Clearwater County AURI Bio-Energy Report

Prepared by the Headwaters Regional Development Commission

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Acknowledgements

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- Agricultural Utilization and Research Institute, Crookston, Minnesota
- Clean Energy Resource Teams
- Northwest Minnesota Foundation
- The Assessor's offices of Beltrami, Clearwater, Beltrami, Lake of the Woods, and Mahnomen Counties

Disclaimer

This document provides the reader an estimation of energy demand and bioenergy resources at the County level. The inventory of available resources is a starting point and identifies potentially underutilized resources. The existence of a resource does not necessarily mean it should be exploited and this is particularly true with respect to crop and forest residues.

No assurance is given and none should be inferred that any financial estimate, projection or forecast contained in this report will in fact be realized. Nothing in this report should be construed as recommending a specific investment or the undertaking of a specific project of any kind.

Introduction

The Headwaters Regional Development Commission in partnership with, Clean Energy Resource Teams, Agricultural Utilization Research Institute, Northwest Minnesota Foundation, and Beltrami, Clearwater, Hubbard, Lake of the Woods, and Mahnomen Counties, exploring opportunities to utilize natural resources to generate bioenergy in the Headwaters Region.

As part of this process the Headwaters Regional Development Commission has created an inventory of bioenergy resources available and energy used at the County level. This report was created using the "AURI Template for Estimating County Level Energy Use and Renewable Energy Potential." Created by 6Solutions LLC on behalf of the Agricultural Utilization Research Institute, this document provided a step by step method for summarizing energy use and the renewable energy potential at the County level.

This report is envisioned as a planning tool for county and regional economic development.
A critical step in developing the bioenergy energy industry is to assess local strengths and weakness. The overall objective of this report is help individual and organizations exploring ways to utilize bioenergy resources to generate renewable energy.

Currently a minimal percentage of energy in the United States is produced from renewable sources. This presents the Region with a unique opportunity because barriers to entry are still low and demand continues to rise. This trend will be especially strong within the state of MN. In his 2006 State of the State speech, Governor Tim Pawlenty set Minnesota on a course to have 25% of our energy come from renewable sources by the year 2025. This 25/25 initiative is the most aggressive in the nation and will require a sustained effort from our energy industry, state government and the citizens of Minnesota.

This shift presents rural communities, such as those in Clearwater County, new opportunities for economic development. Renewable energy not only offers an alternative to fossil fuels, but also acts as a potential source for economic growth. The benefits of this growth come in various forms, including job creation, diversified tax revenue and increased ability to compete as a Region.

The primary forms of bioenergy evaluated for use in were:

- **Wind Energy:** Wind energy is harvested from moving air that is converted to electric power to create electricity. Due to unequal solar heating of the earth, wind is generated. As air flows past the rotors of a wind turbine, the rotor spins and drives the shaft of an electric generator. Wind turbines with small rotors are often used for battery charging while larger rotors are used to generate large amounts of electricity that is fed into the regional grid.

- **Biomass:** Biomass energy is harvested from organic materials in the environment. Originating as solar energy absorbed by plants, it is converted into chemical energy through photosynthesis. This energy is available in wood, crops, crop residues, industrial and municipal organic waste, food processing waste, and animal wastes. These by-products of various human and natural activities can be burned to create heat and/or steam that are used to generate electricity.

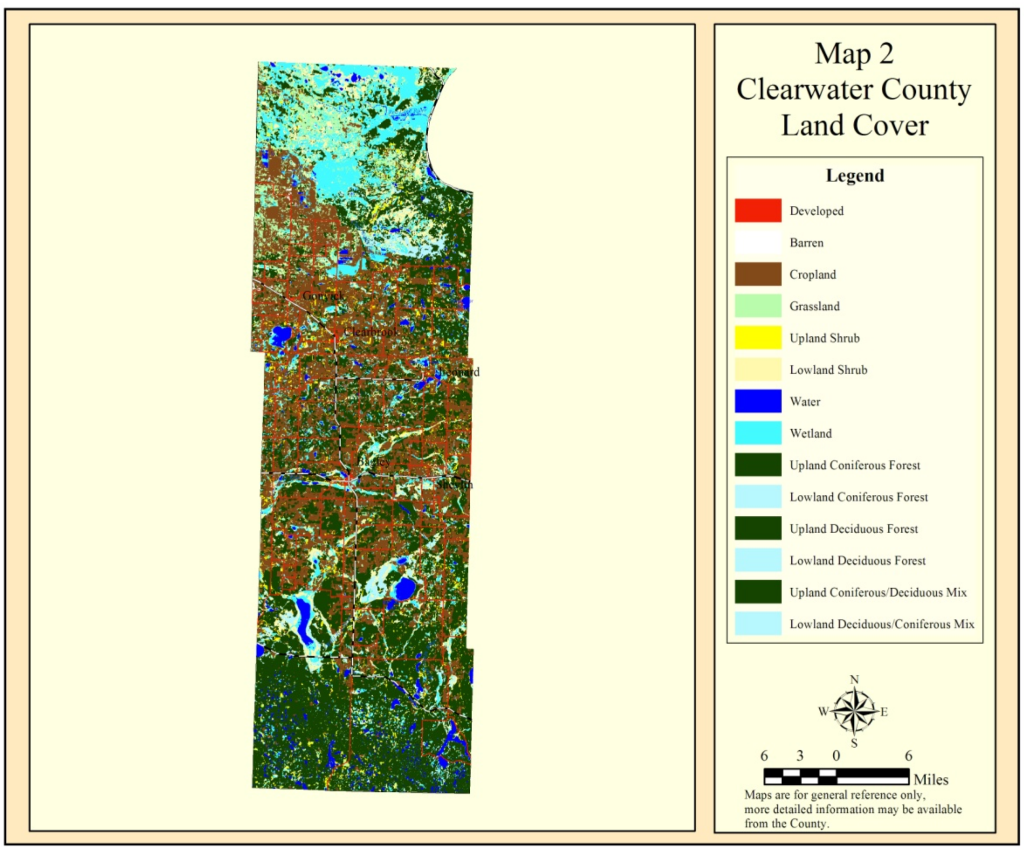
- **Solar:** Photovoltaic (or solar electric) systems convert energy in sunlight directly into electricity. Photovoltaic (PV) cells are made primarily of silicon, the second most abundant element in the earth's crust, and the same semiconductor material used for computers. When the silicon is combined with one or more other materials, it exhibits unique electrical properties in the presence

All units used in this document are in conventional English units such as pounds, tons, and Btu's. All final values are converted to BTU's, because a conversion to a common unit is needed in order to summarize and totalize energy consumption and production.

The report was completed using publicly available on-line data sets. These consist chiefly of Census Bureau data and Department of Agriculture databases for crop and forestry operations.

Study Area: Clearwater County, Minnesota

Clearwater County has tremendous potential in the renewable energy industries. The County has a diverse topography; it is 60 miles in its length and 18 miles in width, lying north and south. The southern part of the County is primarily covered by forest land, and a good portion of the northern part of the County is covered by agricultural land. The land cover in the middle has a mix of agriculture and forest land. The predominant land use in Clearwater County is Agriculture. The second biggest land use category is Public Lands, and is mostly concentrated in the southern portion of the County.
A continental divide separates the drainage between the lowest third of the county and the upper two thirds. The area below this divide consists of lakes, mixed conifer and deciduous forests, and most of the developed uses in the County.



The table below provides a summary of potential renewable energy sources available in Clearwater County. In the following sections each individual resource will be discussed and the template worksheets will be provided. The AURI template provided a method to calculate a fairly general and very liberal assessment of the renewable energy potential at the County level. As can be seen below, Clearwater County has the potential to create over 24 trillion Btu's of energy from renewable sources. If fully utilized this resource could meet current levels of demand. It should be noted that while not calculated in this report solar and geothermal sources can provide almost unlimited energy. At this point these resources are unavailable be transported from source. While this inventory is at best estimation it does provide an overview of the untapped energy resources available.

Resource	Quantity	Units	Energy Content
			Trillion Btu per year
Agricultural Crop Residue	24576	Tons	0.2192
Manures and Animal Wastes	71022820	SCF	0.1
Wood/woody Biomass	13532.4	Tons	0.31172699
Wind	7587591170	kw-hr	23.8402114
Solar	Unlimited		0
Geothermal	Unlimited		
Total			**24.47113839**

Crop Residues

Agricultural activities generate large amounts of biomass residues. While most crop residues are left in the field to reduce erosion and recycle nutrients back into the soil, some could be used to produce energy without harming the soil.

Biomass is any organic material not derived from fossil fuels that can be converted to a fuel useful for energy. Agricultural wastes are good examples of potential biomass fuel. Most biomass is converted to energy the same way it always has been—by burning it. The heat can be used directly for heating buildings, and industrial processes. It can also be used to produce steam and generate electricity. For example, many electric generators and businesses burn biomass by itself or with other fuels in conventional power plants.

Agricultural waste can also be converted into liquids or gases to produce electricity or transportation fuels. A well known example, Ethanol is typically produced through fermentation and distillation, in a process much like that used to make beer. Soybean and canola oils can be chemically converted into a liquid fuel called biodiesel. These fuels can be used in conventional engines with little, if any, modification.

A process that is increasingly being used is "gasification." This method converts organic material into a gas by heating it under pressure without oxygen in a "gasifier." Other biogas applications are still in development, but show great potential

Also included in this section of the report is Brush land, and (CRP) land. The volume of brush and grass in an area can be viewed in several different ways. These grass and brush lands offer exciting potential as a renewable energy feedstock. In most cases these areas grow perennial, grasses or brush that does not have to be replanted every year. Additionally there are few costs associated with producing the feedstock given the minimal inputs required.

While grass and brush lands do have great potential as a biomass feedstock, it must be kept in mind that because biomass is not cultivated specifically to allow for future harvesting, it may be difficult to reach, in an entirely inaccessible area, or on undulating or rocky land that harvesting equipment cannot operate on. It may also be growing on private land that the owner is not amenable to being cut, park land, or other sensitive habitats that cannot be disturbed and are otherwise off-limits for harvesting.

The data used in this report was obtained from the National Agricultural Statistic Service, and can be found at, http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats/index.asp.

When available, 10 years of data for each crop was collected. This report used the average yields and acres planted over the last ten years to calculate the potential of crop residue. It should be noted that there were many instances of missing data, or incomplete data for agricultural statistics in Clearwater County.

The calculations shown in this report required a judgment on the fraction of the crop residue which can be removed and still provide adequate ground cover to mitigate wind and rain erosion. This amount will vary by local weather, soil type and gradient. These figures should be adjusted based on local conditions such as Highly Erodible Land (HEL) or other erosion or environmental conditions.

The table below provides a summary of potential agricultural residues that could be used to generate renewable energy available in Clearwater County. As can be seen below, Clearwater County has the potential to create a .32 trillion Btu's of energy from agricultural residues. As stated before there was missing and incomplete data, however opportunities for creating bioenergy, anecdotal evidence suggests that there is much greater potential in agricultural residues than suggested by these statistics. The greatest opportunities appear from agriculture residues appear to be Barley, oats, and soybeans. The undeveloped brush lands of Clearwater County also appear to hold value as a renewable energy feedstock. This resource could be a valuable asset for pelletization or gasification; however this must be investigated further.

As with the rest of the data in this report, this data should only be used as a starting point. Individuals and organizations interested in using an available resource should do further research before going ahead with a project.

Crop Residue Summary Table											
Column		C	D	E	F	G	H	I	J	K	
Formula										=H*I/10^6	
Crop	Acres Planted	Yield	Units	Convert to pounds	Removal Fraction	Moisture %	Residue to Crop Ratio	Annual Biomass Potential (lbs)	Btu content per dry lb	Million Btu/year	
Barley	2000	40.5	bu	48	1	14.5%	1.2	3989088	7500	29918	
Canola	0		lbs	50	1	8.0%	2.2	0	7500	0	
Corn for Grain	1640	92	bu	56	0.5	15.5%	1	3569820.8	7768	27730	
Cotton	0		lbs	1	1	12.0%	4.5	0	7500	0	
Dry Edible Beans	0		lbs	1	1	13.0%	1.2	0	7500	0	
Flaxseed	0		bu	1	1	8.0%	1.2	0	7500	0	
Oats	3500	48.6	bu	32	1	14.0%	1.3	6085497.6	7626	46408	
Peanuts	0		lbs	1	1	9.9%	1	0	7500	0	
Potatoes	0		cwt	100	1	13.3%	0.4	0	7500	0	
Rice	0		lbs	1	1	15.0%	1.4	0	7500	0	
Rye	0		bu	56	1	10.0%	1.6	0	7500	0	
Safflower	0		lbs	1	1	8.0%	1.2	0	7500	0	
Sorghum for grain	0		bu	56	1	12.0%	1.4	0	7500	0	
Soybeans	4910	28	bu	60	1	13.0%	2.1	15070557.6	7500	113029	
Sugar Cane	0		lbs	1	1	62.8%	1.6	0	7500	0	
Sunflower	0		lbs	1	1	10.0%	2.1	0	7500	0	
Wheat - all	5500	38.8	bu	60	1	13.5%	1.3	14398098	7375	106186	
CRP and similar grassland	5010	2	tons	2000	1	0.0%	1	20040000	7500	150300	
Brushland on 5 yr cycle	2	0.84	tons	2000	1	0.0%	1	3360	7500	25.2	
Total Energy Potential	64876							31578.211		323271.687	mm Btu/yr
IN TRILLION BTU/year										0.32327169	trillion Btu/yr

B. Animal Wastes

Energy from animal wastes can be produced by anaerobic digestion. Anaerobic digestion is a biological process in which biodegradable organic matters are broken-down by bacteria into biogas, which consists of methane, carbon dioxide, and other trace amount of gases. The biogas can be used to generate heat and electricity.

Combustion of animal wastes is not usually considered a high priority due to the high moisture content of animal waste; moreover many consider the loss of the nitrogen content to be problematic. Poultry wastes are not generally good candidates for digestion due to ammonia toxicity. Hog manure is typically too dilute to be a good candidate for methane production but may become a suitable substrate either by concentration or as part of an odor emission control program. Even with these limitations, in the right scenario animal wastes have the potential to be a good bioenergy feedstock.

The data used in this report was obtained from the National Agricultural Statistic Service, and can be found at, http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats/index.asp. When available, the last 10 years of data for each Animal was collected. This report used the average number of each animal from over the last ten years to calculate the availability of animal wastes.

The table below provides a summary of animal wastes that could be used to generate renewable energy available in Clearwater County. As can be seen below, Clearwater County has the potential to create only .1 trillion Btu's of energy from agricultural residues. As stated before there was missing and incomplete data, however opportunities for creating bioenergy from animal wastes remain limited at best in Clearwater County. The greatest opportunities would most likely be in creating a byproduct from waste, or in a farming operation large enough that small scale anaerobic digestion is economically feasible.

As with the rest of the data in this report, this data should only be used as a starting point. Individuals and organizations interested in using an available resource should do further research before going ahead with a project.

Animal Residue Methane Potential									
Column		B	C	D	E	F	G	H	I
Formula					=B*C*D			=E*F*G	=H*970/10^6
Herd Invenstory	Assumed herd composition	Animal Count	Typical Animal Mass	Volatile Solids/lb TAM	Total Vol. Solids	Vol Solids	Cu Ft Methane Yield	Methane Yield	Methane Yield
Enter herd or flock inventory reported by USDA in column C			lbs	per year	per year	% Destruction	per lb VS destroyed	cu ft/year	mm Btu/year
Beef Cows	**Enter total here --->**	9858							
Steers and Heifers	33%	3253.14	915	2.6	7739220.06	55%	5.29	22517260.76	21841.74
Calves	33%	3253.14	397	2.6	3357891.108	55%	5.29	9769784.18	9476.69
Steers		0	794	2.6	0	55%	5.29	0.00	0.00
Heifers		0	794	2.6	0	55%	5.29	0.00	0.00
Cows	33%	3253.14	1102	2.6	9320896.728	55%	5.29	27119149.03	26305.57
Bulls		0	1587	2.6	0	55%	5.29	0.00	0.00
Dairy Cattle	**Enter total here --->**	1216							
Calfs	18%	218.88							
Heifers	18%	218.88	903	3.65	721417.536	55%	3.84	1523633.84	1477.92
Cows	64%	778.24	1345	3.65	3820574.72	55%	3.84	8069053.81	7826.98
Swine	**Enter type below**								
Market		2300	101	3.1	720130	65%	7.53	3524676.29	3418.94
Breeding		150	399	3.1	185535	65%	5.77	695849.02	674.97
Poultry	**Enter type below**								
Layers		0	3.5	4.4	0	60%	5.45	0.00	0.00
Broilers		0	1.5	6.2	0	60%	4.81	0.00	0.00
Turkeys		0	7.5	3.32	0	60%	4.81	0.00	0.00
Sheep			154	3.36	0	55%	5.77	0.00	0.00
Total annual energy potential in mm Btu/year									71022.82
Total annual energy potential in trillion Btu/year									0.1

Woody Biomass

The term ‘woody biomass’ encompasses all feedstocks derived from harvested trees. For the purposes of this report, only material left behind in timber harvesting and processing operations is evaluated. This report does not examine harvesting timber for renewable energy production because the alternative value as lumber or paper feedstock is too important to make diversion to energy desirable.

Forest wastes arise from logging and thinning operations and have historically been left to decompose in the forest or used in other byproducts. Using these residues for renewable energy has caused a re-examination of this practice.

Generally, if wood waste is used for energy it is burned, to produces heat (as in any simple fireplace or furnace). In most power plants this heat is captured by boiling water to generate steam, which turns turbines and drives generators that convert the energy into electricity.

Like with agricultural waste, wood waste has the potential to be used for biomass gasification in which biomass is heated to convert it into a gas. This gas is used directly in a gas turbine, which drives a generator (a *simple gas turbine* system). In some cases, the waste heat from the gas turbine may be used to drive a secondary steam turbine, thus converting more of the fuel energy into electricity (a *combined-cycle* system).

Data on forest residues was obtained from the Department of Agriculture Forest Service at http://www.ncrs2.fs.fed.us/4801/fiadb/rpa_tpo/wc_rpa_tpo.ASP.

The table below provides a summary of logging residues available in Clearwater County. As can be seen below, Clearwater County has the potential to create .31 trillion Btu’s of energy from logging residues. Woody biomass is one of the greatest potential sources of bioenergy in the Region; however Clearwater

County is not as rich in this resource as neighboring Counties. Much of the current economy in the Headwaters Region is dependent upon the forest, either through the harvesting and manufacturing of the wood product, or through tourism. Given this dependence, finding a way to utilize logging residue is a natural fit with current economic strengths.

It should be noted that removing forest residues is potentially controversial and best practices are subject to debate and interpretation. Forests work on a much longer time frame than crops and there is less understanding about the issues of soil tilt and habitat associated with residue removal than with crop residue.

As with the rest of the data in this report, this data should only be used as a starting point. Individuals and organizations interested in using an available resource should do further research before going ahead with a project.

Logging Residue Energy Estimate						
Column	B	C	D	E	F	G
Formula				=B*C/D		=E*F
Units	cu ft/year	% harvested	cubic feet/cord	cords/year	million Btu/cord	million Btu/year
Hardwood	2,800,900	33%	85	10874.1	25	271852.0588
Softwood	684,720	33%	85	2658.32	15	39874.87059
Total energy potential million Btu/year						311726.9294
Energy potential in trillion Btu/year						0.311726929

Wind

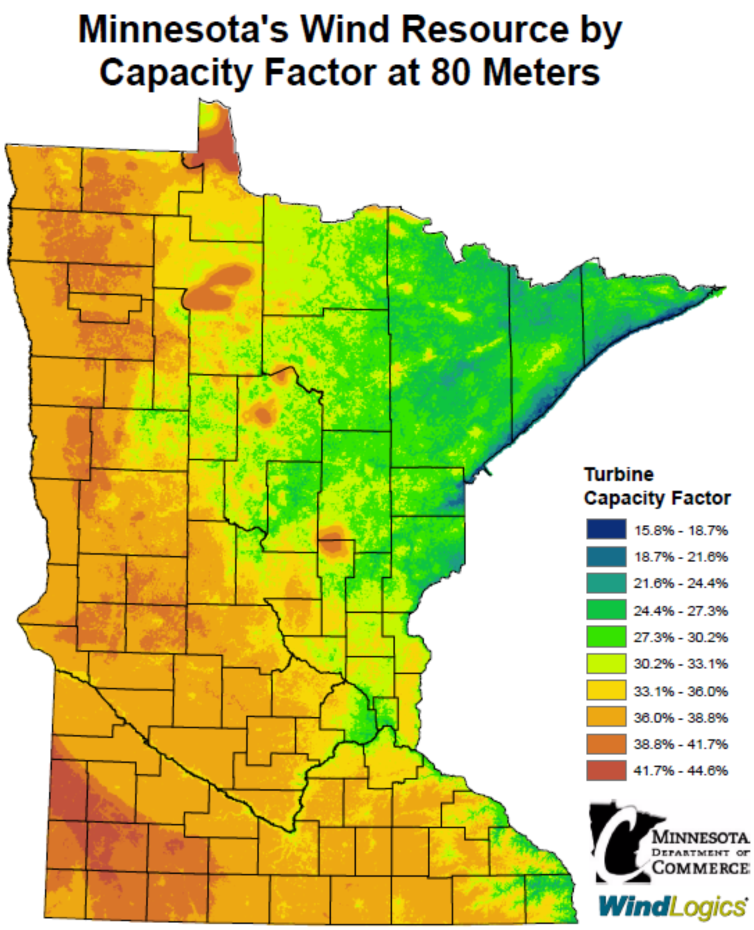
Wind energy systems transform the kinetic energy of the wind into mechanical or electrical energy that can be harnessed for practical use. Wind electric turbines generate electricity for homes and businesses and for sale to utilities. The output of a wind turbine depends on the turbine's size and the wind's speed through the rotor. Wind turbines being manufactured now have power ratings ranging from 250 watts to 5 megawatts

Utility-scale wind turbines for land-based wind farms come in various sizes, with rotor diameters ranging from about 50 meters to about 90 meters, and with towers of roughly the same size. A 90-meter machine, definitely at the large end of the, with a 90-meter tower would have a total height from the tower base to the tip of the rotor of approximately 135 meters (442 feet). Small wind turbines intended for residential or small business use are much smaller. Most have rotor diameters of 8 meters or less and would be mounted on towers of 40 meters in height or less.

Within the limits of the currently available technology a “rule of thumb” is that one 1.65 megawatt rated turbine can be installed per each 40 acres. Among the reasons for this limitation is required spacing between turbines to mix higher speed wind with the wind that has been slowed down by passing through the turbine. While turbine size and efficiencies will probably improve with time, the mixing distance seems likely to remain close to this value indefinitely.

In general, wind speeds and available energy are higher at higher altitudes. The usefulness of low altitude, single homeowner is limited by low speed winds close to the ground. Some systems have been built by individuals either to offset part of their energy use or to supply power to off-grid locations

A turbine rated for 1 megawatt almost never operates at that output because the wind velocity is not constant at the design rate. The capacity factor is the per cent of the nominal annual potential output of a turbine operating at design rate for 8760 hours which is actually achieved. The capacity factor is turbine specific and height specific. Nevertheless, capacity factors provide a good qualitative indication of a region's wind resource. Capacity factor maps provide a convenient way to summarize the relative wind resource across a region.



The table below provides a localized estimate of the wind resource in Clearwater County. As can be seen below, Clearwater County has the potential to create over 2 trillion Btu's of energy from wind energy. Wind energy is one of the greatest potential sources of bioenergy in the Region. As shown in the above map, Minnesota has a plentiful wind resource across much of the state. Unlike biomass and animal waste resources which are limited by source, wind resources are chiefly limited by restrictions on land use. A further limitation is the ability of the grid to absorb power produced. Finally, the cost of wind systems can be barrier to all but the largest of companies.

Wind Energy Estimate				
Line				Formula
A	County area is acres	636,300		
B	% available for wind development	0.01	acres	
C	Acres available for development	6363		=A*B
D	Turbine size	1.65	MW	
E	Acres per unit	40		
F	MW installed per acre	0.04125	MW/acre	=D/E
G	Capacity factor	0.33		
H	Annual hours	8760	hours/year	
I	MW hours per year	758759.1165		=C*F*G*H
J	Trillion Btu/year	2.384021144		=I*3.412/10^6

The calculation method described above is a very crude estimate of the wind energy potential. To further evaluate the potential a wind analysis and economic analysis is required. Consult experts in the field for guidance.

Solar Intensity

The total solar energy flux annually is a staggering sum and only 0.2% of the solar energy striking the continental United States would be required to supply the entire 102 quadrillion Btu used annually. Unlike wind or biomass sources, however, solar energy is not usually exportable. The significance of this is that when estimating the renewable energy potential for a region, the solar component is limited by the demand and applications for solar energy rather than the supply.

Solar energy may be collected either by photovoltaic cells as electricity or as thermal energy. At this writing photovoltaic cells are prohibitively expensive and find application only where the high cost of the cells does not determine their economic viability. Thermal energy capture, however, finds application under present conditions. Thermal solar applications are legitimately renewable energy production but the energy collected cannot be economically transported away from the site. Therefore, the chief limitation on solar energy production is matching it to a co-located demand.

The solar resource may be characterized either by its intensity or by the annual flux. In addition, the solar resource varies with season and with method of collection. Minnesota average solar radiation intensity has been mapped by the Minnesota Department of Commerce as shown in the map below for the period 1998 to 2002. The reported inter year variability is about 15%. The northern tier of counties has a solar intensity of around 135 watts per square meter while the southwest counties have a solar intensity around 160watts per square meter. These values are useful for estimating photovoltaic potential.

NREL provides maps of the daily solar thermal potential by month at
http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/atlas/

Collector orientation affects the total available solar radiation. A flat plate at an angle of the latitude plus 15 degrees is the most efficient for winter operation. Since our primary interest is in heating, this is the most appropriate angle for Minnesota. Minnesota falls in the region of 3 to 4 kWh per square meter per day. Translated to English units this amounts to about 1000 Btu per square foot per day.

Although we may feel in the dead of January that the sun is scorning us, there are still plenty of opportunities for solar energy in Minnesota. Minnesota has more annual solar energy potential than Houston, Texas and nearly as much as Miami, Florida. The amount of potential solar energy available in Clearwater County is almost unlimited. Unfortunately as stated above solar energy can only be utilized at the source. Due to these limitations, the most pragmatic approach to estimating the solar energy contribution appears to be as displacement of home or commercial space heating. Although the cost of generating solar electricity is currently expensive relative to traditional sources, solar energy can be economic in many situations, such as for heating hot water and when it is impractical to connect to the electric grid. When buildings are designed to maximize the light and heating potential from the sun, significant "passive solar" energy savings can be realized.

Geothermal/Earth Energy Systems

Geothermal and earth energy systems are frequently used interchangeably to describe extraction of heat energy from the ground. This refers to Earth Energy Systems or EES.A few feet beneath the surface, the earth's temperature remains fairly constant year round, ranging from 45º or so in northern latitudes to about 70ºF in the Deep South.

This constant temperature can be taken advantage of to provide extremely efficient heating and cooling. In winter, a water solution circulating through pipes buried in the ground absorbs heat from the earth and carries it into the home. A system inside the home uses a heat pump to concentrate the earth's thermal energy and then to transfer it to air circulated through standard ductwork to fill the interior space with warmth. In the summer, the process is reversed: heat is extracted from the air in the house and transferred through the heat pump to the ground loop piping. The water solution in the ground loop then carries the excess heat back to the earth. The only external energy needed for this process is the small amount of electricity needed to operate the ground loop pump and fan. An EES can displace energy consumption but cannot produce energy for export. As with solar thermal systems, the renewable energy potential is based on the energy use displaced not on the basis of what could theoretically be available.

As with solar energy, the amount of energy available through geothermal systems is almost unlimited and the most pragmatic method to use the renewable energy potential from earth energy systems is as a displacement of the energy used to heat and cool building space.

Energy Use Estimate

In addition to making estimates about potential bioenergy available to the County, The AURI template also made estimations of local energy demand. Identifying local energy use can guide individuals and organizations to match local resources with local demand. As noted in the sections on solar and earth energy systems, the local demand creates the opportunity for application of these technologies. All of these estimates are annualized energy use, sizing for peak hourly or daily demand is not within the scope of this estimates.

Energy Use Summary Table						
Energy Type	Residential	Transport	Agriculture	Industrial	Commercial/Public Bldg	Totals
All units in Trillion Btu/year						0.000
Gasoline	0.000	0.580	0.011	0.000		0.591
Diesel Fuel	0.000	0.180	0.127	0.000		0.307
Heating Oil	0.336	0.000	0.000	0.000		0.336
Natural Gas	0.291	0.000	0.000	0.681		0.972
Kerosene	0.069	0.000	0.000	0.000		0.069
Coal/Coke	0.000	0.000	0.000	0.000		0.000
Wood	2.372	0.000	0.000	0.000		2.372
Delivered Electricity	0.149	0.000	0.000	0.542		0.692
Geothermal	0.000	0.000	0.000	0.000		0.000
LPG	0.139	0.000	0.082	0.000		0.221
Other	0.000	0.000	0.000	0.167		0.167
Total	3.357	0.760	0.138	1.390	0.000	**5.727**

The following sections will explore local energy demand by the following users:

- **Residential**
- **Farm/Agriculture**
- **Industrial**
- **Commercial**

Residential Energy Use

The ability to maintain a desired temperature, lighting, and modern appliances in the home are all important parts of modern life. Keeping our homes comfortable uses a lot of energy, therefore residential properties are large consumer of energy.

While all the homes in the County use all different fuel types, the Census Bureau calculates the average energy consumption per household. This value can be used to provide a quick, simple estimate of residential energy consumption. We use this to get a rough calculation of the average total energy used in residential units. Results for Clearwater County are shown below.

Estimated Residential Energy Consumption by Household Number Method			
Total number of households	3330	Enter from census QuickFacts	
Column	B	C	D
Formula	=household number * B		
Energy Type	million Btu per household per year	Annual Energy Million Btu per year	On Site
Electricity - Primary	*111.5*	371,295	
Electricity - Site	*37.3*	124,209	124,209
Natural Gas	*85.0*	283,050	283,050
Fuel Oil	*75.4*	251,082	251,082
Kerosene	*0.0*	-	-
LPG	*63.9*	212,787	212,787
Wood	*29.3*	97,569	97,569
Total	*365.1*	1,215,783	968,697
In Trillion Btu per year		1.22	0.97

The Total Household Method is quick and easy but lacks specificity for the community in question. An alternate method of estimating household energy consumption takes into account the year when the housing stock was built. The year of construction is available in the DP-4 Profile of Selected Housing Characteristics from the US Census. As shown in the following table, the year of construction method provides a more detailed look at residential energy consumption and may provide a more robust test of reasonableness.

Estimated Residential Energy Consumption by Age of Household Method							
	1990	*1980*	*1970*	*1960*	*1950*	*1949*	
	to	*to*	*to*	*to*	*to*	*or*	
	2000	*1989*	*1979*	*1969*	*1959*	*before*	
Census Data on Household Energy Consumption by Year of Construction							
Electricity Primary	*130.9*	*127.9*	*97.8*	*97.2*	*85*	*85*	
Electricity Site	*43.8*	*42.8*	*40.8*	*32.7*	*28.4*	*28.4*	
Natural Gas	*70.9*	*64.3*	*63*	*64.6*	*72.9*	*84.3*	
Fuel Oil	*77.8*	*91.4*	*77.3*	*68.3*	*79*	*87.5*	
Kerosene	*21.3*	*13.5*	*23.2*		*11.4*	*11.6*	
LPG	*41.1*	*36.6*	*37.5*	*34.2*	*26.3*	*51.6*	
Wood	*14.8*	*20*	*23*	*21.1*	*2706*	*48.5*	
Total	*254.9*	*248.6*	*241.8*	*199.8*	*218.0*	*263.4*	
Houses per group	596	499	886	421	843	869	
Energy Use in Million Btu per year							On Site
Electricity Primary	78,016	63,822	86,651	40,921	71,655	73,865	
Electricity Site	26,105	21,357	36,149	17,177	23,941	24,680	149,408
Natural Gas	42,256	32,086	55,818	26,523	61,455	73,257	291,395
Fuel Oil	46,369	45,609	68,488	32,543	66,597	76,038	335,643
Kerosene	12,695	6,737	20,555	9,767	9,610	10,080	69,444
LPG	24,496	18,263	33,225	15,788	22,171	44,840	158,783
Wood	8,821	9,980	20,378	9,683	#######	42,147	2,372,166
Total for all households							3,376,839
In Trillion Btu per year							**3.4**

Transportation Energy Use

In the transportation sector, energy provides mobility for people and goods. For people, mobility provides access to employment opportunities, friends and family, grocery and clothing stores, entertainment and leisure activities, and medical and financial services, to name a few. For businesses, mobility provides access to the means of production (raw materials, human resources, and the output of other businesses), as well as access to markets for their products.

The transportation sector energy demanded is related to the number of vehicles in the region and to the number of vehicle miles traveled (VMT). The VMT is used in this report as an indicator of the fuel consumption that actually occurs in a region because it is tied to actual vehicle operation.

The VMT method of estimating fuel consumption assumes the composition of vehicle miles traveled in the region is approximately the same as the national average.

To make the estimates used in this report we used VMT data that is available at the Minnesota Department of transportation website. Results for Clearwater County are shown in below.

Annual Fuel Consumption Estimate Based on VMT by County.				
Column	B	C	D	E
	Annual Vehicle Miles Traveled			
County Name	Bituminous	Concrete	Dirt	Total
				111,050,885
				-
				-
				-
				-
Total VMT in Region				111,050,885
		= B*Total VMT		= C/D
Composition of VMT	% of VMT	Miles Traveled	Mileage	Annual Fuel Use
Passenger Cars	55.8%	61,966,394	22.4	2,766,357
Light Trucks/SUV	36.1%	40,089,369	18	2,227,187
Single Unit Trucks	2.7%	2,998,374	8.2	365,655
Combination Trucks	4.7%	5,219,392	5.1	1,023,410
Total	99.3%	110,273,529		
			= B*C	= D/10^12
Convert Fuel Use to Btu's	Gallons per yea	LHV Btu/gallon	Btu/year	Trillion Btu/yr
Gasoline	4,993,544	116,090	5.79701E+11	0.58
Diesel	1,389,065	129,060	1.79273E+11	0.18

Agricultural On-Farm Energy Use

Agriculture requires energy as an important input to production. U.S. farm production whether for crop or animal products has become increasingly mechanized and requires timely energy supplies at particular stages of the production cycle to achieve optimum yields. Energy's share of agricultural production expenses varies widely by activity, production practice, and locality.

For the purposes of this report, on-farm energy use refers to the energy actually used on the farm to plant and harvest crops, dry corn for storage and raise livestock. This does not include the energy used to manufacture fertilizers which is a separate and substantial figure.

The Department of Applied Economics at the University of Minnesota has studied energy use on the farm and its impact on global climate change. One of the results of these studies was an estimation of energy used by different on the farm activities. These results were used in the template to create an estimation of on the farm energy use. The results of these calculations can be found below.

On Farm Energy Use Estimate										
Column	B	C	D	E	F	G	H	I	J	K
Formula							= B*C	= B*D	= B*E	= B*F
		Energy Input per Unit					Annual Energy Use			
Commodity	Acres	Diesel	Gasoline	LP Gas	Electric	Unit	Diesel	Gasoline	LP Gas	Electric
		gallons	gallons	gallons	kW-hr		gallons	gallons	gallons	kW-hr
Barley All	2000	*7.24*	*0.89*	*0.82*	29.88	acre	14480	1780	1640	59760
Beans Dry Edible	0	*7.43*	*0.91*	*0.75*	27.5	acre	0	0	0	0
Canola	1000	*4.5*	*0.75*	*0*	26.8	acre	4500	750	0	26800
Corn for Grain	1600	*8*	*1.15*	*9.58*	35.63	acre	12800	1840	15328	57008
Corn for Silage	1400	*9.37*	*1.15*			acre	13118	1610	0	0
Flaxseed	0	*7.24*	*0.89*	*0.82*	29.88	acre	0	0	0	0
Green Peas for Processing	0	*5.19*	*0.64*	*0.35*	12.75	acre	0	0	0	0
Hay Alfalfa (Dry)	29400	*9.8*	*0.81*	*0*	32.73	acre	288120	23814	0	962262
Hay All	41390	*9.8*	*0.81*	*0*	32.73	acre	405622	33525.9	0	1354694.7
Hay Other (Dry)	0	*9.8*	*0.81*	*0*	32.73	acre	0	0	0	0
Oats	3400	*7.24*	*0.89*	*0.82*	29.88	acre	24616	3026	2788	101592
Potatoes Dry Land	0	*24.18*	*2*	*0*	170.73	acre	0	0	0	0
Potatoes Irrigated	0	*48.89*	*2*	*0*	345.38	acre	0	0	0	0
Rye	0	*7.24*	*0.89*	*0.82*	29.88	acre	0	0	0	0
Soybeans	7100	*7.43*	*0.91*	*0.75*	27.5	acre	52753	6461	5325	195250
Sugarbeets	0	*28.92*	*3.54*	*2.76*	100.75	acre	0	0	0	0
Sunflower All	0	*7.18*	*0.88*	*1.87*	40.75	acre	0	0	0	0
Sunflower Seed for Oil	0	*5.7*	*1*	*2*	30.72	acre	0	0	0	0
Sunflower Seed Non-Oil Uses	0	*5.7*	*1*	*2*	30.72	acre	0	0	0	0
Sweet Corn for Processing		*7.99*	*0.98*	*0*	0	acre	0	0	0	0
Wheat All	5500	*7.24*	*0.89*	*0.82*	29.88	acre	39820	4895	4510	164340
Wheat Durum	0	*7.24*	*0.89*	*0.82*	29.88	acre	0	0	0	0
Wheat Other Spring	0	*7.24*	*0.89*	*0.82*	29.88	acre	0	0	0	0
Winter Wheat All	0	*7.24*	*0.89*	*0.82*	29.88	acre	0	0	0	0
	Head count									
Dairy	1216	*0.13*	*0.02*	*0.11*	4	cwt	23712	3648	20064	729600
Swine Farrow	1500	*9.05*	*1.11*	*4.06*	148.25	litter	3330	3330	12180	444750
Beef Calf	11,000	*6.07*	*0.74*	*1.62*	59.25	head	66770	8140	17820	651750
Beef Cattle	9548	*3.78*	*0.46*	*1.08*	39.38	head	36091.44	4392.08	10311.84	376000.24
Turkeys	0	*0.09*	*0.01*	*0.5*	1.24	head	0	0	0	0
Total Units per year							985,732	97,212	89,967	5,123,807
Conversion factor Btu/unit							*129,090*	*116,090*	*91,547*	*3412*
Trillion Btu per year							0.1272	0.0113	0.0082	0.0175

Industrial Energy Use

Industrial/ manufacturing often times can be the largest energy users in a community. A stable, competitively priced energy supply is potentially a significant advantage for attracting or maintaining a local industry. The cost of energy can be one of the largest inputs that firms have in many industries. Therefore, identifying local energy demand can be an important to help explore opportunities to match local demand with local renewable energy supply.

In this report we estimated industrial energy using three elements; volume, intensity and composition. The template provided formulas to calculate industrial energy use in two different ways:

The formulas below present the options available for calculating industrial demand. No approach will always be preferable. Testing of the template has shown the industrial energy consumption figures are widely scattered based on the method used. This appears to be an inherent limitation of the methods and data sets available.

Manufacturing Dollars Shipped Method
Clearwater County had $ 126,756,000 in manufacturing shipments in 2002. The template provided the total energy use per $ of GDP was 9,740 Btu. Therefore the total industrial energy budget for Clearwater County is estimated to be trillion Btu per year. Energy Use = 126,756,000 * 9,740 = 1,234,603,440,000, or 1.2 Trillion Btu's.

People Employed in Manufacturing
Clearwater County reported 376 people employed in manufacturing. The template provides that the average energy use per employee is 1,007.4 million Btu. The calculated industrial energy budget use on employment is 1.73 trillion Btu annually.
Energy budget = 376 * 1,007.4 *10^6 = 378,782,400,000, or .378 Trillion Btu's annually.

Commercial, Retail and Office Energy Use

Commercial, office and retail space is a large energy consumer. In some communities studied schools, public buildings and hospitals are among the largest users of natural gas ranking behind only large industrial users.

The minimum data required to estimate commercial space energy use are the square feet of space and the energy intensity (Btu/square foot per year). Refinements may be made based on building age, use and Census region.

At this time no generally applicable and readily available database of building area has been identified. Data on building size and use is catalogued by County Assessor offices but navigating these records is a slow cumbersome process. The template was still included in this report as it can be helpful for public officials and building owners to help determine individual energy demand.

Commercial Building Energy Use					
A	*B*	*C*	D	E	F
Principal Bldg Activity	*kwhr/sq ft*	*thousand Btu/Sq ft*	Total Area by Use	kw-hr/yr	thousand Btu/yr
				=D*B	=D*C
Education	*11*	*38.1*		-	-
Food Sales	*49.4*	*51.7*		-	-
Food Service	*38.4*	*145.6*		-	-
Health Care	*22.9*	*95.3*		-	-
Inpatient	*27.5*	*113.2*		-	-
Outpatient	*16.1*	*51.8*		-	-
Lodging	*13.5*	*50.4*		-	-
Mercantile	*19.2*	*33.5*		-	-
Retail	*14.3*	*31.9*		-	-
Enclosed and Strip Malls	*22.3*	*34.4*		-	-
Office	*17.3*	*32.8*		-	-
Public Assembly	*12.5*	*37.5*		-	-
Public Order and Safety	*15.3*	*45*		-	-
Religious Worship	*4.9*	*31.2*		-	-
Service	*11*	*55.8*		-	-
Warehouse and Storage	*7.6*	*24.1*		-	-
Other	*22.5*	*69.7*		-	-
Vacant	*2.4*	*23.7*		-	-
Total energy use				-	-
Million Btu per year				-	-
Trillion Btu/year				-	-

Resources Data Base

There are a number of different local, state, and federal resources that are beneficial to individuals and organization looking to learn more about energy production, use, or efficiency. These have been included in this report to help interested parties explore next steps. There are many other resources that can be helpful to a party interested in developing a renewable energy project. The ones listed below are good places to start when investigating a potential project.

AURI: The AURI is a nonprofit corporation created to improve the economy of rural Minnesota through new uses and new markets for the state's abundant agricultural commodities. For more information, please visit their website at www.auri.org

CERTS: The Clean Energy Resource Teams (CERTs) Project**,** started in 2003, is made up of community members across Minnesota who share a bold vision for Minnesota's energy future: to foster strong communities, to create local jobs, and to develop clean and reliable energy from

clean sources. For more information, please visit their website at
www.cleanenergyresourceteams.org/

DSIRE: The Database of State Incentives for Renewable Energy (DSIRE) is a comprehensive source of information on state, local, utility, and federal incentives and policies that promote renewable energy and energy efficiency. For more information, please visit their website at www.dsireusa.org

HRDC: The Headwaters RDC is a regional development organization that is committed to helping create successful communities and a successful region. They have a number of resources to help assist individuals and organizations pursuing a renewable energy project. For more information, please visit their website at

REDI: The Rural Energy Development Initiative (REDI) is a statewide program administered by the Southwest Initiative Foundation (SWIF) and sponsored by the State of Minnesota and the Center for Rural Policy and Development. The goal of REDI is to maximize rural economic development and stabilize rural economies by building renewable energy capacity, expertise and leadership throughout Minnesota.

Windustry: Windustry promotes progressive renewable energy solutions and empowers communities to develop and own wind energy as an environmentally sustainable asset. Through member supported outreach, education and advocacy we work to remove the barriers to broad community ownership of wind energy.