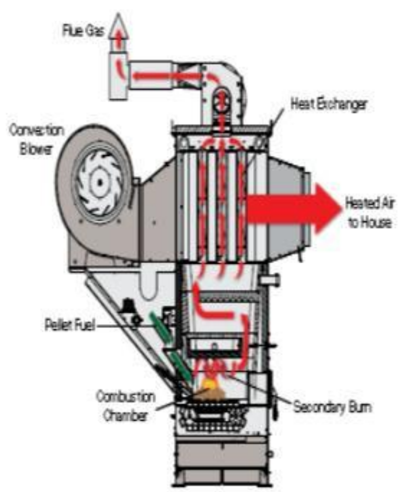
A number of technologies exist to convert biomass into heat and/or power including combustion, gasification and pyrolysis. The focus of this guide is the combustor technology – the simplest and most mature technology to convert biomass into heat – that feeds biomass into a combustion chamber, burns it and circulates the hot flue gases around the boiler tubes within which water or air (or oil) is circulated, transferring the heat (Figure 5-2) to the fluid. As part of this guide, a Request for Proposals (Appendix C) was sent to manufacturers and distributors of biomass combustion equipment. Those who responded are featured in this section.

Figure 7-1: Stoker Boiler Diagram [16]



Another type of combustor, shown in the following diagram, circulates air through a heat exchanger that receives heat from the burned pelleted biomass fuel.

Figure 7-2: Biomass Furnace Diagram[17]



[16] Alternative Energy Solutions International: http://www.aesintl.net/technologies/eos-series-diagrams
[17] Heartland Energy Systems: http://www.heatwithheartland.com/

Still another burner method is to feed the biomass up from the bottom through an auger feed system.

Figure 7-3: Central lower biomass feed system[18]

7.1 Response to the Biomass Equipment Request for Proposals

The following section provides information from the biomass combustion technology providers who responded to the RfP. A summary of the technologies is provided at the end of this section. The RfP requested information on units which produced heat at: 500,000Btu/hr and 2 MMBtu/hr and 5 MMBtu/hr. All of the units featured below can be used to heat greenhouses and poultry barns. Each entry provides some information about the unit, and each is rated at a set input Btu/hr capacity. (For more information, footnotes are provided with a web link on the bottom of each page featuring the combustion units in this section.) The output of each unit depends on many factors including:

- Rated combustion efficiencies in the lab vs. real life conditions;
- Differing types of fuels that directly affect the actual performance of the unit (i.e., low or higj BTU fuels);
- Moisture content of the fuel that impacts the efficiency of each of the above fuels, compounding the output results;
- Overall heating system transfer efficiency – after the water or air is heated, there are additional efficiency variables in actually getting the heat to where you need it;
- Boiler efficiency is impacted by the capacity at which it is being used – e.g., running at 50% of capacity (lower heat demand) yields lower efficiency than at higher demand rate;
- Some combustion/boiler units are designed to be located outside of a shelter, which requires additional energy to maintain temperature when it is very cold, and more energy must be expended, which impacts and is impacted by all the other variables above.

[18] BioPact: http://news.mongabay.com/bioenergy/2007_05_06_archive.html

7.2 Combustion Unit Survey Results

1. Heartland Energy Systems – The Bio-500F unit (input of 500,000 Btu/hr) burns wood pellets and produces hot air.

Figure 7-4: Heartland Energy Systems Heatilator[19]

2. LEI Products – The BB500 (input 500,000 Btu/hr) produces hot water and can burn a variety of biomass products including: woodchips, hogfuel, pellets, corn stover, sawdust, waxed cardboard, hay and straw.

Figure 7-5: LEI Products Bio-Burner[20]

[19] Heartland Energy Systems: http://heatwithheartland.com/

[20] LEI Products: http://www.leiprod.com/bb500.html

[18] BioPact: http://news.mongabay.com/bioenergy/2007_05_06_archive.html

3. AFAB-USA – The VanerTekno Models 200 and 500 have input capacities of 680,000 and 1 MMBtu/hr respectively and can burn wood pellets, cubes, woodchips and poultry litter.

Figure 7-6: AFAB-USA VanerTekno[21]

4. Also distributed by AFAB-USA are the OsbyParca Models P500/50 and 1500, which have input capacities of 2 MMBtu/hr and 5 MMBtu/hr respectively, units which can burn wood pellets, cubes, woodchips and poultry litter. Note the mobile biomass fuel feed trailers to the side of the unit, which provides district heating in Sweden.

Figure 7-7: AFAB-USA OsbyParca[22]

[21] AFAB-USA: http://www.afabusa.org/index.php , http://www.vanerpannan.se/
[22] AFAB-USA: http://www.afabusa.org/index.php, www.OsbyParca.se

5. Marth-EarthWise: The WoodMaster BM130, BM650 and BM1650 have input capacities ranging from 450,000 Btu/hr to 2.2MMBtu/hr to 5.6 MMBtu/hr respectively and can burn wood pellets and woodchips and can provide a variety of hot water, low pressure steam and hot air.

Figure 7-8: Marth-EarthWise WoodMaster[23]

6. Prairie Bio-Energy: The Blue Flame Stoker is custom built for every application and is available in all sizes. The unit specified was for an input of 2 MMBtu/hr and is capable of burning straw, stover, woodchips, pellets, cubes, pucks and poultry litter, producing hot water or steam.

Figure 7-9: Prairie Bio-Energy Blue Flame Stoker[24]

7. Biomass Briquette Systems: The LINKA Energy units (sized for input capacities of 680,000 Btu/hr, 2 MMBtu/hr, and 5.1 MMBtu/hr) can burn straw, stover, woodchips, pellets, cubes, pucks and poultry litter, producing steam or hot water.

[23] Marth: http://marthwood.com/ WoodMaster: http://www.woodmaster.com/
[24] Prairie Bio-Energy: http://www.prairiebioenergy.com/biomass.html

Figure 7-10: Biomass Briquette Systems LINKA Energy [25]

8. ITASCA Power Company: A custom built 5 MMBtu/hr system can burn hog fuel, pellets and poultry litter, producing steam, hot water or hot air.

Figure 7-11: ITASCA Power Company[26]

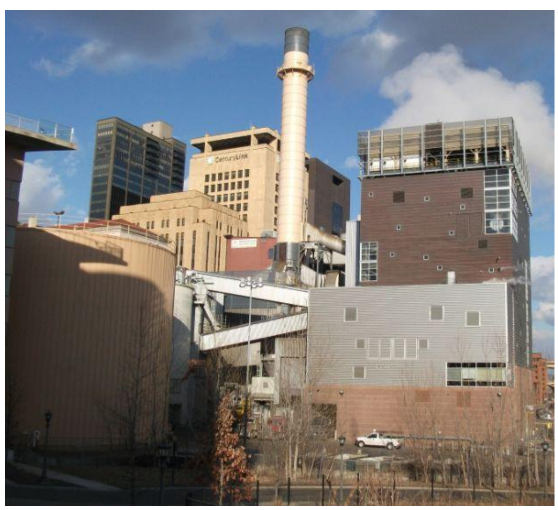
9. Pork and Plants: The 2 PELCO units heating this operation are sized at 2.5 MMBtu each, located in the figure below with the pellet fuel bins in the background and ash bins in the foreground.

[25] Biomass Briquette Systems: http://www.biomassbriquettesystems.com/products/5 LINKA Energy: http://linka.dk/content/us/plant_types/hot_water_plant/straw_60_%E2%80%93_1500kw
[26] ITASCA Power Company: http://www.itascapower.com/about.html

Figure 7-12: Pork and Plants PELCO units[27]

10. St Paul District Energy System: This report would be remiss without a brief mention of this significant energy system, which provides electricity, and heats and cools 31.7 million ft^2 of office and residential space with a combination woodchips, coal and fuel oil as well as solar PV and thermal.

Figure 7-13: St. Paul District Energy[28]



[27] Pork and Plants: http://www.porkandplants.com/index.html PELCO: http://www.profab.org/products/profabproducts/pelco/
[28] St. Paul District Energy: http://www.districtenergy.com/

7.3 Biomass Combustor Summary

The table below displays the results of the biomass combustor survey, which includes information from a total of 23 units examined from nine companies – distributors as well as manufacturers. The information is given in aggregate format as considerable detail was supplied.

Table 7-1: Summary of Biomass Combustor Systems Reviewed

Combustor Unit Size	0 to 500kBtu	500kBtu to 2MMBtu	2MMBtu to 5MMBtu
# Units surveyed	9	7	7
Feedstocks	Wood chips, hog fuel, pellets, corn stover, sawdust, dirty "waste" chips, grass pellets, waxed cardboard, hay, straw, cubes, poultry litter	Wood Pellets, Straw, stover, wood chips, shavings, cubes, pucks, poultry litter	Hog fuel, Wood Pellets, Straw, stover, poutry litter, cubes, chips,
Output	Hot Air, Hot Water,Steam	Hot Air, Hot Water,Steam	Hot Air, Hot Water,Steam
Combustion Efficiencies	75% - 95%	76% - 95%	77% - 94%
Ash Handling Options	Manual or Automatic	Mostly Automatic	All Automatic
Emissions Options	Cyclone/Multi-Cyclone	Cyclone/Multi-Cyclone	Cyclone/Multi-Cyclone
Fire Suppression Options	Some offer automatic shutdown on heat overload	Some offer automatic shutdown on heat overload	Some offer automatic shutdown on heat overload
PC Remote Access	Most Include as Option	Most Include as Option	Most Include as Option
Installation Requirements	Some 3ph power (others require 220V Single Phase), Some require water or compressed air	All require 3ph power, Some require water, Some require compressed air	All require 3ph power, Most require water, Some require compressed air
Pricing: Average / Stnd Deviation*	$56k / $30k	$145k / $48k	$250k / $65k
Price per Btu*	$0.05 - $0.19	$0.05 - $0.09	$0.05 - $0.11
Units Suveyed	Heartland Energy Systems, LEI Products, AFAB-USA, Marth - Earth Wise, Biomass Briquette Systems, Woodmaster	AFAB-USA, Marth - Earth Wise, E-Mission Free, Biomass Briquette Systems, Woodmaster	Itasca Power Co., AFAB-USA, Marth - Earth Wise, Biomass Briquette Systems, Woodmaster
Components Included	Varies	Varies	Varies
* Outliers removed			

In summary, many companies exist with a wide variety of combustor units designed for many applications. Located in both North America and Europe, these companies have units operating that can provide further reason to examine their products for heating applications (see table below). It is important to note that more companies than these listed were given the opportunity to respond, and of those listed, each offers a range of systems which may not be fully included in the table below.

Table 7-2: Summary of Biomass Combustor Systems RfP Respondents

Company Name	Location	Contact	Combustor Size
Heartland Energy Systems	Minnesota	David Fiebelkorn	500k
LEI Products	Kentucky	Rick Jones	500k
Itasca Power Co	Minnesota	Dean Sedgewick	Custom; 5M
AFAB-USA: VanerTekno, OsbyParca	Sweden - US Dist	Dave McNertney	500k - 1M
Marth EarthWise / Wood Master	Wisconsin / Minnesota	Danny Gagner	500k - 5M
Blue Flame	Manitoba	Eugene Gala	Custom: 500k - 5M
Biomass Briquette Systems: LINKA	Denmark - US Dist	Dave Schmucker	500k - 5M

8 Balance of Systems

This section covers the systems that must be in place in order to have a functioning biomass heating system. As covered above, fuel and fuel issues are key to understand as well as the combustor itself. The balance of systems covers the following items:

- Feasibility study
- Site preparation
- Engineering
- Other legal, permitting fees
- Combustor building (may not be required)
- Biomass storage
  - Bin/silo
  - Building
- Heat distribution
  - Trenching
  - Pipes
  - Insulation
- Controls
- Intersection with existing heating system
- Electrical and water service as required
- Ash / Dust handling

The following table provides a review of the many components of a balance of system for a biomass heating system and the characteristics of each different type of biomass heating system featured in this guide. The information provided for this table (as well as costs for Section 9 below) was collected from data submitted by Eugene Gala of Prairie Bio-Energy and Dean Sedgewick of ITASCA Power Company.

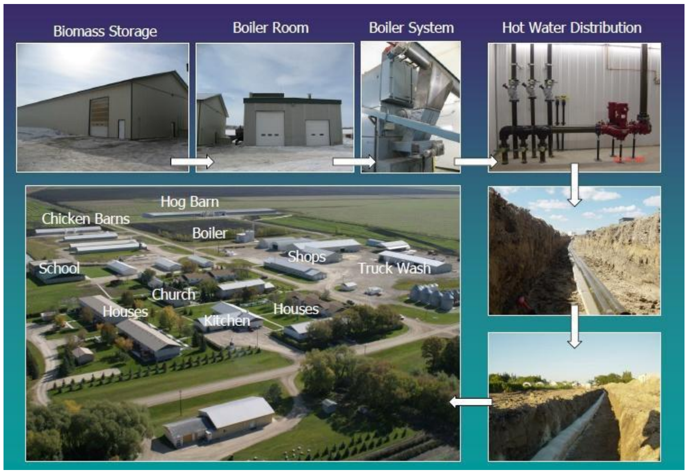
Table 8-1: Biomass Balance of System Characteristics

	Fuel Type	Propane - BASE CASE	Pellets		Woodchips	Bales	Bulk Biomass
	System		1	2	3	4	5
1	**System Type**	Forced Air, Radiant heat, Hot Water	Direct Air Heat	Hot Water (Air)	Hot Water (Air)	Hot Water (Air)	Hot Water (Air)
2	**Fuel Production**	Offsite	Offsite	Offsite	Offsite	Onsite	Offsite
3	**Transportation**	Long Distance	Long Distance	Long Distance	Long Distance	Short Distance	Long Distance
4	**Fuel Storage**	Tank	Bin / Silo	Bin / Silo	Bin / Silo	Building	Building
5	**Combustor Building**	Yes - small	No	No	No	Yes	Yes
6	**Fuel Conveyance**	Underground Pipes	Auger	Auger	Auger	Loading Required onto Bale Conveyor	Loading Required onto Walking Floor
7	**Fuel Processing direcly prior to combustion**	None	None	None	None	Slicing / Grinding, Rock / Metal detection	Rock / Metal detection
8	**Heat Storage**	None	None	Yes	Yes	Yes	Yes
9	**Heat Conveyance**	None - heat produced at place and time of need	Air ducting	Underground, Insulated Water Pipes	Underground, Insulated Water Pipes	Underground, Insulated Water Pipes	Underground, Insulated Water Pipes
10	**Utilities**	Electricity	Electricity	Electricity, Water, Air	Electricity, Water, Air	Electricity, Water, Air	Electricity, Water, Air
11	**Ash / Dust storage**	None	Limited	Cyclone/Auto/Bin	Cyclone/Auto/Bin	Cyclone/Auto/Bin	Cyclone/Auto/Bin
12	**Additional Equipment Req**	No	No	No	No	Yes - Fork Lift	Yes - Front End Loader

	NOTES
1	Type of heating provided (transfer to air possible)
2	Except in the cases where the farmer is producing own fuel or purchasing stover/straw
3	Except in cases where the fuel is closer or farther from the farmer
4	Where fuel is stored
5	Location of the unit converting the fuel into heat
6	How fuel is moved from storage to the combustor
7	How fuel is processed prior to being burned
8	Refers to the combustor/boiler unit's direct internal capacity to store heat
9	How the heat produced is primarily moved
10	Types of utilities required
11	Fly and bottom ash processing and handling, bin refers to a automated storage unit
12	Required for biomass handling

Biomass heating systems can be as small as a residential fireplace, and as large as a system that heats an entire city. The figure below shows a rural community with its own district heating system powered by biomass along with various key components of the system itself: biomass storage, boiler room, heating system and underground piping network.

Figure 8-1: Diagram of Biomass District Heating System[29]



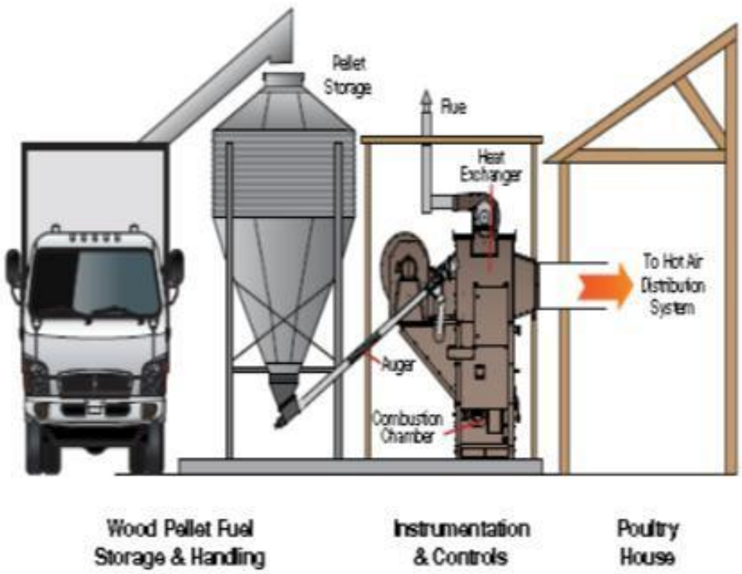
The distribution of heat provided by biomass heating systems is no different than distributing heat from a fossil fueled system (see figure below). Whether floor heating or overhead heating or fan/radiator style units, biomass heated water or air can be used. Existing fossil fuel system (also figure below) can be left in place and the biomass heating system interconnected to use the existing systems as peaking, fill-in, or back-up heating units.

Figure 8-2: Floor Heating and Existing Natural Gas Heating System[30]

[29] Government of Manitoba: http://www.gov.mb.ca/agriculture/agrienergy/pdf/gala_mb_3rd_annual_biomass_workshop_20100226.pdf
[30] Drummers Garden Center, Mankato, MN: http://drummersgardencenter.com/

Smaller pellet fired air heating units (see figure below) are manufactured in Minnesota and require a separate furnace room. This diagram shows the various components required for this type of system.

Figure 8-3: Biomass Pellet Heating System Diagram[31]



Other larger biomass heating systems require a boiler shed/building as shown in the figure below. This particular one houses the biomass stoker/boiler, which supplies heat to livestock buildings and houses using an underground piping system.

Figure 8-4: Biomass Heating System Building

Heat storage can be done using very large water vessels as shown on the left figure below in order to heat a small town in Denmark, as well as smaller heat storage tanks as shown in the figure on the right at a greenhouse operation in Minnesota.

[31] Heartland Energy Systems: http://heatwithheartland.com/

Figure 8-5: Biomass Heat Storage

In addition to heat, the by-products of biomass combustion are ash and soot, which when handled properly are valuable soil amendments that help to restore soils whose biomass has been removed for heat generation. These systems collect both the ash that falls from the combustion chamber (bottom ash) as well as the fly ash, which is lighter and is partially removed using a cyclone or multi-cyclone unit (examples shown below). Where restrictions are tight on emissions and particulate matter, then more expensive bag houses and electro-static precipitators are used to remove higher percentages of the particulate matter and other regulated substances.

Figure 8-6: Ash and Soot Handling

In summary, the balance of systems cost general is at least as much as the combustor/boiler unit itself in addition to the fact that each component of the system requires knowledge of the biomass itself, processing requirements, transportation issues, and storage dynamics as well as understanding the value of ash and its handling and use.

9 Feasibility Analysis

The tables and explanations, displayed below, for the cost and financial feasibility analyses in this section of the report have been developed using the **RETScreen Clean Energy Project Analysis Software**, from Natural Resources Canada[32]. In determining the feasibility of using biomass for greenhouses and turkey farms in Minnesota, there were a large number of variables with which to contend, including:

- Fuels: Natural Gas, propane, biomass
- Biomass Fuels: Wood residues, agricultural residues
- Biomass Types: Densified, loose, baled
- Facilities: Greenhouses and turkey farms
- Size of operations: Large, medium, small
- Biomass Combustors: Air or water based, in addition to variations in size
- Balance of Systems: Fuel and ash handling systems, fuel processing, type of heating system (hydronic, air), trenching, ducting etc.
- Fuel storage: Bin, barn, silo
- Pricing of all the above

The number of variables and potential combinations were more than could be meaningfully analyzed, therefore the following scenarios were chosen:

1. Indoor located air heating system, using pellets
2. Outdoor located water heating system, using pellets
3. Outdoor located water heating system, using woodchips
4. Indoor located water heating system, using straw/stover bales
5. Indoor located water heating system, using bulk biomass (hogfuel, loose biomass)

Each of these scenarios was worked out for both turkey barns as well as greenhouses, and in order to simplify the output, a single heating capacity was chosen (2 MMBtu/hr) – using the modelling software – which can provide sufficient heat for a 50,000 ft^2 barn or a 22,000 ft^2 greenhouse. In fact, this size system may not be able to provide for all the peak loads of these facilities, but a key assumption is that the existing propane heating system is functioning and will remain in place.

[32] RETScreen by NRCAN: http://www.retscreen.net/ang/home.php

9.1 Environmental Data

The RETScreen software begins with a query as to where the modelling will take place, and provides a global database from which to choose a location. Mankato, Minnesota, was chosen as a location similar to many of the towns in or near the locations visited or researched for this guide.

Table 9-1: Climate Data – Mankato MN (RETScreen)

	Unit	Climate data location	Project location
Latitude	°N	44.2	44.2
Longitude	°E	-93.9	-93.9
Elevation	ft	1,020	1,020
Heating design temperature	°F	-8.1	
Cooling design temperature	°F	86.2	
Earth temperature amplitude	°F	45.6	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°F	%	kWh/m²/d	Inch Hg	mph	°F	°F-d	°F-d
January		15.4	72.3%	1.46	28.9	11.0	11.4	1,518	0
February		21.0	71.3%	2.24	28.9	11.0	17.0	1,215	0
March		31.1	67.6%	3.39	28.9	11.0	29.3	1,032	0
April		46.6	58.4%	4.72	28.8	11.9	46.7	535	0
May		57.9	58.8%	5.39	28.8	11.2	60.1	201	246
June		68.0	63.2%	6.13	28.8	9.6	69.3	0	540
July		71.6	69.8%	6.32	28.8	7.8	72.9	0	670
August		68.9	73.0%	5.33	28.9	7.6	70.3	0	586
September		60.8	66.4%	4.20	28.9	9.2	60.8	108	324
October		48.7	63.3%	2.65	28.9	10.7	47.3	485	0
November		34.2	68.0%	1.56	28.9	10.7	30.1	907	0
December		21.6	73.1%	1.21	28.9	10.7	16.1	1,328	0
Annual		45.6	67.1%	3.72	28.9	10.2	44.4	7,329	2,365
Measured at	ft					32.8	0.0		

9.2 Load and Network

The economic feasibility analysis is based on an existing and a proposed base case scenario, which sets out the following:

- **Base case heating system** – This refers to the existing propane gas system now in place.
- **Proposed base load heating system** – The biomass heating system is the new proposed base load system to take over the majority of the heating load from the existing natural gas system.
- **Peak load heating system** – The existing natural gas system is the new proposed peak load and fill-in heating system with more than enough capacity for all the buildings.

The remainder of the values were filled in as needed; this table and the rest following are for the turkey barn application, but apply in load to the greenhouse facility as well. This section of the software allows for considerable latitude in terms of efficiency, fuels to choose from, and the determination of heating loads. This table and the one for the greenhouse below it are based on data gathered from real locations.

Table 9-2: Load and Network – Turkey Barn Scenario (RETScreen)

Heating project	Unit		
Base case heating system	Single building - space heating		
Heated floor area for building	ft²	50,000	
Fuel type		Propane - gal	
Seasonal efficiency	%	80%	
Heating load calculation			
Heating load for building	(Btu/h)/ft²	40.0	
Domestic hot water heating base demand	%	5%	
Total heating	million Btu	4,024	
Total peak heating load	million Btu/h	2.0	
Fuel consumption - annual	gal	52,756	
Fuel rate	$/gal	1.600	
Fuel cost		$	84,409
Proposed case energy efficiency measures			
End-use energy efficiency measures	%	0%	
Net peak heating load	million Btu/h	2.0	
Net heating	million Btu	4,024	

Greenhouse Scenario

Heating project	Unit		
Base case heating system	Single building - space heating		
Heated floor area for building	ft²	22,000	
Fuel type		Propane - gal	
Seasonal efficiency	%	80%	
Heating load calculation			
Heating load for building	(Btu/h)/ft²	90.0	
Domestic hot water heating base demand	%	5%	
Total heating	million Btu	3,983	
Total peak heating load	million Btu/h	2.0	
Fuel consumption - annual	gal	52,228	
Fuel rate	$/gal	1.600	
Fuel cost		$	83,565
Proposed case energy efficiency measures			
End-use energy efficiency measures	%	0%	
Net peak heating load	million Btu/h	2.0	
Net heating	million Btu	3,983	

9.3 Cost and Financial Analysis

The cost analysis contains a listing of the **estimated** initial and annual costs for the biomass heating project. A number of assumptions were made in this section including:

Table 9-3: Cost Assumptions

Assumptions	Air/Water Outdoor Systems	Water bulk and bale biomass Systems
Initial Costs		
Feasibility	$ 1,000	$ 5,000
Development	$ 2,000	$ 7,000
Engineering	$ 3,000	$ 10,000
Contingency	5%	5%
Annual Costs		
Parts and labor - annual	$ 5,000	$ 10,000
Contingency	5%	5%
Financial Parameters		
Fuel cost escalation rate	2%	2%
Inflation rate	2%	2%
Discount rate	6%	6%
Project life (yr)	15	25
Incentives and grants	$ -	$ -
Debt ratio	75%	75%
Debt interest rate	6%	6%
Debt term (yr)	10	10

The following table provides specific data used in the model (based on real data), which includes both cost and financial information. This table includes data covering the fuels that can be used by various technologies, preferred moisture levels, and type of system itself. The combustor costs are based on information submitted to the study and are based on the average of the technologies within one standard deviation.

Table 9-4: Cost and Financial Analysis (RETScreen Data)[33]

	Facility: Greenhouse @ 22K ft2 or Turkey Barn @ 50K ft2 Combustor Size: 2 MMBtu/h					
	Fuel Form	**Pellet**	**Pellet**	**Woodchip**	**Bale**	**Bulk**
	Combustor	**Indoor Air Heater**	**Outdoor Water Heater**	**Outdoor Water Heater**	**Indoor Water Heater**	**Indoor Water Heater**
		Wood Pellet	Wood Pellet	Woodchip	Baled Straw / Stover	Woodchips / Hogfuel / Biomass (loose stover)
2	**$ / Ton**	$ 175	$ 175	$ 75	$ 60	$ 60
3	**Moisture**	6%	6%	30%	15%	15 - 45%
4	**System Type**	Hot Air	Hot Water	Hot Water	Hot Water	Hot Water
5	**Combustor Cost**	$ 120,000	$ 165,000	$ 165,000	$ 165,000	$ 165,000
6	**Balance of System Cost**	$ 120,000	$ 105,000	$ 105,000	$ 320,000	$ 350,000
7	**Initial Costs**	$ 258,000	$ 290,000	$ 305,000	$ 532,000	$ 564,000
8	**Annual Costs**	$ 47,000	$ 47,000	$ 25,000	$ 28,000	$ 27,000
9	**Annual Savings**	$ 84,000	$ 84,000	$ 84,000	$ 84,000	$ 84,000
10	**Annual Debt**	$ 31,000	$ 35,000	$ 32,000	$ 55,000	$ 57,000
11	**Pre-tax Internal Rate of Return (equity)**	17.1%	13.0%	42.0%	11.1%	11.9%
12	**Net Present Value**	$ 95,000	$ 67,000	$ 280,000	$ 91,000	$ 112,000
13	**Simple Payback (Yr)**	8.2	9.1	5.2	9.6	9.3
	NOTES					
1	The fuels listed cover the gamut of feedstocks reviewed in the report					
2	Prices vary, however, those listed are based on supplier data from Minnesota in response to the request for proposal					
3	Moisture is a key factor of any biomass fuel impacting storage, handling and boiler efficiency.					
4	Heat generated can be used in a number of ways, e.g. Air heat can be converted, with efficiency losses to water heat, and vice					
5	Costs based on an aggregated review of combustor information provided in response to the request for proposal					
6	Costs cover what the rest of the system requires e.g. Pumps, controls, pipes, concrete, buildings etc.					
7	Total of the lines 5 and 6 in addition to other expenses (such as 5% contingency cost). IMPORTANT: the bulk and bale systems require manual loading equipment which is not included in this price.					
8	Includes fuel, operations and maintenance. For transportation add $2-3 per mile.					
9	Calculated based on what will be saved by NOT using propane @ $1.50 per gallon					
10	Based on 75% of the project financed @ 6% over 10 years					
11	Based on 2% inflation, 2% cost of fuel increase, 6% discount rate, 15 year project life					
12	Present value of future discounted cash flows - if NPV is positive, the investment is worth examining					
13	Amount of time for the project to pay for itself based on savings paying off the investment					

[33] Based on data submitted in response to AURI/DLF Consulting Requests for Proposals for Biomass Fuels, Biomass Combustors and Biomass Balance of Systems.

Initial costs range from a low of $258,000 to a high of $564,000, consisting of combustor costs, cost to install, the heating equipment, ash handling, fuel handling, trenching, pipe and insulation. These costs are ballparks, intended as a rough guideline in determining feasibility. Important to determining financial viability is a combination of a number of factors including the consideration of:

- Pre (or post) tax IRR (Internal Rate of Return) are also referred to as Return on Equity (ROE) and Return on Investment (ROI). If the internal rate of return is equal to or greater than the required rate of return, then the project can be considered financially acceptable (assuming equal risk).
- Simple payback is a measure of time necessary to recover the investment. *The simple payback method is not a measure of how profitable one project is compared to another. Rather, it is a measure of time in the sense that it indicates how many years are required to recover the investment for one project compared to another.* ***The simple payback should not be used as the primary indicator to evaluate a project.*** *It is useful, however, as a secondary indicator to indicate the level of risk of an investment. A further criticism of the simple payback method is that it does not consider the time value of money, nor the impact of inflation on the costs.* (RETScreen Help screen comments on Simple Payback)
- Net present value (NPV) is the future value of cash flows over the lifetime of the project, and debt service is the ratio of operating benefits of the project over the debt payments.

Summary:
Factors that lead to the best decision for heating a greenhouse or turkey barn with biomass will be quite varied. The table above provides information on a specific scenario (2 MMBtu system) only, and the rates of return and NPV are dependent on the assumptions made. Based on those assumptions, the outdoor water heating unit using woodchips showed the best return on investment and the shortest simple payback due to: 1) the low cost of fuel; and 2) the low cost of infrastructure (especially no need for a boiler barn). Other factors will come into play for each farmer/grower including the types of fuel available, the existing infrastructure on location, personal preference, and location.

9.4 Sensitivity Analysis

The above financial analysis is based on a certain set of assumptions that can change depending on a number of factors. Some of these have been considered below in an analysis of sensitivity regarding the costs of fuel (both propane and biomass) and interest rates. The following analysis is based on equity payback (years) – other analyses include IRR and NPV.

Examples:

1. First set of data (Fuel Cost Base case) – if propane (base case fuel) increases by 10% (to $92,850) and the initial costs remain the same, the equity payback decreases from 2.5 years to 2.0 years.
2. Second set of data (Fuel Cost Proposed case) – if biomass costs decrease by 20% (to $16,169) and the initial costs increase 20%, the equity payback increases from 2.5 years to 3.2 years.
3. Third set of data (Debt Interest Rate) – if interest rates increase 20% from 6.0% to 7.2%, and the initial costs decrease 20%, the equity payback decreases from 2.5 years to 1.6.

Many other iterations are possible to derive from this single table and many other types of analysis can also be done using RETScreen.

Table 9-5: Sensitivity Analysis (RETScreen)

Perform analysis on	Equity payback
Sensitivity range	20%
Threshold	5 yr

Fuel cost - base case		Initial costs				$
		244,440	274,995	305,550	336,105	366,660
$		-20%	-10%	0%	10%	20%
67,527	-20%	3.2	4.2	5.5	7.3	9.7
75,968	-10%	2.2	2.8	3.5	4.4	5.5
84,409	0%	1.7	2.1	**2.5**	3.1	3.7
92,850	10%	1.4	1.7	2.0	2.4	2.8
101,291	20%	1.2	1.4	1.6	1.9	2.2

Fuel cost - proposed case		Initial costs				$
		244,440	274,995	305,550	336,105	366,660
$		-20%	-10%	0%	10%	20%
16,169	-20%	1.5	1.9	2.2	2.7	3.2
18,190	-10%	1.6	2.0	2.4	2.9	3.5
20,211	0%	1.7	2.1	**2.5**	3.1	3.7
22,232	10%	1.8	2.2	2.7	3.3	4.1
24,254	20%	1.9	2.4	2.9	3.6	4.4

Debt interest rate		Initial costs				$
		244,440	274,995	305,550	336,105	366,660
%		-20%	-10%	0%	10%	20%
4.80%	-20%	1.6	2.0	2.4	2.9	3.5
5.40%	-10%	1.7	2.0	2.5	3.0	3.6
6.00%	0%	1.7	2.1	**2.5**	3.1	3.7
6.60%	10%	1.7	2.1	2.6	3.2	3.9
7.20%	20%	1.8	2.2	2.7	3.3	4.1

9.5 Conclusions

The proposed biomass heating systems cover a lot of ground and depend on many factors to determine feasibility. Based, however, on the cost and financial analysis table above:

- All of the systems fall into the profitable category based on net present value considerations
- All of the systems also have an internal rate of return over 11%
- All have a simple payback less than ten years
- All scenarios are based on the use of propane
- None of the analysis counts on grants
- The analysis above does count on borrowing 75% of the costs.

A decision to invest in such a system will require that the heating system is more than a call to the propane company to drop off more fuel. These systems will require more time and input of effort than a fossil-fueled system and require attention at least on a weekly basis if not more often. This extra cost needs to be seen against the backdrop of:

- Additional economic development in the area of biomass production and sales
- Growth in local manufacturing and installations
- Pushing Minnesota further down its renewable energy pathway already well underway with its ***25 by 25*** initiative (see www.25by25.org for more information – this initiative has the goal of generating 25% of Minnesota's electricity from renewable resources by 2025)
- Reducing the state's GHG emissions
- Reducing reliance on fossil fuels

The replacement of limited, finite fossil fuels with renewable energy is a sustainable, long-term perspective, which will allow for these fuels to be used by future generations in applications where replacing their use with renewable energy is cost prohibitive.

10 Recommendations

Due to the many factors considered in this guide, it is not possible to provide a recommendation for a single system best for a given turkey farm or greenhouse operation. The recommendation of this guide is the following process, which should be reviewed prior to the adoption of biomass heat:

1. Economic: The decision to heat with biomass versus fossil fuels requires it to be economically viable. The information provided in Section 9 demonstrates that given a base fuel case of propane at today's prices (ranging from $1.50 to $2.00 per gallon) biomass heating is a viable economic option with positive NPV and rates of return exceeding 11%.
2. Facility heating assessment: How much heating is required? How can this energy be reduced through the reduction of demand? How can the facility's energy efficiency be increased?
3. Biomass fuel – What type(s) are available close to the location? What pricing is available? Are long-term fuel contracts available? What types of fuel are best suited for the combustor chosen?
4. Biomass fuel handling – What type of storage and processing will be required? What equipment or facilities does the farmer or grower have on hand that will assist with the use of the biomass?
5. Biomass combustion equipment – Based on the above considerations, what type of equipment can utilize the fuel available? Does the manufacturer have demonstration sites you can visit? What is included in the price? Warrantees?
6. Biomass balance of system – What other equipment or facilities are required? Who can provide this service? How about licensing, codes and regulatory requirements? How about ash handling and use of this resource as soil amendment?
7. Environmental considerations – Biomass fuels are carbon neutral, with benefits to our environment. What is the role your operation can play in making an environmental difference?

For more information on proceeding to biomass heating, please contact AURI.

11 Appendix A: Companies/Individuals Interviewed for this Project

Poultry Producers

- Randy Gronseth
- Gene Brownfield
- Paul Kvistad
- Unnamed participant

Greenhouse Operators

- Eric Kreidermacher – Pork and Plants
- Bryden Jones – Drummers
- Tom Martin

Biomass Fuel Suppliers

- Great Lakes Renewable Energy Inc
- Hedstrom Lumber Company Inc
- Hill Wood Products Inc
- Koetter & Smith Inc
- Marth Wood Shavings Supply
- Root River Hardwoods Inc
- Minnesota Valley Alfalfa Producers
- Ever-Green Energy: Environmental Wood Supply

Biomass Heating System Providers

- Heartland Energy Systems – Minnesota, USA
- LEI Products – Kentucky, USA
- Itasca Power Company – Minnesota, USA
- AFAB-USA – Sweden
- OSBYPARGA – Sweden
- MARTH – EarthWise – Wisconsin, USA
- E-Mission Free – Manitoba, Canada
- LINKA (Biomass Briquette Systems) - Denmark
- WoodMaster – Minnesota, USA

Balance of System Providers

- Itasca Power Company
- E-Mission Free

Other

- Agricultural Utilization Research Institute (Al Doering and Randy Hilliard)

12 Appendix B: Existing Turkey and Greenhouse Systems Survey

DLF Consulting

Location Survey Jan – Apr 2012 (ver 1)
AURI Biomass Heating Feasibility Study
Survey completed by:

Company-Facility Name:	
Address:	
Tel:	
Email:	
Web:	
Contact Person:	

Heating System

Type of facility (greenhouse, farm etc)	
Size of facility(ies) being heated	
Age of facility(ies)	
Products (eg plants, trees, eggs, turkey meat etc)	
Use of biomass: (if any - heating, biogas, cooling, power)	
Heating system 1	
Size of heating system (MMBtu)	
Manufacturer of heating system	
Heating fuel being used now	
Quantity of fuel being used per year	
Cost of fuel (per unit, and per year)	
Heating system 2	
Size of heating system (MMBtu)	
Manufacturer of heating system	
Heating fuel being used now	
Quantity of fuel being used per year	
Cost of fuel (per unit, and per year)	
Cost of electricity ($/kWh)	
Annual cost of electricity	
Name/contact info for the company who installed the heating equipment	
Heat distribution system(s)	
Backup heating system	
Other information	

Biomass Heating Technology Manufacturer

Type of combustor	
Fuels usable	
Controls	
Experience	
Sizes	

Biomass Fuel Producer

Type(s) of fuel	
Btu value(s) per ton (lb)	
Transportation costs per mile	
Fuel cost per ton	

13 Appendix C: Biomass Heating System Request for Proposals

NOTE – Three separate RfP's were sent out: 1) Heating Systems; 2) Fuels; and 3) Balance of System. This Appendix is a compilation of the three.

February 8, 2012

Request for Proposal

1. **Introduction**
   DLF Consulting, on contract with Minnesota's Agricultural Utilization Research Institute (AURI), is soliciting proposals on biomass heating equipment, fuels and installation of biomass heating systems. This information will be collected and used to create a ***Minnesota Biomass Combustion Heating Feasibility Guide*** (referred to as "Guide") to be completed by mid-2012. This Guide will be focused on the feasibility of turkey production and greenhouse industries to replace fuels such as propane and fuel oil with biomass fueled heating systems. Biomass refers to any agricultural or forestry derived product which can be fed into a combustor and burned to generate heat. Biomass can be in bulk form (e.g. straw bales, agricultural processing by-products, wood chips, hog fuel, sawdust or turkey litter) or densified form (e.g. pucks, pellets, cubes).

2. **Background**
   Many of the turkey producers and greenhouse operators in Minnesota currently use propane or fuel oil to heat their buildings. Most are located in rural areas where they do not have access to lower cost fuels such as natural gas. Propane and fuel oil are some of the most expensive heating fuels available and an opportunity exist for the replacement of these high cost fuels with biomass. Heating costs for these operations are a significant portion of their operating expenses and more cost effective heating systems are needed for these industries to stay competitive and grow in Minnesota.

3. **Description of Project**
   The pricing and information provided by the respondents will be used in the Guide to assist in the assessment of biomass heating technologies, fuels and systems. The Guide will be a tool to assist greenhouse owners and poultry farmers in Minnesota to determine the feasibility of conversion to a biomass heating system. The Guide will have three separate sections:

   A. **BIOMASS HEATING SYSTEMS**: This Guide will provide (based on your proposals) general information on pricing for the three following sizes of biomass heating systems:
      - Small: 500,000 Btu/h
      - Medium: 2 Million Btu/h
      - Large: 5 Million Btu/h

   B. **BIOMASS FUELS**: This Guide will provide (based on your proposals) information on the pricing for biomass fuel to be used in these biomass heating systems.

   C. **BALANCE OF SYSTEM**: This Guide will provide (based on your proposals) information on the engineering /installation/ mechanical/ electrical costs (balance of system) for these biomass heating systems.

4. **Requirement and Scope of Work**
   The respondent to this RfP will select any one or all of the section(s) below (A, B, C) to which they can respond.

   A. Biomass Heating Equipment. **Please specify:**
   - Size of System: _____________(Small, Medium or Large). *If you can provide information on more than one size, please fill out Section A for EACH size.*
   - Description & photo of biomass combustor/boiler
   - Output options (hot oil, steam, hot water, hot air)
   - Types of feedstock (fuels) which can be used (Ag or Forestry):
     - Bulk (bales, loose chips or ag by-products, poultry litter)
     - Densified (pellets, pucks, cubes)

  - Poultry litter
- Feedstock moisture requirements
- Fuel storage and handling options
  - Bulk fuel (including building, and processing and conveyance of fuel to combustor)
  - Densified fuel (including building, storage bin, and conveyance of fuel from truck to bin, bin to combustor)
- Ash storage and handling
- System efficiency (specify conditions)
- Emissions data on existing locations
- Emissions handling options (cyclone, bag house, ESP, stack)
  - Stack height required
- Installation requirements
  - Electricity (specify voltage)
  - Water
  - Other
- Any other required equipment: controls, transformers
- Warranty/Support

Pricing to Include (FOB Minneapolis):

  - Combustor / boiler
  - Fuel storage (one week minimum at high heat)
  - Fuel conveyance to combustor
  - Ash handling
  - Emissions system (price separately)
  - Controls
  - Design, engineering, layout and drawings
  - Installation, start-up, and operator training
  - Estimated hours for installation

Include at least 3 locations where similar systems are operating, with brief descriptions and operator contact information, and photographs of a representative system

B. Biomass Fuel. **Please specify:**

- Types of biomass fuel you manufacture (pellets, pucks, cubes)
- Types of biomass fuel you produce (bales of hay/straw, loose byproducts, wood chips, hog fuel, sawdust, poultry litter)
- Energy value (Btu or GJ / ton)

Pricing to Include (FOB Minneapolis):

- Cost per ton of biomass fuel FOB plant
- Delivery charges per mile

Include at least 3 locations where your fuel is being used, with brief descriptions and operator contact information

C. Installation/Mechanical/Electrical Costs (balance of systems). **Please specify:**
Cost to install a biomass heating unit in a rural Minnesota location (use 100 miles from Minneapolis).

Pricing to include:

- A 30 ft cube post and beam building (metal siding) for the burner/boiler including cement floor
- Electrical and water service delivered 100 ft
- Fuel storage options:
  - Bale/Bulk: A 50 ft (W) x 100 ft (L) x 30 ft (H) post and beam building for bale/bulk biomass storage adjacent to burner/boiler building including cement floor
  - Densified: A 30 ft cube post and beam building (metal siding) for the storage bin(s) adjacent to burner/boiler building including cement floor
- Heat distribution underground piping to existing hydronic equipment:

- 300 ft of 4" insulated pipe (specify type) buried at 3 feet underground – include all related trenching costs

Include at least 3 locations where you did similar mechanical contracting work brief descriptions and contact information.

5. **Proposal Submission**
   A. Cover letter indicating your understanding of the requirements of this RfP and identifying the primary contact person.
   B. Description of your company, principals, experience and years in business
   C. Estimates of costs for one or more of the following (as described above):
      - Biomass Heating Equipment
      - Biomass Fuels
      - Installation/Mechanical/Electrical Costs (balance of systems)

Response is required by:
February 20, 2012

For any additional information regarding this proposal request, please contact:

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