Wisconsin Strategic Bioenergy Feedstock Assessment

2012

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WISCONSIN BIOENERGY INITIATIVE

Building a renewable energy landscape in Wisconsin and beyond

Our Mission

Created in 2007 by the University of Wisconsin-Madison College of Agricultural and Life Sciences, the Wisconsin Bioenergy Initiative seeks to cultivate bioenergy expertise among UW-Madison, UW-System and Wisconsin stakeholders to anchor the innovative research that is being conducted within our great state. We are a university-based coalition that helps the talent across Wisconsin create, commercialize and promote bio-based solutions.

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Background:

Photo by: UW–Madison Communications

The Wisconsin Division of Energy services contracted with the Wisconsin Bioenergy Initiative (WBI) to complete a strategic assessment of biomass in our state to see what renewable energy business opportunities might best be targeted and what policy changes might assist advancing these opportunities. Too often biomass assessments only provide a snapshot in time of overall state feedstock quantity. To better filter out barriers and opportunities and to see what makes strategic sense for Wisconsin, the WBI looked at a combination of biomass quantity, quality, price factors, and conversion technology. First, a review of the existing literature on biomass quantity studies was done along with other relevant topics. The research team completed extensive biomass quality analysis to match up feedstock with best production uses. Finally, a robust price analysis was done in the woody biomass sector to make sure consideration was given to the highest and best use for wood products and economic growth. The research team then took all this work to examine regional or even local opportunity for biomass energy site locations.

When comparing previous biomass assessment studies and looking at the various biomass feedstock databases it is important to consider that all have some limitations. Foremost, it must be kept in mind what limitations and underlying assumptions each database has. Likewise, the authors of this study make some underlying assumptions that we will explain at each section. Every study of biomass availability estimates a theoretical level of availability. Some studies are based on current land use while others are driven more by how much feedstock would be available at a set of prices. This study attempts to give a realistic feedstock availability for Wisconsin based on land use, price, historical market trends of agriculture and woody feedstock uses, location of the feedstock (an intensity factor), and to some degree the authors understanding of the Wisconsin market. It is not a perfect process, but because quantity, quality, price and market are used it provides the best picture to date. If a business wanted to locate a biomass to energy facility in Wisconsin, as a part of their due diligence, the business would do its own feedstock assessment in the planned location. This is a feedstock potentials study, but grounded by the methods used.

This analysis shows that Wisconsin has strong opportunities with anaerobic digesters producing biogas (dairy animal waste, municipal waste diversion from landfills, processing wastewater treatment materials, and food processing business sector waste), woody biomass for thermal use, and corn stover for advanced biofuels or other uses. Smaller potential pockets of regional opportunity exist with dedicated woody biomass crops, dedicated perennial grasses, such as switchgrass, and using existing Conservation Reserve Program (CRP) lands for biomass grasses where appropriate for smaller regional needs.

Coupling Wisconsin Biomass Quality, Quantity and Price to Help Shape a Statewide Energy Plan: July 2012

Wisconsin has a tremendous opportunity for renewable energy production from biomass. We have a strong legacy of business innovation in forestry, agriculture and developing infrastructure for using biomass, both as commodities and as co-products. As renewable energy options advance in Wisconsin, our state's competitive advantage is with biomass to energy; however, growth in this sector will require strategic steps, including favorable policy.

Some Key Findings:

- Wisconsin has a large amount of biomass available for bioenergy projects. The three leading biomass feedstocks of wood residues, corn stover and manure total more than 10.1 million dry tons available per year.
- The state of Wisconsin can be a national and global leader in biogas production using waste from agriculture and other sectors. Dairy cow manure biomass feedstock alone represents 4.77 million dry tons available per year. This manure feedstock represents the energy equivalent of replacing a large-scale coal plant.
- Pockets of high-density biomass create opportunities for regional aggregation sites for energy use in Wisconsin. There are ten large biomass feedstock clusters of manure, three large biomass wood residual clusters, three large corn stover clusters, a dedicated woody crop opportunity cluster and smaller clusters for possible energy crops such as switchgrass.
- Woody biomass is the only potential energy source tested that consistently has the quality needed for thermal conversion. A detailed biomass quality chapter is included in this report. (See page 29)
- Only wood residuals can be used without impacting regional wood prices, because of Wisconsin's developed and mature forest products industry. The research shows that an expansion of large-scale thermal energy sites should be strategically placed to avoid impacting existing prices of pulpwood for product use. For example, in Wisconsin's:

  Northwest region – At least two plants at 200,000 ton/year each could be developed before market price impacts would occur.
  Northeast region – One plant at 200,000 ton/year could be developed before market prices impacts would occur.
  Southeast region – Better suited for small-scale woody biomass projects and possibly one plant at 200,000 ton/year could be developed.

- Wisconsin can increase the use of wood and grass pellets for residential heat or business thermal needs. A recently formed group called Heating the Midwest sponsored a conference in 2012 and is setting some more aggressive policy goals for Wisconsin and the Midwest to use wood and grass pellets for the thermal energy market.
- An integrated biorefinery producing either cellulosic ethanol or another form of advanced biofuels will likely emerge first through the development of products marketable today such as biochemicals and bioproducts. The choice of biomass feedstock would greatly influence whether Wisconsin would be an early candidate for an integrated biorefinery though commercial development is likely several years away.
- Wisconsin and the rest of the United States are underutilizing food waste and other organics now buried in landfills. Diverting these organics to anaerobic digesters and possibly combined heat and power (CHP) units is an undeveloped waste to energy resource.

Energy in the United States

According to the United States Energy Information Administration (EIA), total energy consumption between 2012 and 2035 is expected to grow by 10 percent in the United States (EIA, 2012). Fossil fuel energy is projected to decrease slightly from 83 to 77 percent, while renewable fuels are anticipated to increase from 7 to 11 percent. Excluding hydroelectricity, biomass is projected to account for 30 percent of the growth and wind will produce 44 percent. This projected fuel shift is due to changes in both federal and state policies such as the Renewable Fuel Standard (RFS), Corporate Average Fuel Economy (CAFÉ), and Renewable Portfolio Standard (RPS).

Energy developers recently discovered vast new stores of natural gas (shale gas deposits) and EIA projects that low natural gas prices ($4-6 per thousand cubic foot) will continue in the foreseeable future (Artgetsinger, 2012). Over the next 25 years, natural gas use is expected to rise from 24.1 trillion cubic feet in 2010 to 26.5 trillion cubic feet in 2035, driven by its use in electrical generation. During this period, 33 trillion gigawatts of coal electrical generation is expected to be retired. Although natural gas is generally thought to be an ideal and clean burning fuel, many concerns are now being raised over hydraulic fracturing (fracking), its carbon footprint and its potential to contaminate groundwater.

Coal is projected to remain the dominant fuel source of electric energy production for some time. However, very few new coal plants will be built, and it is projected that coal use will increase gradually over this time as current coal facilities are used more intensively and old plants are shut down.

Approximately 83 percent of the energy used in the United States comes from non-renewable sources (uranium, coal, petroleum, nuclear and natural gas); renewable energy (biomass, geothermal, solar, wind, hydro) provides the other 8 percent (Figure 1). Although the total amount of power or heat generated from biomass is fairly small, biomass makes up the largest percentage (53 percent) of renewable energy, vastly more than wind (11 percent) and solar (1 percent).

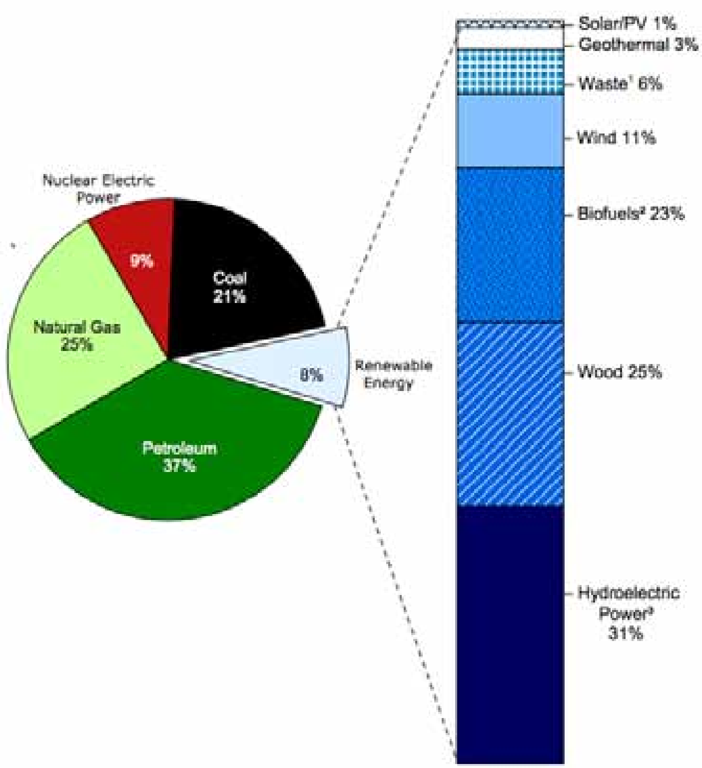


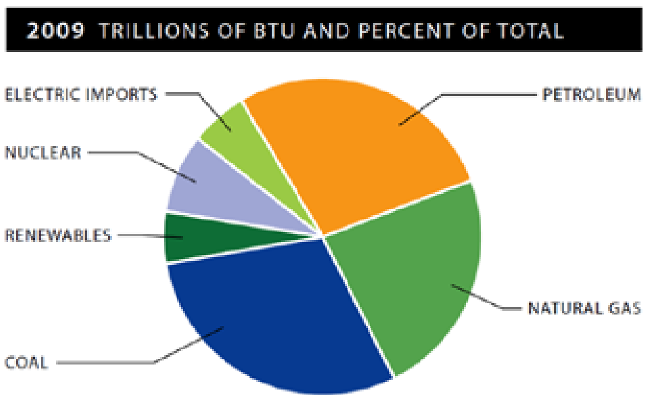
Figure 1. U.S. Energy Consumption by Energy Source, 2010
U.S energy consumption broken down by source, renewables further broken down by type. Source: U.S. EIA, Monthly Review (June 2011).

There is potential to expand the use of biomass energy in the Midwest because of the abundance of agricultural land and the large number of facilities that can be converted at relatively low cost (Repowering the Midwest, 2001). The North-Central Region of the U.S. (12 states) produces 49 percent of the country's biomass (Reading, 2007).

However, although biomass is renewable, it is not limitless. As we look at our current fuel mix, we need to be aware of the relatively small role biomass (and renewable energies for that matter) has in current consumption and predicted production. While its role may expand, the current trajectory for biomass will not provide enough capacity for major shifts in overall dependencies on coal and petroleum. From both an energy and environmental perspective, we must make decisions carefully on how to best utilize this important Wisconsin resource.

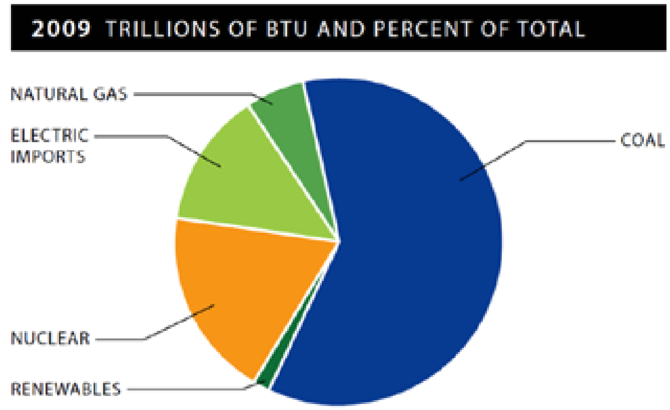
Energy in Wisconsin

In Wisconsin, 81 percent of our energy resources consumed are from fossil fuels with approximately 30 percent from coal, 28 percent from petroleum, and 23 percent from natural gas. Wisconsin produces only 5.2 percent of its own energy needs from renewable resources, with biomass accounting for over 55.9 percent of the renewable portfolio, with ethanol, biogas, hydro, and wind accounting for 22.2, 11.7, 6.1 and 4.1 percent respectively (Wisconsin Energy Statistics Book, 2010).



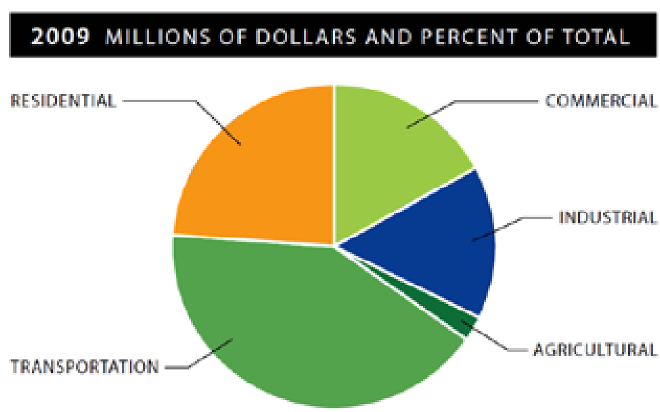
Type of Fuel	2009 Trillions of Btu	2009 Percent of Total
Renewables	87.4	5.2%
Electric Imports	95.5	5.7%
Nuclear	137.0	8.1%
Natural Gas	391.4	23.3%
Petroleum	470.8	28.0%
Coal	499.0	29.7%

Figure 3. Wisconsin Resource Energy.
Source: Wisconsin Office of Energy Independence



Type of Fuel	2009 Trillions of Btu	2009 Percent of Total
Renewables	10.9	1.5%
Natural Gas	43.4	6.0%
Electric Imports	95.5	13.1%
Nuclear	137.0	18.8%
Coal	441.4	60.6%

Figure 2. Wisconsin Electricity Generation.
Source: Wisconsin Office of Energy Independence



Economic Sector	2009 Millions of Dollars	2009 Percent of Total
Agricultural	494.2	2.6%
Industrial	2,825.4	15.1%
Commercial	3,154.3	16.9%
Residential	4,507.9	24.1%
Transportation	7,702.4	41.2%

Figure 4. Wisconsin Energy Expenditures.
Source: Wisconsin Office of Energy Independence

Executive Summary:

Now is the time for Wisconsin to move ahead with homegrown biomass and biogas to energy projects. The state is too dependent on high cost coal and petroleum for energy and the future of any high carbon energy is precarious. In June 2012, a U.S. Energy Information Administration report examined a range of future energy and fuel projections. The report found that coal and petroleum costs could rise steadily going forward, sometimes by as much as 42 percent, as was the case between 2010 and 2035 by one analysis. Similarly, crude oil prices could rise to $132.95 a barrel by 2035 in the scenarios modeled by the EIA (2012). Likewise, in June 2012, a Court of Appeals upheld the Environmental Protection Agency (EPA) greenhouse gas regulatory program meaning there will be continued regulation on coal plants to reduce emissions, or in some cases, retire the facility (Blattner, 2012). Wisconsin has the feedstock for energy alternatives in its backyard, with farmlands and forestlands abundantly capable of providing a portion of the state's energy needs. With the current low natural gas prices now is a good time for Wisconsin to begin incrementally moving toward biomass and biogas and away from coal and petroleum. A strategy of promoting medium-to-small-scale biomass and biogas for energy projects along with letting the energy and private industry market take advantage of low natural gas prices can level the costs of transitioning away from coal and petroleum. Local units of government should be encouraged to use stranded assets such as wastewater treatment plants and organic waste (such as food waste) being buried in landfills for biogas to energy in combined heat and power energy systems. Our Wisconsin farmers and foresters would have many value-added opportunities to connect with the energy generation system.

The Public Service Commission (PSC) has already documented that a planned move to renewable energy sources does not have to cause a major energy price disruption. Analysis done by PSC staff on Wisconsin's Renewable Portfolio Standard (RPS) law requiring modest steps by utilities to move toward more renewable energy generation only raised the ratepayer costs by 1 percent (PSC, 2012). Wisconsin can again encourage these steps away from costly, high carbon energy toward renewable energy with a portfolio of biomass and biogas projects at homes, businesses and local governments, joining existing and furthering development of solar and wind energy generation. Also, Wisconsin is a technology leader in biogas systems and microgrid research. We can take advantage of our technological leadership in Wisconsin, but it will take some strategic planning by the state along with policy that encourages market investment in renewables. Failure to act now will only pass on the higher cost of energy transition to our children. In addition, homegrown energy can create strong, resilient Wisconsin communities with local jobs in growing, harvesting and delivering biomass and biogas energy to residents and businesses. Wisconsin can be a component producer for wind, solar, biomass and biogas energy projects that will create good paying jobs for our state if we send the right policy signals to the market.

How can Wisconsin achieve this transition toward a future of using more biomass and biogas and less high carbon coal and petroleum for energy? The state could easily set goals for biomass and biogas to energy through existing mechanisms such as the Renewable Portfolio Standard (RPS) or find other ways to encourage greater market investment. The state may wish to set priorities for better use of biomass for combined heat and power facilities first using waste as a feedstock of choice. A second priority area could be looking to biogas with an array of settings including more on-farm anaerobic digesters, more wastewater treatment plants and/or landfills as regional waste collection sites with added energy generation, or looking upstream in pretreatment of wastes and conversion to energy before sending materials to landfills or wastewater treatment plants. The volume of feedstock is not the barrier to this opportunity.

** The authors of this report recognize that today coal can be bought by some or all Wisconsin-based utilities at prices below some or all renewable energy options including biomass and biogas. All energy feedstock purchase prices are subject to negotiation between energy generator (for example a farmer with a digester) and the utility. Coal can be purchased through long-term or short-term contracts at negotiated prices as well. The EIA 2012 report models and projects steady and growing prices for coal in the United States and closure of coal plants at a steady rate. At what point renewable energy source prices achieve what some call "grid parity" is not clear. Technology advances resulting in cheaper prices for renewable energy, a carbon tax or cap and trade policy in the U.S., or many other factors, could drive the future of grid parity. But, the EIA 2012 report clearly projects that coal and petroleum will not remain cheap energy options in the future. From 2010 to 2035 renewable energy options are projected to increase nationally from about 10 to 15 percent and coal-fired power plants decline in the energy model projections for the U.S. The authors of the EIA 2012 report say coal electricity will change due to factors including natural gas prices, increased renewable energy generation and new environmental regulation. None of the externalities of paying for public health care costs due to high carbon energy emissions, large-scale environmental degradation or the long-term U.S. historic public subsidization of coal and petroleum and its generation and distribution infrastructure are even factored into this shifting future trend. The world is changing. Wisconsin as a heavily coal-dependent state needs immediately to accelerate the transition from the high carbon legacy economy to the new energy economy or our state will fail to remain competitive locally or globally.*

Wisconsin Biomass Quantity: Current Inventory

We started the inventory assessment by looking at several Wisconsin biomass types and scenarios that are currently available including:

1. Roundwood – wood harvested in log form
2. Wood processing residuals – bark, chips, and sawdust remaining after primary processing
3. Wood harvest residuals – limbs remaining after tree harvesting
4. Corn Stover – remaining corn stalk, cob, and leaves that can be sustainable harvested after corn grain removal
5. Grasses from CRP/fallow pastures – switchgrass or other herbaceous material that could be harvested from fallow pastures or conservation reserve programs (CRP)
6. Dairy manure – animal waste from dairy operations

Other biomass sources such as food or feed processing waste (distiller grains from corn ethanol, oat hulls, and vegetable waste) were not considered as the materials typically are fairly small in volume and already used for cattle feed or other applications.

The research on quantity and quality suggest that dairy manure represents the "lowest hanging fruit" for biomass. It has the highest mass (~4.7 million dry tons) and an established conversion technology in anaerobic digestion (AD) that is fairly well developed. The utilization of the manure in AD offers additional ecological benefits, primarily in nutrient management and watershed quality. The natural location of the ADs will be on large confined animal feed operations (CAFOs), although with policy and technical innovation one can envision employing ADs on smaller farms throughout Wisconsin.

Corn stover represents the next underutilized biomass opportunity for Wisconsin. Approximately 2.5 million dry tons can be harvested annually, which is expected to grow as corn breeding continues to improve plant yields. Although cellulosic ethanol is a natural avenue to be explored with corn stover, additional conversion technologies should be sought, especially since cellulosic ethanol has not advanced far enough yet to be economically feasible. Coupling corn stover with dairy manure in anaerobic digestion may enable energy and economic improvements to both biomass sources, but more innovation is needed in this area.

Wood residuals also represent an underutilized biomass source that should be explored for use. These residuals quality suggest they would best be used in a thermal conversion such as combustion or gasification. With approximately 1.5 million dry tons this resource could be utilized in the state, but additional policy or technical innovations may be required to affordably remove these residuals and improve their logistics.

Table 1. Inventories of Biomass of Interest in Wisconsin

Biomass Type	Dataset	Mass (MM Dry Tons/yr)	Energy (MMBtu/yr)
Roundwood harvested	TPO	3.43	4.46E+07
Wood harvest residuals	TPO	1.46	1.90E+07
Wood processing residuals	TPO	1.05	1.37E+07
Unused processing residuals	TPO	0.03	3.90E+05
Corn stover	NASS	2.81	3.65E+07
Dairy manure	NASS	4.77	2.39E+07

Excluding the roundwood harvested and processing residuals, which are currently used in existing forest products industries, leaves nine million dry tons of biomass in Wisconsin that is available for bioenergy use. Assigning useable energy values of 6500 Btu/lb for woody and herbaceous materials (to account for low energy values from moisture), and biogas production of 5 ft^3/lb at 500 Btu/ft^3 (or 2500 Btu/lb) we can determine the contribution to WI energy use, also shown in Table 1. Summing up the energy contents, we obtain 7.98×10^8 MMBtu/yr from these resources. Unfortunately, Wisconsin consumes 1.68×10^9 MMBtu/yr[10] of fuels, so even these large amounts of biomass would only account for 4.8 percent of the state's energy use, assuming similar conversion efficiencies, emphasizing the importance of energy conservation along with finding renewable energy sources.

Organic Waste Going to Landfills:

Based on some analysis of Wisconsin population and the Environmental Protection Agency organic waste generation percentages, we created an illustration of county level waste generation going to landfills. This illustration shows large volumes organics could be available for processing in anaerobic digesters or thermal combustion by local units of government. Specifically, food scraps going to landfills was estimated at 454,828 tons per year or 10.6 percent of all materials; wood waste at 193,087 tons per year, paper waste estimated at 841,002 tons per year and yard trimmings at 180,214 tons per year. The total potential waste to energy materials going to state landfills is 1,806,439 tons per year or 42 percent of all materials. If only half of the food waste in the state were diverted to anaerobic digesters it would generate 2.13 E6 MMBtu. The energy from wastewater treatment plants and industrial sites would be potentially even greater. While not every unit of government would be able to divert some or all of this waste it is illustrative of a missed opportunity to take a waste feedstock and make energy.

This research project also combines quality and price analysis to best determine biomass feedstock opportunities. Woody materials are best utilized in thermal conversion of either combustion or gasification. Herbaceous materials are best used for biological conversions. The report contains a much more detailed biomass quality analysis. The price analysis shows that markets for new dedicated energy crops are not well established although in comparison to crops such as corn the establishment of switchgrass and miscanthus would be high. A detailed analysis was done on the existing woody biomass market to best measure at what point using forest materials impacts competing uses for traditional woody biomass products such as paper. This work shows that if biofuel/bioenergy demand exceeds about 1.2 million dry tons per year that price impacts do spillover into the pulpwood market. This has implications for larger utility scale energy projects, but should not be impacted by promotion of woody biomass to thermal use for residential or commercial heating.

Proposed Business Development Targets for Wisconsin Bioenergy Initiatives

1. Agriculture (on-farm) & Wastewater Treatment Plant (WWTP) anaerobic digester biogas production.

- At least ten clusters exist for on-farm anaerobic digester use in concentrated dairy sectors of Wisconsin.
- Anaerobic pretreatment of high organic waste streams at WWTP and Food Processing exist statewide.
- Biogas storage opportunities can likely be developed for electric on-peak generation and include generation of biogas cleaned to either pipeline quality or compressed natural gas (CNG).
- Many more anaerobic digesters could be installed with the goal of generated compressed natural biogas as a transportation fuel substitute.
- If natural gas prices remain low, biogas production can take advantage of any increased infrastructure investments in pipeline, storage or conversion to transportation fuel resulting in more natural gas pump stations.
- Long term opportunity both at WWTP and On-Farm Sites including enhanced value added product development with improved nutrient and mineral recovery.

2. Biomass heat that replaces propane, fuel oil and electric heat

- Wood pellets, wood chips for homes or businesses
- On-farm or coop production of grass/corn stover pellets

3. Biomass or biogas Combined Heat and Power (CHP) at industrial sites and/or municipal sites

- Target facilities not using natural gas
- Facilities with a useable waste stream or one that is nearby

4. Long-term opportunity for Advanced Biofuels and/or Cellulosic Ethanol Biorefinery

- Early adoption may be in biochemicals and bioproducts
- Modification of existing first generation ethanol plant

Areas that seem less likely to be developed during a period of low priced natural gas would be utility-scale electricity or biopower projects using either wood or grasses as a feedstock. Likewise, corn-to-ethanol growth is likely not to increase beyond the current levels because of the blending wall, but could change as the technology creates opportunities for advanced bioproducts and/or biofuels from corn stover and other feedstocks.

Wisconsin has some clear clusters of biomass feedstock for project development. This map (Figure 5 and 13) shows the Northern third of the state has three large wood residual aggregation areas of about a 36 mile radius and a nearby North-central woody biomass dedicated crops section of about a 20 mile radius. In the Southern part of the state three corn stover aggregation areas of about a 24 mile radius exist. The Eastern regions along Lake Michigan and parts of Southwest Wisconsin region have opportunities for dedicated perennial crops. Many regions around the state have manure aggregation opportunities, primarily where any CAFO is located. A more detailed subset of 10 regions combining dairy farms and cheese whey production is identified in a study done by Baker Tilly for the State Energy office. The most abundant opportunity for manure anaerobic digester to energy projects is what some call “the dairy donut” of counties around Lake Winnebago.

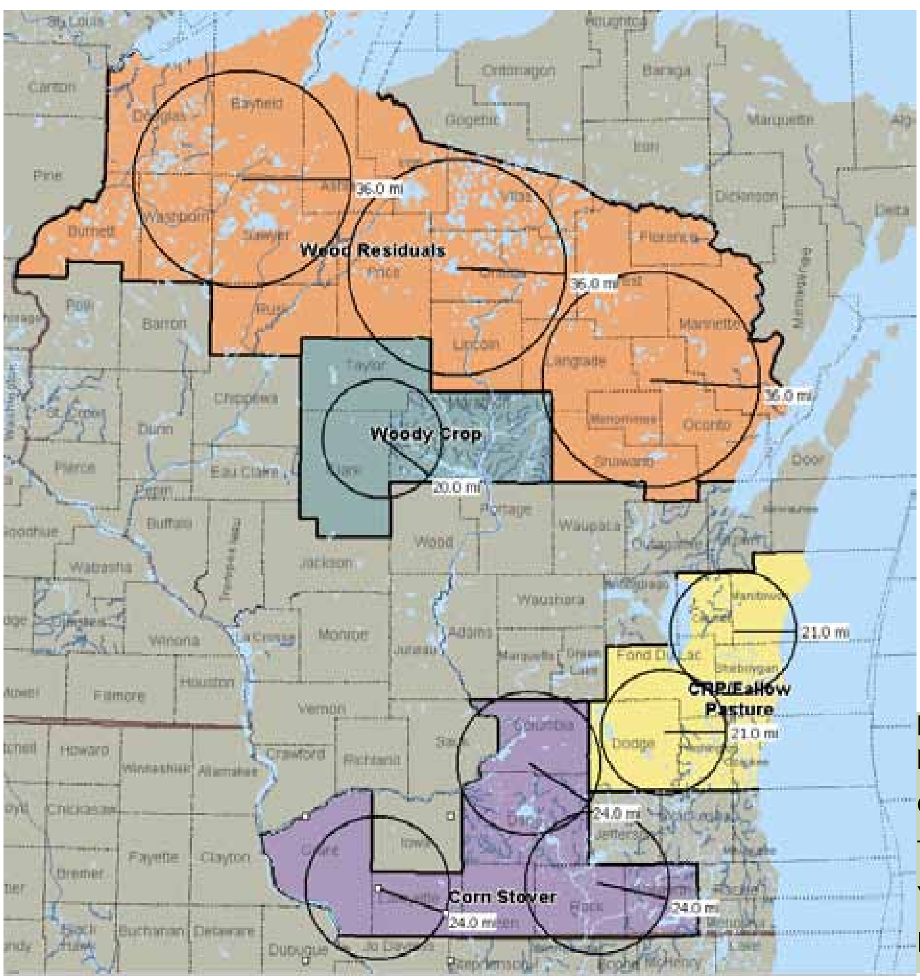


Figure 5. Wisconsin Map with Natural Aggregation Centers.

Orange: Wood Residuals

Teal: Woody Crop

Yellow: CRP/Fallow Pasture

Purple: Corn Stover

Overview

To understand the "Wisconsin Strategic Bioenergy Feedstock Assessment" requires understanding of a couple core concepts. First, what is biomass? The definition below captures the breadth of biomass materials.

"Biomass includes plant and animal-based organic material including energy crops, agricultural crops, trees, food, feed, and fiber crop residue, aquatic plants, forestry and wood residues, agricultural, industrial, and municipal wastes, processing by-products and other non-fossil organic material." – American Society of Agricultural and Biological Engineers.

Second, some biomass studies are inventory studies, but not biomass availability studies. Availability requires access to the feedstock (can you get in to harvest, chop or somehow remove) and that the feedstock is not going to another use (e.g. some wood goes to make paper and some corn is used as an animal feed). Therefore, biomass for energy use will often be in competition for other uses. Third, this strategic biomass assessment further bounds availability by the primary units of analysis of quantity, quality and price. Finally, a further refinement of the study includes a strategic consideration of the feedstocks, technologies and end uses together to better understand the opportunity for biomass to energy in Wisconsin.

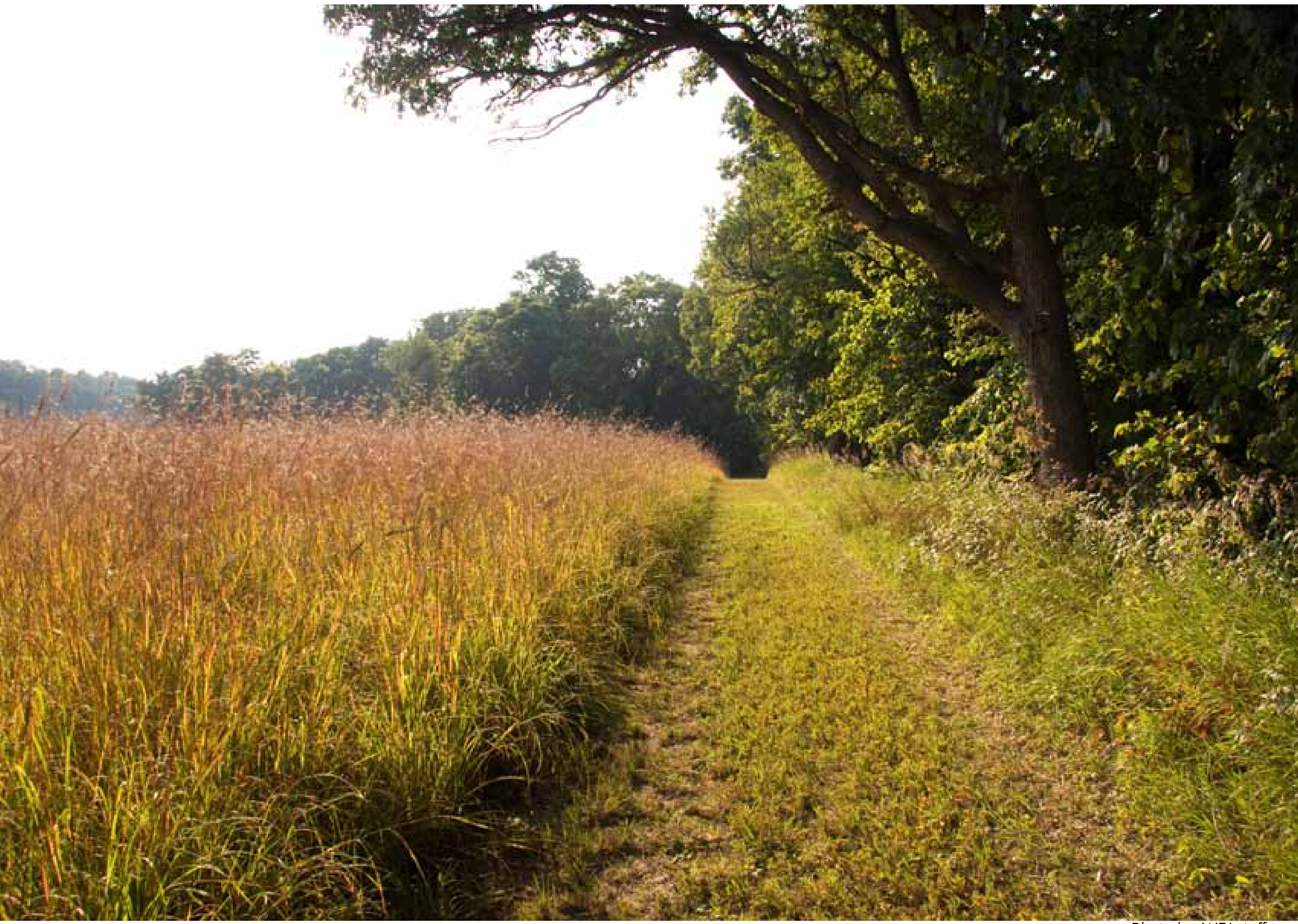


Photo by: WBI staff

1. Wisconsin Biomass Quantity

Existing Databases

There are several databases that contain inventory of Wisconsin biomass from satellite imagery, production report compilations, or producer surveys. The primary databases that were utilized for detailed analysis in this report include:

- National Agricultural Statistics Service (NASS) - The United States Department of Agriculture (USDA) houses the NASS which maintains a database on U.S. agriculture output. The NASS data is the product of hundreds of annual surveys every year covering every major aspect of U.S. agriculture, including corn production and dairy animals used in this report. As seasonal variation has a large impact on corn production, average production between 2000 and 2010 were used for this report.

- NREL Billion Ton Study (BTS) refers to the "U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry" study sponsored by the U.S. Department of Energy, Office of the Biomass Program. The study provides an estimate of the biomass resources available in the continental U.S. available for bioenergy conversion. As part of the study, a separate database containing the biomass supplies by county and state was made available through a Web-based Bioenergy Knowledge Discovery Framework (http://bioenergykdf.net) that was used in this report.

- Wisconsin Bioenergy Atlas (WBA) is a web tool created by the Wisconsin Bioenergy Information and Outreach Network, established in January 2010 as a collaborative effort among the Wisconsin Bioenergy Initiative, the University of Wisconsin's Land Information and Computer Graphics Facility, the Energy Center of Wisconsin, and the University of Wisconsin-Extension. This website is a portal that provides stakeholders with the information they need to make sound business decisions and foster a value chain for biomass production, harvest, aggregation and delivery. The online tool provides the means to look at biomass density from a variety of databases including NASS, FIA, Wisconsin Department of Natural Resources, and satellite imagery. It is the most comprehensive tool for WI biomass inventory.

- Timber Product Output (TPO) - The USDA Forest Service's Forest Inventory and Analysis (FIA) program conducts Timber Products Output (TPO) studies to estimate industrial and non-industrial uses of roundwood in individual states. The studies use questionnaires sent to primary conversion facilities to estimate roundwood harvested by type and location, and the residues generated during processing. Additionally, the FIA conducts logging utilization studies by visiting a cross-section of logging operations in a state to characterize the sites logged, trees cut, products taken, and residues left behind. The 2008 survey data which was obtained in draft form was used as the most recent data (NRS, 2012).

In general, all the databases have their strengths and weaknesses. The NASS and TPO databases are considered very accurate as they use surveys and receipts from the industries they report on. Unfortunately, they are limited in biomass types and in the case of the TPO report, published sporadically. These may be contrasted with the BTS model which has numerous scenarios and crops, and is able to predict future production based on price. However, as the data is based on models at a national scale it is less accurate at a local level. For this paper we have used the more specialized databases where appropriate, while also providing a comparison to the comprehensive BTS.

Figure 6. Wisconsin Map of Industrial Roundwood Biomass Removed - 2008 (ton/mile^2) by County.

Current Inventory

We started the inventory assessment by looking at several Wisconsin biomass types and scenarios that are currently available including:

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5. Grasses from CRP/fallow pastures – switchgrass or other herbaceous material that could be harvested from fallow pastures or conservation reserve programs (CRP)
6. Dairy manure – animal waste from dairy operations

Figure 7. Wisconsin Map of Manure Biomass Density (ton/mile²) by County.

Figure 8. Wisconsin Map of Harvest Residuals Biomass Density (ton/mile²) by County.

Other biomass sources such as food or feed processing waste (distiller grains from corn ethanol, oat hulls, and vegetable waste) were not considered as the materials typically are fairly small in volume and already used for cattle feed or other applications. A discussion of other possible biomass feedstocks occurs separate of this section and includes: state organic waste that goes to landfills, particularly food waste; industrial waste going to Wastewater Treatment Plants (WWTP), especially industrial food processing wastes; and some other industrial production waste. There will also be more detailed consideration of all feedstocks for use in anaerobic digesters.

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Corn stover	NASS	2.81	3.65E+07
Dairy manure	NASS	4.77	2.39E+07

Excluding the roundwood harvested and processing residuals, which are currently used in existing forest products industries, leaves nine million dry tons of biomass in Wisconsin that is available for bioenergy use. Assigning useable energy values of 6500 Btu/lb for woody and herbaceous materials (to account for low energy values from moisture), and biogas production of 5 ft^3/lb at 500 Btu/ft^3 (or 2500 Btu/lb) we can determine the contribution to WI energy use, also shown in Table 2. Summing up the energy contents we obtain 7.98×10^8 MMBtu/yr from these resources. Unfortunately, Wisconsin consumes 1.68×10^9 MMBtu/yr[10] of fuels, so even these large amounts of biomass would only account for 4.8 percent of the state's energy use, assuming similar conversion efficiencies, emphasizing the importance of energy conservation along with finding renewable energy sources.

Additional Biomass Potential in Wisconsin

There are limits in determining the current biomass inventory including not capturing increases in crop yields, and potential cropping or harvesting changes based on different economic incentives such as price. The Billion Ton Update database provides insight into the biomass potential for Wisconsin through their model that allows users to specify different scenarios for yield increase and supply amounts at different prices. To understand the magnitude of different price potentials with the model, three price scenarios were investigated of $40/dry ton, $60/dry ton and $80/dry ton. The biomass potential was estimated for using the database's standard assumptions for annual yield improvements:

Figure 9. Wisconsin Map of Corn Stover Biomass Density (ton/mile^2) by County.

1. Small diameter roundwood harvested– wood harvested in log form that is too small to be used economically for timber or pulp production

2. Wood harvest residuals – limbs remaining after tree harvesting

3. Unused wood processing residuals – amount of wood processing residuals not currently being used as a feedstock for products such as animal bedding, pulp, or solid fuel

4. Wood energy crops – short rotation woody plants such as *Salix* or *Populus* hybrids grown on existing agricultural land

5. Corn Stover – remaining corn stalk, cob, and leaves that can be sustainable harvested after corn grain removal

6. Grass energy crops – switchgrass or other herbaceous material that could be grown on existing agricultural land

Table 3. Wisconsin Biomass from Billion Ton Study

Biomass Type	MM[a] dry tons/year @ $40/dry ton	MM dry rons/year @ $60/dry ton	MM dry rons/year @ $80/dry ton
Small diameter roundwood	0.00	0.00	0.30
Wood processing residuals	0.07	0.07	0.07
Wood harvest residuals	1.05	1.05	1.05
Woody energy crops	0.00	2.29	3.51
Corn stover	0.75	3.11	3.13
Grass energy crops	0.00	0.00	0.15

[a]MM=Million

The results in Table 3 indicate that the only significant forest material available at these prices would be wood harvesting residuals, with amounts slightly lower than the TPO report estimates. This indicates that the roundwood and processing residuals are already being used by forest product industries for board, pulp, and other products, and suggests that expanding the use of forest products for bioenergy may have an economic impact on current industry, which is further investigated in section 3. Beyond woody harvest residual, the BTS suggests that wood energy crops have significant potential in Wisconsin, with 2.29 million tons predicted to be available at $60/ton (d.b.) it could be a significant future source of biomass.

Looking at the herbaceous resources predicted by the BTS model, corn stover is shown to be significant with estimates similar to those predicted by past NASS data and large amounts available at higher prices. Grass energy crops were also inspected and do not appear to have much potential according to the BTS model, presumably due to lower yields in Wisconsin versus southern states, affecting the economics and making other crops more profitable for farmers.

Beyond the Billion Ton Study prediction, we wanted to inspect two additional forest biomass resources in Wisconsin, including:

1. Additional wood harvest – Additional roundwood and their resulting harvest residuals not currently being utilized by the existing forest product industry.

2. Perennial grasses from marginal land – switchgrass or other herbaceous material that could be harvested from land that exists as fallow pastures or conservation reserve programs (CRP).

Figure 10. Wisconsin Map of Grasses from CRP and Fallow Pasture Biomass Density (ton/mile^2) by County.

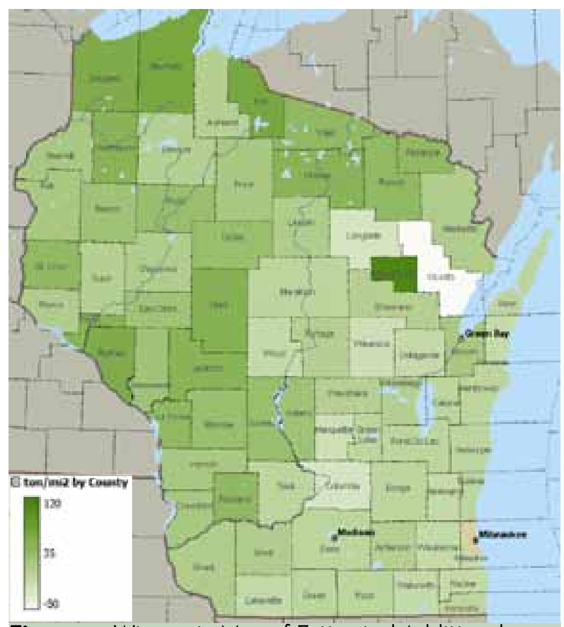


Figure 11. Wisconsin Map of Estimated Additional Roundwood Biomass Available (ton/mile^2) by County.

The first resource, additional wood harvest, captures the forest biomass that could be available with an increase of forest management or policies to encourage private land owners to participate in this market. With three pulp mill closures in the last decade, significant roundwood may be available in the 16.4 million acres of Wisconsin forests. According to the Wisconsin Statewide Forest Assessment, between 1996 and 2007 the average net annual growth of Wisconsin forest was 586 million ft^3 of roundwood, with only 327 million ft^3 removed annually. This would provide an additional 259 million ft^3 of biomass or 3.05 million tons. Whereas this may be possible, it is unlikely that enough landowners would participate to achieve such high productivity. Another estimate of how much additional forest biomass could be available, would be to inspect the TPO data from the last two decades when forest products demand was at a higher level. The data garnered from past TPO reports was plotted in Figure 12, and indicates a steady decline of approximately 1 million dry tons in roundwood removal from 1996 to 2008—primarily driven by the pulp mill closures at Brokaw (Wausau Paper), Port Edwards (Domtar), and Niagra (New Page). Soft housing markets have continued to lower wood removal, but would be most dramatic after 2008.

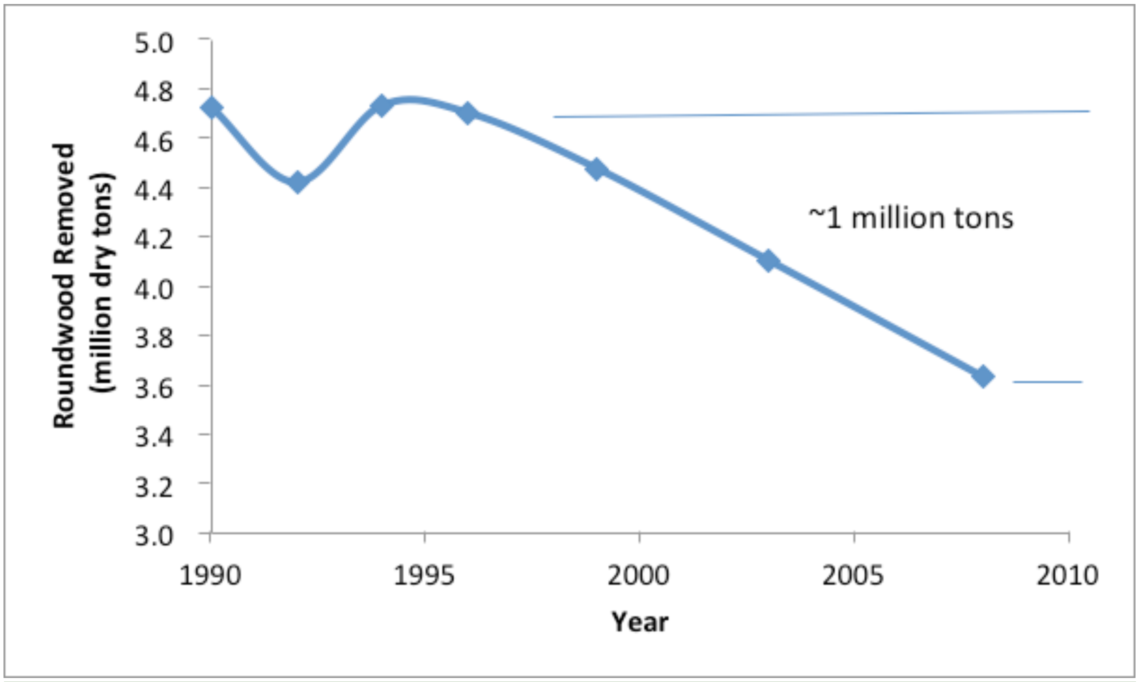


Figure 12. Wisconsin Roundwood Removed based on TPO reports.

Assuming 1 million tons more of roundwood had been sustainably harvested in the 1990s, and every ton of roundwood produces 0.40 tons of harvest residuals, then it may be estimated that an additional 1.4 million tons of forest biomass is available. This is approximately half the estimate based on the Forest Assessment and represents a conservative amount.

The last potential biomass that can be inspected for Wisconsin is grass produced from either crop reserve programs or fallow pastures. The Wisconsin Bioenegy Atlas provides an estimate of open land potentially available for bioenergy crop production in Wisconsin based on satellite imagery and soils data. From this data, open land not being cultivated was considered to have the potential to grow mixed grasses or an energy crop such as switchgrass. Assuming 2.5 tons per acre production provides 3.14 million tons of biomass. Although the BTS model suggests grass energy crops would be too expensive to produce, much of this land is already growing herbaceous materials that are not being utilized.

Summing the potential biomass of wood energy crops, additional forest products and grasses grown on fallow pastures or CRP, one can estimate another 6.83 million dry tons of biomass that could be available for bioenergy. Converting this to energy content, as was done with current resources in Table 2, allows the construction of Table 4 that depicts an additional 8.88 $\times 10^7$ MMBtu/yr from these resources.

Table 4. Potential Biomass Energy

Biomass Type	Dataset	Mass (MM Dry Tons/yr)	Energy (MMBtu/yr)
Wood energy crops	BTS	2.29	2.98E+07
Additional wood harvest	TPO[a]	1.40	1.82E+07
Perennial grasses from marginal land	WBA	3.14	4.08E+07

[a]Calcualted with assumptions from the TPO datasets

Adding the energy content of the biomass from Tables 2 and 4 provide 1.69 x 108 MMBtu/yr from these resources, which could supply approximately 10 percent of current Wisconsin energy use, assuming similar conversion efficiencies as the existing fossil fuels. If we acted on all this biomass we would be able to move the state's renewable energy utilization from 5.2 to approximately 15 percent. Although the biomass percentage is fairly low, this amount would offset ~10 million tons of low heat Wyoming Powder River Basin coal, predominately used in the state (8500 Btu/lb). Removing 10 million tons of this low rank coal per year from Wisconsin would reduce our greenhouse gas emission by 18 million tons of CO2.

Biomass Aggregation

To further understand the quantity of biomass, it is also useful to understand its location. The quantity data was collected at a county level and transformed into a biomass density of ton/mile^2 to remove biases of larger counties. This transformed data was then mapped to identify the potential for natural aggregation areas in the state. Of the maps produced, we decided to first focus on underutilized biomass, including woody harvest residuals, corn stover and manure (Figures 7 - 9). These figures depict natural high densities of wood harvest residual in the Northern half of the state, corn stover in the Southeast, and manure throughout the state. Since the manure is already aggregated in confined animal feeding operations (CAFOs) it is unlikely that aggregation would be necessary. Furthermore with a low solids content and transport issues, the economics of manure hauling are unfavorable. Some exceptions for aggregating manure may exist with a regional or community digester similar to models being used in Dane County.

Beyond the certain biomass available, potential biomass from energy crops were also plotted. Woody energy crops predicted by the Billion Tons Study depicts a natural aggregation in Central Wisconsin. Herbaceous energy crops, likely switchgrass, were mapped based on land that is currently fallow or in CRP and shown in Figure 10. The figure depicts the Southeastern portion of the state, north of Milwaukee as the likely home. Another pocket exists in Southwestern Wisconsin.

The last potential biomass that was mapped was additional forest roundwood available from the decline in the pulp industry in the last decade. The difference in tons/mile^2 between 1996 and 2008 were plotted in Figure 11. This figure surprisingly shows the industrial roundwood decline to not be aggregated in any specific state location, but rather diffuse throughout the state.

Taking the location and the average biomass density from those areas suggested aggregration sites were modeled. The biomass density was used to calculate a radius of collection to provide 200,000 tons (d.b.) of biomass which was deemed to be a reasonable amount for a conversion plant (shown in Table 5). These radius were in turn used to create a map of aggregration center by biomass type in Figure 13. The additional roundwood, was not mapped as it did not have any natural aggregration centers.

Local units of government in Wisconsin also have the potential to be aggregation sites for biomass and waste materials. Wisconsin wastewater treatment plants already receive and process waste materials. Some already have anaerobic digesters to process waste, but may not be used for energy. This next section will consider opportunities with waste material feedstocks and producing energy at wastewater treatment plants and landfill sites.

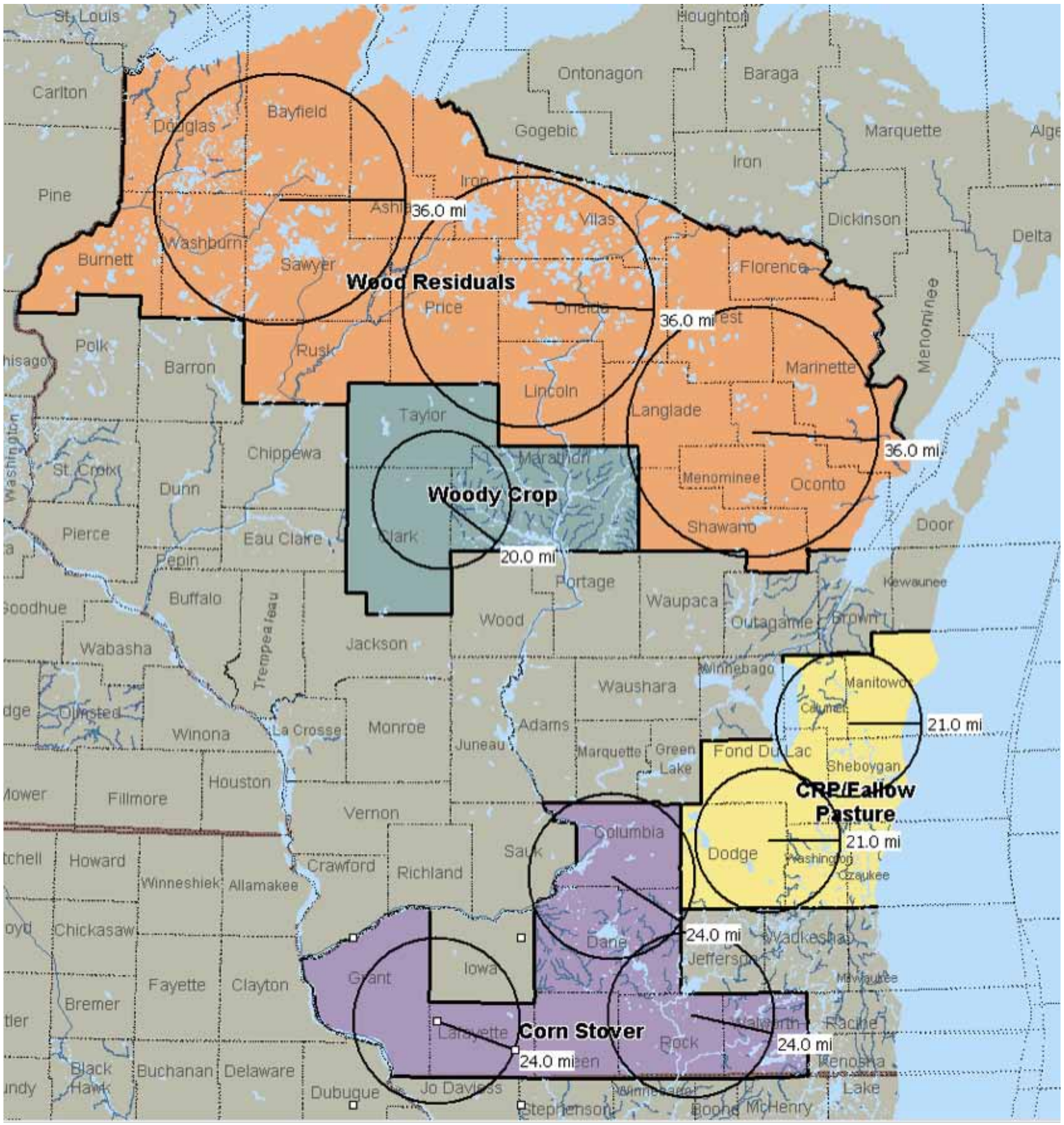


Figure 13. Wisconsin Map with Natural Aggregation Centers by Biomass Type.

Table 5. Wisconsin Biomass Aggregation Areas

Biomass Type	Avg. Biomass (Tons/ mile² d.b.)	Area for 200,000 tons (mile²)	Radius (mile)
Wood harvest residuals	50	4,000	36
Corn stover	110	1,818	24
Wood energy crop	160	1,250	20
Fallow Hay/CRP grasses	150	1,333	21

Waste, it is a terrible thing to waste

Wisconsin, like most of the United States, spends a lot of financial and human resources on handling and treating waste materials whether it is at landfills, wastewater treatment plants, at an industrial food-processing site or on farms. Now more communities and businesses are looking closely at whether some or all of their waste materials can be used to generate on-site energy or even enough energy for use by others. This next section will examine opportunities at wastewater treatment facilities, diverting organic waste from landfills, and on-farm manure where waste to energy options can be considered.

Wastewater Treatment Plants and Industrial Sites: Using anaerobic digestion at a Wastewater Treatment Plant as a stand alone, or in tandem with a large industrial user who may need the heat, is a great opportunity for some local government entities, especially when considering the costs of processing waste without AD on site. According to the EPA, wastewater treatment plants (WWTP) consume up to four percent of the energy used in the United States (EPA, 2011). Remarkably, a large municipal wastewater treatment facility contains almost ten times the energy required to treat it (Bagley, 2004). So it is clear that many WWTP have excess energy that can be generated.

The percentage of WWTPs that generate energy today is small across the nation, possibly as few as two percent of total centralized municipal plants (Bullard 2009; EPA, 2011). Many of these facilities use anaerobic digesters as apart of waste management, but the biogas is flared or not fully used for energy. The primary purpose of anaerobic digesters at municipal WWTPs is to reduce the volume of volatile organic solids, remove pathogens and stabilize sewage sludge for land application. Federal and state data in this area is lacking; although, a new study by the Water Environment Research Foundation is trying to address this data gap. The EPA has estimated that more than 3,100 WWTPs have adequate flows to use anaerobic digestion and combined heat and power on site and, possibly half of those facilities may already use AD processing.

Wastewater Treatment Gas by the Numbers

- A typical WWTP facility processes 1 million gallons per day (MGD) of wastewater for every 10,000 in population served.
- Anaerobic digesters are generally used when wastewater flow is greater than 3 MGD. A recent EPA study on wastewater treatment plants and CHP opportunities indicated that facilities with a flow of 1.00 MGD could be candidates for on-site heat and energy use.
- For each MGD processed by a plant with anaerobic digesters, the available biogas can generate up to 35 kW.
- The heating value of the gas produced from the anaerobic digesters is nominally 60 percent that of natural gas (1000 Btu per cubic foot), but with maximum digestion and proper cleanup can be increased to as much as 95 percent (DOE-FEMP, 2004).

Why target Water and Wastewater Treatment Plants as potential regional waste processing and energy generation facilities?

- Water and wastewater treatment facilities on average consume between 25 and 40 percent of the entire local government energy budget.
- These water and wastewater treatment facilities are 24/7/365 operations.
- Energy costs at water and wastewater treatment plants are estimated nationally at $4-9 billion annually.
- Water and wastewater treatment plants nationally consume 50 to 75 billion Kwh per year (Cantwell, 2008).

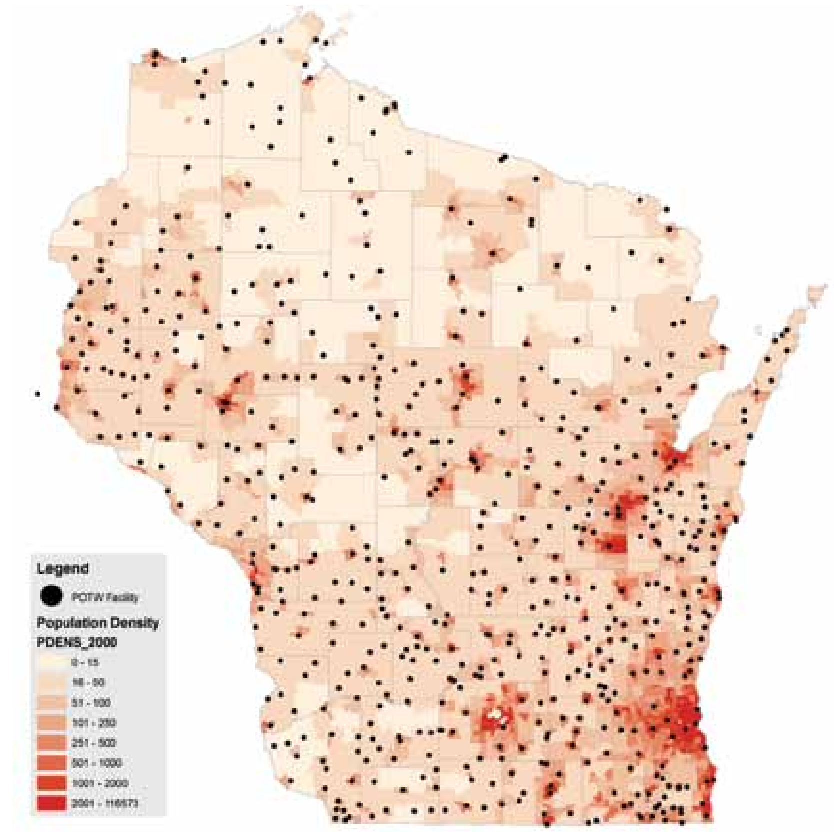


Figure 14. Wisconsin wastewater treatment plants and population density.
Map designed by Math Heinzel, Land Information and Computers Graphics Facility, University of Wisconsin-Madison.

A study by the EPA on combined heat and power and wastewater treatment plants list potential Wisconsin WWTP candidates as Chippewa Falls, Janesville, Kaukauna, Oak Creek, Sun Prairie and Beaver Dam (the study was published before the partnership with Kraft foods at Beaver Dam WWTP). (EPA 2011) Other communities in Wisconsin have experience with AD to energy, such as: Sheboygan (profiled later), Madison, and several others including the Milwaukee Metropolitan Sewage District (MMSD). MMSD makes milorganite - an organic fertilizer that is popular with golf course superintendents and homeowners at its Jones Island and South Shore plant where biosolids are sent to anaerobic digesters and converted into methane gas. Next up, MMSD is taking methane gas from the Emerald Park Landfill and shipping it to the Jones Island facility where three new turbines will convert it to energy. So, the lessons from MMSD may be helpful for other Wisconsin WWTP to study and consider. Recently, Green Bay wastewater treatment district announced a major expansion including anaerobic digesters and three engines for producing energy. Wisconsin may have up to 80 WWTP that meet the average daily flow threshold to be candidates for AD and CHP. Further, research followed by an education and outreach program is needed to help in determine the best WWTP candidates for AD, and possibly in combination with CHP in Wisconsin.

Wastewater Treatment Plants, Industrial Plants and Landfills Today

Again, today the primary purpose of anaerobic digesters at municipal wastewater treatment plants is to reduce the volume of volatile organic solids, remove pathogens, and stabilize sewage sludge for subsequent land application or disposal. Some of the Wisconsin wastewater treatment plants may be using on-site anaerobic digesters, but not as effectively using the system for energy, either flaring the biogas or only using some of the energy capacity. These could be sites to target for expanded energy use because the infrastructure is in place (AD system, tanks, controls, permits, licensed operators), they have some experience using the heat or power, and they are well positioned to partner with other industries to share costs for equipment or address under-loaded system problems. The barriers might be that their experience with biogas to date was not good, possibly due to cleaning the gas challenges, or the cleaning equipment

Table 6. Number of Wisconsin wastewater treatment plants and average flow

MM[a] Gallons per Day	Number of Facilities	Total Average Design Flow
0 - 0.25	402	33.7
0.26 - 0.50	93	35.3
0.51 - 1	55	38.0
1.01 - 2	34	52.0
2.01 - 5	37	112.1
5.01 - 10	11	75.5
10.01 - 20	11	165.5
20.01 - 50	5	171.4
>50	2	236.0
Total	**650**	**919.5**

[a]MM=Million
Credit: Joe Cantwell, PE, Focus on Energy Program

was expensive, and there may be a lack of local government funding for this further processing step. Other unique community-by-community factors could include that it is a small processing plant or some communities may have over built their processing plant. The later overbuilt facility might be a good candidate for importing substrates from, for example, a cheese or other food manufacturing facility. The barriers for these types of facilities might be a lack of knowledge of available substrates, locations, types and costs, and again local government resources to invest in expanding these operations for being a substrate collection point. (A more detailed discussion on WWTP opportunities, barriers and further research needs are discussed further in another section of this report).

There are different estimates of how many anaerobic digesters exist at wastewater treatment plants and industrial sites in Wisconsin. According to a 2003 study prepared for Focus on Energy, approximately 85 Wisconsin communities have anaerobic digesters at wastewater treatment plants. Dennis Totzke, an industry analysis with Applied Technologies, placed the number at 60 municipal systems and 28 industrial systems (Totzke, 2012). The Wisconsin Wastewater Operators Association database lists 62 facilities with anaerobic digestion. So, the precise market in this space remains somewhat unclear and further research is needed on the economic opportunity. More demand at process plants is projected, although the overall economic downturn in 2011-12 combined with changes in the Focus on Energy Program has delayed some proposed AD projects that were in development. Analysis by Totzke shows that the 28 industrial anaerobic digester systems produce a flow of 14.3 mgd and are capable of generating 30 MW of power, while the 60 municipal systems produce a flow of 390 mgd and are capable of generating 20 MW of power (Totzke, 2012). There are some wastewater treatment plant success story models to consider, such as in Sheboygan.

Sheboygan Wastewater Treatment Plant

The Sheboygan Wastewater Treatment Plant took a novel approach in 2005 when it was studying how to get more energy from its facility. Methane gas was already produced on site from an anaerobic digester, but more than 25 percent of the gas was still being flared. The plant worked with Unison and Alliant Energy and the utility agreed to purchase 10 (30-kilowatt) microturbines from Capstone Turbine, pay for electrical connections from the wastewater plant to the electrical grid, purchase a gas-cleaning system that removes moisture and siloxanes from the raw methane gas and purchase a gas-compression system that compresses the clean methane gas fed to the microturbines. In exchange, the City of Sheboygan agreed to purchase from Alliant all electricity the microturbines produce, install a heat-recovery module to capture waste heat and provide the methane fuel for the microturbines. In addition the City is purchasing over time the microturbine system at a reduced cost. This system has been operational since February 2006.

Food Processing Opportunities

Wisconsin has over 1,000 food processing facilities, including 125 cheese processors, and is considered a cluster development area for the state. Wisconsin also ranks number one in the nation in processing beans, cheese, cranberries and corn for silage. Wisconsin ranks second in the nation in processing butter and milk. The state is third in the nation in processing carrots, green peas, potatoes and sweet corn. (NASS) There are three food processing facility regional pockets near the urban/suburban areas of Milwaukee, Madison and Green Bay along with the Central Sands area where many vegetables are grown (Forward Wisconsin, 2006). Food waste in general can be collected from multiple sources including supermarkets, schools, prisons, hospitals, restaurants, as well as food processing and production sites (EPA, 2012). The study being done by Baker-Tilly for the state energy office details the dairy food processing sector and other opportunities.

The state has several success stories with food processing waste and anaerobic digesters. For example, the City of Beaver Dam wastewater treatment plant and Kraft Foods have a successful partnership to pre-treat cream cheese waste with the electricity created being sold to Alliant Energy. JBS Green Bay, a beef production facility, has done pre-treatment at anaerobic digesters since 1987. Saputo Cheese in Waupun also uses anaerobic digestion (Kramer, 2011). For more examples of food processing waste to anaerobic digesters to energy see Joe Kramer's casebook.

Diverting Landfill Waste for Energy

In the last forty years, there has been a major shift in our municipal solid waste (MSW). Today we recycle more but we generate a lot more household and overall municipal waste. In 1960 the average person in the U.S. generated 2.68 pounds of trash per day with 94 percent of that waste being sent to the landfill (6 percent recycled). By 2010, the amount of trash generated per person per day had increased to 4.4 pounds of trash per day but less was landfilled (66 percent) and more was recycled (34 percent) (USEPA, 2010).

Food and other organic waste contribute methane, a greenhouse gas that is 21 times more potent than carbon dioxide. Diverting select organic materials from landfills for energy could generate new sources of income for municipal budgets, provide renewable energy and potentially improve greenhouse gas emissions, depending on the waste diverted and the energy technology selected. Today 90 municipalities including Toronto, Ontario; Duluth, Minnesota and Dubuque, Iowa have household organic diversion programs. Oshkosh and Madison have both recently initiated pilot programs (Ryan, 2011).

But diverting waste to energy is not without controversy. For example, some opponents argue that waste to energy programs dilute recycling and related recycling businesses and jobs; others suggest that composting recovers more energy than combustion energy systems produce. Therefore, it would be important for a community to evaluate all its options with diverting waste and look at a technology such as anaerobic digesters to divert waste further upstream or, alternatively, whether to use methane from a landfill site for electricity or convert further to compressed natural gas–as being done in Dane County and a project under development in the city of Janesville, WI.

The Wisconsin DNR produced a comprehensive report, "2009 Wisconsin State-Wide Waste Characterization Study" detailing the states' waste streams by weight (DNR, 2009). The report was a large-scale effort that summarized the residential, industrial, commercial, institutional, and construction and demolition (C&D) waste streams. In 2009, Wisconsin generated 4,290,503 tons of waste. Of this, organic materials (food scraps, wood, yard clippings etc.) made up the largest percent (23.2 percent) of Wisconsin's waste stream and contributed nearly one million tons of waste annually. The report recommends, "Wisconsin continues to have opportunities to divert additional wastes from landfill disposal. Organics remain the most significant fraction."

Material from the DNR waste to landfill study, including statewide waste sector percentages, was then combined with an approximate per capita breakdown to provide an estimate by county for the organics available for a diversion from the landfill.

Co-digestion and Food Waste: Another way Wisconsin can turn "waste" into a societal benefit is anaerobic digestion of food waste. This is the number one material going to most U.S. landfills and it has a strong potential for producing methane to make energy. The EPA estimates that if half of the United States' annual food waste was processed through anaerobic digesters it would generate enough electricity to power over 2.5 million homes for a year (EPA AgStar, 2012). Wisconsin's recent waste study shows that 10 percent of the material going to state landfills is food waste. Food waste can be either pre-consumer (food processing and manufacturing waste from food prep, slaughterhouse waste, brewery waste, dairy waste and what are called fogs; fats, oils and greases) or post-consumer waste (household food scraps or restaurant leftovers). Some Wisconsin owners of anaerobic digesters do utilize co-digestion, but more feedstock options remain to generate greater amounts of biogas. Fats, oils and greases greatly increase biogas production. Feedstocks ranging from corn and grass silage to brewery and bakery waste can all produce more biogas than cow manure.

There are many decisions and factors that may go into the selection of feedstocks for co-digestion. The technical issues are site specific, but economics may also be a large factor. Economic factors include the cost of obtaining feedstock, transporting and processing material. Under some business models a tipping fee can be charged to process the waste. The use of energy and heat on site can be a deciding factor for some facilities or if a nearby user exists for the heat generated. The key is that many options exist for a regional site whether it is an on-farm digester, a WWTP, an industrial site or landfill. Many combinations of energy generator and different energy user exist.

Wisconsin is also a center for research on microgrids. Microgrids are integrated energy systems consisting of distributed energy resources (DERs) and multiple electrical loads operating as a single, autonomous grid either in parallel to or islanded from the existing utility power grid. In many ways, a microgrid is really just a small-scale version of the traditional power grid that the vast majority of electricity consumers in the developed world rely on for power service today. Yet the smaller scale of microgrid results in far fewer line losses, a lower demand on transmission infrastructure, and the ability to rely on more localized sources of power generation. As this research advances in combination with energy storage systems, anaerobic digesters taking waste-to-energy may be prime microgrid system candidates along with on-site solar and wind generation.

Connecting the Dots in Wisconsin:

Wisconsin businesses, local governments, farms, cooperatives, and utilities need to think about ways to form innovative partnerships on biomass and biogas to energy projects. We call this section connecting the dots in Wisconsin because there are so many sources of biomass feedstock, particularly with waste materials, and potential energy users that have not considered partnerships. Yet, many have successfully formed partnerships in Wisconsin and we can build from the lessons learned at these projects. One new partnership getting started in the woody biomass section is the Domtar paper mill in Rothschild and We Energies utility.

Major cheese processors in Wisconsin

1. Schreiber Foods, Inc.
2. Sargento Foods Inc.
3. Great Lakes
4. Marathon Cheese Corporation
5. Masters Gallery Foods, Inc.

Wisconsin's largest meat plants:

1. Cargill-Taylor, Milwaukee (Beef)
2. Smithfield Processing Plant, Green Bay (Beef, 5th largest in the nation)
3. American Foods Group, Green Bay (all)
4. Gold n' Plump, Arcadia (Poultry / broilers)
5. Hormel Plant, Beloit (Midwest's largest integrated turkey plant)
6. Oscar Mayer Plant, Madison (Beef and pork processor)
7. UW Provision, Middleton (all)
8. Johnsonville, Sheboygan Falls (Pork)
9. Abbeyland, Abbotsford (Pork, esp. sausages)

Wisconsin's largest dairy plants processing fluid milk include:

1. Verifine Dairy Products Co., Sheboygan (now Dean Foods)
2. Golden Guernsey Dairy, Waukesha
3. Kemps LLC, Cedarburg
4. Morningstar Foods, Richland Center (recently converted to yogurt)
5. Kwik Trip Dairy, LaCrosse
6. Lamers Dairy Inc., Appleton
7. Morning Glory Dairy, DePere (now Dean Foods)
8. Foremost Farms USA

Wisconsin's largest cheese plants are:

1. Foremost Farms, USA (multiple locations)
2. Alto Dairy Cooperative, Waupun (now Saputo)
3. Saputo Cheese USA, Inc. (multiple locations)
4. Land O' Lakes (Kiel, Denmark and Spencer)
5. Associated Milk Producers Inc. (Portage, Jim Falls, Blair)
6. Grande Cheese Company (Brownsville, Juda, others)
7. Trega Foods (Little Chute, Weyauwega, Luxemburg)
8. Mullins Cheese, Mosinee
9. Sartori Food Corp., Plymouth
10. Ellsworth Cooperative Creamery (Ellsworth and Comstock)
11. BelGioiso Cheese, Inc., Denmark (multiple locations)
12. Nasonville Dairy, Inc., Marshfield
13. Churny Company (Kraft), Wausau
14. Wisconsin Dairy State Cheese Co., Rudolph
15. Klondike Cheese Co., Monroe
16. Burnett Dairy Cooperative, Grantsburg
17. Arla Foods, Inc., Kaukauna
18. Cady Cheese Factory, Inc., Wilson
19. Baker Cheese Factory, Inc., St. Cloud
20. Park Cheese Company, Inc., Fond du Lac

Credit: Wisconsin Department of Agriculture, Trade and Consumer Protection

Joint Paper Industry and Utility Project: The Domtar paper mill in Rothschild and We Energies are partnering on a 50-megawatt cogeneration plant. The project, which was approved by the Public Service Commission and is being built, combines supplying renewable electricity to We Energies and heat to the Domtar plant. The project estimated at $260 million and has created construction jobs in the region and new jobs once operational. The plant now uses 130,000 tons/yr of biomass, of which 50,000 tons per year is produced as a result of Domtar's paper making process. An additional 370,000 tons/yr of (wood, waste wood and sawdust) biomass will be purchased when the project is fully operational.

Other Aggregation and Processing Sites: Wisconsin has opportunities to promote the use of anaerobic digesters and/or combined heat and power energy projects in its showcase dairy sector, robust food processing sector, ethanol plants, wastewater treatement plants, landfills and other private businesses. The state has abundant feedstock for energy conversion, but now needs to connect the dots for possible regional centers or collaborations among waste generators. Partnership with other industries can solve high-cost biogas cleaning equipment or under-loaded system problems. The partnership between City Brewing Company and Gundersen Lutheran in La Crosse is a useful example.

What is biogas?

Biogas is produced by the decomposition of organic matter in the absence of oxygen. For typical biogas systems, this organic matter can include manure or plant substrates such as crops or food waste. These inputs are then fed into an anaerobic digester where microbes in the presence of heat and absence of oxygen break down the organic matter, producing biogas (which is composed of methane and other gases). In addition to biogas, the solids that have been digested are also a product of anaerobic digestion.

Biogas Outputs and End Uses: The biogas produced from this process can be combusted for electricity and heat, can be used directly by upgrading the gas to pipeline quality or upgrading it further for use as a transportation fuel. Thus, biogas is a versatile energy source. The digested solids can also be utilized as an organic fertilizer or as animal bedding.

Here are a few areas that the state needs to consider when connecting the dots. (See figure 5 or 13).

- Dairy Farm Sector: Wisconsin has lots of dairy farm operations including 78 farms with a 1,000 or more head, 194 farms with 500 to 999 head and 798 farms with 200 to 499 head.
- Hog Farm Sector: Wisconsin has 99 swine farms with more than 1,000 head.
- Wisconsin is home to over 1,000 food processing firms and as an economic development strategy the state has made growing the food processing cluster a top state economic development priority. This likewise makes these facilities candidates for anaerobic digesters and/or combine heat and power plants.
- Wisconsin has more than 80 wastewater treatment plants that should at minimum be researched and have some cost-benefit analysis done on whether they could be regional waste aggregation sites, have or expand anaerobic digester and combined heat and power processing capacities.

Anaerobic Digesters at a Wastewater Treatment Plant

Landfill and Wastewater Treatment Plant Sector: Some use digesters now and more could in the future. There are up to 80 Waste Water treatment plants that meet the average daily flow threshold set by the Environmental Protection Agency for AD use. More of them could be using the gas for energy. Food waste can be co-digested at WWTPs, livestock digesters, or digested alone. There are currently only a few WWTPs around the country using co-digestion, although these projects have demonstrated potential. Agriculture digesters (AD) tend to use food waste materials from industrial generators that can be consistently supplied, such as whey or off-spec yogurt. There is currently only one stand-alone food digester in the U.S., although there are several additional projects in development in the U.S. as well as existing projects outside the country (EPA, 2012).

Table 7. Typical Food Processing Wastewater Organic Loads

Wastewater Source	BOD (mg/L)
Brewery	850
Dairy	1,000 – 4,000
Fish	500 – 2,500
Fruit	1,200 – 4,200
Meat	1,000 – 6,500
Potatoes	2,000
Poultry	500 – 800
Slaughterhouse	1,500 – 2,500
Vegetable	1,000 – 6,800

Currently, more than 80 percent of food processing waste is treated at municipal wastewater treatment plants. (McCord, 2011).

Commercial Food Waste Sector: Businesses, universities, and other facilities that generate large volumes of waste food could source separate and use a digester on site or in partnership with a community or nearby farm. The University of Wisconsin-Oshkosh project using the dry digester technology to process waste streams should be showcased as a model for other state facilities and private entities. (See "Connecting the Dots" chart on pages 21-22).

Wisconsin has a wide variety of types of food processing plants. Many facilities are too small for an on-site anaerobic digester. Some might be candidates to contribute to regional collection facilities. This table is an older breakdown of numbers of candidates for combined heat and power applications. While the numbers may have changed in recent years it does provide an illustration of the variety of types of food processing in the state and the types that could collaborate by providing feedstock for waste-to-energy.

Table 8. Number of candidates for CHP applications in Wisconsin

Beverage	Bakery	Confectionary	Meat	Dairy	Grain Milling	Vegetable Processing	Snack Food	State Total
20-43	50-116	36-70	65-80	45- 59	1-5	50	15-43	292-494*

Source: Midwest Heat and Combined Power Center

Landfill and Wastewater Treatment Plant Sector: Some use digesters now and more could in the future. There are up to 80 Waste Water treatment plants that meet the average daily flow threshold set by the Environmental Protection Agency for AD use. More of them could be using the gas for energy.

Wisconsin has learned a lot from success and failure in anaerobic digester development on-farms and elsewhere to lead us into future growth and development. There are hundreds of potential candidate facilities around the state. Likewise, there is abundant feedstock. A policy strategy can be built into a state energy plan to push biomass and biogas to energy leadership in Wisconsin.

Ethanol Plant Sector: All of Wisconsin's existing ethanol plants should consider having an anaerobic digester and look at capturing other value added economic opportunities.

Table 9. Ethanol plants in Wisconsin and their production

Wisconsin Ethanol Plants	
Ace Ethanol LLC, Stanley, WI	41 million gallons a year
Badger State Ethanol, LLC, Monroe, WI	50 million gallons a year
Big River Resources, Boyceville, WI	40 million gallons a year
Didion Ethanol, Cambria, WI	40 million gallons a year
Marquis Energy, Necedah, WI	50 million gallons a year
United Ethanol, Milton, WI	52 million gallons a year
United WI Grain Producers, Friesland, WI	53 million gallons a year
Utica Energy, Oshkosh, WI	48 million gallons a year
Valero Renewable Energy, Jefferson, WI	130 million gallons a year

Source: Nebraska State Government website (www.neo.ne.gov/statshtml/121.htm)

Wisconsin has learned a lot from success and failure in anaerobic digester development on-farms, likewise, there are success and failure with anaerobic digesters at wastewater treatment plants. But, Wisconsin can be a leader by building from this knowledge and looking to better models for future success and new development. There are hundreds of potential candidate facilities around the state. There is abundant feedstock statewide. A policy strategy and a research and development strategy can be built into a state energy plan to push biomass and biogas to energy leadership in Wisconsin.

Wisconsin Corn-to-Ethanol Production (Biofuels in Wisconsin)

Wisconsin remains a leader in the United States in production of corn-to-ethanol ranking 7th nationally by producing 504 million gallons per year. The state ranks 8th in nameplate production capacity, so it maximizes its nine large ethanol plants capabilities. The Midwestern states overall dominate the corn-to-ethanol sector with the leading production coming from Iowa followed by Nebraska, Illinois, Minnesota, Indiana, South Dakota, Wisconsin, Ohio, Kansas and North Dakota. Only Texas breaks the Midwest state dominance by ranking 11th overall in ethanol production and they are followed again by two more Midwestern states of Michigan and Missouri. The Midwest's leadership in ethanol is aided by location along the "Corn Belt" and leading the nation in growing corn. For the short-term, the corn-to-ethanol sector is not expected to see much growth or expansion due to what is called the "blend wall" meaning they majority of the fuel is used as a 10 percent blend into petroleum gasoline sold at the pump. Minnesota has a law requiring a 20 percent blend of gasoline by 2015. That has prompted waiver requests to the Environmental Protection Agency (EPA) to allow for a national E-15 blend. In July of 2012 the first E-15 pumps were starting to open around the Midwest. The fuel is approved for vehicles built after 2001, under the new rules. The U.S. Department of Energy notes that slow growth in ethanol production is due to three factors: the blend wall, lack of vehicle and fuel pump infrastructure for E-85 blends (85 percent ethanol fuel used in what are commonly called flex-fuel vehicles), and the overall decline in gasoline consumption. Further, corn ethanol production is constrained to some degree because of the reluctance to develop pipeline infrastructure due to the water contact in the ethanol. More than 90 percent of ethanol in the U.S. is made from corn and more than 30 percent of all corn grown in the U.S. goes to ethanol production depending on the year. Above are the nine Wisconsin ethanol plants and production capacity.

In May of 2012, Wisconsin announced that its agriculture exports were up 16 percent from the previous year and ethanol exports were an important part of that increase. Wisconsin exported $75 million in ethanol making it the second largest in the country behind Texas. The state sales were primarily to Canada who purchased about 2.2 million gallons a month to meet renewable fuel mandates. The distiller's grains from ethanol production also are sold in both domestic and international markets. The distiller's grains are fed to livestock.

Biomass and Forest Management

In Wisconsin, timber is primarily harvested for pulp or paper production, and to a lesser extent saw timber—which is milled into hardwood flooring, furniture and construction lumber. Commonly utilized species include fast-growing aspen and red pine (preferred for pulp production) and oak, maple, cherry, birch and walnut for flooring, furnishings and cabinetry.

Pulp and paper harvesting often use "even-aged" management or clear-cutting, where an entire stand is cut down and hauled away to be chipped up for pulp. (Some pulp producers use selective harvests as well.) Saw timber harvesting tends to use more selective approaches in the search for high quality trees. Both approaches often use thinning to reduce competition and improve growth rates.

The main stem of the tree (the bole) is considered the most valuable for wood products and is also the most easily harvested and transported wood source for pulp. Branches, small limbs and treetops are considered waste wood or "slash," and typically left behind after a logging operation. This wood "leftover" has been promoted as an optimal source for wood biomass; however, it is difficult to gather and the process can collect soil debris that contaminates the woody fuel and reduces its combustion efficiency. In addition, the "leftover" parts of the tree (tops and limbs or leaves and stems) hold the most nutrients, and thus play a role in supporting forest fertility. Removing them may accelerate depletion of forest soils.

Currently, the majority of biomass in Wisconsin comes from forests as a byproduct of timber harvesting. Few public or industrial forests are being managed or harvested primarily for biomass. However, the state's pulp and paper production have been suppressed by the globalization of timber markets. Many forests and plantations that have been primarily managed to produce trees for regional pulp production are not currently being harvested for those purposes. This leads some to argue that the region has a surplus of wood available for biomass energy production.

Our forests are a patchwork of federal, state, local (counties, schools, etc.) and private lands—in fact, even with extensive federal and state forestlands, the majority of Wisconsin forests are privately owned. Across this fragmented landscape, the forests include isolated patches of wilderness, extensive industrial monoculture plantations, lands managed to promote particular species (such as grouse or deer), tree stands in various stages of growth and regeneration, recreational lands, family woodlots, and much in between. We depend on the forested landscapes for watershed protection, water quality regulation, oxygen production, habitat, recreation, erosion control, climate moderation, carbon sequestration, wood supplies and more. All are factors in the balance of determining whether biomass is the highest and best use of forests.

The context for biomass needs to include the broader picture of what we are managing Wisconsin forests for, which ecological and social functions we want and need them to provide, and where energy fits into that hierarchy of needs. It should also include an analysis of which forestlands are best suited to meet which needs and functions. Aging aspen plantations, for example, may provide optimal biomass capacity with minimal ecological damage. Natural forests, on the other hand, that serve as refuges for biodiversity or support clean headwaters, are the last sites we would want to consider for converting trees into energy. These analyses, and comparison of tradeoffs associated with other energy sources, will be a valuable and necessary screen to help determine biomass potential within the larger forest and landscape management strategy of the region.

Next Generation Biofuels and Cellulosic Ethanol

The future of advanced biofuels still has a fair amount of uncertainty associated with matching feedstock, conversion technology and end product. While the Midwest states, including Wisconsin, remain well positioned due to access to larger volumes of agriculture and wood feedstock, there is no guarantee that feedstock access means a project will be developed soon.

Flambeau Rivers Biofuels, Inc. (FRB) is a renewable energy company located in Park Falls looking to commercialize a renewable diesel fuel. The operation affiliated with Flambeau River Papers pulp mill wood use a wood feedstock and the biorefinery at Park Falls will process 871 dry tons of biomass per day at the site. A proprietary gasification process would convert the cellulosic material into a synthesis gas and then be catalytically converted (a Fischer-Tropsch process) to lgnocellulosic diesel and jet fuel blend, according to the company website (http://frbiofuels.com/). In 2008, the company received a U.S. Department of Energy start up award of $30 million for construction and operation of the facility. At the time of the DOE award it was projected to be a 6 MMgy project. Construction has not advanced on the original timeline proposed.

Virent Energy of Madison uses a thermo-catalytic process to make what is called a next generation fuel or a drop-in fuel. Virent's process is trademarked as BioForming which is feedstock flexible, meaning it can use a wide variety of plant sugas to make its fuel or use for other chemical products. This patented catalytic process can convert from the conventional feedstocks of sugar cane and corn starch and the cellulosic feedstocks of corn stover, grasses, sorghum and wood. The process technology is being licensed to Shell Oil for the development of a pilot plant at the Westholllow Technology Center in Houston, TX. Virent has tested the process at a smaller scale at its pilot plant in Madison. Virent also is moving into the bioplastics production process through a partnership contract with Coca-Cola to develop a 100 percent plastic bottle. So this company has the opportunity to enter the marketplace through chemical production, plastic products and fuels (both a diesel fuel and a drop fuel for aviation or other end use). This flexibility positions the company well for next steps toward commercialization. Much more information about Virent Energy technology is available at their website (http://www.virent.com/).

Throughout the Midwest other advanced biofuels projects of note include Gevo, Inc. which has announced plans for isobutanol production plant in Luverne, MN., (note: A patent dispute between Gevo Inc. and Butamax Advanced Biofuels of Wilmington Del., a joint venture of BP and DuPont, is now in court). POET energy is a large Midwest corn ethanol operation using a corn stover feedstock through enzymatic hydrolysis to make generation cellulosic ethanol at its Project Liberty facility in Iowa; and Mascoma Corporation is partnering with Valero Energy to develop a 20 million gallon cellulosic ethanol plant in Kinross, Michigan. Mascoma is also partnering with Lallemond Ethanol Technology of Milwaukee to market the first commercial application of the company's consolidated bioprocessing technology platform to produce a bioengineered drop-in substitute for conventional fermenting yeast. This product is used to transform enzyme delivery in first generation ethanol. In addition, DuPont Danisco Cellulosic Ethanol was awarded a contract for engineering and design for its proposed cellulosic ethanol plant in Nevada, Iowa. (DuPont Industrial Biosciences Group already produces cellulosic ethanol at its precommercial plant in Vonore, Tennessee.) The proposed Iowa cellulosic plant will be designed to process 1,300 tonds/day of corn cobs, leaves and stalks to produce 27.5 million gal/year of cellulosic ethanol. If the project breaks ground as proposed in late 2012 it would take about 12 to 18 months to be operational.

Whether a Wisconsin-based advanced biofuel facility using a local feedstock develops could be well into the future. Certainly, the existing Wisconsin ethanol plants are large enough for conversion or alternatively some type of bolt on use with corn stover as a feedstock could occur (the DuPont cellulosic ethanol plant in Iowa is next to an existing corn ethanol plant). Given the longer timelines to advance a commercialization of a production facility, this could not be classified as a short-term opportunity for Wisconsin and probably falls more in the mid-term to long-term opportunity category.

How fast will the advanced biofuels market of either cellulosic ethanol or so-called drop in biofuels develop in the United States? Somewhat surprisingly, the mainstream petroleum industry has now publicly stated this market will grow. Katrina Landis, CEO of British Petroleum (BP) alternative energy business line, said the company has already invested about $7 billion since 2005 into this advanced biofuels market and projects more investment. The BP corporate official said their company sees biofuels taking up to 30 percent of the gasoline fuel market by 2030 with cellulosic ethanol being the likely leading product. Projections by BP see cellulosic ethanol competing in the traditional fuels market at $80 per barrel by 2022. “This is what is driving us to invest hundreds of millions of dollars in the industry,” Landis said in a July 2012 speech to the Atlantic Council in Washington D.C. and she pointed to the BP investment in Florida cellulosic ethanol facility. The United States military is investing more and more into advanced biofuels, the University of Wisconsin engineering professor Rolf Reitz and his research team was awarded a $2 million grant to model bio-derived fuel system for the U.S. Navy. Other military awards are pending for advanced biofuels.

Baker Tilly Study:
Energy Applications from Agriculture and Cheese Production Feedstocks

In addition to the analysis performed as a part of this study, Baker Tilly Virchow Krause LLP (“Baker Tilly”) was commissioned by the State of Wisconsin to perform a comprehensive assessment of “Energy Applications from Agriculture and Cheese Production Feedstocks”. Summary lessons learned related to technology evaluations include a recognition that existing capital flowing into the waste to energy market (relative to agricultural or cheese production waste) is almost entirely applications involving conversion of biogas to heat, electricity, or both, with significant long term growth prospects seen in the biogas conversion to transportation fuel sector. Therefore, the roadmap by Baker Tilly almost exclusively focused on steps to implementation of projects utilizing these technologies. These steps include an online mapping tool, laboratory testing equipment for feedstock characterization, and a biogas project economic assessment tool.

The online mapping tool will help to identify feedstocks and critical project site factors including utility infrastructure and service territories, existing farms and dairy facilities. Laboratory testing equipment is being established at UW Oshkosh to allow feedstock providers to accurately test the respective biogas potential. Finally, this biogas potential estimate will be used as input to an economic model which will help characterize the primary financial drivers to determine if further effort should be put into developing the project. These primary drivers include the electrical and thermal generation potential, establishing capital and operating budgets as well as factoring in the use of any credits, incentives or bank debt. The combination of these three tools was learned to be critical to identifying and accurately quantifying project areas of opportunity.

From a feedstock assessment perspective, evaluations concluded that significant prospects for additional biogas potential from cheese plants and dairy farms exist; however, the current data relative to feedstocks from cheese plants is somewhat difficult to ascertain, resulting in a need to make certain assumptions on what is a very critical variable in the evaluation of a project’s viability. Additional discussion at a local level is likely needed if assessment of the specific quantities of feedstock is desired earlier in the stakeholder feedstock evaluation process.

2. Wisconsin Biomass Quality

Understanding the amount of biomass in Wisconsin only provides half the picture of the state's biomass-to-energy or fuel potential. Equally paramount is an understanding of the quality characteristics of the available biomass. Simply put, not all biomass is equal in its appropriateness for conversion technologies. This section of the paper takes a look at the various types of general biomass-to-fuel or energy conversions, potential biomass quality concerns for the conversions, and the pairing of Wisconsin biomass natural aggregation centers with likely biomass-to-energy or fuel conversions.

Bioenergy conversions

Production of biobased fuels or energy can be accomplished through biological, chemical, thermal and thermochemical pathways. Many of the conversions are in research or early development phases. Only four pathways have been widely commercialized, including the thermal processes of combustion and gasification, and the biological processes of ethanol fermentation and anaerobic digestion.

Biological conversions

Biological routes utilize enzymes from microorganisms to convert sugars through fermentation into ethanol and, less commonly, to propanol and butanol. These agents carry out the fermentation of saccharides from sugar, starch, or lignocellulosic biomass. If lignocellulosic biomass is utilized, the process must start with the hydrolysis of polysaccharide components to fermentable monomeric, reducing sugars (Kumar, 2009). A hydrolysis step is required and may consist of multiple steps to hydrolyze the biomass and break the recalcitrant material's polysaccharides into its constituent sugars, which are usually catalyzed by acids or enzymes (Alvira, 2010). Although pentose and hexose can both be fermented, most fermenting organisms are adapted for six-carbon hexoses (Chandel, 2011). Furthermore, furfural and acetic acid formed as hemicelluloses degradation products can inhibit fermentation organisms, suggesting the need to fractionate the material prior to this step (Lynd, 1999).

Thermochemical conversions

Commercial thermal conversion of biomass into energy or fuels may be categorized into two major categories: combustion and gasification. Combustion being the most developed, but also limited to heat and electricity production. Biomass combustion is a complex process that consists of consecutive chemical reactions which result in the production of heat, because the majority of these reactions are exothermic (Nussbaumer, 2003). In ideal combustion, the dry organic portion of the fuel is completely oxidized into the CO_2 and H_2O (Obernberger, 2006). Unfortunately, real biomass contains both water and inorganic chemicals that can create issues arising in one or more of the following areas: low efficiencies, hazardous air emissions, boiler deposit and corrosion problems, and ash agglomeration (Van Loo, 2008; Jenkins, 1998; Obernberger, 2004; Ryu, 2006).

The second developed thermal conversion is gasification, which may be defined as the thermal degradation of a solid fuel, such as biomass, in the absence of an external supply of an oxidizing agent (air) (Van Loo, 2008). The reader is directed to several authors for the chemistry and available reactor designs (Obernberger, 2006; Van Loo, 2008; Werther, 2000). The main products of gasification are low molecular weight gases and small amounts of tar or carbonaceous charcoal (Van Loo, 2008). Combustion of the formed gases, in a boiler or engine, can be used to produce heat and electricity. Alternatively these gases, primarily hydrogen or methane, can be used as the starting material to produce liquid fuels or chemicals (Huber, 2009).

For thermal conversions biomass competes directly with coal, which has the largest greenhouse gas and hazardous air pollutant emissions of all the fossil fuels. Coal is also inexpensive, currently around $60/ton in Wisconsin for a bituminous grade (EIA, 2010). Coal's low cost and existing logistical infrastructure decreases the incentives to use biomass over coal. However, biomass use in thermal conversions has advantages in regulatory requirements as it has been shown to reduce Hg, SO_x, and NO_x emissions (Van Loo, 2008; Obernberger, 2004; Permchart, 2004; Munir, 2010). Additionally, these air pollution gains may be seen through co-firing biomass and coal in combustion operations, allowing biomass introduction without a complete boiler system retrofit (Nussbaumer, 2003).

There are several important logistical issues that need to be contemplated in order to consider biomass as an alternative to coal. Biomass materials are often harvested during a limited harvesting season; therefore, they need to be stored and utilized at processing facilities year-round (Kaliyan, 2006). In their original form, biomass materials have high moisture content, irregular shape and size, and low bulk density. Biomass materials are very difficult to handle, transport, store and utilize for energy production (Kaliyan, 2008). Additionally, there is variability in the feedstock from year-to-year, and even day-to-day depending on harvesting conditions. These logistical issues can be partially addressed through drying, mixing and densification of the biomass materials into pellets or briquettes. By drying and mixing the biomass to create a more formulated homogenous solid fuel much of the source variability can be removed. Densification can increase the bulk density of unprocessed or baled biomass material from 40-200 kg/m^3 to a final bulk density of 600-800 kg/m^3 through compaction that removes inter- and intra-particle voids (Balatinecsz, 1983). Additionally, the densified biomass can be formed into a consistent shape that is easier to handle, store and feed into processing equipment (Kaliyan, 2006; Kaliyan, 2008).

Biomass quality impact to energy or fuel conversions

Fuel characteristics affecting thermal conversion operations

The primary properties of biomass solid fuel that affect operations in thermal conversions are moisture, volatiles and fixed carbon, particle size and energy density (Van Loo, 2008; Rhen, 2007). Moisture content reduces the maximum possible combustion temperature leading to an increased residence time in the combustion chamber. The necessary increased residence time in combustion chambers leads to a need for larger combustion chambers. Increased moisture content also reduces the Lower Heating Value (LHV) of the fuel reducing the efficiencies (Van Loo, 2008; Demirbas, 2007; Porteiro, 2010; Boyle, 2004). Volatiles in biomass form a higher content than they do in coal, and char forms a lower content in biomass than in coal. The high volatile and low fixed carbon content makes biomass a highly reactive fuel which makes biomass burnout faster than coal.

Boiler design should ensure that the volatile content undergoes complete combustion to improve efficiency and reduce incomplete combustion related emissions. The optimum airflow levels for biomass may be different to that of coal due to differing volatile and char contents and the speed at which they burn. Energy density determines the combustion chamber volume for a designed heat or power output of the fuel (Van Loo, 2008; Boyle, 2004). Particle size can affect handling systems and residence time of fuel. Smaller particles need lower residence times because there is a larger active surface area that influences the reactivity of the fuel. Handling systems for fuel are determined on their fuel particle size (Van Loo, 2008).

Biomass combustion can raise operational issues such as ash agglomeration, deposit and corrosion. Ash agglomeration can occur when ash sinters or melts to the grate due to low ash sintering and melting temperatures determined by the elemental composition of the ash. Deposits and corrosion can occur due to fly-ash sintering or other aerosols and emissions related to the elemental composition of the ash and unburned biomass fuel. Deposits and corrosion degrade heat transfer surfaces leading to lower efficiencies and shorten the life of those surfaces increasing capital costs. Agglomeration on feed grates can negatively affect the fuel feeding systems (Van Loo, 2008).

Chlorine corrosion can be severe in biomass boilers and gasifiers that reach high temperatures. Severe corrosion can occur above steam temperatures of 450°C (Michelsen, 1998; Nielsen, 2000). Potassium (K) and sodium (Na) can combine with chlorine to form alkali chlorides which deposit on heat exchanger surfaces lowering efficiencies and corroding the surface. Sulfur may also react with K and Na to form alkali sulfates which also lowers heat transfer and is corrosive, although less severe than chlorine related corrosion (Van Loo, 2008; Michelsen, 1998; Nielsen, 2000; Riedl, 1999).

Fuel characteristics affecting thermal conversions air emissions

Biomass, like other solid fuels, can contain elements such as sulfur, nitrogen, chlorine, and heavy metals, that can create hazardous air pollutants (HAPs) during combustion (Van Loo, 2008). Thermally processing biomass with high levels of these elements can lead to sulfur oxides (SO_x), nitrogen oxides (NO_x), hydrogen chloride (HCl), dioxin and furans, and heavy metal emissions (Van Loo, 2008; See EPA Pollutants). Additionally, biomass that has high levels of ash or is not completely combusted can lead to increased particulate emissions. These emissions have been found by the EPA to have a negative impact on human health and the environment, with effects including smog, particulate formation in the atmosphere, acid rain and carcinogens.

Like other solid fuels, the HAPs from thermally processing biomass can reduce air quality if no mitigation steps are taken. The emissions can be greatly reduced with proper practices and controls. Common combustion processes to minimize emissions include insuring adequate mixing of air and fuel, staged combustion, sufficient oxygen availabilty, and high combustion temperatures and residence times (Van Loo, 2008; Boyle, 2004). Additionally, air emission control equipment like filters, wet scrubbers, alkali injection, and activated carbon can be used. However, beyond these practices, achieving low HAPs emissions may require contaminants to be minimized in the incoming solid fuel.

Biomass quality for biological conversions

Biological routes utilize enzymes from microorganisms to convert sugars through fermentation to ethanol, propanol or butanol for liquid fuels and methane in anaeribc digestion. These enzymes can carry out the fermentation of saccharides from sugar, starch, or lignocelluloses biomass. If lignocellulosic biomass is utilized, the process must start with the hydrolysis of polysaccharide components to fermentable monomeric, reducing sugars (Kumar, 2009). A pre-treatment step is typically required before hydrolysis and is employed to break the recalcitrant biomass material's polysaccharides to its constituent sugars, which is usually catalyzed by acids or enzymes (Alvira, 2010; Jergensen, 2007). Care must be taken during pre-treatment and hydrolysis to insure degradation products which can inhibit fermentation organisms are not formed.

Biomass quality for biological conversion is more complicated than thermal conversion as it involves accessibility of enzymes into cell walls, reactivity of polysaccharides, inhibitory compounds present and formed. Most research has focused on pre-treatments to reduce recalcitrance, but in general the primary biomass qualities that impact biological conversions are the relative amounts of pentosan, hexosan, and lignin. For best conversion biomass should have a high hexosan and low lignin content, which is why most herbaceous material are more easily degraded by micro-organisms than woody material.

Biomass Properties Survey

Wisconsin is fortunate to have a wide variety of biomass materials with land and water resources to grow more. Unfortunately, that variety also creates feedstocks with a wide range of chemical and physical properties that affect processing and emissions. Little data has been published that compiles the composition data of biomass and its suitability for combustion. A project was funded in 2010-2011 by Focus on Energy to create a survey of the composition of Wisconsin's bioenergy feedstocks in regards to combustion operations and emissions. This data will be summarized here with a full report available at Focus on Energy.

Materials and Methods

Thirty-five biomass samples were collected from around Wisconsin and potential suppliers for the planned Charter Street combined heat and power plant at the University of Wisconsin–Madison. These materials represent a fuel survey representing what Wisconsin biomass fuel suppliers thought to be a quality fuel for combustion. A listing of the materials collected by category is shown in Table 10 with qualitative descriptions. The fuels were analyzed for desirability based on operations and emissions characteristics. Although the fuel suppliers could not be disclosed due to confidential procurement practices through the Charter Street Heating Plant project, a map with locations for the fuels was produced and is shown in Figure 15. The samples were collected, air dried and cold stored (4°C) prior to testing. Each sample was tested for all characteristics, except mineral ash analysis which was performed only on select samples due to resource considerations. Materials were tested either by the commercial testing facility Twin Ports Testing in Superior, WI or our biomass characterization lab in Madison, WI following the same ASTM protocols shown in Table 11.

Table 10. Biomass sample descriptions

Sample #	Category	Description
1	Woody	Industrial Pellet - 80% Hardwood (debarked), 20% recycled ag. Plastic
2	Woody	Industrial Pellet 90% Hardwood (debarked), 10% recycled ag. Plastic
3	Woody	Premium Wood Pellet Fuel
4	Woody	Premium Wood Pellet Fuel
5	Woody	Premium Wood Pellet Fuel
6	Woody	Wood chips - Mixed softwoods
7	Woody	Wood chips - Mixed hardwoods
8	Woody	Hardwood hog fuel - primarily bark waste
9	Woody	Wood chips - Mixed hardwoods
10	Woody	Wood - Locust (whole tree)
11	Woody	Wood - Pine (whole tree - high amount of needles)
12	Woody	Wood - Maple (whole tree)
13	Woody	Mixed hardwood (whole tree)
14	Woody	Mixed softwood (red & white pine)
15	Woody	Municipal Tree Trimmings
16	Woody	Woody Biomass, Whole tree
17	Herbaceous	Switchgrass Pellets
18	Herbaceous	Switchgrass Pellets
19	Herbaceous	Switchgrass
20	Herbaceous	Switchgrass
21	Herbaceous	Briquetted corn stover
22	Herbaceous	Corn stover
23	Herbaceous	Corn stover
24	Herbaceous	Ditch grass bale 1
25	Herbaceous	Ditch grass bale 2
26	Herbaceous	Ditch grass bale 3
27	Herbaceous	Big Bluestem Pellets
28	Herbaceous	Miscanthus stalks
29	Herbaceous	Miscanthus stalks
30	Residuals	Industrial pellet made from paper mill sludge, waste paper, film waste
31	Residuals	Distiller's Grains - Ethanol Plant A
32	Residuals	Distiller's Grains - Ethanol Plant B
33	Residuals	Manure briquette - Dried & densified manure, bedding, and sawdust
34	Residuals	Manure briquette - Dried & densified manure, bedding, and sawdust
35	Residuals	Manure & sawdust bedding

Table 11. Characterization test methods

Test	Standard Method
Moisture	ASTM E871
Ash	ASTM D1102
Heating Value	ASTM E711
Elemental analysis, C, H, N, O	ASTM D5373
Elemental analysis S	ASTM D4239
Elemental analysis Cl	ASTM D6721
Elemental analysis Hg	ASTM D6722
Mineral Ash Analysis	ASTM D3682

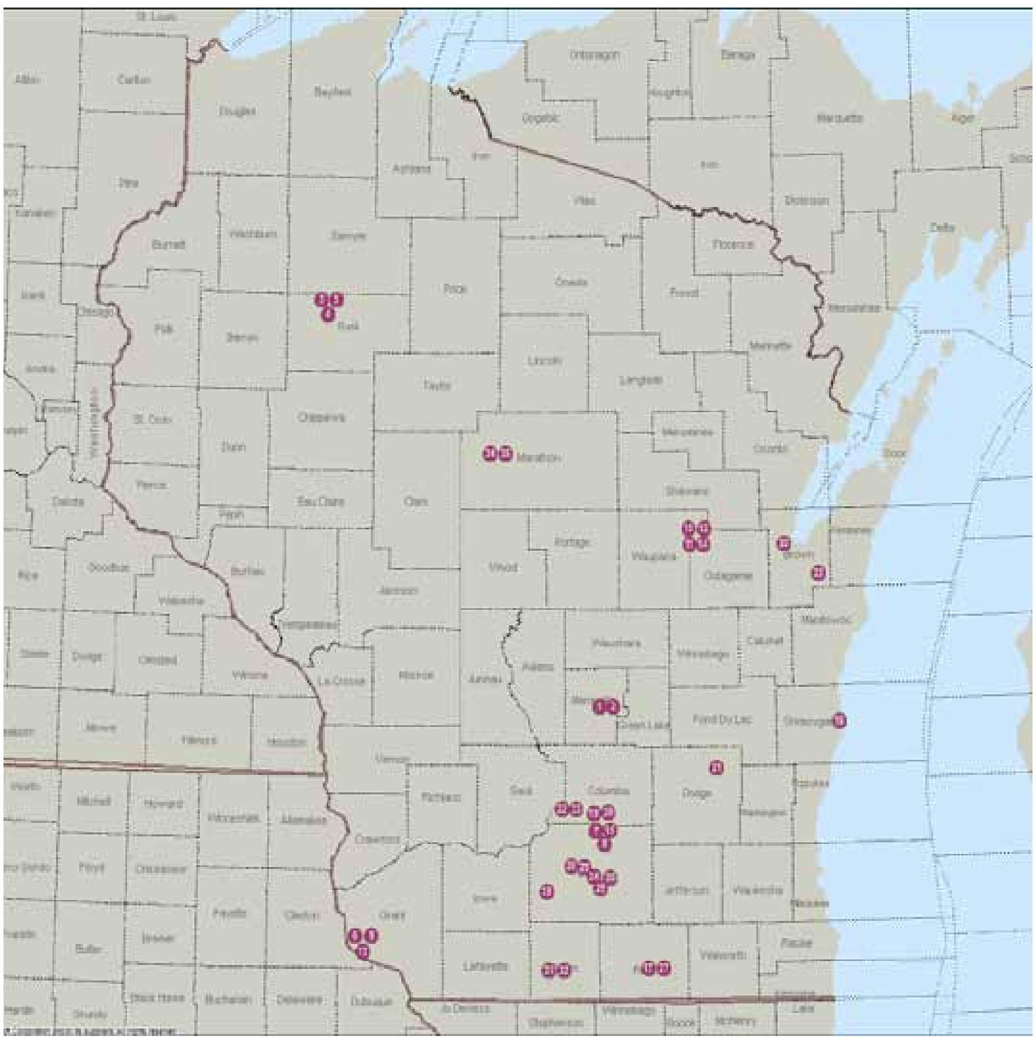


Figure 15. Location of source of 35 biomass fuel samples

Quality Results and Discussion – Thermal Conversion

Table 12. Summary of Biomass Characterization for Thermal Conversion

Fuel Characteristic (Units)	Upper limit	Woody	Herbaceous	Other[a]
Moisture (% wt wb)	<50%	2.74% - 49.94%	2.45% - 18.32%	6.96% - 28.62%
LHV (Btu/lb)	N/A	3200 - 8946	5926 - 6923	5019 - 8145
Ash (% wt db)	<10%	0.63% - 9.33%	2.66% - 10.83%	5.21% - 19.38%
N (ppm db)	<25000	200 - 10200	3700 - 15500	2500 - 42700
S (ppm db)	<1000	110 - 670	370 - 3130	1400 - 8590
Cl (ppm db)	<1000	19 - 617	293 - 6516	786 - 12550
Hg (ppm db)	<0.020	<0.001 - 0.024	<0.001 - 0.017	<0.001 - 0.027
Fouling Index (lb alkali/MMBtu)	<0.80	0.099 - 1.471	0.227 - 1.919	0.314 - 1.482

[a]Other includes DDG, manure, and plastic/sludge samples

Woody fuel represents the feedstock with the most favorable composition for a combustion application with the least amount of complications indicated from the chemical compositions. Due to the nitrogen content in wood, there is a need for staged combustion. High moisture and ash content are problems arising with woody fuel that can be controlled through proper harvesting and pre-processing (drying) of the material to minimize moisture and ash. Operational modification, such as particulate matter filters and periodic cleaning of equipment, can be employed to reduce high ash content related operational and emission problems. Bark content can sporadically create issues with mercury, which appear to be problematic for the proposed MACT major source new boiler standards. The contamination appears to be site specific and is likely due to contamination from nearby coal combustion or other industrial sources.

The next most desirable fuel would be paper mill waste or herbaceous fuels, and would depend on the design of the combustion plant and control technologies. Paper waste was high in sulfur, had detectable mercury levels, and had high ash content. Due to herbaceous fuel's nitrogen content, staged combustion would be required. Herbaceous fuels were also high in sulfur content, and had potential for high ash content and fouling indices. Both fuels had levels of chlorine that indicate potential corrosion and hydrogen chloride emission problems. Since staged combustion is the typical technology for medium to large-scale projects, herbaceous fuel's low mercury content makes it more desirable than paper waste.

Residuals fuels are high in variability and the results show that they should be reviewed on a case-by-case basis. Comparing similar residuals of manure briquettes with manure and sawdust samples highlights the significant variation in their elemental compositions of nitrogen, sulfur, and chlorine. The manure briquettes even showed a significant difference in chlorine content between the two samples. All residuals except the paper mill waste had significant enough levels of nitrogen to require staged combustion. The DDG's had very high levels of nitrogen that would require more aggressive SCR or SNCR emission abatement equipment. The DDG's had levels of sulfur and chlorine that require scrubbing or dry sorption equipment and would require cleaning to prevent corrosion. As a result, DDG's are likely more valuable as an animal feed rather than a fuel. Manure briquettes had a range of sulfur and chlorine values that indicate dry sorption or scrubbing equipment would be necessary to reduce sulfur oxides and hydrogen chloride emissions, and proper cleaning would be required to protect the boiler from chlorine and sulfur related corrosion. The manure and sawdust had levels of nitrogen near the limit requiring SCR or SNCR equipment and very high levels of chlorine requiring more aggressive activated carbon sorption equipment to reduce dioxin, furan and hydrogen chloride emissions.

Assuming that emission reduction equipment and corrosion increase the cost of biomass heat and power production, woody fuel is the most favorable fuel based on composition in biomass only systems because there would be less need for emissions reduction equipment. Herbaceous fuels that don't have elevated chlorine contents are the second most desirable fuel creating some sulfur and chlorine related emissions and operational concerns. Paper waste is the next most desirable fuel with need for sulfur and mercury emissions reduction equipment and corrosion prevention measures. DDGs and manure based residuals present a need for more aggressive emissions reduction equipment.

Quality Results and Discussion – Biological Conversion

Table 13. Summary of Biomass Characterization for Biological Conversion

Fuel Characteristic (Units)	Woody	Herbaceous	Other[a]
Moisture (% wt wb)	2.74% - 49.94%	2.45% - 18.32%	6.96% - 28.62%
Ash (% wt db)	0.63% - 9.33%	2.66% - 10.83%	5.21% - 19.38%
Crude Protein (%)	0.13% - 6.38%	2.31% - 9.69%	1.56% - 26.69%
Hexosan (wt % d.b.)	40.4% - 53.8%	35.3% - 49.8%	15.1% - 36.2%
Pentosan (wt % d.b.)	7.1% - 16.2%	17.1% - 28.2%	3.3% - 22.8%
Lignin & other acid insolubles (wt. % d.b.)	19.5% - 28.3%	12.4% - 19.1%	9.4% - 39.1%b

[a]Other includes DDG, manure, and plastic/sludge samples

[b]Samples with plastic were not measured for lignin

Summary – Recommended conversion by biomass type

Wisconsin's biomass represents an important resource for reaching renewable energy goals, but there can be high variability in the quality characteristics of feedstocks due to inherent differences between species or harvesting methods that need to be properly accounted for in the design and operation of bioenergy projects. Linking the quality parameters to conversion technologies, the following generalized recommendations can be made:

- Woody materials are best utilized in thermal conversions of either combustion or gasification. Whole tree chipping can cause issues with high moisture, ash and fouling. Improved harvesting practices should be investigated.
- Herbaceous materials are best used for biological conversions. Their high carbohydrate levels (pentosan and hexosan) along with low lignin content make the materials less recalcitrant. With higher ranges

of chlorine and sulfur, thermal conversions of these materials will experience higher air pollutant and corrosion issues.

- Corn stover has the most opportunity based on volume, followed by grasses grown on conservation land or fallow pastures. Roadside grass, although plentiful, had enough contaminants that even biological conversion is questionable.
- Paper waste with plastic was designed for thermal applications and performs well in this conversion.
- Manure samples with their high ranges of ash, chlorine and sulfur should be used for biological conversion, presumably anaerobic digestion as the industry has already evolved to this platform. Thermal conversion of manure in either gasification or combustion is not advisable.
- Dried distiller grains have very high nitrogen, due to their proteins, and should be considered for biological conversion only.

Based on this survey the following opportunities for Wisconsin are evident to this researcher.

- Dairy manure represents the "lowest hanging fruit" for biomass. It has the highest mass (~4 million dry tons) and a conversion technology in anaerobic digestion (ADs) that is fairly well developed. Additional utilization of manure in ADs will offer many ecological benefits, primarily in nutrient management and watershed quality. The natural location of the ADs will be on large confined animal feed operations (CAFOs), although with policy and technical innovation one can envision employing ADs on smaller farms throughout Wisconsin.
- Corn stover represents the next underutilized biomass opportunity for Wisconsin. Approximately 2.5 million dry tons can be harvested annually, which is expected to grow as corn breeding continues to improve plant yields. Although cellulosic ethanol is a natural avenue to be explored with corn stover, additional conversion technologies should be sought, especially since cellulosic ethanol has not advanced far enough to be economically feasible. Coupling corn stover with dairy manure in anaerobic digestion may enable energy and economic improvements to both biomass sources, but additional innovation in this area is needed.
- Wood residuals also represent an underutilized biomass source that should be explored for use. These residual's quality suggest they would best be used in a thermal conversion such as combustion or gasification. With approximately 1.5 million dry tons, this resource could be utilized in the state, but additional policy or technical innovation may be required to affordably remove these residuals and improve logistics.

3. Price Dynamics of Wisconsin Biomass

Historical trends in price for bioenergy crops

Most bioenergy crops do not have much of a history to understand price impacts over time. Very few bioenergy crops outside of corn and woody biomass are grown today in any wide-scale commercial use. Still, some projections and analysis can be done. In the biomass quantity section of this paper potential volumes were examined based on three prices of $40/ton (d.b.), $60/ton (d.b.), and $80/ton (d.b.) contained in the Billion Ton update study. There are some important factors to consider including it will take time for growers to learn the best agronomic practices and research over time will allow breeders to develop more varieties to improve yields. Likewise, many of the crops are perennials and may take 2-3 year to establish fields ready for harvest. Some analysis done at Michigan State University as a part of the Great Lakes Bioenergy Research Center took a look at the question of profitability for biofuel crops compared to corn. Not too surprisingly corn won on price.

Evaluated in the study were switchgrass, a grass mix, a prairie grass, miscanthus (2 scenarios with an expensive and cheaper rhizome), and hybrid poplar all compared again cost. The study evaluated prices from 2006-2009 period and then converted costs over a 10-year period. Three price scenarios were evaluated for establishment costs ($30/ton, $60/ton, $90/ton) and none of the energy crops could meet annual expenses at $30/ton. At the $60/ton level the miscanthus with the cheaper rhizome was able to exceed the break-even level. It was not until the $90 per ton level that all biofuels crops in the study could break even with the exception of miscanthus with the more expensive rhizome. It is worth pointing out that the modeled price of corn from 2006-2009 is $2.50/bu to $4.50/bu compared some recent spikes up to $7/bu. That was the 10-year forward price projection from the USDA at the time of the study (James, 2009).

The study was also useful because it also modeled a subsidy along the lines of the Federal Biomass Crop Assistance Program (BCAP). The BCAP program has three components: a 75 percent reimbursement for certain establishment costs, an annual incentive payment and a matching payment of up to $45 per dry ton for a maximum two year for harvest, storage and transportation costs to a biofuel refinery. These subsidy payments only helped the high costs to establish crops of the miscanthus with the more expense rhizome and the native prairie establishment. For miscanthus, breakeven prices are $200 at current costs, but only $45 if rhizome costs fall to what they sell for in Europe. The breakeven prices would be $110 to $130 for poplar, switchgrass, and mixed grasses in the model scenario. More study is needed in this area because assumptions are important. For example, continuous corn is grown primarily on the best lands (flat, fertile soils). Potentially, energy crops could be grown on marginal lands (although current establish costs remain high). Also, corn has genetic breeds for high yield after years of crop research. It is known that years of growing continuous corn has produced environmental damage and the other crops could enhance eco-system benefits. Still, these externalities are not yet figured into cost. Therefore, the most economical biomass feedstock under this scenario was taking the corn stover from continuous corn (James, 2010).

Switchgrass for Wisconsin farm use

A recently published Focus on Energy-funded study, "Wisconsin Farm Biomass Production and the Emerging Carbon Economy", took a closer look at switchgrass opportunities in Wisconsin (Barford et al., 2012). It validates the challenges with high production prices, and also illuminates some issues of sustainable management of energy crops. This study looked at switchgrass production for both heat and power on Wisconsin farms. Among the findings is that switchgrass yields may vary widely across the state – from 3.5 Mg/ha to 8.7 Mg/ha – which influences how much financial benefit a farm may realize. In the study, the state median production cost of switchgrass was $74.21/Mg, or $4.28/MMBtu. The biggest costs were in the establishment of the crop. Farm size also created some variability, with large farms seeing more benefit. Income opportunities also depended on the demand for bio-heat and power on the farm. For example, if the farm had a greenhouse, large heated barn or higher than average grain drying needs, growing switchgrass for heat and power on-site was more likely to be profitable. Generally, switchgrass production did not seem economically viable unless yields improve, other establishment or production costs decrease, or coal and natural gas prices significantly increase. One exception to this is offsetting propane use with switchgrass-based heat on-farm, which is profitable at current prices. The conclusions were that today switchgrass production and on-farm use could work at some locations, but should be a tactical decision examined closely by the landowner. The best regions for economic outcomes for switchgrass were central and southern Wisconsin counties – consistent with other findings in this report.

Corn, Soybean and Hay Prices: 2008-2012

Agriculture commodity prices do impact bioenergy production costs and when combined with supply and demand of gasoline, and the prices of gasoline, it does impact the corn-to-ethanol industry. The Midwest as a region is hit especially hard since both the majority of corn ethanol plants are located in the region as well as most of the corn is grown in the Midwest. Recent high corn prices and decreased demand for gasoline because people are driving less have impacted the corn-to-ethanol industry to the point that about five plants in Kansas were idled for a time, as were a couple of plants in Nebraska and Indiana. Overall U.S. stocks of ethanol reach a record of 23 million barrels in March 2012, hence the supply and demand curve impact hurting producers. Overall production in 2011 was 18 million barrels of ethanol from corn. Most of the corn ethanol sold for passenger vehicles in the U.S. goes to blending, 10 percent ethanol and 90 percent gas. Corn planted in the U.S. is close to record levels, with 96.4 million acres planted this spring, although the USDA is adjusting its estimates and there is concern about spring and summer drought conditions impact harvest and yield of corn in the Midwest. Wisconsin corn planted in 2011 was higher that 2010, according to the National Agricultural Statistics Service (NASS), Wisconsin office. There is no measureable tracking of switchgrass or any other energy crop by the USDA, NASS agricultural survey data, therefore no trend analysis is available.

The next section of this report takes a much closer look at the price dynamics of woody biomass markets. This analysis quantifies the potential impact of biofuels development on the pulpwood markets in Wisconsin by accounting for the availability of regional forest residues, demand of the state Renewable Portfolio Standard (RPS) mandate, and the slack pulpwood supply induced by the recent economic recession. Given the limited amount of regional forest residues, demand for primary forest resources over 1.2 million dry tons will likely spillover into the local pulpwood market and have an impact on regional pulpwood prices.

Table 14. Agricultural commodity prices from Spring 2008-2012.

	Corn Price (per bushel)	Soybean Price (per bushel)	Alfalfa Hay Price (per baled ton)
Spring 2008	$3.89	$9.80	$113
Spring 2009	$3.57	$9.62	$106
Spring 2010	$5.35	$11.40	$107
Spring 2011	$6.47	$12.60	$100
Spring 2012	$6.00	$13.40	$135

Source: Wisconsin Crop Review

Photo by: WBI staff

Price Dynamics in Wisconsin Woody Biomass Markets

Concerns about climate change and national security have driven efforts to reduce greenhouse gas emissions and the United States' reliance on imported fossil fuels. Developing sustainable energy sources, including primary forest products, has begun to receive increased attention. In recent years, there has been an exposition of state and federal energy policy changes to encourage production and consumption of renewable energy sources. For example, the Renewable Portfolio Standard (RPS), which mandates that a minimum portion of electricity be generated from renewable energy sources like wind, solar, biomass and geothermal energy (Lyon, 2010). The RPS has been enacted by many states with state-specific percentage targets and timelines. Wisconsin established a statewide target of 10 percent by 2015. Those policies are expected to have a significant impact on both market supply and demand of forest resources. As the number one paper making state in the nation, and the leading producer of lumber and other wood products, it is meaningful to investigate current trends of forest product markets and analyze the price impact of biofuel and bioenergy development in Wisconsin.

Forest residues are at the top of the list for potential biomass materials that can be employed for the production of heat, bio-based materials and advanced biofuels because of their relatively greater availability and lower economic costs. The recently published update to the Billion Ton Study (BTS) by the Department of Energy (DOE) makes an effort to qualify the forest residues' availability at county levels within individual states. The potential development of biofuel and bioenergy industries, coupled with heavily promoted renewable energy resources, including primary forest resources, could provide profitable market opportunities for producers, but will intensify the competition for raw feedstock materials impacting traditional consumers and wood-using industries (Sedjo, 2010). The pulpwood market is a good example. Exceeding the limited amount of local forest residues, high market prices resulting from biofuel and bioenergy development will generate spillover feedstock demand in the integrated forest product markets including pulpwood. In the long run, continuously evolving price signals will influence and change the structure of the U.S. industrial wood sector (Sedjo, 2010).

An increasing number of studies pay attention to forest biomass supply and its interactions with potential bioenergy production. For example, Galik, Abt, and Wu (2008) investigate the potential supply of woody biomass for regional bioenergy production and summarize this information into supply curves. While a significant amount of forest residues are available in the study regions, exceeding the residues supply could induce dramatic price spikes in other raw materials. Kong, Rönnqvist, and Frisk (2011) developed an integrated model for all raw forest resources including sawlogs, pulpwood and forest residues. However, their focus was on minimizing the total cost for wood procurement and distribution processes. Several recent studies investigated issues and opportunities associated with forest product markets in the development of emerging renewable energy industries (BioBusiness, 2012; Dovetail, 2011).

A related line of research developed an econometric model for the supply and demand of pulpwood market. Polyakov, Teeter, and Jackson (2005) conducted an empirical analysis of factors influencing pulpwood supply and demand in Alabama. Adams (1975) considered models for pulpwood harvest, consumption, price and inventory patterns in Wisconsin and the Great Lakes states. Our study applies a similar empirical method to the pulpwood market in Wisconsin.

In the study, we developed an integrated analytical framework for the primary forest product markets including sawlogs, pulpwood and forest residues. The supply of regional forest residues is quantified using the BTS/DOE database. After accounting for the demand of forest residues needed to satisfy the state mandated RPS and the slack pulpwood supply due to the recent economic recession, we evaluated the potential impact of biofuel and bioenergy development on the pulpwood market in Wisconsin. Given the limited amount of regional forest residues, demand for primary forest resources over 1.2 million dry tons will likely spillover into the local pulpwood market and have a significant price impact. The effects could be strengthened if local pulp and paper industries experience an important expansion at the same time. The impact on pulpwood markets is investigated in an econometric supply and demand system. To our knowledge, this is the first attempt to quantitatively analyze the spillover demand of high-value primary forest resources generated from biofuel and bioenergy development.

Background

In this study, we focus on the primary forest products – mainly the industrial roundwood products. Sawlogs and pulpwood are two major roundwood products we considered.[1] According to the primary wood-using mill survey conducted by the Wisconsin Department of Natural Resources, pulpwood and sawlogs accounted for about 71 percent and 25 percent of total industrial roundwood production in 2008 (NRS/USDA, 2012). Another distinct feature of roundwood markets is the market localness. Restricted largely by transportation cost, the majority of primary forest products are consumed close to the production sites. In 2008, 82 percent of locally produced roundwood was consumed in Wisconsin and the rest went to neighboring states, Minnesota and Michigan. Consequently, the related trade is limited, which justifies the ignorance of inter-regional trade in our model.

Sawlogs, pulpwood and biomass residues represent three different types of primary forest resources and are produced for different final uses. Sawlogs are on top of the forest product value chain having a larger diameter and thus higher economic value. Pulpwood is better suited for pulp and paper mills, and is typically associated with relatively lower market value. The associated markets for the three products are separated with large price gaps. For example, the average delivered prices (averaged over selected species) for sawlogs and pulpwood were $99.20 and $44.40 per dry ton in Wisconsin from 1996-2011. However, all three markets are integrated, especially the pulpwood and residues markets. Typically we assume forest residues are the first to be employed to satisfy biofuel and bioenergy demand given its relatively low economic costs. The current market demand for forest residues mainly comes from the need to satisfy the RPS mandated in the state's legislation. Among the mentioned renewable energy sources, use of wood/wood waste was about 1.0-1.3 percent in 2003-2009 in Wisconsin, which is equivalent to approximately 203,000 tons of forest residues (EIA/DOE, 2011).[2] Under certain circumstances, when the biofuel and bioenergy demand of forest residues exceeds the amount that can be economically extracted and provided in a local market, demand will be spilled over into the pulpwood market in addition to existing industrial demand. Consequently the development of biofuel and bioenergy industries could potentially impact the pulpwood market through spillover demand, pushing up pulpwood prices and crowding out traditional pulpwood consumers.

Analytical framework

Figure 16 presents the analytical framework we apply in this study.[3] In Panel A there are three separate supply curves for forest residues, pulpwood, and sawlogs, each of which intersects with the corresponding demand curve for the individual market. As discussed above, the vertical price gap between sawlogs and pulpwood is much larger than that between residue and pulpwood markets. Current demand for forest residues comes mainly from the RPS, and there is no overlap between pulpwood and residues as the pulpwood is the production input only for the traditional pulp and paper industry.

Note that the limit of economically available forest residues is indicated by $\overline{Q}$. Increasing demand of residues for potential biofuel and bioenergy feedstocks likely exceeds the limit and will spill over into the pulpwood market (B to B'), which is the scenario that we illustrate in Panel B of Figure 16. Note that represents the spillover demand for pulpwood. One more complication we introduce into the framework is the dynamics of pulp and paper industrial demand for pulpwood, i.e., potential expansion (D to D') or contraction (D' to D") of pulp and paper industry and corresponding changes in pulpwood demand. The overlaps between residues and pulpwood markets resulting from the development of biofuel and bioenergy sectors, together with an expanding pulp and paper industry, will generate significant price impact on the pulpwood market.

1 By the transformation process from the raw material into the intermediate and end products, detailed product groups can be defined. For example, Raunikar et al. (2010) classified forest products into 14 groups for primary products (fuelwood, industrial roundwood, other industrial roundwood, other fiber pulp, and wastepaper), intermediate products (mechanical wood pulp and chemical/semi-chemical wood pulp), and end products (fuelwood, other industrial roundwood, sawnwood, veneer/plywood, particleboard, fiberboard, newsprint, printing and writing paper, and other paper and paperboard).

2 There are other sources of wood and wood wastes that are currently used for renewable electricity generation. For simplification, we don't consider them in this study and further assume here that: (i) the portion of all RPS met by biomass energy demand are all satisfied by forest residues only, and (ii) the mandatory RPS percentage from forest residues will stay as 1.3 percent as in 2009 for the short run (2011-2014) and will increase to 2.0 percent in the long-run (2015).

3 The supply and demand curves are simplified as linear only for illustration. To be accurate, the price and quantities demanded and supplied should all be in log form.

The Economic Model

Suppose there are I sub-regions or markets indexed by $i = 1, 2, ..., I$ in Wisconsin. For each region/market i, let $p_{i,t}$ denote the delivered pulpwood price at year t, and $q_{i,t}$ denote the corresponding quantity of transacted product in the same time period. $q_{i,t}$ is distinguished into $q_{i,t}^{S}$ and $q_{i,t}^{D}$ denoting quantity supplied and demanded, respectively.

The supply function at region i is assumed to follow the constant elasticity function:

$$q_{i,t}^{S} = A_i^S \cdot \left(p_{i,t}\right)^{\beta_i^S} \cdot \left(q_{i,t-1}^{S}\right)^{\gamma_i} \cdot \varepsilon_{i,t}^{S} \qquad \textbf{(1)}$$

where A_i^S is a constant term, $q_{i,t-1}^{S}$ is the lagged quantity supplied in the period $t-1$, and ε_i^S is an observable error disturbance for each product in the region. β_i^S and γ_i are parameters to be estimated, and they imply supply elasticities with respect to own price and production in the previous period, respectively. Equation (1) can be rewritten as the log-linear supply model by taking logarithms at both sides of Equation (1) as:

$$\ln q_{i,t}^{S} = \ln A_i^S + \beta_i^S \cdot \ln p_{i,t} + \gamma_i \cdot \ln q_{i,t-1}^{S} + \ln \varepsilon_{i,t}^{S} \qquad \textbf{(2)}$$

Demand function for each product in an individual region is modeled similarly as the constant elasticity demand function, and is expressed as:

$$q_{i,t}^{D} = A_i^D \cdot \left(p_{i,t}\right)^{\beta_i^D} \cdot \left(C_{i,t}\right)^{\delta_i} \cdot \varepsilon_{i,t}^{D} \qquad \textbf{(3)}$$

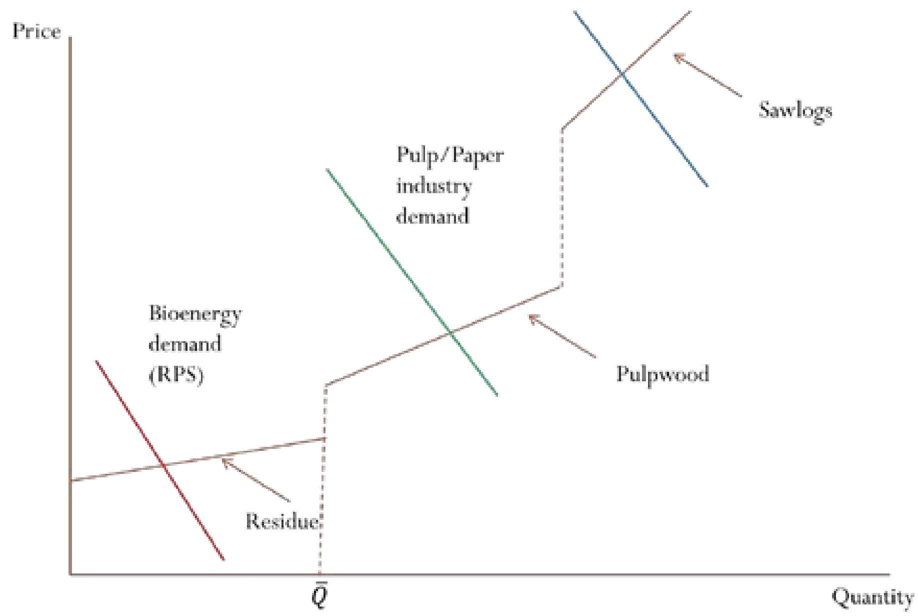
where A_i^D and ε_i^D are constant terms, and, respectively, region- and product- specific error disturbances. $C_{i,t}$ is the pulp mill production capacity representing pulpwood demand from the pulp and paper industry in each region. Note that in the latter empirical estimation, the variable of pulp mill capacity functions as the so-called demand shifted in order to distinguish the quantity supplied and demanded, and identify the coefficients in the supply and demand functions properly. The log-linear form for Equation (3) is

$$\ln q_{i,t}^{D} = \ln A_i^D + \beta_i^D \cdot \ln p_{i,t} + \delta_i \cdot \ln C_{i,t} + \ln \varepsilon_{i,t}^{D} \qquad \textbf{(4)}$$

Primary forest product markets are local and thus assumed to clear at each region, which means that each transaction $\left(p_i, q_i\right)$ is assumed to be an equilibrium outcome. In other words, the price p_i operates to equate the supply and the demand for each regional market. Therefore the market clearing condition implies that:

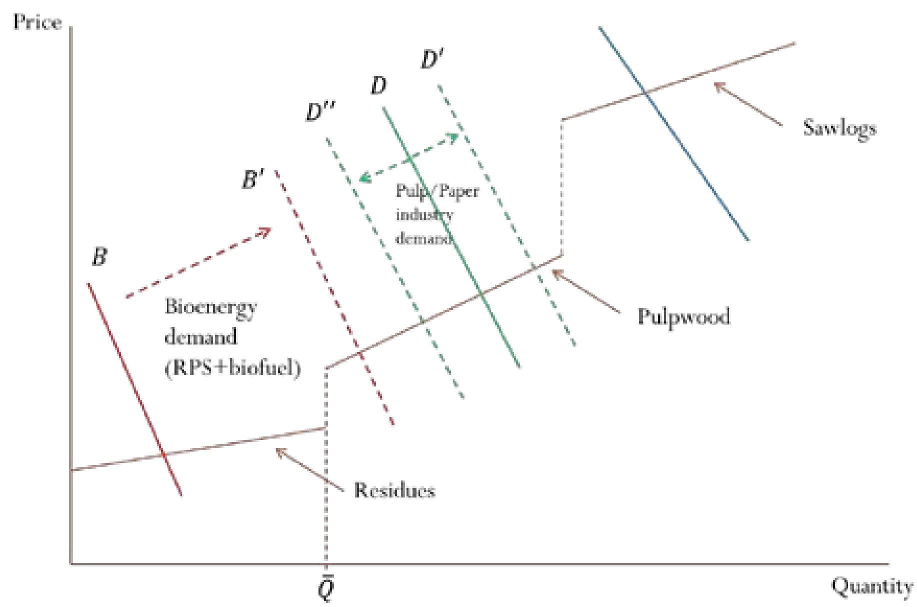
$$q_{i,t}^{S} = q_{i,t}^{D} \qquad \textbf{(5)}$$

The model structure of the supply and demand in the pulpwood and forest residues markets are illustrated in Figure 17. We abstract the sawlogs market in the scenarios as it is less likely to be affected significantly given its high market prices.



Panel A. Baseline

Supply and demand curves for forest residue, pulpwood and sawlog markets highlighting the vertical price gap differential between the three markets.



Panel B. Scenarios

Three scenarios of supply and demand curves for forest residue, pulpwood and sawlog markets illustrating the likely spillover effect of increased bioenergy feedstock demand.

Figure 16. The Analytical Framework.

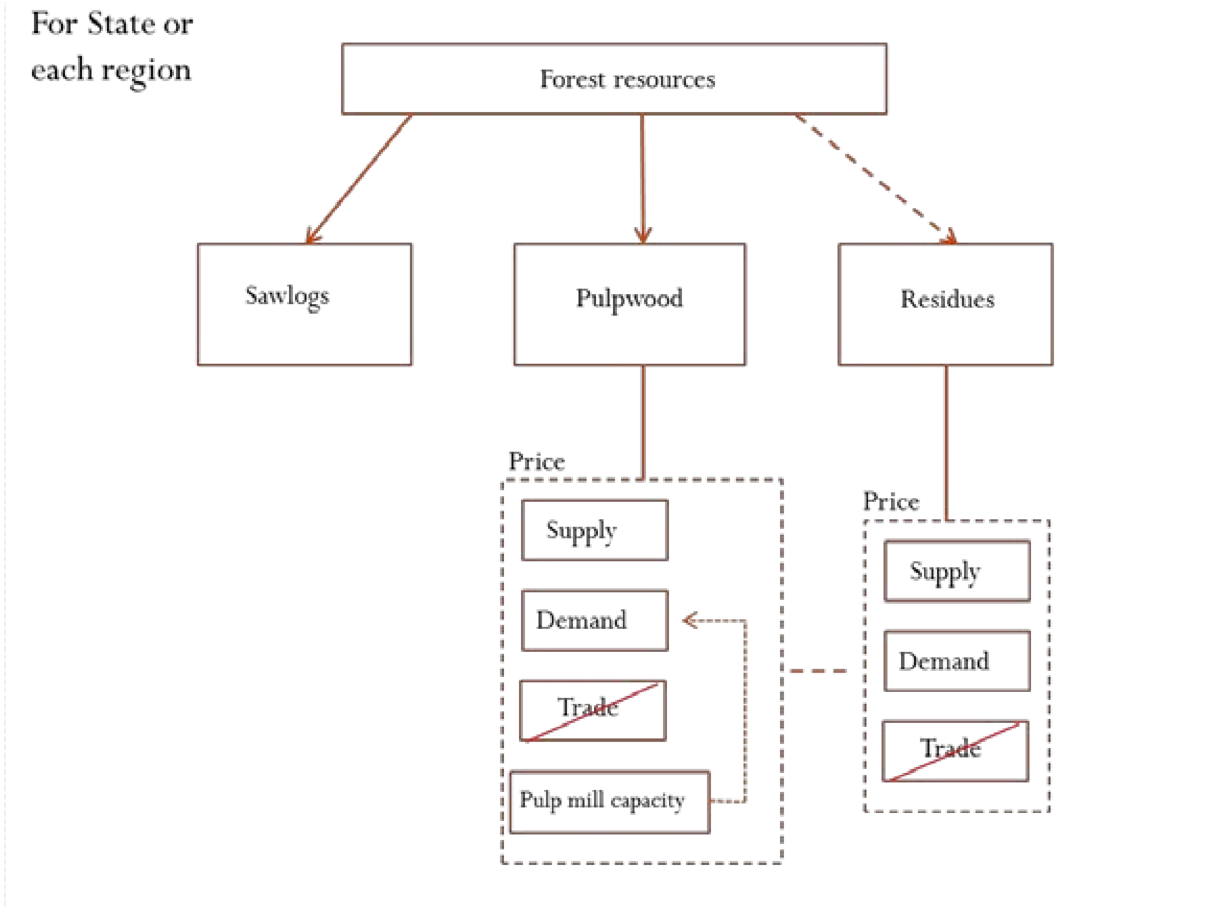


Figure 17. Supply and Demand Model Structure.

Data and estimation results

In this study, we employ the annual pulpwood quantity data over the period 1996-2008 generated from the Timber Product Output (TPO) report (Hackett, 2002).[4] Regional pulpwood prices are obtained from the Timber Mart North Price report. The price reports are compiled from surveys of timber professionals and published twice a year.[5] The prices are for three regions in Wisconsin, namely region 1 (South), region 2 (Northeast), and region 3 (Northwest). Figure 18 presents the map for the three regions. These are also the regions on which our analysis is based. Our final prices are averaged over species and transformed to dollars per dry ton. Annual pulp mill capacity data are compiled from the Lockwood Post Annual Directory.

Figure 19 presents the pulpwood price, production and pulp mill capacity in Wisconsin over the period of 1996-2011. Two interesting patterns emerge. The first is that pulp mill production capacity has followed the changes in pulpwood prices closely over the sample period, which indicates that in the last 15 years pulpwood demand was largely driven by pulpwood prices. We also see a sudden drop in the pulpwood production in the period 2006-2008, which was mainly due to the recent economic recession and the slumping U.S. pulp and paper market. We drop this period for our supply and demand estimation because (i) including it may significantly distort the estimated production responses to price, and (ii) pulp and paper industry is expected to get back on track in the next few years, which will generate a price and production pattern more consistent with the previous period.

4 See Hackett, Piva, and Whipple (2002) for more details on the dataset. We thank Ronald Piva for providing us with the TPO data.
5 See more details of the price reports on the website http://www.prentissandcarlisle.com/content/4044/Timber_Mart_North/.

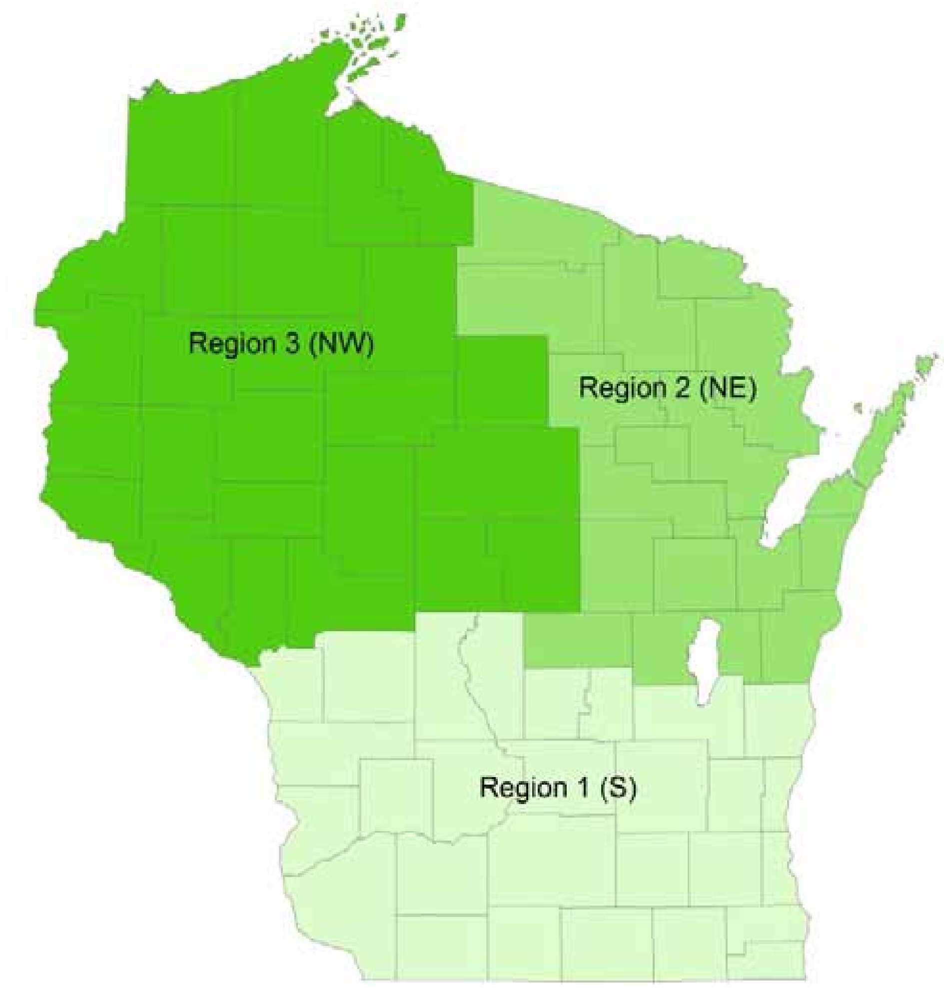


Figure 18. Regions Map for Wisconsin.

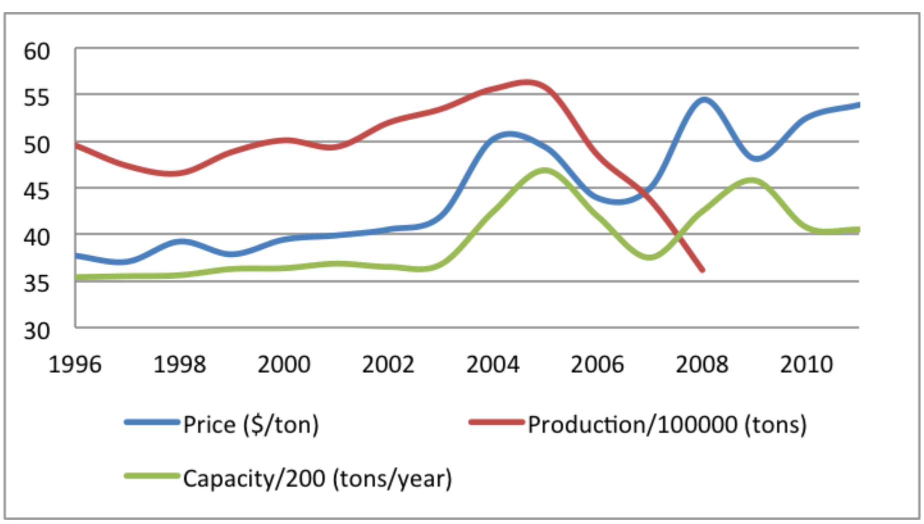


Figure 19. Pulpwood Price, Pulpwood Production, and Pulp Mill Capacity in Wisconsin, 1996-2011.

The relationship between pulpwood production capacity and prices appear closely related. There is also a drastic drop off of pulpwood production starting in 2006.

The supply and demand functions for the pulpwood market, Equations (2) and (4), are estimated jointly as a system to take into account contemporaneous correlation and improve estimation efficiency. The estimation results are reported in Table 15. All variables have expected signs. In the supply equation, the estimated supply elasticity, 0.20, is statistically significant at the five-percent level. The estimated elasticity is consistent with those reported in the literature, for example, 0.23 for the U.S. southern softwood market in Newman (1987). The elasticity estimate implies that for one-percent increase in pulpwood price supply increases by 0.20 percent. In other words, pulpwood price needs to be five percent higher in order to increase supply by one percent. This inelastic supply response is consistent with the data we observed in Figure 19. In the demand equation, after controlling pulp mill capacity, the pulpwood price is not significant at the ten-percent level. But, the price demand elasticity estimate is consistent with the elasticity applied in other empirical studies; for example, average elasticity of -0.21 for other industrial roundwood in the Global Forest Products Model (Buongiorno, 2003).[6] Additionally, pulpwood demand increases by 0.89 percent for every one percent increase in mill capacity. With these estimated parameters, we turn to analyze the impact of the biofuel and bioenergy development on the pulpwood market.

Table 15. Pulpwood supply and demand equations estimation results.

	Coefficient	Estimate	Std. Err.	P value	R^2
Supply					0.99
	Log(price)	0.20**	0.10	0.05	
	Log(lagged production)	0.98***	0.02	<0.01	
	Constant	-0.37	0.45	0.42	
Demand					0.96
	Log(price)	-0.15	0.18	0.42	
	Log(mill capacity)	0.89***	0.04	<0.01	
	Constant	7.92***	0.68	<0.01	

Note: Single (*), double (**), and triple (***) asterisks denote significance at 0.10, 0.05, 0.01 levels, respectively.

Impact of biofuel and bioenergy development on regional pulpwood market

In this section, we first discuss the availability of forest residues in individual regions, as the residues will be the first category of primary forest products to be employed for biofuel and bioenergy production. Once the bioenergy demand is over the existing limit of available residues, demand spills over into the pulpwood market. In this study, three scenarios are considered under the analytical framework described above, which represent the corresponding expansion or contraction of the pulp and paper industry: 1) no change, 2) 10-percent expansion, and 3) 10-percent extraction in the pulp mill capacity, which represent the corrsponding expansion or contraction of the pulp and paper industry.

6 There are few elasticity estimates for primary forest products in the existing literature. Buongiorno et al. (2003) reports only the demand elasticities for end products (p. 60).

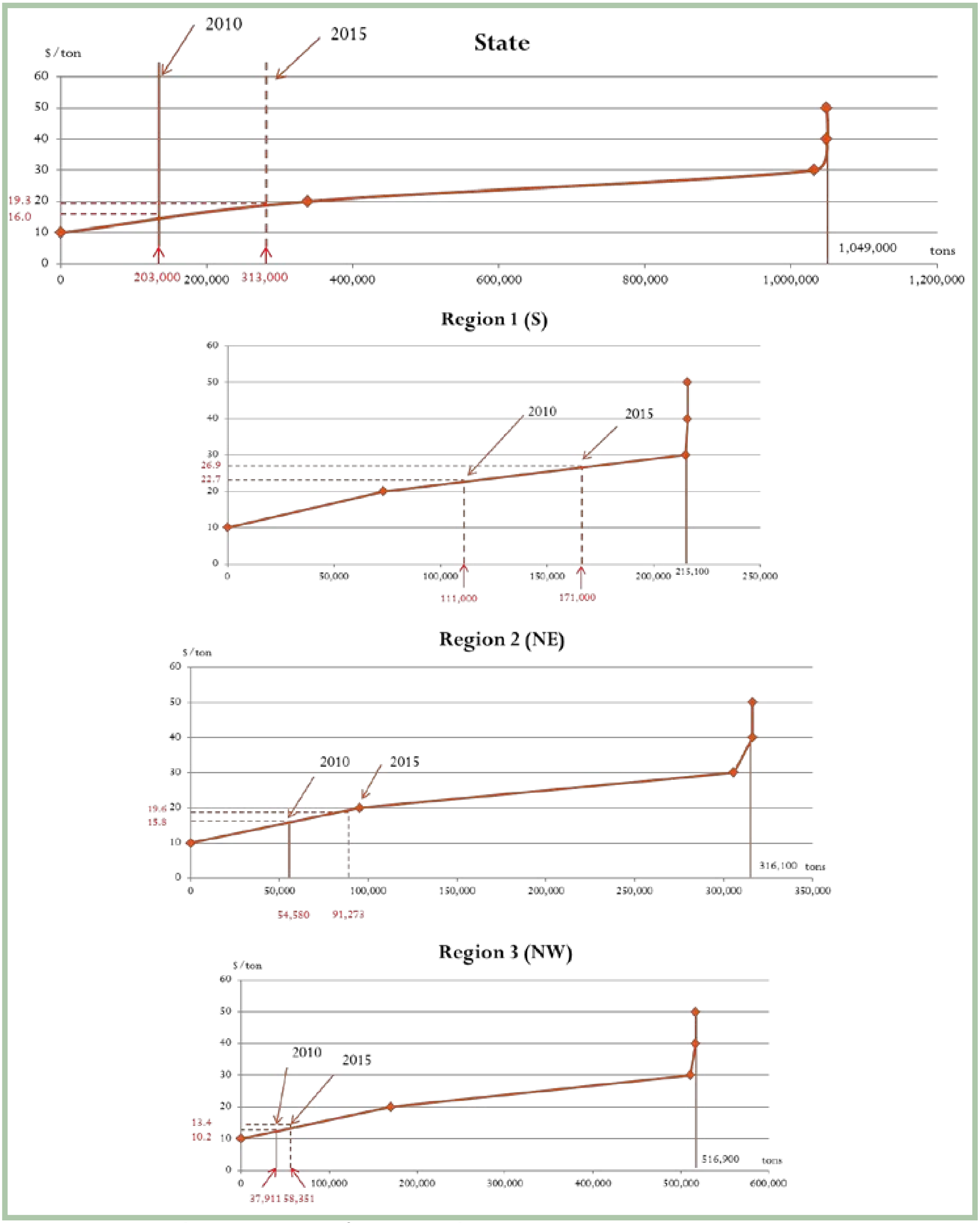


Figure 20. State and Regional Supply of Forest Residues.

Graphs of regional supply showing that an increase in price leads to greater supply, but only up to a certain point. This limit is representative of total available supply in the region or state.

Analysis of forest residues availability

State and regional supply curves of forest residues are generated using the database from the BTS update.[7] Figure 20 presents the supply curves. Basically, higher prices encourage more residue supply, but only up to a limit, which indicates the total availability of forest residues in the state or an individual region. For Wisconsin, the maximum 1,049,000 tons of forest residues are available at the price of $30/ton. To satisfy the state mandated RPS (1.3 percent from woody biomass in 2010 and 2 percent in 2015), about 203,000 tons and 313,000 tons of forest residues are needed in 2010 and in 2015, respectively. The rest, approximately 736,000 tons of residues, could be used for biofuel and bioenergy production; but, the availability of forest residues for biofuel and bioenergy varies across regions.

To quantify regional RPS demand for forest residues, we aggregate regional electricity generation capacity based on the Annual Electric Generator Report maintained by the Energy Information Administration (EIA) and equally allocate the RPS demand to individual generators located in each region.[8] For Region 1, about 44,100 tons of forest residues are available after satisfying the RPS demand. The total amounts are 224,827 tons and 458,549 tons for Regions 2 and 3, respectively. In summary, given the fact that a majority of forest resources are located in the Northern regions of the Wisconsin, and the localness of the forest product markets, it is economical to locate large-scale biofuel/bioenergy conversion facilities in Regions 2 and 3.

Impact of biofuel and bioenergy development on regional pulpwood market

In this section, we combine Regions 2 and 3 for our discussion. To analyze the potential impact of biofuel and bioenergy demand on local pulpwood markets, we first assess the spillover demand for the local pulpwood market. Notice that due to the economic recession in the last few years, there is significant slack pulpwood supply, i.e., the amount of pulpwood that loggers are willing to supply to the market at prevailing prices. We proxy the slack supply by using the decrease in pulp mill capacity over 2006-2008, which is about 12 percent (881 tons/year) of total capacity and corresponds to approximately 10.4 percent of pulpwood demanded/supplied (485,267 tons)[9] Together with the excess supply of forest residues in Regions 2 and 3, which is about 683,376 tons, the total primary forest resources in Wisconsin that can be used for biofuel and bioenergy production without impacting pulpwood market amounts to 1,168,643 tons. This is the starting point shown in Figure 21, which is associated with the sample average pulpwood price $42.50/tons.

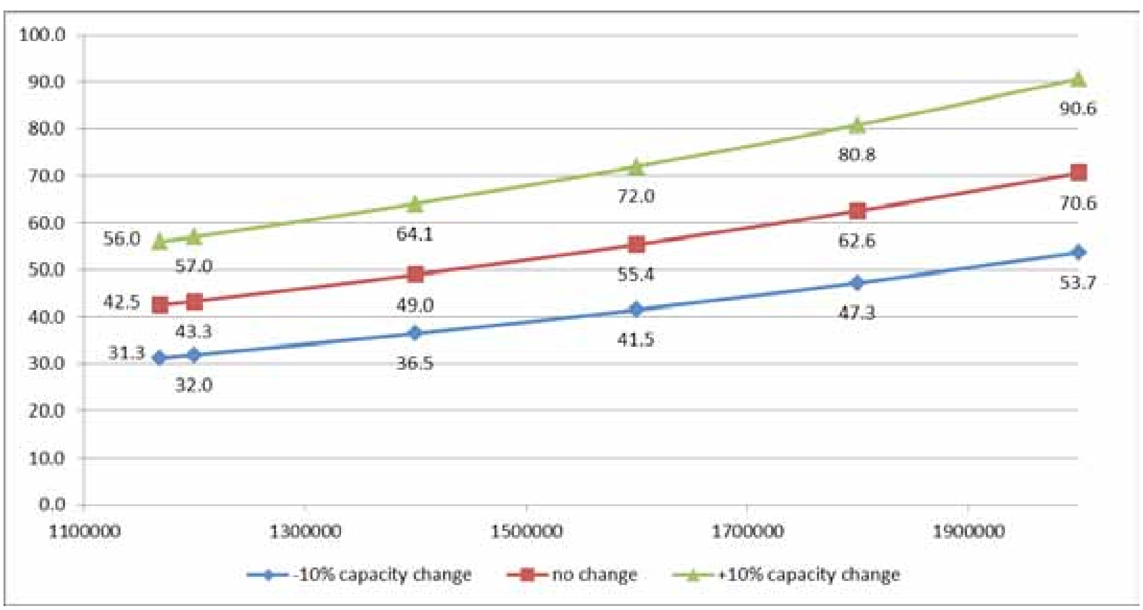


Figure 21. The Impact of Spillover Demand on Regional Pulpwood Market.

7 The data is available at https://bioenergykdf.net/content/billiontonupdate.
8 The data of Annual Electric Generator Report is available at http://www.eia.gov/cneaf/electricity/page/eia860.html.
9 The 10.4 percent comes from multiplying 12 percent by the estimated capacity elasticity of 0.89 in Table 1.

Furthermore, we consider three scenarios in our analysis given incremental increase of biofuel and bioenergy demand for pulpwood of 200,000 tons, which is considered to be the minimum economical scale of a thermochemical conversion facility: 1) no change in the demand of pulpwood from the pulp and paper industry, 2) 10 percent expansion of pulp mill capacity, which is represented by the corresponding changes in the pulp mill capacity, 3) 10 percent contraction of pulp mill capacity.[10] The equilibrium pulpwood prices are solved for each scenario using the demand/supply system we specify in Equations 1-5. Figure 21 summarizes the results. Clearly, excess demand of pulpwood generated from biofuel and bioenergy development puts upward pressure on the pulpwood price. For example, about 200,000 tons extra pulpwood demand will push up price from $42.50/ton to $49/ton. If this demand happens together with the expansion of pulp and paper industry, the impact is significantly higher reaching $64.10/ton. Contraction in pulp demand will weaken the price impact to about $36.50/ton.

Conclusion

Using an integrated analytical framework of sawlogs, pulpwood, and forest residues, this study quantifies the excess feedstock demand that results from biofuel and bioenergy development and spills over into the pulpwood market. The price impact is found to be significant if the total demand of biofuel and bioenergy sectors exceeds about 1.2 million dry tons per year. In calculating the spillover demand and corresponding price impact, we take into account the RPS demand for forest residues and the slack pulpwood supply. The future dynamics of pulp and paper industry also contribute to the magnitude of the price impacts.

10 Note that if information is available regarding geographic location and production capacity of other types of biofuel and bioenergy production facilities, e.g., cellulosic ethanol plants and small scale combined heat and power (CHP), the impact on regional roundwood markets can be quantified in the framework of the current study.

4. The Biogas and Thermal Energy Opportunity in Wisconsin

Wisconsin has both the feedstock and technology in place today to move ahead on small scale distributed energy options for greater biomass to thermal use and biogas energy for heat, electricity, pipeline quality gas and compressed natural gas use. Bringing these renewable energy options online throughout Wisconsin will not be disruptive to energy prices because they are smaller scale, distributed throughout the state, and the planning, construction and implementation timelines are well established so the Public Service Commission and state energy department could plan for their integration into the state energy mix. Policies to encourage small-scale thermal energy and biogas energy could capture this timeline for development and integration. The Focus on Energy program has already targeted biomass and biogas as its funding priority and further policy to de-risk project financing could occur to encourage private investment.

Thermal energy, the heat (and cooling) for our homes, hot water, and steam for industrial applications comprises more than one third of our energy use, yet is largely absent from energy policy. In the U.S. renewable electricity and transportation technologies have received significant policy incentives (i.e. RPS, RFS etc.) while more cost effective thermal technologies have been largely overlooked.

In growing recognition of the critical need for comprehensive energy policy and the opportunity renewable thermal energy can provide, and the critical need for comprehensive energy policy, several states, are exploring policies to help drive the thermal sector. A recent study by the state of Massachusetts found significant opportunity for thermal technologies, both in terms of savings and GHG reductions (Massachusetts DER, 2012).

Five states, including Wisconsin, have included thermal energy in state's RPS. Wisconsin's law allows thermal energy from a renewable resource to get credit if the thermal energy offsets electricity from conventional resources. Initially they only allowed the electric provider – the utility – to create the credit. The law was recently changed to enable customers to create and sell credits, which are eligible for the Wisconsin RPS.

Several states are also exploring a range of thermal policies including financial incentives and building code revisions and development of a Renewable Thermal Energy Standard (RTS). An RTS would be a counterpart to the RPS setting a thermal standard for suppliers of natural gas, propane and heating oil. States would set rules on eligibility, but thermal technologies could potentially include: solar thermal, geothermal, biomass thermal, advanced biodiesel, biogas and heat pumps.

Advanced Renewable Thermal Biomass Energy Systems

Supported via policy and public opinion, Europe has long advanced the use of renewable biomass thermal systems. These systems are highly automated, highly efficient (80-90 percent) and have strict air pollution controls.

Wisconsin and the upper Midwest have deployed many good examples of renewable biomass thermal systems that are operating today to produce heat and electricity. These systems can be found at hospitals (Ashland Memorial Hospital in Ashland and Gunderson Lutheran in LaCrosse), schools (16 schools currently heat and cool with wood chips and/or pellets) and more than 200 businesses all across the state. Wisconsin is in a good position to expand renewable biomass thermal systems, and a good place to look for ideas is Upper Austria.

Between 1999 and 2009, Upper Austria (a state with a population of 1.4 million) increased renewable heating technologies from 32 percent to 85 percent and reduced oil use from 36 percent to 0.01 percent. The state adopted a goal that renewable energy (solar thermal and biomass) will provide 100 percent of their space heating and electricity by 2030.

Upper Austria was able to build a significant biomass heating market because of several factors: forward thinking farmers and forest owners, a cooperative-based business model, policies that reward renewable energy development (advanced renewable tariffs and investment grants), and strict emission and efficiency standards.

Today Upper Austria uses automated wood pellet systems in single-family homes with bulk delivery. Trucks deliver pellets using computer controlled pneumatic delivery systems. Commercial and public buildings use automated wood chip systems, and communities have biomass fueled district heating systems and large-scale CHP systems.

A modern Austrian home typically uses a biomass boiler (often in the basement) in combination with solar thermal for central hydronic systems. They have central control devices and fuel storage–pellets for residential and wood chips for larger commercial or institutional systems.

District Energy located in St. Paul, Minnesota is North America's largest hot water district energy system and is a model for the integration of renewable energy, combined heat and power, and a district energy system. In 1983, they began providing district heating and in 1994, District Energy built a combined heat and power (CHP) plant fueled by clean wood chips (urban tree trimming and wood chips). They hired Anders Rydaker as CEO for this new venture. Rydaker, a native of Sweden, had been a leader in bringing biomass fired CHP district cooling to the Swedish market, and helped Sweden make a conversion from primarily fossil fuels to primarily renewable fuels.

District Energy's new plant uses wood chips as its primary fuel and has reduced coal use by 80 percent. Today the plant serves 80 percent of buildings in downtown St. Paul, including several major corporations, the state capitol complex, all downtown city offices and 300 single-family homes. It supplies 25 MW of power to the grid. In 2011, District Energy completed the Midwest's largest solar thermal array and one of the largest in the United States. They are continuing to pursue the use of biogas as a source of energy.

St. Paul Travelers Insurance, listed as number 93 on the Fortune 500's list of the largest publicly traded U.S. corporations, is a fan of wood chip energy.

> "We like District Energy because we can budget a year ahead and don't need to worry about fluctuating natural gas prices. District Energy is good for the environment and has an unlimited supply of waste wood to use as fuel." **-- Ken Zahradka** St. Paul Travelers Insurance

Utilization of Biomass: Considering Efficiency and Economics

Wisconsin policy makers should give careful thought on how to design the most efficient and economical energy systems. Thermodynamics tells us that we lose energy at each step of energy conversion. Producing heat, or thermal energy, is by far the most efficient (80-90 percent) conversion of biomass into energy. Combined heat and power (CHP) systems are an integrated technology, utilizing both heat and electricity with efficiencies in the 60-80 percent range. Electricity production is far less efficient (20-30 percent) and requires the intermediary step of converting the heat from biomass combustion into heated water and steam to drive electrical turbines.

> *"If the heating, cooling and electricity needs of a larger collection of buildings can be linked together in an integrated system without major distribution losses, then significant savings in primary energy use are possible – beyond what can be achieved by optimizing the design of a single building. Community scale energy systems also offer significant new opportunities for the use of renewable energy."* - Intergovernmental Panel on Climate Change

From an economic standpoint, strengthening the Wisconsin thermal market in the areas not served by natural gas may be a way to provide homes and businesses with economical fuel choices and also be better suited to the existing forest products industry. Natural gas prices have fallen by more than 70 percent since their historic peak in 2008, while propane and heating oil prices are on the rise. Biomass used in areas of the state can help families and businesses save money.

From an efficiency standpoint, Wisconsin and the upper Midwest have significant forest products, paper and food processing industries that have needs for both heat and electricity. Utilizing the heat and steam in their energy processes can improve energy efficiency by more than 35 percent (U.S. EPA, 2007).

Scale Influences on Electrical and Thermal Efficiencies

Large-scale electrical plants and refineries have higher initial costs than thermal biomass uses, are less efficient at converting wood to energy, and require long-distance transport of both raw wood inputs and electricity or fuel outputs. Equipment for generating electricity is much more complex than boilers designed for heating alone, so initial capital investment will be much greater when converting wood to electric power rather than heat. Bergman and Zerbe (2008) estimate that the capital cost per MW for a wood heat installation would be less than one-third that of a large electricity generating facility (Gehl, 2008). Overall, community scale thermal uses are more efficient than large-scale electricity or biofuels plants, and are likely to generate more community benefits.

For example, when local wood resources are produced and used to provide local energy it bolsters the local economy. Directing biomass into appropriately scaled applications such as heat (or CHP) for schools, hospitals, office buildings, college campuses and district heating systems is essential for creating a local biomass energy economy that is flexible and resilient over time.

Biomass and Grasslands

Today, prairie grasslands are a shrinking part of the landscape, among the most endangered ecosystems in the United States, and support many threatened species (Noss, 1995). Decades of row cropping on highly erodible land has put waters—our lakes, streams and drinking water—under siege, along with the wildlife that are dependent on these resources. Wisconsin could, with some of the most productive soils in the world and billions of investments in agricultural infrastructure, transition hundreds of thousands of acres into perennial energy crops. Doing so would reduce the tolls on soils, waterways, and habitat.

While grasses are more expensive per ton, and provide more combustion challenges than wood, the region has extensive acreage that is likely suitable for grassland management. Wisconsin could become a national leader in grassland biomass energy development done right. Bioenergy could create market opportunities to restore grass-based landscapes with native perennials, providing benefits to lakes, streams and wildlife.

A bold vision to "perennialize the landscape" in Wisconsin could potentially have a major positive impact on climate, while simultaneously improving our water and wildlife. A goal of a large, new USDA funded project, CENUSA (short for central USA) led by Iowa State University seeks to strategically place perennial grasses and energy crops on marginal lands to improve the environmental benefits and explore as a feedstock for liquid transportation fuel. Seven North-central states are working on this effort, including Wisconsin. Perennial grasses, which maintain the same root systems for many years (sometimes decades) provide a stable carbon storage capacity. Also, unlike forests, perennial grasses cycle nutrients on an annual growing season, and therefore have a much shorter period between carbon "debt" and "dividend." In short, with grasses, we don't have to wait 30 years for a timber stand to mature to a level where the storage of carbon matches the initial release to the atmosphere. In that sense, bioenergy production on grasslands offers opportunities for experimentation and learning with less risk.

Lands that are difficult to farm for conventional crops due to topography, soil conditions, etc., are sometimes called "marginal" lands. These sites are most frequently discussed for grass biomass production. As with forests, both the carbon and ecological impacts of harvesting grasses depends on the kind of grass or plant, the way they were raised and harvested, the site and scale of the grasslands, and how these factors affect other ecological functions of the landscape. Using GIS technology, preliminary analysis in Wisconsin identified millions of acres of land not currently in production (so these sites would not compete with food crops) that could be suitable for growing perennial grasses (Ventura, 2009).

Native perennials require the least cultivation and soil disturbance, have natural disease resistance and other assets that promote resilience. Moreover, native grasslands can provide important habitat for grassland species that have been in decline for decades, including songbirds such as meadowlarks and bobolinks.

If poor quality farmlands could be converted to native grasslands and harvested in ways that sustain ecological functions, perennial grasslands could meet conservation objectives such as soil stabilization, water filtration, nutrient cycling and habitat protection and also produce biomass for energy. Research in this arena is in its early stages. As noted, long-term trends have not yet been analyzed and federal bioenergy policy has largely overlooked grassland potential.

Energy Crops

Within actively cultivated croplands, the ecological footprint takes on a different profile. Commodity crops that require annual cultivation (e.g. corn, soybeans) are a major source of nutrient pollution, herbicide and pesticide pollution, and soil erosion (and resulting sedimentation) to the region's waterways. Cultivation itself releases carbon from soils and increases erosion and polluted runoff. In Wisconsin agricultural runoff is the dominant source of nutrient pollution. In lakes and rivers runoff contributes to heavy loads of phosphorus and nitrogen, leading to eutrophication, algal blooms and dead zones in both the Great Lakes and Mississippi River watersheds. Pollution from corn farming is a leading cause of water quality problems in the Upper Mississippi river watershed, polluting drinking water in agricultural areas and degrading rivers and lakes while also expanding the Gulf of Mexico's "dead zone"—a large area deprived of oxygen (NRC, 2008; Union of Concerned Scientists).

Two scientists in the forefront of studying the global warming impact of Midwestern cropping systems, Dr. Phil Robertson (Michigan State University) and Dr. Chris Kucharik (University of Wisconsin–Madison), have attempted to quantify the GHG impacts related to crops.

Robertson evaluated the global warming impacts of different kinds of crops. These included annual corn crops (chisel plowed corn, "no till" corn, and; organic corn), perennial biomass crops (alfalfa and poplar trees) and unmanaged perennial grass-based systems (early succession). Biomass produced from perennial grasses requires lower fertilizer, less tillage, etc. and has better net energy ratios and reduces global warming more than biomass produced from row crops. Among the cropping systems studied, corn based systems (with higher fertilizer, more tillage, drying etc.), increase global warming the most (Robertson, 2008). Perennial grass systems reduce global warming by the largest amount, reducing CO_2 by –211 ($CO_{2\ eq}$/m2/y) while corn grown with conventional tillage increases CO_2 by 114 ($CO_{2\ eq}$/m2/y) (Robertson, 2008).

The simple act of planting grass is a surprisingly effective tool for reducing global warming emissions. Converting one acre of corn to perennial grasses reduces CO_2 by 1.32 MT/year. A field converted from high input corn to low input perennial grass and kept in grass for 10 years would decrease emissions by 13.2 MT. (1.32 x 10 years = 13.2 MT)– an amount equal to removing 2.4 cars off the road. This is due to the grasses' ability to sequester CO_2 from the air as well as lower inputs (less or no pesticide and fertilizer) and tillage needs (perennial crops do not require annual tillage).

Using these figures, one can look at the significant impact grass could have on Wisconsin's environment. For example, if a state launched a new Grass Energy Program, and for illustration purposes, recruited farmers to plant 500,000 new acres of perennial grasses (on par acreage wise with other conservation farm bill programs) - the impact would be equal to removing 1.2 million cars from the road for one year (Porter, 2008). In addition, planting 500,000 acres to perennial grasses could produce 2 million tons of biomass (at 4 tons/acre), enough to meet an average Midwest state's energy needs for a year (based on assumptions projected for the year 2013). This could also reduce pressure on our forestland for bioenergy and reduce competition with traditional wood markets.

Crop and Food Processing Residues

Using the leftover plant material from grain and grass crops is a different story. Wringing extra energy from these crop residues doesn't offset their production impact, but does capture an energy source from what is typically viewed as a waste product. However, the fiber and nutrients from these residues have traditionally played an important role in enriching soils, retaining moisture, and preventing runoff. A general practice in development of biomass energy from crop residues is to leave 75 percent of harvest residues on the fields.

Growing grasses and other plants primarily for biomass feedstock is not yet a widespread practice in Wisconsin or the Midwest. As with forests, or any limited land base, an analysis of competing needs, tradeoffs, and suitability of sites for growing energy crops would be an important calculation. Although, as noted, the Ventura study indicates there are likely millions of acres with good potential for biomass production in the region.

Given a choice between acreage dedicated to corn production for ethanol or perennial grass feedstocks grown for heat or electrical production, the ecological advantage from the standpoint of water quality, soil conservation, and carbon sequestration is with the perennial grasses.

Wisconsin Can Be the United States Leader in Biogas Energy

Wisconsin has the opportunity to be a U.S. leader of anaerobic digestion (AD) biogas production making renewable clean energy and addressing multiple environmental challenges while growing our state economy. Anaerobic digestion, the production of biogas energy from manure biomass and other wastes, is a natural extension of Wisconsin's showcase dairy and food processing industries. The dairy and food processing sectors spend millions of dollars managing waste products and paying energy costs. A greater utilization of anaerobic digestion can turn an operating cost into a profit center if the state advances a strategic approach to managing waste and promoting clean energy solutions. In this study, the authors project the potential of anaerobic digestion to process 4.7 million dry tons of manure per year based on a conservative analysis of annual farm production.

Taking organic waste and processing it through anaerobic digesters to make biogas could be the "low hanging fruit" opportunity for Wisconsin's bioeconomy. Annually, the state spends an estimated $16 to $18 billion for energy to run businesses, power and heat homes, and fuel vehicles (WI Energy Stats, 2011). Much of these energy costs go to out of state sources and limit our state's ability to maintain sustainable economic growth. Wisconsin can reverse this trend with greater production and use of homegrown energy, while bolstering the dairy and food processing sectors by reducing liabilities with waste management.

Wisconsin Dairy Biogas Clusters

Regional opportunities in biogas exist for Wisconsin where there are clusters of dairy farms, particularly larger dairy farms. One major cluster is the Northeast section of the state, sometimes called the dairy donut – or roughly the counties circling Lake Winnebago. Based on the research of this report leading opportunities are the specific counties of Manitowoc, Fond du Lac, Kewaunee, Outagamie, Sheboygan, Shawano and Calumet all containing large dairy farm clusters. Likewise two of the largest concentrations of dairy cows are in the adjacent counties of Marathon and Clark County in the North-central region of the state. There are other regional pockets worth investigating, including Dane and Dodge counties in the South-central Region. Matching up regional areas with larger numbers of food manufacturing facilities and dairy farms makes this South-central region and East-central region more interesting for targeted efforts.

The Wisconsin Biogas Opportunity

Biogas is a product of anaerobic digestion, a process that decomposes organic matter like manure, crops and food waste to produce biogas energy and other by-products. Biogas can be combusted to produce electricity or combined heat and power, cleaned and upgraded to pipeline quality gas for injection into the existing natural gas system, or cleaned to create compressed natural gas (CNG) for vehicle fuels. While Wisconsin leads the nation with 31 anaerobic digesters, there is ample opportunity to expand the use of these biogas systems throughout the state (EPA AgSTAR 2012, Kramer, 2009). Along with dairy operations and food processors, anaerobic digesters can be installed at landfills, wastewater treatment plants, and businesses with steady streams of organic wastes. Utilizing waste streams to create energy from biogas would help build and retain wealth in Wisconsin.

A motivating factor in pushing for greater use of anaerobic digesters is to keep the Wisconsin dairy and food processing sectors competitive in a changing global market. Managing waste products is expensive, and political and economic factors make investment in the waste management infrastructure, such as wastewater treatment systems and landfills, more expensive for the future. The Wisconsin dairy industry is second in milk production and number one in cheese production in the United States. Each year, the estimated 1.26 million dairy cows at the state's 12,500 licensed milk herds generate approximately 23 million tons of manure (WASS, 2012). Our state's dairy operators spend $48.5 million annually on manure management with the goal of protecting our state's waters. The current land-spreading system is getting more expensive as land prices rise. There are an estimated 13 million pounds of cheese whey requiring disposal per year. In the past, this waste also required land-spreading disposal and processing through wastewater treatment systems. In addition to economic considerations, the environmental issues, including phosphorus runoff, must be calculated into the costs of the agriculture and dairy processing sectors.

One of the big advantages of using anaerobic digesters for biogas energy is the versatility of end uses. Whether the anaerobic digester is placed on a dairy farm or industrial site it can reduce Wisconsin's dependency on energy from outside the state. Biogas energy uses include:

Electricity: This is the most common conversion of AD biogas through a connection with a genset (electrical generator) to make electricity for the electrical grid. It can also produce electricity for "off-grid use." If electricity is sold to a utility it is subject to negotiated buy-back rates. This baseload renewable power is scalable and can be competitive with other renewable energy options.

Heat: To maximize statewide efficiency, the heat generated by an anaerobic digester is often used on-farm or in-plant. If there is a nearby industrial space or facility, like a greenhouse, that needs heat, an anaerobic digester can be used in tandem to generate electricity and provide heat.

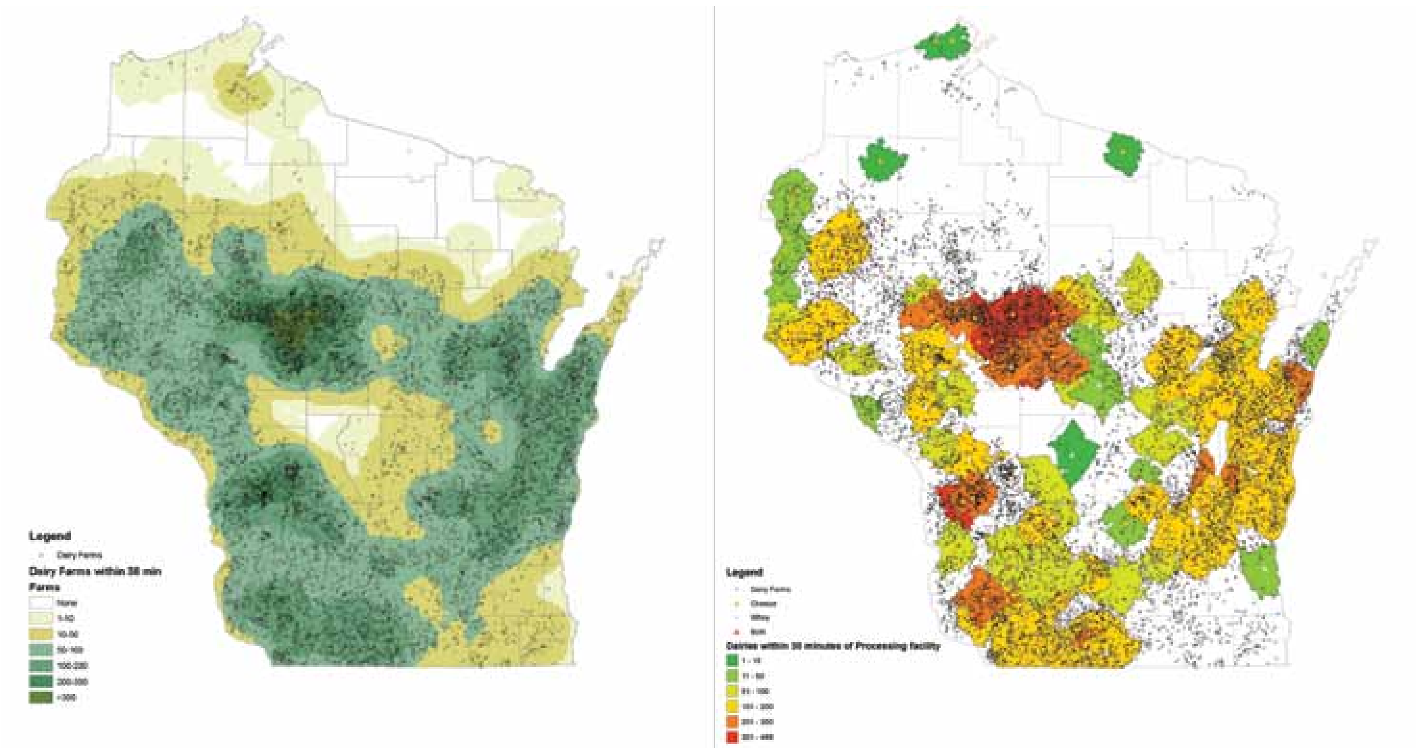


Figure 22. Dairy Farm Density (left) and Dairy Farm Location Relative to Processing Facilities (right).
Credit: UW–Madison Land Information and Computer Graphics Facility.

Co-generation: A combined heat and power facility operates at a high efficiency rate and makes a great partnership with anaerobic digesters where there is shared user demand.

Vehicle Fuel: Can combine an anaerobic digester with equipment to clean and compress for a vehicle fuel of compressed natural gas (CNG). This renewable fuel can power a CNG vehicle, currently more common as fleet vehicles. In Wisconsin, the School District of Cadott has been running a CNG fleet of school buses for 20 years. More recently, the Dane County landfill has used an anaerobic digester and conversion equipment to run approximately 20 county vehicles on CNG with plans to expand to 30 vehicles by the end of 2012 (Dane County, 2011).

Renewable Natural Gas: Another emerging opportunity is to take methane from an anaerobic digester and clean it to pipeline-quality renewable natural gas. This process is more common in Europe, but could be attractive at some U.S. locations with existing gas pipeline structures.

Barriers to Anaerobic Digester Growth in Wisconsin

A combination of investor risk with anaerobic digester costs and inadequate utility energy buy-back rates results in a lengthy return on investment for most purchasers. Many more Wisconsin dairy farms could add digesters with a higher energy buy-back rate. The benefits of having an anaerobic digester system on dairy farms, particularly those over 500 head, include odor reduction, nutrient cycling, greenhouse gas reduction, energy generation, and the potential for animal bedding from the soild by-products of the process. A better accounting of the public benefits from the use of anaerobic digesters on dairy farms could occur from a landscape perspective of these renewable energy systems. A landscape perspective would allow policymakers and the public to take into account the positive (and negative) impacts on the natural resource systems of using these feedstocks for energy. Using a waste product for a feedstock in a renewable energy system makes sense, and accounting for the other positive impacts on the natural resource systems could be a factor in justifying policy support or subsidies (Brick, 2011).

Increasing the number of on-farm anaerobic digesters in Wisconsin would have economic benefits to the state. Analysis done by Amanda Bilek of the Great Plains Institute concluded that adding digesters to the 250 farms, as projected by the EPA AgSTAR program, would generate $250 million in economic benefits (Bilek, 2011; Altman, 2007). While more site-specific data for Wisconsin would be helpful in measuring the economic impact of increasing the number of anaerobic digesters statewide, the state is already considered a key market.

There are several Wisconsin sector opportunities for anaerobic digesters and biogas energy production sites. These include:

Dairy Farm Sector: The bioeconomy opportunity in the Wisconsin dairy farm sector—with over 12,000 registered dairy herds and a large volume of manure waste—makes this the center of focus for combining nutrient management and renewable energy through an increased use of anaerobic digesters. Wisconsin has more than 250 dairy farms with at least 500 cows. With 32 systems operating today, it is clear that a market opportunity exists in the state. These larger dairy farms alone could generate 386 megawatts of power per year – the equivalent of about 386,000 homes in the state (EPA AgSTAR, 2011). However, large dairy farms should not be the only focus, technology improvements for small-scale anaerobic digestion creates opportunities for regional or community digester projects.

Small-Scale Anaerobic Digesters: The Wisconsin-based business BIOFerm, a subsidiary of the German-based Viessman Group, has teamed up with a dairy farm near Oshkosh to site a small-scale biodigester. The State Energy office awarded the project a $125,000 grant to help pay for the installation and promote the technology. The BIOFerm digester is called "Titan 55," for its 55-kilowatt engine, and is designed for a smaller dairy herd operation.

Combining Greenhouses, Aquaponics with Anaerobic Digesters: John Vrieze of Baldwin Farm has always been an innovator of dairy farm operations. His latest venture is a partnership with Steve Meyer for an aquaponics-focused business, Future Farm Food and Fuel, LLC – a 27,000 square-foot greenhouse in Baldwin. The project combines energy and heat from Vrieze's anaerobic digester, recirculating water and fish tanks. The water, which carries the waste from the tilapia and catfish, is transferred to the greenhouse's growing bays providing natural nutrients that are absorbed by the plants' roots. The plants, in turn, serve as a sort of filter for the water, purifying the water that is circulated back to the fish tanks. This method—the combination of aquaculture and hydroponics—is called aquaponics. The greenhouse can provide food to businesses within a 60-mile radius of Baldwin. Given that two major global issues are food security (providing enough food for an increasing population) and energy security (providing enough energy for the same increasing population) this Wisconsin-based operation is right on target for providing a model of sustainable agriculture.

Benefits of Anaerobic Digesters

The early adopters of Wisconsin's on-farm anaerobic digesters were large dairy farms worried about odor issues, compliance with the federal Clean Water Act, and improving nutrient management strategies. As more housing is built in rural areas near farms, the odor issue has become more significant for dairy operators. Large dairy farms with 1,000 animal units (equivalent of about 700 cows) are regulated under the Clean Water Act, and licensed as Confined Animal Farm Operations (CAFO). The Wisconsin licensed CAFO operations must have an implemented nutrient management plan. While other dairy farms are required to have nutrient management plans, the implementation is voluntary if state supportive funds are not available. For CAFO, having an anaerobic digester can stabilize manure solids while the majority of nutrients remain with the liquid. The dry digester solid is easier to handle and can be transported for bedding or a soil amendment on farm. Studies in Wisconsin have shown that 20 of the farms with anaerobic digesters report using the solid material for bedding, representing a savings of

$7.25 per cow per month (Kramer, 2009). Other farms can sell the digested solids as a nutrient rich soil additive. A homegrown energy source from the anaerobic digester is subject to a negotiated buy-back rate with the utility where the farm is located. Currently, the buy-back rates are not adequate for a rapid return on investment for the digester, but allow for an added regular stream of income for the farm. This energy income can be helpful when commodity prices rollercoaster up and down, because the negotiated energy rate is a steady consistent income stream.

Anaerobic Digesters and Compressed Natural Gas

One of the nation's largest dairy cooperatives has become a high profile project for making compressed natural gas in conjunction with its anaerobic digester. The Fair Oaks Farm in Indiana makes enough CNG from its dairy operations to power 42 milk delivery trucks. The operation of ten dairy farms and 35,000 cows has six anaerobic digesters. The CNG-powered trucks are capably hauling 300,000 gallons of milk a day in a three state area of Indiana, Kentucky and Tennessee (Gibson, 2011).

Wisconsin and the U.S. can learn from several European countries on the value of setting ambitious targets for biogas usage in vehicles. Germany and Austria now have mandates requiring that 20 percent biogas be used in natural gas vehicles. Germany leads the world with installed anaerobic digesters thanks to its innovative feed-in tariffs. Germany has 6,800 agricultural digesters, an increase from 4,000 in 2009 (IEA, 2011 & PEW, 2011). Sweden, which has nearly 11,500 natural gas vehicles, estimates that biogas meets half of its fuel needs, and continues to support the use of biogas as a vehicle fuel. Globally, it was estimated that 70,000 vehicles were powered with biogas in 2010, according to the U.S. Department of Energy (Pew, 2011).

What are leading opportunities for Wisconsin?

Anaerobic Digesters and Combined Heat and Power: Taking a waste product to make both energy and heat is a logical step for communities or businesses that can use the heat. An anaerobic digester can produce power, typically below retail electricity, and displace existing fuel purchases for thermal usage. The biogas, produced from an anaerobic digester, and heat, from a closed heat and power (CHP) system, can use reciprocating engines, micro turbines, or fuel cells. This combination of AD and CHP can create reliable, efficient power for a business venture. A local government using this at a wastewater treatment plant could lower costs to the taxpayers funding their systems. A study by the EPA on using AD and CHP at wastewater treatment plants details the benefits:

- Efficiency benefits: CHP requires less fuel than separate heat and power generation to produce a given energy output. CHP also avoids transmission and generation losses that occur when electricity travels over power lines from central generating units.

- Reliability benefits: CHP can provide high-quality electricity and thermal energy to a site regardless of what might occur on the power grid, decreasing the impact of outages and improving power quality to sensitive equipment.

- Environmental benefits: Because less fuel is burned to produce each unit of energy output, CHP reduces emissions of greenhouse gases and other air pollutants.

- Economic benefits: CHP can save facilities considerable money on their energy bills dues to its high efficiency, and it can provide a hedge against unstable energy costs (EPA, 2011).

Innovative Partnerships with Anaerobic Digesters: Including the AD and CHP scenario described previously, there could be collaboration among energy needing operations. For example, a larger dairy and/or food processing facility might have a nearby partner business that needs some of the heat or power. A short distance pipeline could be cost-effective, especially if the energy production is co-located near an industrial park. Data centers would be one potential partner with high demand that needs cost-effective energy solutions.

Wisconsin has already received national recognition for using food wastes to create energy with anaerobic digester systems. A University of Wisconsin–Oshkosh project uses dry digester technology combining food waste, crop residuals and lawn clippings at a near-campus city wastewater treatment plant to produce heat and electricity. Wisconsin has other sites using anaerobic digesters with dairy manure and high fat food waste, including the Stargest Power LLC in Elk Mound and the Norswiss Digester in Rice Lake, both producing electricity. In December of 2011, the Potawatomi Casino in Milwaukee announced plans for an $18.5 million bioenergy project adjacent to its Menomonee Valley site for the development of an anaerobic digester that will produce electricity and heat. The 2 megawatts of electricity will be generated primarily from on-site food waste and will provide heat for the casino's water usage. The project, scheduled to be completed in spring of 2013, provides enough power for 1,500 homes.

More innovative partnerships could occur in settings with larger food waste supplies such as hospitals, restaurants and food courts, supermarkets, food manufacturing and processing facilities, and institutions such as schools, prisons or other locations providing multiple meals to large populations.

Co-products or by-products: "The solid material remaining after anaerobic digestion is commonly referred to as "separated solids" (agriculture) and "biosolids" (wastewater treatment plant) and may be used to produce marketable by-products such as fertilizer, soil amendments, compost, livestock bedding, and other products. Supernatant is the liquid that is separated from the solids and usually sent back to the wastewater treatment plant. Supernatant is rich in nutrients and some facilities use a process to extract phosphorus from supernatant, which is then sold as a fertilizer product. In the agricultural context, the separated liquid is referred to as "digestate" or liquid effluent." (EPA, 2011)

Co-digestion and Food Waste: Another way Wisconsin can turn "waste" into a societal benefit is anaerobic digestion of food waste. This is the number one material going to most U.S. landfills and it has a strong potential for producing methane to make energy. The EPA estimates that if half of the United States' annual food waste was processed through anaerobic digesters it would generate enough electricity to power over 2.5 million homes for a year. Wisconsin's recent waste study shows that 10 percent of the material going to state landfills is food waste. Food scraps or waste going to Wisconsin landfills is 454,828.1 tons/year. Remember that food scraps have a 265 m3/t fresh mass biogas yield compared to cattle manure that is 25 m3/t fresh mass biogas yield. Food waste can be either pre-consumer (food processing and manufacturing waste from food prep, slaughterhouse waste, brewery waste, dairy waste and what are called fogs; fats, oils and greases) or post-consumer waste (household food scraps or restaurant leftovers).

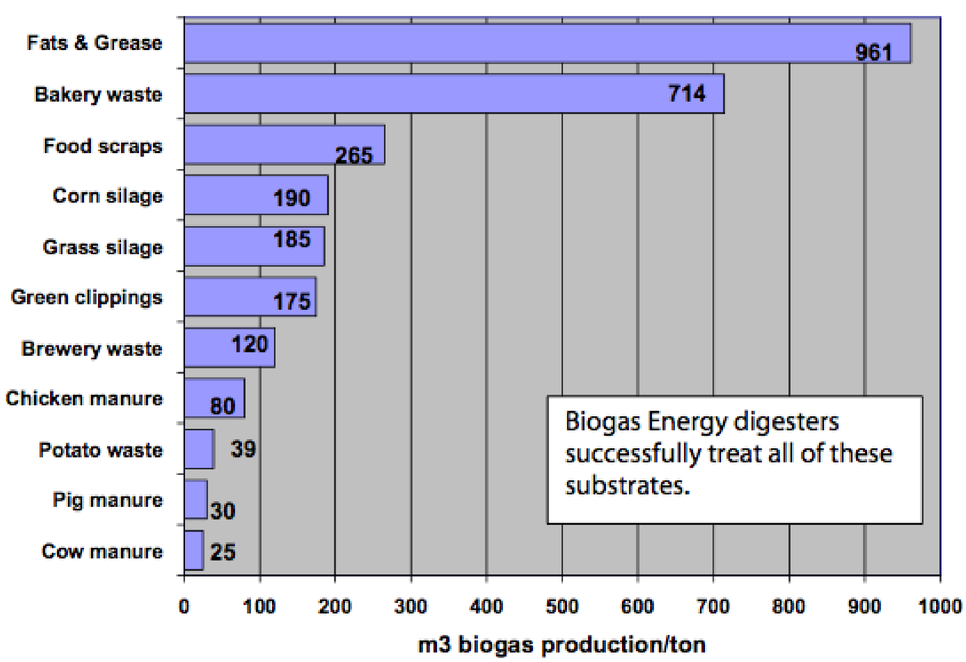


Figure 23. Substrates for Biogas Production by Effectiveness.
Credit: Basisdaten Biogas Deutchland, 2005.

This report did a rough calculation for Wisconsin counties and their waste production, to measure organic waste opportunity for a potential anaerobic digester system. More research is needed to see how much could be diverted to anaerobic digester processing, the logistics and science, and what this means for energy production. Some Wisconsin owners of anaerobic digesters do utilize co-digestion. The Wisconsin Agricultural Casebook said that 9 of the then 21 operating on-farm anaerobic digesters did take substrates and six of them took food-processing waste. More feedstock options remain to generate greater amounts of biogas–for example, fats, oils and greases (fog) greatly increase biogas production (see Figure 23). Feedstocks ranging from corn and grass silage to brewery and bakery waste can all produce more biogas than cow manure. Here are some of the benefits and concerns with substrates in anaerobic digesters:

Benefits:

- Integration of waste streams to produce energy
- Decrease waste streams currently sent to landfills and municipal treatment plants
- Increased opportunities for businesses (i.e. food processors) to integrate combined heat and power projects
- Decreased odors from current methods (i.e. composting)

Concerns:

- Requires consistent quality of the substrate (minimize shock loads and inhibitory concentrations)
- Availability and proximity of substrates to on-farm digesters

In Germany, many of the farms use an approximately 30 percent manure to 70 percent substrate mixture (mostly corn silage) to maximize biogas production. Wisconsin may have regulatory as well as practical reasons to use more manure and less agricultural crops in a mixture. Still, an increase in substrate usage must be considered to maximize energy yields. A similar question of taking other products for an anaerobic digester at a landfill or wastewater treatment might be considered. Questions that would need to be considered include how reliable are the substrate sources, how consistent is the substrate qualities, what is the cost of transporting the substrate to the digester site? Each site must consider what is the ideal mixture but it may well be that agricultural, municipal and industrial co-substrates could mutually be beneficial at a regional collection site. Wisconsin should do more to encourage greater use of co-digestion (McCord, et. al. 2011).

What are other drivers and factors impacting Wisconsin leadership in bioenergy?

Wisconsin's New Phosphorus Rule:

Wisconsin's new phosphorus rule could be one potential driver for getting farmers, local governments, and private industry to consider adoption of anaerobic digester technology. Wisconsin has more than 172 lakes and streams formally listed as impaired due to phosphorus pollution or sediment. This is also a public health issue because each year when algae forms in state waterways, fueled by phosphorus, dozens of residents become ill. Finally, Wisconsin takes an economic hit as our robust tourism sector, and state agencies dependent upon fish and boating licenses, lose customers who don't want to use the state's degraded waters. Changes in Wisconsin administrative rules (Chapters NR 102 and NR 217) set the highest phosphorus levels allowed for Wisconsin waterways. Likewise, changes in Chapters NR 151 require farmers to curb phosphorus, coming off farm fields, to an eight-year average based on land slope, average precipitation and phosphorus levels in the soil. Municipalities have already begun strategies to reduce particulate pollutants carried in their storm water. In 2008, federal and state rules required a 20 percent reduction, and about 75 percent of Wisconsin communities met this first threshold. Now the rules call for a 40 percent reduction of particulate pollutants by 2013.

The new phosphorus management rules in Wisconsin, driven by EPA and DNR policy goals, will require capital additions to WWTP facilities statewide. The DNR estimates as many as 150 municipal facilities and 50 industrial plants may have to make these capital investments over the next decade (Baumann, 2011). Now may be the time to develop support policy that includes complementary investments in waste-to-energy generation equipment. The investments could cost communities more than $1.3 billion statewide.

The new Wisconsin phosphorus rule and a novel implementation in Dane County with the local wastewater treatment facility could provide an incentive for more sustainable cropping systems and an opportunity to expand the use of grass production as a water quality practice. The law, via the "adaptive management" option, is the first in the country to allow permit holders flexibility in achieving these standards. Adaptive management allows point sources to reduce treatment costs by deploying less expensive land management practices upstream.

In the Yahara Watershed, the cost for upgrading the Madison Metropolitan Sewerage District (MMSD), the local wastewater treatment plant, to meet the new water standards is estimated to approach $100 million dollars. A memorandum of understanding between the MMSD, Wisconsin DNR and contributing municipalities was recently signed to pilot upstream practices beginning in spring 2012. It is expected that $40-50 million will be spent in a suite of water quality practices that reduce phosphorus pollution and comply with the new state law.

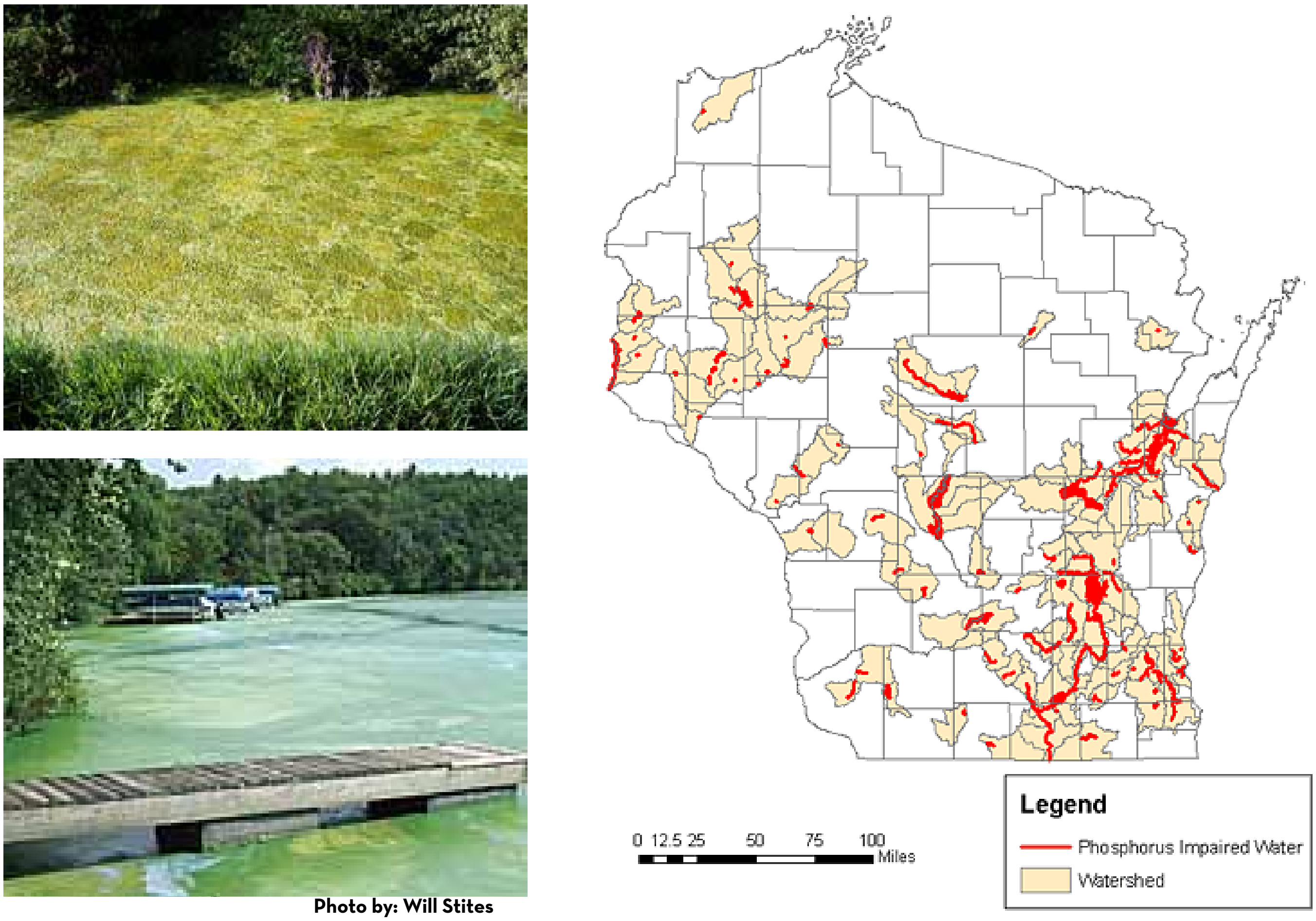


Photo by: Will Stites

Figure 24. Phosphorus Pollution in Wisconsin
Images of phosphorus pollution in Wisconsin waterways. Map, at left, shows Wisconsin watersheds that contain phosphorus impaired waters. Credit: Wisconsin Department of Natural Resources

Incentives to encourage investments in anaerobic digesters, solid separation technology, and growing grasses for energy crops and water quality protection could be part of a suite of policy options that the state can consider to maximize the dual goals of energy security and environmental protection.

Focus on Energy program: Without question Wisconsin's Focus on Energy program has been a positive attribute in the move toward improved energy efficiency and expanded distributive energy opportunities. On April 13, 2012, the Wisconsin Public Service Commission approved, on 3-0 vote of commissioners, a scenario for technologies of biomass and biogas to receive 75 percent of the Focus on Energy renewable resource program funding. The ramifications of this commission action may not be immediate because the program has about $8 million of current project commitments and an annual budget of $10 million for this portion of the program. Still, this policy decision by the commissioners should open the door to greater support for Wisconsin's bioeconomy.

"The new mix in the Focus on Energy program recognizes where our state's strengths in renewables are," said

Commission Chairperson Phil Montgomery. "The agricultural and forest products industries are two of the largest and most important industries in the state. Weighing the renewables component of Focus on Energy towards biomass and biogas technologies, which have higher overall benefits makes sense for Wisconsin." (Focus on Energy Press Release, 2012)

Conclusion

Wisconsin has much to gain by maintaining a targeted strategy for biogas-to-energy development. The dairy sector has a high growth curve with the potential for an additional 250 systems for on-farm anaerobic digesters. Further targeting the state's food processing sector could help maintain our core dominance in that industry with dozens of companies being candidates for AD biogas production. Finally, the state should look to local government units with large wastewater treatment plants or landfills as candidates for anaerobic digestion to biogas energy. There are abundant biomass feedstocks being managed as waste products that can power these AD systems. As long as Wisconsin remains a leader in the dairy sector there will not be feedstock shortages. When one looks back to early 2010, before the economic slow down with cautious lending practices and changes in the Focus on Energy program froze investments, the state was on track for a 14 percent increase in anaerobic digesters (Wichert, 2011). If that 14 percent growth could be maintained annually Wisconsin would have 400 AD systems by 2020. With even more favorable policy in place that number could be 500 or more AD systems for the state by 2020.

Keep in mind that Wisconsin has a very large AD to biogas market opportunity. Wisconsin has 798 farms in the 200 to 500 head of dairy cattle category, 194 farms in the 500 to 1,000 head of dairy cattle category, and 78 farms with more than a 1000 head of dairy cattle. The state has 100 swine farms with more than 1000 animals and none use anaerobic digesters now. Wisconsin has over 1,000 food processors and, while many are smaller operations, there are opportunities for some regional AD processing centers. There are hundreds of municipal wastewater treatment plants and landfills, some of which have AD systems, but still plenty of opportunity exists for new and replacement systems. Wisconsin could divert all food and organic waste from landfills creating ample feedstock for regional systems.

The policy options for Wisconsin are numerous. Some have suggested a model like Vermont with the Cow Power program. This would create a higher required or voluntary utility buy-back rate for energy from on-farm anaerobic digesters. Another option would be to boost funding for AD in the Focus on Energy program or other economic development programming. Landowners and investors favor grant programs because they go onto the investment ledger. Lower interest loans can help with some project developers. Tax credits typically are not that beneficial to farmers, but might work if third-party ownership of the digesters occured. An increase in the renewable portfolio standard (RPS) might help if biogas were a specifically categorized, designated policy goal within the law; otherwise, utilities use wind power and other options to meet the mandate. Proposals such as nutrient trading and carbon trading would help, but do not get specifically at the project financing challenges. An extension policy menu was included in the Wisconsin Bioenergy Initiative publication, *The Wisconsin Biogas Opportunity: 2011 Strategic Plan*. The state could look closer at fostering innovative partnerships for biogas projects. Another option is changing state law to allow for utility ownership of equipment, such as equipment to clean the biogas to pipeline quality and convert it to compressed natural gas. Likewise, policy that rewards the extremely efficient match of biogas and combined heat and power (CHP) might work for a wide array of settings including hospitals, colleges and universities, data centers and other businesses.

Baker Tilly Virchow Krause: Roadmap for Biogas

In addition to the analysis performed as a part of this study, Baker Tilly Virchow Krause LLP ("Baker Tilly") was commissioned by the State of Wisconsin to perform a comprehensive assessment of "Energy Applications from Agriculture and Cheese Production Feedstocks". As a result, an initial roadmap has now been created to leverage previous work performed by the state specifically in the area of biogas potential, to allow for stakeholders to efficiently assess the viability of specific biogas to energy projects and opportunities across the state.

Baker Tilly took a multi faceted and methodical approach in getting to its conclusions, including development of 1) the tools needed to determine if an opportunity for biogas to energy exists 2) the economic model needed to evaluate if the opportunity provides for a return on investment to justify direct or third party investment into a given project 3) the process to proceed with further evaluation of a project once it shows adequate returns 4) the interplay of various key project criteria including; economic incentives, electric and gas utility infrastructure, and existing waste treatment infrastructure relative to project development and investment decisions.

The tools needed to determine if an opportunity exists primarily revolved around an attempt to assess the feedstock availability of biogas resources within the state from sources including small and large dairy farms, existing wastewater treatment plants, and cheese manufacturing facilities. Once the assessment of feedstock was made, specific areas of the state were identified where there was likely to be more feedstock available for the development of a larger project, thus realization of economies of scale. General takeaways from this portion of the roadmap was that the current accounting of biogas feedstocks in the state was not readily available for the most part and that significant assumptions were needed at this stage to determine biogas potential estimates. Recommendations were made relative to potential ways to evaluate this resource with more certainty in the future.

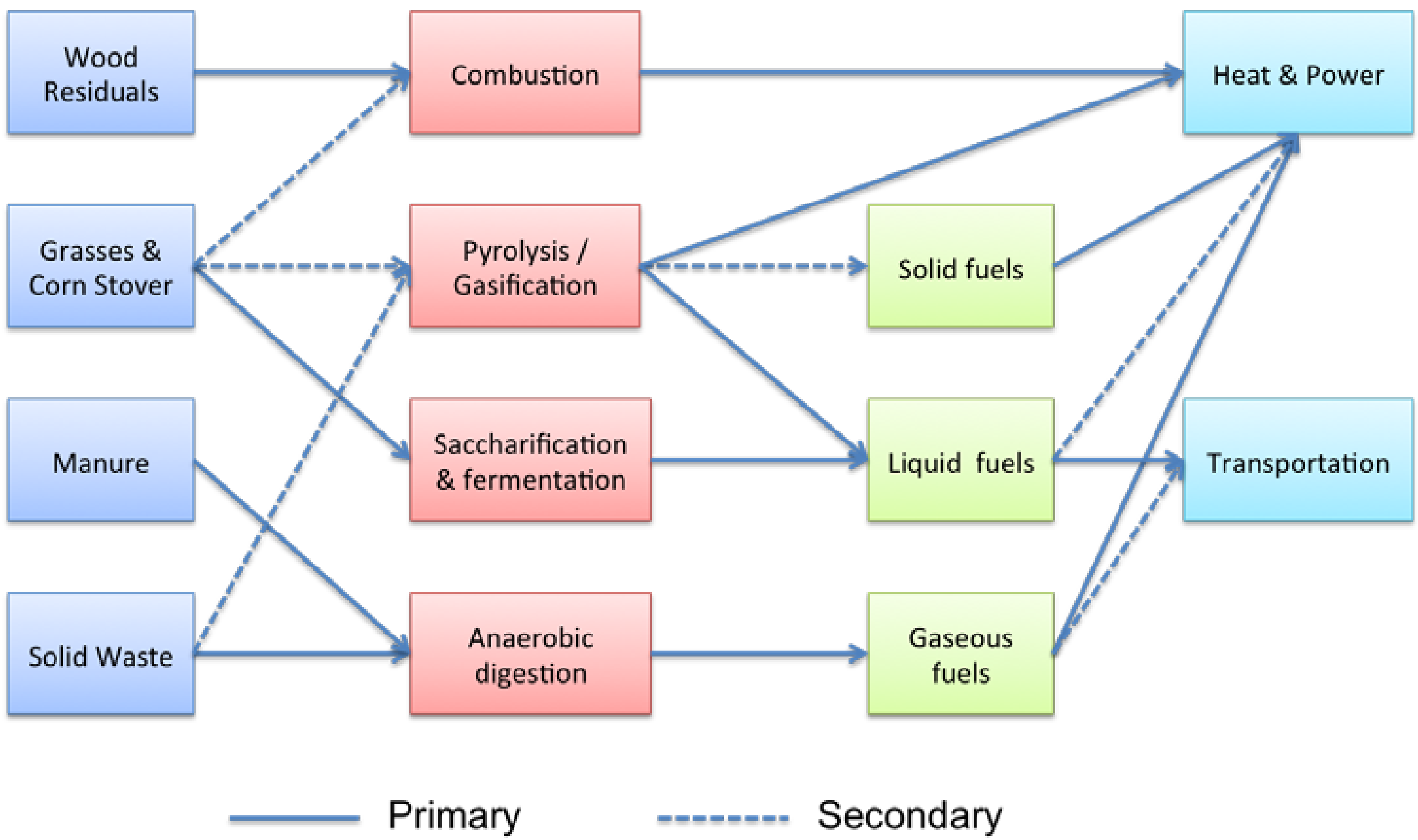
The economic model was created to allow for full and transparent, and user interface friendly evaluation (via Microsoft Excel) of the initial viability of virtually any size waste to energy project in the state, utilizing dairy farm waste cheese plant waste, or both feedstocks in varying combinations. In a partnership with the University of Wisconsin – Oshkosh, certain funds from the Baker Tilly roadmap were appropriated for biogas testing equipment to be installed at the Environmental Research Innovation Center (http://www.uwosh.edu/eric). This equipment will be made available to the public to evaluate prospective waste streams for such parameters as energy potential, and results can be easily input into the economic model as a part of the review, with the feedstock availability and representative energy content being a cornerstone of any prospective evaluation.

Baker Tilly then further described the process by which additional due diligence is performed on project viability and true development of a project can potentially begin in earnest. This involves, among other things, formal interface with potential feedstock providers that have been identified to determine interest in supply and on which terms, discussions with utilities to determine interest in offtake of gas or power, and further detailed evaluation and formal pursuit of credits and incentives, among other tasks.

The conclusion of the Baker Tilly roadmap suggested that Wisconsin appears to be in position to continue to be a leader in waste to energy development and implementation. However, the nature of waste to energy projects with feedstocks evaluated is such that the returns are extremely sensitive relative to a number of primary project drivers, such as feedstock availability and value proposition of a waste to energy project to the feedstock supplier, credits and incentives available at a federal and state level for such projects and relative location of a given project to certain utility infrastructure. Through the Baker Tilly roadmap, the State of Wisconsin should be in a better position to assist stakeholders in more efficiently determining which opportunities to pursue in the near term and quantifying a more realistic idea of potential future waste to energy opportunities.

For additional information and detail, please reference the Baker Tilly roadmap issued in August 2012, Energy Applications from Agriculture and Cheese Production Feedstocks.

Simplified Conversion Pathways: Biomass to Energy/Fuels



Final Thoughts on Wisconsin Energy Planning

Photo by: WBI staff

Thermal Energy Recommended Strategies and Policies

- Develop an energy policy that is outcome based vs. sector based. This means focusing on across energy sectors (thermal, electrical and liquid fuels), and using various energy sources based on their efficiency, economics and minimal environmental impacts.

- Explore different thermal policy mechanisms that focus on offsetting fossil fuel (natural gas, heating oil and LP) heat; the credit might just be for offsetting therms.

- Efficiency and the fuel displaced matters – Focus on using biomass for heat and CHP; limit use for electricity. We should displace dirty fuels first. Natural gas displacement should be a lower priority.

- Embrace grass along with wood for energy – Develop an energy strategy that supports the most efficient uses of biomass and one that protects ecological function of intact forests and grasslands. A forward thinking Wisconsin bioenergy vision should include both woody and agricultural resources. While grasses are more expensive per ton, and provide more combustion challenges than wood, the region has severe water quality problems and has extensive cropland acreage that is likely suitable for grassland management. Wisconsin could become a national leader in grassland biomass energy development done right. Moreover, grasslands are an important ecosystem that has been in decline. Bioenergy could create market opportunities to restore grass-based landscapes with native perennials, providing benefits to lakes, streams and wildlife.

- Whole tree chipping needs careful assessment - With the onset of emerald ash borer and other diseases, there may be appropriate opportunities to combine forest restoration with a harvesting regime, using diseased wood for bioenergy and reducing forest fire. At the same time, whole tree harvesting will have impacts on soil and water quality and forest nutrients. We need a comprehensive nutrient and landscape assessment of whole tree harvests before committing to management of policy decisions.

- Explore biomass gasification. There are inherent efficiencies with gas fuel, such as the potential for a combined cycle with 70 percent or higher efficiencies. With co-generation, gas fuels can reach 85 percent burn efficiency.

- Develop regional assessment tools to develop planning and decision making criteria for forest and grassland biomass strategies with components such as:

    - Assessments of ecological functions

    - Tradeoff assessments

    - Market Feasibility analysis

Biogas Opportunity in Wisconsin Recommendations

Barriers

- Initial investment for some is a high capital cost and further challenging in a time when lenders are cautious with taking on risk with loans.
- Wisconsin has excess energy capacity due to recent additions of a coal plant and added natural gas and wind capacity.
- Lack of stable or robust carbon offset and credit markets.
- Most Wisconsin utilities are close to compliance with the Renewable Portfolio Standard (10 percent by 2015).
- Current utility incentives are electricity only and there are great opportunities for heating, process fuel and vehicle fuel uses needing supportive policy.
- Utility buy-back rates are inadequate and a patchwork across the state.
- Current societal views and public policy promoting the relative ease in disposing of waste materials (landfills and wastewater treatment plants) needs to shift toward encouraging reuse and energy conversion of these material.
- The lack of coherent state energy policy has resulted in questionable decision making to expand high risk coal use, add large transmission projects and resulted in higher Wisconsin rates than our neighboring states.
- Wisconsin has not developed adequate biogas project de-risking policy to assure investment community. Project costs are high if cash flow stays weak from low buy-back rates extending the overall project payback.
- Local government projects for wastewater treatment plants and landfill options are limited by available funds for feasibility studies and then development. (Some research proposals later in this section could assist WWTP projects).

Business models are key energy generator and end users:

- For on-farm digesters the farmer has assets and equity in land, cows, and equipment. Farmer needs to cash flow investments and needs predictable income. Could Wisconsin create a program similar to Vermont Cow Power that targets on-farm anaerobic digesters as a priority and provides a higher energy buy back rate from utilities.
- How about getting Wisconsin farmers off the commodity price rollercoaster by giving them a standard offer contract (15-years guaranteed income from biogas energy)?
- Renewable energy developers need a confident market. Developer needs some certainty in public policy. Developers need scale in order to bring down costs. Create an expanded Renewable Portfolio Standard or set goals for biogas energy through standard offer contracts at PSC.

Innovative Partnerships

- Utility and farmer: The utility makes it rate of return on assets owned (equipment). How about utility owning equipment to clean gas to pipeline quality or convert to compressed natural gas (CNG) and farmer owns digester. Maybe a policy change is needed to allow utility to a partial owner in projects?

- Turnkey Operations: Third party owns and operates the digester. Farmers provide biomass and manure feedstock and gets end products from digestion. Examples of third party operations in Wisconsin include Pieper Electric/Clear Horizons LLC at the Dane County community digester in Waunakee.

- Combined Heat and Power is the ideal use of biomass and biogas. Good candidates for partnerships include a college or university, hospitals or health centers, and data centers (example Hewlett Packard has shown an interest in digesters).

- Community (Public Benefit payment for investment) -- Tax Incremental Financing District and an Industrial Business Park or an Agriculture Enterprise Area (AEA) designed by DATCP.

- Could Wisconsin do more with the new market tax credits? See Baker Tilly Study.

Additional Policy Ideas for the Wisconsin Biogas Opportunity:

- Include biogas in air construction permits: Develop legislation that allows biogas to be included as a permissible fuel when used in boilers that are presently exempt from Air Construction permits [NR 406.04(1)(a)5] and Air Operation permits [NR 407.03(1)(a)5]. These permit exemptions are presently restricted to natural-gas fueled boilers at a size 25 million btu/hr. and under. Biogas is not included in the definition of "gaseous fossil fuel," which is limited to include natural gas. Therefore, boilers of any size that use any percentage of biogas are required to apply for and receive Air Construction and Air Operation permits.

- Financing Distribution Upgrades: Develop legislative proposals that would allow utilities to provide customers with long-term, low-interest financing, with a forgiveness clause, for the costs of distribution upgrades to:

    - Expanding rural businesses presently served with single phase power, and

    - Rural biogas energy generation (farm digester) that operates in peak mode (60-70 percent on-peak, exact specifications TBD).

Legislative Requirements:

Legislation will be needed to direct PSC to make changes to PSC 113 and PSC 119 that accomplish this policy objective. These rules have sections that govern who must pay for distribution line extensions and upgrades for electric customers (PSC 113) and distributed generation (PSC 119).

Key Issues Addressed by Proposed Policy:

A. Expanding rural businesses: Rural businesses looking to expand operations are required by PSC 113 to pay the cost of power line upgrades. The high cost of upgrades and extensions prevent some rural business expansions. Others may simply stick with single-phase power, which leads to higher electric equipment costs (single phase motors are more expensive.) The costs of building and maintain rural power lines, with few customers per mile, are shared by all customers because those few customers cannot support all those costs via electric use. Increasing electric load in rural areas helps utilities spread the costs of maintaining the many miles of rural electric lines over more kwh, which benefits all customers.

Many rural businesses are served by single phase power. Once the business' load grows to a certain size, upgrading the line to three-phase power allows the business to purchase equipment that is less expensive. Three phase power also offers better power quality and reduces stray voltage concerns, which is important for automation and computer-controlled equipment. Three-phase power also has power quality benefits to the other customers whose loads are served on the same power line as the rural business.

B. Rural Biogas Energy Generation - two big issues with dairy farm biogas generation:

- The increasing cost of power line extensions or upgrades, sometimes for than $1 million, all of which is all borne by the farmer, and

- Farm biogas generators operate 24-7, which yields about 60 percent of the energy produced is during off-peak hours when it is least valuable and largely unwanted by utilities. In some cases, the off-peak power causes grid operation problems for the utility.

The key to this change is that it would allow a utility to offer financing under the prescribed circumstances, but very importantly, not require them to do so. This change would open the door for utilities to investigate and develop financing options and build knowledge of how small, rural peaking units should be controlled and operated. The policy change also gives an impetus for farm digester vendors and farmers to seek out more information on farm biogas storage and technologies that enable biogas systems to operate as peaking plants. In the long term, on-farm biogas storage may lead to higher value uses for farm biogas such as compressed biogas for transportation or local ammonia fertilizer production.

The combination of increasing grid connection costs and too much low-value energy being produced is a key barrier to making rural energy production more viable. Perhaps a solution lies in approaching the two issues in tandem; moving the cost of power line upgrades from the farm to ratepayers, but only if the biogas generator is operated as a peaking unit. The farm would need to invest in biogas storage, which is likely a lower cost than the power line upgrade.

Further Research Ideas:

Wastewater Treatment Plant as Resource Recovery Facility

The goal of this project is to change the standard operating procedures (SOP) of Wisconsin wastewater treatment sites; moving from today's safe disposal of waste SOP to a future of cost-effective resource recovery and safe disposal of waste SOP. In other words, what are the opportunities for wastewater treatment plants to generate some profits to cover some or all operating costs? The resources we can recover range from biogas to plant nutrients, minerals, fibers, animal bedding, etc. There may also be opportunities to increase the value of what is recovered by current resource recovery systems.

There are three main types of wastewater treatment plants:

- Publicly-owned wastewater treatment plants (POTW)

- Privately-owned wastewater treatment plants (Industrial)

- Farm digesters

There are some important barriers to the goal which are:

- WI's regulatory structure for POTW and Industrial systems is focused primarily on safe disposal.

- WI's electric regulatory system including buy-back rates, interconnection costs, etc.

- There is no repository of knowledge and data on resource recovery opportunities. We don't know where to look and what to look for.

- The science and engineering of resource recovery is not well developed and there aren't specific pathways developed for existing systems to follow. (We don't know which resources to pursue and if the recovery of one resource helps or hurts the recovery of another.)

- There is little experience in WI on resource recovery beyond biogas and use of solids for soil amendments or bedding.

- Many of our present business models don't work well for resource recovery projects. (May require public-private partnerships and/or other risk sharing and financing models.)

The following projects are proposed, in no particular order, to help us better define and understand interrelationships, barriers and costs and benefits of moving Wisconsin forward toward resource recovery at wastewater treatment facilities:

A. Wastewater Treatment Plant Resource Recovery Scoping Project

B. Wastewater Treatment Plant Value-Added Projects

A. Wastewater Treatment Plant Resource Recovery Scoping Project

This is envisioned as a scoping exercise that would:

1. Identify current and potential resource recovery opportunities for each of the three types of wastewater treatment plants. This may require a waste stream characterization study via DNR data to flesh out where the best opportunities are at, although polling a few experts may well provide enough information. The Assn. of Wastewater Treatment Directors would be a good group to partner with.

2. Combine the current and potential opportunities into single product opportunities and/or "product packages" (products of value that are/can be produced in tandem, e.g. biogas, electricity, heat, bedding), and prioritize which will receive further analysis.

3. Conduct SWOT and Policy analyses for the priority single products or "product packages."

4. Develop pilot projects for the top priority single product or product packages.

B. Wastewater Treatment Plant Value-Added Projects

There are likely several products presently being recovered at wastewater treatment plants that could have their market value increased by adding further processing or additional technology included so that higher value markets can be served. There are clearly technology, market and/or regulatory barriers to each, otherwise they would already be more widespread.

There are four basic steps to identify and prioritize these opportunities:

1. Identify the range of value-added opportunities that may be cost-effective.

2. Develop a list of barriers and potential solutions that reduce or remove the barriers.

3. Model the cost-effectiveness with barriers removed and estimate barrier removal cost.

4. Develop and implement a pilot project to ground truth barriers, costs and benefits

Potential Value-Added Targets

- Biogas Storage to Maximize On-Peak kWh Production at WWTP
- BioCNG as Transportation Fuel
- Utility Pilot – Voluntary BioNatural Gas Pilot
- Develop an Co-Digestion Substrates Database and Casebook

The first three of the four value-added targets address the following issue. Biogas-fueled electricity generation is the standard practice to get dollar value from WWTPs. However, 24-7 generating practices produce about 60 percent of the energy during off-peak hours, when the product is at minimum value to the buyer, and in some cases, presents a difficulty to the buyer. The first three targets can be considered methods to reduce the amount of off-peak generation by using the biogas for other purposes. The fourth target could be considered as a research project that could help increase the amount of biogas produced and also potentially add tipping fees into the project's cash flow.

Value-Added Target 1. Biogas Storage to Maximize On-Peak kWh Production

Nearly all biogas to electricity plants operate on a 24-7 basis, meaning that about 60 percent of the energy is produced off-peak, when utilities don't need the power. There are few businesses that operate successfully using a business model of marketing the majority of their product when it is not wanted. Biogas storage is being used in other states and countries to allow more of the energy to be produced when it is needed, and therefore more valuable to the buyer (utility).

Known Barriers:

- Little experience with biogas storage in WI and unknown regulatory issues
- Impacts on intermittent operation on engine and generator life is unknown
- Costs of interconnection increase. Potential remedies to investigate could be:
- Utility financing of interconnect costs w/ payback via per kWh charge
- Utility-customer cost-sharing agreement based on:
- Percent of on-peak production
- Dispatchable vs non-dispatchable
- Size
- The point is that if a utility was locating a natural gas intermediate station, all ratepayers would pay for the interconnection. Why should intermediate operation farm- or WWTF-owned be different if they can provide the same level of service?
- The on- vs off-peak spread in current utility buy-back rates don't offer enough incentive for biogas storage and on-peak production.
- Could a "dispatchable, on-peak tariff be developed that would reward systems that could meet the timing and reliability criteria of a traditional utility peaking or intermediate plant? Perhaps tariffs could be developed based on percent kWh on-peak, dispatchability, and system reliability benefits.

Value-Added Target 2. BioCNG as a Transportation Fuel

To better scope this value-added opportunity, it may need to be broken in the three types of wastewater treatment plants and landfills.

- Publicly-owned wastewater treatment plant
- Privately-owned wastewater treatment plants
- Farm digesters
- Landfills

Natural Gas in the U.S. and the Impact on Renewable Biomass

Unlike natural gas, biomass is not a nationalized commodity and does not have historic fuel prices. It is sold in a local market and estimates must be made for that specific market. Some observers have said renewable energy, including some biomass projects, has stalled or died because of record low natural gas prices—at the Henry Hub price of close to $2.00/MMBtu in April 2012 (Henry Hub, 2012). Cheap natural gas does change the equation for some projects. Renewable energy, such as wind and solar, may be challenged by today's natural gas prices, but renewable options including biomass and biogas still have opportunities in this dynamic and changing energy marketplace of the future.

In 2010, shale gas comprised 23 percent of U.S. natural gas supply, but in 2012 the production of shale gas was predicted to double in the next 25 years (EIA, 2012). The future remains uncertain, as natural gas demand increases from the low dollar and expanded pressures to build liquid natural gas terminals to export American natural gas; new pollution laws that force retirement of old coal plants that can't be economically upgraded; and as numerous power and heating plants rush to take advantage of low cost natural gas, these low prices may not last. There are many factors to consider on how long the U.S. will enjoy cheap natural gas and what that means for biomass to energy. First, the natural gas price probably won't stay this cheap long-term when you compare the U.S. price to the global market. Today, while the U.S. may see $2-4.00/MMBtu, the price in Europe is over $10.00/MMBtu and $16.00/MMBtu or higher in Asia (April 2012). The U.S. was at nearly $14.00/MMBtu in 2008. Even with new discoveries the price will likely rise and all energy, including natural gas, plays in a global market, not just domestic market. Natural gas supplies, while abundant now, are not likely to stay at the current level of discovery for the next 100 years. Those bullish on natural gas like to ignore the externalities that tapping into natural gas has many negative environmental consequences. Agencies like the Environmental Protection Agency are poised to tighten regulations as existing and future damage to drinking water supplies results in litigation. Natural gas is a fossil fuel and fugitive methane emissions may be even more troubling to regulators soon.

Renewable energy options can be cost competitive, as natural gas prices start to go up again, and biogas may right now complement a trend toward greater use of compressed natural gas (CNG). If greater infrastructure investments occur because CNG makes for a cheaper vehicle fuel, the pathway to renewable natural gas such as biogas could benefit from the current and future trends. Liquid petroleum prices traditionally drove the energy market. That has changed some today as natural gas prices parted from the traditional tracking of petroleum prices. Still, long-term petroleum prices will again impact all energy prices and whether or not alternatives such as cellulosic ethanol, bio-butanol or drop-in fuels being developed by companies like Madison-based Virent Energy are able to gain market share. Petroleum prices will continue to stay high over the long-term. Coal is not the cheap option some make it out to be as its price has risen every year for a decade, except for some small adjustments when the global economy was at its lowest point. While the existing energy system may not disappear quickly, it is in transition, and the future is not with high carbon coal and oil. Wisconsin's biomass and biogas resources, in combination with existing hydro, wind and solar renewables, continue to position our state for this transition to the new energy economy. In the energy world, a thoughtful long-term view benefits over the short-term view.

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