Midwest Biomass Inventory Assessment

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1. Forward

The objective of this study was to determine potential biomass resources within the Midwest for thermal heating applications in order to provide a “snapshot” of the Midwest biomass inventory for presentation at the 2012 Heating the Midwest Conference & Expo and for furthering the vision of the Heating the Midwest Initiative. This was done, in part, by developing a regional biomass inventory database of previously completed state-level assessments and datasets, which guided the methodology used to conduct the inventory as well as to validate its results. Most importantly, the outcomes of the study can serve as a platform to begin the development of biomass-related projects.

The Midwest Biomass Inventory Assessment supports the Agricultural Utilization Research Institute’s involvement with the Heating the Midwest Initiative, which has a mission to: *“Advance biomass thermal heating in the Midwest for a more sustainable future, while improving the economic, environmental and social well-being of the region.”* This initiative is comprised of a group of volunteers representing industry, government, nonprofit, university and tribal organizations with a serious interest in growing awareness and usage of agricultural and woody biomass and dedicated energy crops for thermal fuel for heat in the Midwest United States. There are five actions teams affiliated with this initiative: Demographics, Biomass Resources, Benefits & Consequences, Biomass Combustion Technology and Policy.

Since its inception, the Agricultural Utilization Research Institute (AURI) has been actively participating in the Heating the Midwest Initiative by serving on the steering committee and leading the Biomass Resource Action Team. AURI’s goal was to partner in raising awareness around biomass-fueled thermal energy, and to collaborate on related activities that contribute to the overarching goal of future economic prosperity, job creation and energy security in the Midwest through the use of non-woody/agricultural biomass and woody biomass feedstocks.

This partnership involved going outside Minnesota’s boundaries to bring together and build working relationships with experts from organizations representing Illinois, Iowa, Michigan, Minnesota, North Dakota, South Dakota and Wisconsin to build a unified strategy and action plan to promote wider growth in the biothermal energy industry. It is hoped this network of professionals will continue to grow in scope and geographically into the future. AURI contributed its leadership, expertise and knowledge in the areas of biomass and innovation networking, and other resources for the purpose of driving this initiative forward in the Midwest. By committing personnel support and cost sharing, AURI was able to move the *Midwest Biomass Inventory Assessment* to fruition as it recognized the potential benefits that the results could have on thermal-based projects in Minnesota focusing on the utilization of ag residues and the potential need for energy crops.

A special thank you is given to David Ripplinger and Ridhima Katyal with the Department of Agribusiness and Applied Economics, NDSU. This study represents the culmination of a successful collaboration with the members of the Biomass Resources Action Team of the Heating the Midwest Initiative representing Illinois, Iowa, Michigan, Minnesota, North Dakota, South Dakota and Wisconsin. The support of Greater

Bemidji (formerly known as the Joint Economic Development Commission), Bemidji, Minnesota, and Minnesota Power, Duluth, Minnesota, are gratefully acknowledged.

For questions or additional information, please contact AURI at 800.279.5010.

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The data presented in this report is reflective of current conditions and model assumptions. All future estimates are speculative. The report is not intended nor should it be used in the place of a thorough local biomass supply assessment.

2. Acknowledgements

The Midwest Biomass Inventory Assessment was funded by the Agricultural Utilization Research Institute (AURI); Greater Bemidji (formerly known as Joint Economic Development Commission), Bemidji, Minnesota; and Minnesota Power, Duluth, Minnesota.

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All errors and omissions that remain in the project remain those of the authors.

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4. Executive Summary

This report presents inventories of crop residue, energy crops and hay, and forest and mill residue in seven Midwestern states: Illinois, Iowa, Michigan, Minnesota, North Dakota, South Dakota, and Wisconsin. The goal is to estimate the percentage of current energy used for heating that can be sustainably displaced using biomass. The study was completed as part of the work of the Biomass Resources Action Team of the Heating the Midwest (HTM) initiative, a volunteer organization interested in increasing awareness and use of biomass feedstocks for heating.

The residential, commercial, and industrial sectors in the Midwest consume large amounts of energy to heat space and water. Table ES-1 presents total energy consumption by sector and fuel for the seven-state region. Natural gas is the dominant feedstock in all sectors. However, biomass is an important fuel especially for the residential and industrial sectors.

Table ES-1. Seven State Energy Consumption by Sector and Fuel[#], 2009 (Trillion Btus)

	Residential	Commercial	Industrial
Coal	2	20	326
Natural Gas	1,148	665	859
Fuel Oil	90	31	172
LPG	134	18	113
Biomass	74	19	150
Other*	17	40	39
Total	1,465	793	1,659

Source: State Energy Data System, Energy Information Administration

[#]Does not include electricity of the biofuel co-products

*Kerosene, gasoline, hydroelectric, geothermal, solar

Biomass feedstocks vary greatly among species and from batch to batch. Differences among species and batches such as heat value; density; and ash, sulfur, and moisture content may cause blockages in fuel lines, inefficient heat production, excess emissions, condensation, or in some cases system shutdown. Knowledge of feedstock characteristics is necessary to measure market supply and to determine feedstock price. Differences are usually readily identifiable and measureable allowing for the establishment of standards and the rejection or discounting of supplies that fail to meet specifications. Suppliers need to know which characteristics are valued in the market and take steps to ensure that their supplies meet required specifications.

The study includes the assembly of previously completed state-level assessments and datasets which guided the methodology used to conduct the inventory as well as to validate its results. The inventory relies on data from the Billion-Ton Study Update as it is the only national study to price feedstock supply and incorporate sustainability. The Billion-Ton Study Update includes estimates of agricultural, forest, and secondary biomass feedstock supplies for the years 2012-2030. An online database located at the Knowledge Discovery Framework, https://bioenergykdf.net/models/bts-download, provides access to detailed, county-level data. The Billion-Ton Study Update includes estimates of biomass feedstock availability under different scenarios. These include varying feedstock prices and increases in yield for agricultural and energy crops resulting from improved varieties and production methods. Before compilation of data, these alternatives were reviewed and preliminary prices and yield increases identified. The national price of all biomass (crop residue, energy crops, forest, and mill residue) was set at $50 per ton, low-yields for feedstocks, and no yield improvements for energy crops were assumed.

In addition to the publication of this report, the effort presents a snapshot of the current Midwest biomass inventory and an introductory, high-level determination of availability relative to energy consumption. This is achieved by relying on a uniform methodology and dataset from the Billion Ton Study Update Report (U.S. Department of Energy 2011) to assemble region-wide values that would be compared to existing inventories.

The 2012 inventory of biomass feedstocks for the seven-state region is presented in Table ES-2. Corn stover and hay are the largest sources of biomass feedstock.

Table ES-2. Seven State Biomass Feedstock Inventory, 2012 (1,000 tons)

Agricultural Biomass	**Thousand Tons**	**Trillion Btus**
Crop Residue		
Barley Straw	744	11
Corn Stover	46,229	653
Oat Straw	-	-
Wheat Straw	5,592	76
Total	52,564	740
Hay	29,240	418
Total	81,805	1,158
Dedicated Energy Crops		
Perennial grass	-	-
Woody Energy Crops	-	-
Total	-	-
Forest Biomass		
Logging Residue & Thinnings	3,353	27
Other Removal Residue	2,324	19
Total	5,677	45
Secondary Biomass		
Mill Residue	98	1
Total	87,579	1,204

Biomass feedstocks typically have valuable uses other than the production of thermal energy. Mill residue is used for livestock bedding and combined heat and power (CHP) applications. The vast majority of crop residue is left in the field with the exception of small amounts of straw used for bedding. Feedstock price is determined, in part, by alternative uses. Furthermore, consumers and business will seek high-value, low-cost fuel sources. For example, the use of shelled corn for home heating has waned as higher commodity prices have made it less competitive with other fuels.

Changes in the Conservation Reserve Program are expected to result in a reduction in enrolled acres in the next few years. The use of land removed from the program is not known with certainty, but it is likely that much of it will be used for crop production given high commodity prices. It may also find use in the production of energy crops, especially perennial grasses. Regardless of its use for production of traditional or energy crops, an increase in available biomass either in the form of crop residue or energy crops is possible.

A local biomass supply assessment is necessary when evaluating development of a new biomass enterprise. High-level assessments, such as this report, do not provide the detail necessary to make a site-specific decision. Both Heating the Midwest and the authors caution against using this report for site-specific decisions. The inventory relies on assumptions developed under guidance of the Heating the Midwest Inventory Working Group which may not align with local conditions. While it can serve as a starting point for the siting of a solid biomass aggregation or conversion facility, the inventory does not replace the need for on-site visits, and discussions with producers and owners of biomass. Other firms may be working to secure the same supplies simultaneously. Detailed local analysis by bioenergy professionals is necessary.

5. Heating the Midwest

Residential, commercial, and industrial heating requires massive amounts of energy, the majority of which currently comes from fossil fuels. However, in addition to energy security and environmental concerns, finite availability makes the use of fossil fuels unsustainable.

Although Midwestern states, defined in this report as Illinois, Iowa, Michigan, Minnesota, North Dakota, South Dakota, and Wisconsin, have significant heating needs because of their climate, they have traditionally produced little of the heating fuels they consume. Even with new technically recoverable energy supplies including shale gas in the Bakken in North Dakota, Antrim in Michigan, and New Albany in Illinois, energy security and sustainability remain relevant and will only increase in importance over time.

Biomass, a sustainable alternative to fossil fuels, has long been a primary residential heating fuel. 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 2011). It includes biomass produced directly by photosynthesis that is harvested or collected from the field or forest where it is grown (primary biomass), residues and by-products from food, feed, fiber, wood and materials processing plants (secondary biomass), and post-consumer residues and wastes (tertiary biomass).

Firewood, has been the traditional thermal biomass fuel; however, other forest and agricultural biomass feedstocks can be used for home, commercial, and industrial heating. Growth of the use of biomass as a heating fuel depends on its technical and economic availability, composition, and cost relative to other fuels.

In this report, background information, methods, results, and implications of an inventory of Midwest biomass are presented. Biomass feedstocks of interest in the analysis are limited to agricultural crop residue, energy crops and hay, and forest and mill residue. The goal of the study is to estimate the percentage of current energy used for heating that can be sustainably displaced using biomass. The study includes the assembly of previously completed state-level assessments and datasets which guided the methodology used to conduct our inventory as well as to validate its results. In addition to the publication of this report, the effort presents a snapshot of the current Midwest biomass inventory and an introductory, high-level determination of availability relative to energy consumption. This is achieved by relying on a uniform methodology and dataset from the Billion Ton Study Update Report (U.S. Department of Energy 2011) to assemble region-wide values that would be compared to existing inventories.

The report was completed as part of the work of the Biomass Resources Action Team of the Heating the Midwest (HTM) initiative, a volunteer organization interested in increasing awareness and use of biomass feedstock for heating. Heating the Midwest's mission is "To advance biomass thermal heating in the Midwest for a more sustainable future, while improving the economic, environmental, and social well-being of the region." More information can be found on the organization's Website at www.heatingthemidwest.org.

To better frame the broader heating industry, the study assembled current energy consumption data by fuel and sector, as well as reviewed biomass feedstocks, characteristics, and standards. The scope of the assessment is limited to biomass feedstocks, thermal energy, and seven Midwestern states that were actively involved in the Heating the Midwest initiative: Illinois, Iowa, Michigan, Minnesota, North Dakota, South Dakota, and Wisconsin.

Report Outline

The report presents estimates of state-level biomass inventories. Section 2 discusses current energy consumption for the residential, commercial, and industrial sectors. Section 3 presents an overview of biomass feedstocks, characteristics, and standards. Previous biomass assessments conducted in the seven-state region are reviewed in Section 4. The methodology to assess the biomass inventory is presented in Section 5 with the results of the inventory appearing in Section 6. Findings and implications of the study are discussed in Section 7.

6. Thermal Energy Consumption

The objective of the Midwest Biomass Assessment is to estimate the proportion of energy currently used for heating that can be met using biomass feedstocks. This requires an understanding of current energy consumption as well as biomass availability. In this section, we review current thermal energy consumption in residential, commercial, and manufacturing markets as reported by the U.S. Census and Energy Information Administration (EIA) and the relative cost of common heating fuels.

It should be noted that our geographic definition of the Midwest and that used by the U.S. Census differ. The Census Midwest Region is broader including the states of Indiana, Kansas, Missouri, Nebraska, and Ohio in addition to the seven states under our definition. A map of U.S. Census regions are presented in Figure 2.1.

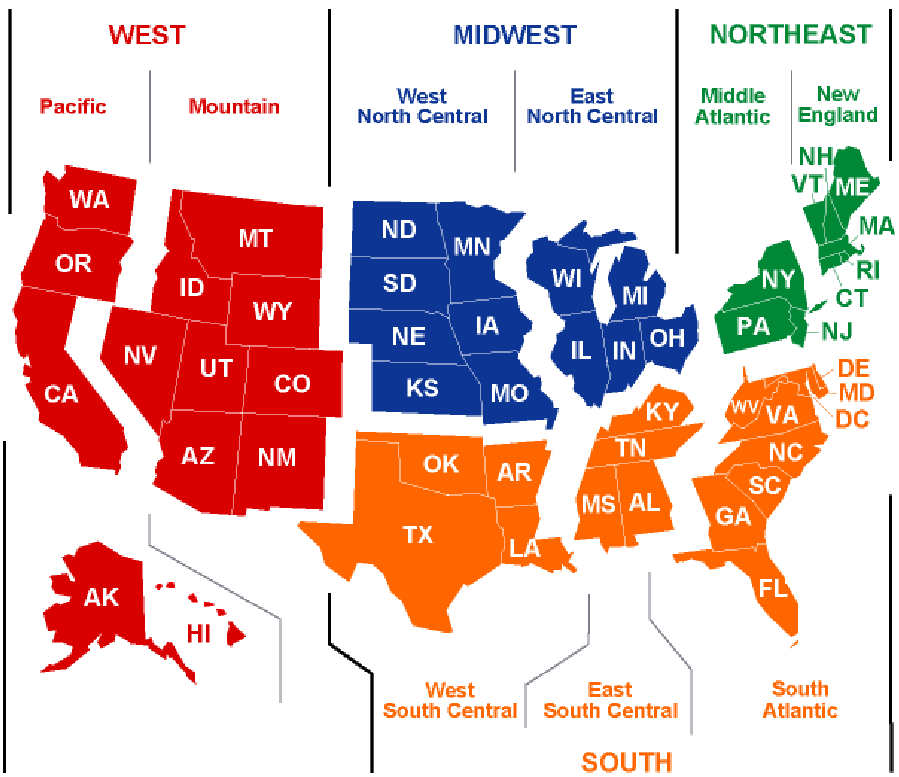

Figure 6.1 Census Regions Map

6.1 Residential Heating

The U.S. Census collects detailed housing unit data as part of the ongoing American Community Survey (ACS). The ACS is sent to 250,000 addresses monthly collecting information previously gathered by the long form of the decennial census.

Among the data available in the ACS, is the primary source of residential heating fuel by housing unit. In the Midwest, natural gas is by far the primary heating fuel and is used by 10.7 million of 14.7 million homes. However, use varies by state from being the primary fuel of 80% of Illinois residences to 40% of North Dakota residences. The second most dominant fuel is electricity in all states except Michigan where liquefied petroleum gas (LPG) takes its place. The use of wood varies greatly from approximately .5% in Illinois and North Dakota to nearly 5% in Wisconsin. While many residences have the ability to utilize more than one type of fuel, use of secondary fuels is not collected by the ACS. The primary fuel used to heat residences is presented in Table 2.1.

Table 6.1 Primary Residential Heating Fuel, Number of Homes

	Illinois	Iowa	Michigan	Minnesota	North Dakota	South Dakota	Wisconsin
Utility gas	3,817,215	787,742	2,955,744	1,404,878	112,756	155,638	1,488,259
Bottled, tank, or LP gas	201,279	166,138	331,330	214,285	41,337	53,407	250,022
Electricity	663,759	220,296	284,011	312,238	104,750	85,447	320,964
Fuel oil, kerosene, etc.	10,714	9,510	61,775	65,801	12,532	9,105	81,908
Coal or coke	602	109	986	354	828	276	308
Wood	22,983	19,924	128,481	54,493	1,632	7,259	106,608
Solar energy	843	184	693	237	73	119	345
Other fuel	19,224	13,059	29,960	26,135	4,035	5,588	22,028
Total*	4,736,619	1,216,962	3,792,980	2,078,421	277,943	316,839	2,270,442

Source: American Community Survey, U.S. Census, 2010

*May not sum due to rounding

While an understanding of the primary type of fuel by residence is informative, our focus is on actual energy use. This is better illustrated with data from the Residential Energy Consumption Survey (RECS) which is conducted by the Energy Information Administration. This survey last collected useable data for our purposes in 2005. The amount of Btus from major sources: electricity, natural gas, fuel oil, kerosene, and LPG are presented in Table 2.2. While there are differences between the Census' Midwest region and our seven states, it is expected that general comparisons should hold.

Nationally, 4.3 quadrillion Btus were used for home space heating in 2005. 1.45 quadrillion Btus were used to heat residential spaces in the Midwest. Of major fuels, almost 70 percent of this energy is supplied by natural gas, followed by fuel oil with 17 percent, and liquefied petroleum gas and electricity with about 7.5 percent. The RECS does not collect data on the number of Btus from wood or other renewable sources. Midwestern homes are most likely to heat their homes with natural gas with 83% of home space heating energy using that fuel. Natural gas supplies ten times the Btus that came from the next highest source, LPG, and twenty times that supplied by fuel oil or electricity.

Table 6.2 Residential Energy Consumption: Space Heating

	U.S. Households (millions)	Total U.S. Using a Major Space Heating Fuel (millions)	Major Fuels Used (quadrillion Btu)					
			Total	Electricity	Natural Gas	Fuel Oil	Kerosene	LPG
Total..............................	111.1	106.3	4.30	0.28	2.95	0.73	0.02	0.32
Midwest......................	25.6	24.8	1.45	0.05	1.21	0.06	Q	0.12
East North Central.....	17.7	17.1	1.08	0.03	0.91	0.05	Q	0.07
West North Central...	7.9	7.8	0.37	0.02	0.30	Q	Q	0.05

Source: Residential Energy Consumption Survey, Energy Information Administration, 2005

The Residential Energy Consumption Survey also reports the amount of energy used for residential water heating which nationally consumes about half as many Btus as residential space heating. In the Midwest, natural gas provides just less than 80 percent of the 520 trillion Btus of major fuels used to heat water. Electricity provides 13 percent followed by LPG which supplies 8 percent. Table 2.3 presents residential energy consumption used for water heating by source.

Table 6.3 Residential Energy Consumption: Water Heating

	U.S. Households (millions)	Total U.S. Using a Major Water Heating Fuel (millions)	Major Fuels Used (quadrillion Btu)				
			Total	Electricity	Natural Gas	Fuel Oil	LPG
Total..............................	111.1	109.8	2.11	0.42	1.41	0.14	0.15
Midwest.......................	25.6	25.4	0.52	0.07	0.40	Q	0.05
East North Central......	17.7	17.6	0.37	0.05	0.29	N	0.03
West North Central.....	7.9	7.8	0.15	0.02	0.11	Q	0.02

Source: Residential Energy Consumption Survey, Energy Information Administration, 2005

The Energy Information Administration provides total energy consumption by sector and state as part of its State Energy Data System (SEDS). However, this data set does not differentiate between the amount of energy used for electricity or heating. Natural gas was the primary source of residential energy in 2009. Wood was used for residential energy in all states and was a significant fuel in Michigan, Minnesota, and Wisconsin. Residential energy consumption by fuel and state for 2009 is presented in Table 2.4.

Table 6.4 Residential Energy Consumption, 2009 (Trillion Btus)

	Coal	Natural Gas	Fuel Oil	Kerosene	LPG	Wood/ Biomass	Geothermal	Solar
TOTAL	**2.2**	**1147.9**	**23.4**	**6.6**	**133.7**	**73.8**	**7.8**	**2.9**
Illinois	0.4	445.7	0.7	0.2	23.2	6.6	1.4	1.5
Iow a	0.6	70.6	1.1	0.1	19.8	4.3	0.4	0.1
Michigan	0.6	333.4	5.4	0.4	35.3	25.5	3.7	0.7
Minnesota	0.1	137.4	6.1	0.1	19.1	10.7	0.9	0.3
North Dakota	0.2	12.2	1.9	5.6	7.6	0.4	0.5	-
South Dakota	-	13.6	0.8	-	5.6	1.2	0.4	-

Source: State Energy Data System, Energy Information Administration

6.2 Commercial Heating

Commercial energy consumption for heating data is collected by the Energy Information Administration using its Commercial Buildings Energy Consumption Survey which last reported useable data in 2003. The last useable survey data was collected in 2003. The commercial sector uses about half as much energy for space heating as does the residential sector. 870 trillion Btus are used to heat commercial spaces in the Midwest. Like the residential sector, natural gas is the primary source of energy for heating providing 70 percent of all Btus in the Midwest. However, district heat, a system for distributing heat from a centralized location, provides 24 percent of Btus in the Midwest. Commercial energy consumed for space heating is presented in Table 2.5.

Table 6.5 Commercial Energy Consumption Space Heating by Source

	All Buildings		quadrillion Btus				
	Number of Buildings (thousand)	Floorspace (million square feet)	Total	Electricity	Natural Gas	Fuel Oil	District Heat
Total	4,859	71,658	2.37	0.17	1.42	0.20	0.58
Midwest	1,305	18,103	0.87	0.05	0.59	-	0.21
East North Central	728	12,424	0.68	0.03	0.45	-	0.18
West North Central	577	5,680	0.20	0.02	0.14	-	-

Source: Commercial Buildings Energy Consumption Survey, Energy Information Administration , 2003

The commercial sector uses about one-fourth the energy of the residential sector to heat water. Across the Midwest, 110 trillion Btus are used to heat water in the commercial sector. About 70 percent of the energy used to heat water in the commercial sector comes from natural gas, 20 percent from electricity and 10 percent from district heat. Commercial energy consumption for water heating is presented in Table 2.6.

Table 6.6 Commercial Energy Consumption Water Heating by Source

	All Buildings		Quadrillion Btus				
	Number of Buildings (thousand)	Floorspace (million square feet)	Total	Electricity	Natural Gas	Fuel Oil	District Heat
Total	4,859	71,658	0.50	0.09	0.35	0.02	0.05
Midwest	1,305	18,103	0.11	0.02	0.08	0.00	0.01
East North Central	728	12,424	0.08	0.01	0.06	-	0.01
West North Central	577	5,680	0.03	0.01	0.02	-	-

Source: Commercial Buildings Energy Consumption Survey, Energy Information Administration, 2003

The State Energy Data System reports energy consumption used by commercial firms. As with the residential sector, most energy comes from natural gas. Furthermore, wood is used in all states to some degree with the greatest use in Michigan, Minnesota, and Wisconsin. Commercial energy consumption by sector is presented in Table 2.7.

Table 6.7 Commercial Energy Consumption, 2009 (Trillion Btus)

	Coal	Natural Gas	Distillate Fuel Oil	Kerosene	LPG	Gasoline	Residual Fuel Oil	Hydroelectric	Wood/ Biomass	Geothermal
TOTAL	**20**	**664.9**	**30.9**	**0.1**	**17.9**	**19.1**	**1.3**	**0**	**18.5**	**2.5**
Illinois	3.5	225.6	5.1	0.1	3.3	4.7	0	0	1.1	0
Iowa	5.5	57.1	3.1	-	3.7	9.8	0	0	1.3	0.6
Michigan	5.7	167.2	8.2	-	2.5	0.7	0.1	0	8.9	0.7
Minnesota	0.9	99.1	6.3	-	2.8	3.4	1.2	0	2.3	0
North Dakota	1.5	11.6	1.2	-	1.5	0.1	-	0	0.1	0.3
South Dakota	0.2	11.6	1	-	1.5	0.1	-	0	0.2	0.9

Source: State Energy Data System, Energy Information Administration

6.3 Industrial Heating

Energy used for industrial heating is collected by the Energy Information Administration as part of its Manufacturing Energy Consumption Survey (MECS). The most recently available data is from the 2006 survey.

Table 2.8 presents industrial uses of fuel by type and use. Wood and other renewable sources are included in the "Other" category. While together this category uses 1.1 quadrillion Btus, we are unable to determine how much of that amount comes from biomass or how much of the energy is released for combined heat and power (CHP) or process heat. Estimated CHP processes use 232 trillion Btus of energy while process heating uses just more than one quadrillion Btus.

Table 6.8 Midwest Industrial Fuel Use (trillion Btus)

End Use	Total	Net Electricity	Residual Fuel Oil	Distillate Fuel Oil and Diesel Fuel	Natural Gas	LPG and NGL	Coal (excluding Coal Coke and Breeze)	Other
TOTAL FUEL CONSUMPTION	4,144	934	37	26	1,582	21	404	1,142
Indirect Uses-Boiler Fuel	--	9	20	1	482	2	216	--
Conventional Boiler Use		9	14	1	416	2	56	
CHP and/or Cogeneration Process		0	6	*	66	*	160	
Direct Uses-Total Process	--	731	13	Q	852	8	167	--
Process Heating	--	127	13	1	770	4	106	--
Process Cooling and Refrigeration	--	68	0	*	6	0	0	--
Machine Drive	--	487	*	Q	16	*	52	--
Electro-Chemical Processes	--	37	--	--	--	--	--	--
Other Process Use	--	13	0	Q	Q	4	9	--
Direct Uses-Total Nonprocess	--	189	Q	12	214	9	2	--
Facility HVAC (f)	--	88	Q	*	197	1	1	--
Facility Lighting	--	76	--	--	--	--	--	--
Other Facility Support	--	21	*	*	15	*	0	--
Onsite Transportation	--	3	--	9	*	7	--	--
Conventional Electricity Generatior	--	--	0	Q	*	*	0	--
Other Nonprocess Use	--	1	*	2	1	1	*	--
End Use Not Reported	1,206	5	4	1	33	1	20	1,142

Source: Manufacturing Energy Consumption Survey, Energy Information Administration, 2006

* Estimate less than .5

Q withheld due to small sample size

The Manufacturing Energy Consumption Survey reports on the use of biomass by source and sector. This includes the use of pulping or black liquor (a co-product of the pulping process) as well as agricultural waste from food processing, wood, wood residue, and wood and paper waste. All told these biomass fuels provided 71 trillion Btus of energy in the Midwest in 2006; however, it is not known how much of this energy was used to produce heat. Table 2.9 presents the use of biomass as fuel in Midwest manufacturing.

Table 6.9 Midwest Biomass Fuel Use (trillion Btus)

	Pulping Liquor or Black Liquor	Biomass Total	Agricultural Waste	Wood Harvested Directly from Trees	Wood Residues and Byproducts from Mill Processing	Wood-Related and Paper-Related Refuse
Food	0	1	*	*	*	*
Wet Corn Milling	0	0	0	0	0	0
Beverage and Tobacco Products	0	0	0	0	0	0
Wood Products	0	Q	0	Q	14	*
Saw mills	0	4	0	0	4	0
Veneer, Plywood, Engineered Wooc	0	5	0	0	5	0
Other Wood Products	0	Q	0	Q	4	*
Paper	42	26	*	3	21	3
Pulp Mills	0	0	0	0	0	0
Paper Mills, except Newsprint	41	24	*	3	19	3
Newsprint Mills	0	0	0	0	0	0
Paperboard Mills	1	2	0	0	2	*
Furniture and Related Products	0	Q	0	0	Q	0
Other Manufacturing	0	1	0	1	*	*
Total	42	28	*	4	35	3

Source: Manufacturing Energy Consumption Survey, Energy Information Administration, 2006

* Estimate less than .5

Q withheld due to small sample size

Industry relied primarily on natural gas as a source of energy for the seven-state Midwest region in 2007. Coal use was significant in all states but South Dakota. Wood/biomass, liquefied propane gas, and distillate fuel oil were also used as fuels. Table 2.10 presents the industrial energy consumption by state and fuel for 2009.

Table 6.10 Industrial Energy Consumption, 2009 (Trillion Btus)

	Coal	Natural Gas	Distillate Fuel Oil	LPG	Gasoline	Residual Fuel Oil	Hydroelectric	Biomass	Geothermal
TOTAL	**326.2**	**858.9**	**172.2**	**112.5**	**36.4**	**2.4**	**2.6**	**149.6**	**0.2**
Illinois	73.9	238.2	32.4	43.4	7.9	0.1	0	12.6	0
Iow a	52.6	165.7	32.8	39.4	6	0	0	18.4	0
Michigan	47.1	140	18.5	3.5	7.5	0.7	0.2	33.2	0
Minnesota	22.4	132.2	32.4	15.3	5.2	0.6	1.3	32.6	0
North Dakota	93.9	24.5	23.4	3.2	2.4	0.2	0	1.5	0
South Dakota	2.1	36.9	11.1	2.5	2.2	-	0	0.2	0.2

Source: State Energy Data System, Energy Information Administration

6.4 The Relative Cost of Fuel

The price of individual thermal energy feedstocks vary widely. While used for the same purpose, these fuels are not perfect substitutes for one another. Each fuel has unique physical and chemical characteristics and are subject to distinct supply and demand forces. The relative cost of common fuels per Btu is presented in Table 2.11. Estimated prices are meant to serve as a general gauge of regional thermal fuel costs and may vary considerably from one location to another.

Table 6.11 Relative Heating Fuel Costs

Fuel	Price Range					2012 Price (est.)
Coal ($ per ton)	20.00	30.00	40.00	50.00	60.00	52.74
$ per million Btu	**1.00**	**1.50**	**2.00**	**2.50**	**3.00**	**2.64**
Natural Gas ($ per MMBtu)	**2.00**	**3.00**	**4.00**	**5.00**	**6.00**	**2.75**
Liquid Propane ($ per Gallon)	1.00	1.50	2.00	2.50	3.00	2.04
$ per million Btu	**10.95**	**16.42**	**21.90**	**27.37**	**32.85**	**22.34**
#2 Fuel Oil ($ per gal)	2.50	3.00	3.50	4.00	4.50	4.00
$ per million Btu	**18.25**	**21.90**	**25.55**	**29.20**	**32.85**	**29.20**
Diesel ($ per gal)	3.00	3.50	4.00	4.50	5.00	4.05
$ per million Btu	**21.90**	**25.55**	**29.20**	**32.85**	**36.50**	**29.56**
Gasoline ($ per gal)	2.00	2.50	3.00	3.50	4.00	3.86
$ per million Btu	**16.00**	**20.00**	**24.00**	**28.00**	**32.00**	**30.88**
Electricity($ per kW-hr)	0.05	0.10	0.15	0.20	0.25	0.15
$ per million Btu	**14.65**	**29.30**	**43.95**	**58.60**	**73.25**	**43.95**
Wood Pellets ($ per ton-bulk)	60.00	80.00	100.00	120.00	140.00	120.00
$ per million Btu	**3.75**	**5.00**	**6.25**	**7.50**	**8.75**	**7.50**
Wood Pellets ($ per 40 lb bag retail)	3.00	4.00	5.00	6.00	7.00	4.05
$ per million Btu	**9.38**	**12.50**	**15.63**	**18.75**	**21.88**	**12.66**
Ag Biomass or Corn Stover ($ per ton)	20.00	40.00	60.00	80.00	100.00	70.00
$ per million Btu	**1.67**	**3.33**	**5.00**	**6.67**	**8.33**	**5.83**
Corn ($ per bushel)	3.00	4.00	5.00	6.00	7.00	6.15
$ per million Btu	**6.86**	**9.15**	**11.43**	**13.72**	**16.01**	**14.06**

Source: Root, 2012

6.5 Summary

The residential, commercial, and industrial sectors in the Midwest consume large amounts of energy to heat space and water. While state-level thermal energy use by feedstock data is not available, other information can provide a helpful understanding of the order of magnitude of energy used for heating in the Midwest. Natural gas is by far the dominant fuel for space and water heating. Displacing this fuel with a sustainable alternative such as biomass may be difficult. The cost of heating fuels per Btu varies considerably. In the next section we review biomass feedstock characteristics and standards.

7. Biomass Feedstock Classification, Characterization, and Standards

The goal of the Midwest Biomass Assessment is to determine the percentage of the Midwest's thermal energy needs that can be met using biomass. In the previous section, energy used for heating data was presented. Before moving on to quantifying supplies, we'll take a brief detour to discuss pertinent differences in biomass feedstocks that may be used as solid biofuels. To accurately quantify supply we must recognize and accommodate the fact that not all biomass is grown or processed into material that is equivalent in terms of heating or handling.

Biomass feedstocks vary greatly among species and from batch to batch. Physical and chemical characteristics can significantly impact handling and heating with batches differing enough so as to affect their usability with a particular combustion system. Differences are usually readily identifiable and measureable allowing for the establishment of standards and the rejection or discounting of supplies that fail to meet specifications. The development of standards is necessary for biomass markets to grow and function. Their role in quantifying and pricing biomass supplies is fundamental. In this section we review solid biomass feedstock classifications, characteristics, and standards.

7.1 Classifying Biomass Feedstock

Solid biomass feedstocks are typically classified according to their source and location in the supply chain. CEN 14961, a European standard for solid biomass, differentiates sources into four groups: woody, herbaceous (agricultural and horticultural), fruit, and blends and mixtures. Biomass can be further classified as primary, secondary, or tertiary depending on its state. Primary biomass is defined as biological materials produced directly by photosynthesis and harvested directly from the forest or field. Primary biomass includes dedicated energy crops such as perennial grasses and short-rotation woody crops, as well as crop and forest residue. Secondary biomass includes materials created from the processing of primary biomass including sawdust from sawmills, black liquor from pulping, and manure. Tertiary biomass consists of post-consumer material such as animal fats and grease, vegetable oil, packaging waste, and construction and demolition debris.

It is important to note that different conversion technologies have different fuel specifications. At the same time, energy users have different preferences and requirements for fuels. For example, residential consumers prefer fuels that produce relatively little ash and the heating appliances that can run automatically in their absence.

7.2 Biomass Feedstock Characteristics

Physical and chemical characteristics affect the quality of biomass as a solid fuel. Differences among species and batches may cause blockages in fuel lines, inefficient heat production, excess emissions, condensation, or in some cases system shutdown. Knowledge of biomass characteristics is also necessary to measure market supply and to determine feedstock pricing. Suppliers need to know which characteristics are valued in the market and take steps to ensure that their supplies meet required specifications.

There are numerous characteristics that impact the quality of biomass feedstocks. Here we focus on those typically considered most important: heat value, ash, sulfur, moisture, and density. Much of the information presented below comes from Pennsylvania State University's *Characteristics of Biomass as a Heating Fuel* Fact Sheet (2010).

Heat Value - is the amount of energy available in a fuel and is measured as higher heating value (HHV) or lower heating value (LHV). Higher heating value considers the full energy content of the fuel including that contained in water vapor and is the value typically reported for combustion processes. Lower heating value does not consider this energy. Heat value is measured in terms of energy per unit of weight, e.g. J/kg or Btus/lb. The amount of energy per unit of mass varies by feedstock, species, and condition. Heat value can be impacted by the climate and soil where biomass is grown.

Moisture Content - impacts that amount of energy in wet fuel that must be used to vaporize water. At the same time, extremely dry fuel can be an explosion hazard. Moisture content is measured as the mass of water divided by the total mass of the fuel (wet basis) or by the dry mass of the fuel (dry basis).

Ash - is the inorganic, noncombustible residue left after combustion. Ash content is typically much higher for grasses, bark, and crop residue. The amount of ash left from combusting herbaceous feedstocks may overwhelm systems designed for wood.

Slagging and Fouling – are molten ash deposits identified as chunks at the base of the combustion chamber (slagging) or on combustion surfaces (fouling). The occurrence of slagging and fouling varies by temperature and can result at lower temperatures due to the presence of minerals such as silica, potassium, and chlorine. Many agricultural feedstocks have high mineral content creating potential slagging or fouling problems. For example, facilities have experienced difficulty using corn stover because of its chlorine content. Specialized systems may address this by ensuring combustion occurs at relatively low temperatures or by including additives to chemically collect and remove unwanted material.

Size and Density – can affect burning characteristics of the fuel as well as the type of handling equipment needed. Improperly sized fuel will impact the efficiency of the combustion process by affecting the rate of heating and drying or may result in jamming or damage to the handling equipment. Low density fuels may combust too quickly or float above the primary combustion zone.

Higher Heating Value, moisture content, ash content, and density of select biomass feedstocks are presented in Table 3.1. Note that the ash content of wood varies greatly depending on bark content and that crop residue contains approximately 8,000 Btus on a dry weight basis.

Table 7.1 Thermal and Physical Properties of Biomass

	Density	HHV	Moisture	Ash
Firewood (hardwood)		24 million btus/cord	12	0.5*
Firewood (softwood)		20 million btus/cord	12	0.3*
Wood pellets	40 lbs/cu ft	8,2000 btus/lb	7.5	0.8
Wood chips	10-30 lbs/cu ft	4,000 btus/lb	45	
Barley	37.2 lbs/cu ft	6,820 btus/lb	11.4	2.5
Corn	45 lbs/cu ft	6,970 btus/lb	15.5	1.3
Corn cobs	13 lbs/cu ft	7,370 btus/lb	7.1	2.2
Corn stover		7,060 btus/lb	9.1	6.8
Oats	26 lbs/cu ft	7,140 btus/lb	12.5	3.2
Wheat	48 lbs/cu ft	7,160 btus/lb	10.4	2.1
Wheat straw		6,840 btus/lb	9.9	10.4

Source: Buffington, 2008; *Pettersen, 1984

The combustion of biomass can result in the release of a number of pollutants. Actual emissions will depend on the fuel, type, and completeness of combustion.

7.3 Biomass Feedstock Standards

Standards play a critical role in the development and operation of markets. The growth and promise of the solid biofuels industry has led to a number of standard development efforts. These include standards for biomass definitions, testing, specifications, and sustainable supply chains. Much of this activity has occurred in Europe which has a larger, more established solid biofuel industry. Here we review select standard development activities to illustrate the importance of biomass standardization.

The Pellet Fuels Institute released its standards for residential/commercial densified fuel in 2011. The standards include the scope of the standard, definition of terms, detailed requirements (presented in Table 3.2), and sampling and testing methods. The standards' detail requirements including three specifications for premium, standard, and utility grade fuels. Requirements include density and size, physical durability, percentage of fines, ash, moisture, chloride, and heating value. The Pellet Fuels Institute mandates that bags of fuel be labeled to identify which grade of material is in the bag as well as any additives. The standard does not differentiate by the type of biomass. The American Lumber Standard Committee will serve as the program's accreditation body.

Table 7.2 Residential/Commercial Densified Fuel Standards

	Residential/Commercial Densified Fuel Standards See Notes 1 - 3		
Fuel Property	PFI Premium	PFI Standard	PFI Utility
Normative Information - Mandatory			
Bulk Density, lb./cubic foot	40.0 - 46.0	38.0 - 46.0	38.0 - 46.0
Diameter, inches	0.230 - 0.285	0.230 - 0.285	0.230 - 0.285
Diameter, mm	5.84 - 7.25	5.84 - 7.25	5.84 - 7.25
Pellet Durability Index	≥ 96.5	≥ 95.0	≥ 95.0
Fines, % (at the mill gate)	≤ 0.50	≤ 1.0	≤ 1.0
Inorganic Ash, %	≤ 1.0	≤ 2.0	≤ 6.0
Length, % greater than 1.50 inches	≤ 1.0	≤ 1.0	≤ 1.0
Moisture, %	≤ 8.0	≤ 10.0	≤ 10.0
Chloride, ppm	≤ 300	≤ 300	≤ 300
Heating Value	NA	NA	NA
Informative Only - Not Mandatory			
Ash Fusion	NA	NA	NA

Source: Pellet Fuels Institute

Comparing the specifications for pellets in Table 3.2 and the properties of biomass from Table 3.1 one can see that only round wood can meet the ash specification for premium fuel pellets. At the same time, corn stover is unable to meet even the utility spec because of its ash content.

In Europe, Technical Committee 335 of the European Committee for Standardization (CEN) has developed 28 related solid biofuel standards. This includes CEN-TS 14961 which was referenced previously in the section when discussing biomass classification. However, these standards are not the only ones that exist in Europe with many individual countries including Austria, Sweden, and Germany having their own.

Work to harmonize international standards has been the goal of a technical committee (ISO TC 238) of the International Organization for Standardization. This group currently has eight standards under development including a common set of terminology, definitions, and descriptions; general requirements; as well as specifications for six distinct fuels: wood pellets, wood briquettes, wood chips, firewood, non-woody pellets, and non-woody briquettes. The American Society of Agricultural and Biological Engineers (ASABE) coordinates the U.S. position in this international effort.

The Council on Sustainable Biomass Production (CSBP) is developing voluntary sustainability standards for biomass production and conversion (Council on Sustainable Biomass Production 2011). The intent is for the standard to serve as the basis for third-party accreditation. CSBP's provisional standard defines the scope as including dedicated energy crops, crop residue, and native vegetation. Its sustainability criteria includes soil quality, biological diversity, water quality and quantity, climate change, socio-economic well-being, legality, transparency, and continual improvement.

7.4 Summary

In this section, solid biomass feedstock classifications, characteristics, and standards were presented. The goal was to recognize the important differences among biomass feedstocks as well as variability that may be found among batches of a particular material. These differences have resulted in efforts to develop standards which are critical to the development and operation of biomass markets.

8. Previous Regional Biomass Assessments

Despite current and growing interest in biomass as a feedstock for transportation fuels and heat, there has been limited work to assess its availability in the Midwest. Studies that have been completed have varied greatly in terms of methodology as well as by geographic scope and feedstocks. Efforts have resulted in the development of online assessment tools as well as traditional published reports. Few assessments consider the impact of land use change that may result from the emergence of new bioenergy markets. Few studies have had good economic or sustainability screens. Online tools and information systems are typically designed to assist users in determining biomass availability for a given location, but don't allow ready access to their database. This makes reporting and comparison of assessed levels of biomass difficult. That being said, knowledge of previously completed biomass assessments and those in the early stages of development are helpful for our purposes as we develop our own methodology.

In addition to overseeing the Midwest Biomass Inventory Assessment which culminated in this report, the Heating the Midwest Biomass Resources Action Team also identified relevant biomass studies, including biomass assessments, from across the region. These works were assembled into a shared database that included citation information and URL if available for each document. A companion database containing supply, price, and other assessment data was also assembled as part of the broader effort. Previously unlisted references were added to the Knowledge Discovery Framework Bioenergy Library (https://www.bioenergykdf.net/).

In this section, we review select biomass feedstock inventories conducted or currently underway in the Midwest. National assessments including the original Billion Ton Study (U.S. Department of Energy 2005), NREL Biomass Resource Availability Studies (eg Milbrant 2005), and the Billion-Ton Study Update are discussed in the next section.

Northeast Iowa Biomass Asset Map

The Northeast Iowa Biomass Asset Map (http://www.decision-innovation.com/biomass.html) is a free, Web-based tool that estimates the volume of biomass available in a given area. It was developed by Decision Information Solutions with funding assistance provided by a Rural Business Enterprise Grant from USDA Rural Development. Users input their willingness to pay for biomass at the farmgate, the maximum distance they are willing to transport, the biomass crop of interest, and if they are participating in the Biomass Crop Assistance Program. The tool uses this information and existing model assumptions to identify the maximum amount of harvestable biomass. Model estimates likely differ from real-world values as they quantify total availability and do not consider individual farmer's willingness and ability to sell biomass. Actual biomass availability would need to be verified by ground-truthing the users' and model's assumptions.

The tool uses two geodatabases: the USDA's Cropland Data Layer and the Iowa Property and Interpretive Database. Current and alternative land use is evaluated by comparing actual and estimated crop yields, crop prices, and cost of production. The tool considers the availability of five biomass feedstocks: corn stover, switchgrass, miscanthus, forage sorghum, and perennial grass. The tool can currently be used to estimate biomass inventories in 11 northeastern Iowa counties.

Michigan Biomass Inventory

The Michigan Biomass Inventory (http://mibiomass.rsgis.msu.edu/) is an online resource created by Michigan State University in conjunction with the Michigan Department of Energy, Labor, and Economic Growth. The tool allows for mapping and analysis of biomass feedstock availability within the state. The emphasis of the tool is on waste biomass which is defined by the Inventory as crop residue, animal waste, and food waste. The mapping tool allows users to zoom to specific counties or communities and map various features including geographic boundaries, facility locations, and land use including crop production.

The companion Biomass Analysis Tool generates information that can be used to assist in the siting of diverse bioenergy facilities by providing estimates of net energy availability. This energy may come from a number of sources including confined animal feeding operations (CAFOs), crop production, as well as correctional facilities, hospitals, schools, and universities. Users select locations within Michigan, the conversion technology (digestion, combustion, gasification, transesterification, or fermentation), the energy output (heat or electricity), distance from the identified point, and if detailed transportation routes should be utilized. The Biomass Analysis Tool then generates net energy availability in the geographic area identified. This data while helpful does not eliminate the need to ground-truth biomass availability. Unlike the Northeast Iowa Biomass Asset Map, this tool does not consider the cost of feedstocks or supplies.

Michigan Forest Biomass Information System

The Michigan Forest Biomass Information System (http://www.michiganforestbiofuels.org/research-project/michigan-forest-biomass-inventory) is an online tool being developed by Michigan Technological University and Michigan State University that provides users with forest biomass availability within a defined geographic area. The area may be identified by defining its boundaries or the certain distance from a selected point. The system uses data from the Forest Information and Analysis (FIA) program of the U.S. Forest Service. It calculates the technical availability of hardwood and softwood biomass inventory, growth, mortality, removal, and residues. Eventually, the system will incorporate transportation, land ownership, and other variables.

Minnesota Forest Biomass Availability

A study by the researchers at the Department of Forest Resources of the University of Minnesota estimated the total physical availability of residual forest biomass (Becker et al 2010). The analysis considers varying levels of forest growth and productivity given harvest and retention practices, forest type, ownership and biomass type. Estimates are made at the statewide and regional level. The analysis also considered the economic and social availability for privately owned woodlands and the willingness to sell. Estimates of forest biomass availability are measured in oven dry tons and vary from

660,000 to more than 2 million tons depending on harvest level and inclusion of bolewood in addition to residual biomass (tops, limbs, branches, and needles).

Minnesota DNR Biomass Program Maps

The Minnesota Department of Natural Resources (DNR) provides a series of maps online that illustrate factors that affect woody biomass availability (http://www.dnr.state.mn.us/forestry/biomass/maps.html). These include land ownership and administration, ecologically sensitive areas, and demand locations.

Wisconsin Renewable Fuel Availability, Extraction, and Usage Potential Impacts Report

The Sustainable Resources Institute (SRI) conducted a study that assessed the amount of woody biomass (Sustainable Resources Institute et al 2010). The study surveyed all primary forest industry companies in Wisconsin and found that a majority sold or used residue on site. Among secondary forest industry firms, utilization of residue was 90% although nearly half of this was given away. A sample survey of Wisconsin manufacturing companies found that of 300,000 tons of wood residue generated each year, one-third was disposed of or went unutilized. The total cost to Wisconsin businesses to dispose of wood waste is $2 million annually. The study also considered logging residue and found that there are sufficient residue supplies available to support collection while still leaving enough material to meet Wisconsin's Forestland Woody Biomass Harvesting Guidelines (WFWBHG).

Biomass Energy Analytical Model (BEAM)

The Biomass Energy Analytical Model (BEAM) is a quantitative geoanalytical model developed by Enegis, LLC, Fairfax, Virginia, to assess available biomass in the lower 48 states of the U.S. Enegis initially developed the model for the National Energy Technology Lab (NTEL) in Pittsburgh, PA, through a USDOE grant. The BEAM was conceived to analyze the use of biomass for federal power generation but can be adapted for transportation fuels. BEAM maps 45 species with a 30-meter resolution land cover dataset (500GB of data) and detailed transportation infrastructure based on classified land use across the U.S., including the Midwest region, to help determine biomass availability. It also estimates full cycle costs, including biomass availability, transport options, and delivery costs. The model allows for examination of various types of biomass to develop biomass supply profiles. The model is ideally suited for site planning and optimization as biomass markets emerge. BEAM can conduct assessments on a site-specific, regional, or national-scale. The BEAM can be readily adapted for a number of resources and scenarios beyond those originally conceived, and has already been used to model biomass to liquids and land-use change scenarios involving growing switchgrass on existing farmland. The model has been calibrated with real world data. BEAM focuses on residuals, consistent with the American Council on Renewable Energy (ACORE) proposed definition for biomass. Additional details about the model can be viewed on the following link: http://www.enegis.com/projects.html.

Regional Biomass Assessments

The regional biomass assessments discussed in this section illustrate the possibilities and limitations of their development and use. Perhaps the biggest lesson is the need for most biomass assessments to be ground-truthed. This is evident in two ways. First, model builders and users need to ensure that their assumptions are realistic, as models require accurate input to produce accurate estimates. At the same time, estimates made with quality data and good models may still deviate from real-world values and need to be validated.

Another important issue is that of incorporating economics into biomass assessments. The decisions to produce, sell, transport, and convert biomass are economic ones. While estimating technical availability can provide an initial understanding of the amount of biomass that is or can be produced in a region, pricing biomass is necessary to determine actual supply. The price of feedstocks is a necessary piece of information for ground-truthing.

9. Biomass Inventory Method

The objective of the biomass inventory assessment is to quantify current and future inventory of forest and agricultural biomass in the seven-state region of Illinois, Iowa, Michigan, Minnesota, North Dakota, South Dakota, and Wisconsin. This data will be used to determine the percentage of the region's thermal energy needs that can be met using renewable biomass feedstocks.

We began with a review of existing biomass assessments. Focus was placed on study goals and objectives, assumptions, methods, and results. It was decided that reliance on an existing national study and dataset would best meet the goals of the Heating the Midwest Biomass Inventory Assessment Team. Use of a single study allows for uniformity of data, assumptions, and methods that is not typically possible when combining individual state or regional assessments. At the same time, it means that our analysis is subject to assumptions and methods with which we may not agree.

Three national studies and their associated datasets were considered as candidates: The Billion Ton Study, the NREL Biomass Assessment, and the Billion-Ton Study Update. The Billion-Ton Study Update was selected as it is the only national study to price feedstock supply and considered and incorporated sustainability into the assessment.

The Billion-Ton Study Update includes estimates of agricultural, forest, and secondary biomass feedstock supplies for the years 2012-2030. An online database located at the Knowledge Discovery Framework, https://bioenergykdf.net/models/bts-download, provides access to detailed, county-level data.

The Billion-Ton Study Update includes estimates of biomass feedstock availability under a number of scenarios. These include varying feedstock prices and increases in yield for agricultural and energy crops resulting from improved varieties and production methods. Before compilation of data, these alternatives were reviewed and preliminary prices and yield increases identified. The national price of all biomass (crop residue, energy crops, forest, and mill residue) was set at $50 per ton, low-yields for crops, and no yield improvements for energy crops were assumed.

A working database consisting of agricultural, forestry, and secondary biomass feedstock estimates was assembled using the Billion-Ton Study Update database. Next, county and state-level estimates of biomass inventory were made based on preliminary price and yield assumptions. Finally, the findings of the regional baseline were compared to those of state and regional assessments to validate our results, to identify differences in assumptions and methodologies, and to identify limitations of our method and results.

The Billion-Ton Study Update Assumptions and Methods

Understanding of the definitions, assumptions, and methods used by the Billion-Ton Study Update is required to appreciate and critique the Midwest Biomass Inventory Assessment. Summary information on these topics are presented by biomass type in this section. Readers looking for additional detail should refer to the published study.

Agricultural Biomass

Agricultural biomass is limited to crop residue in the assessment. Grains and oilseeds are not included in the biomass assessment due to greater value-added opportunity as food, feed, and transportation fuel feedstocks. At the same time, crop residues can be pelletized. As noted before, agricultural biomass tends to be high in ash content and has a relatively low density, making transportation costly.

Energy crops are estimated using POLYSIS, a policy simulation model of the U.S. agricultural sector. Crop residue inventory is estimated by determining the amount of residue produced for each crop (the crop-residue ration), residue production costs, and sustainable residue removal rates. Agricultural biomass is priced at the farmgate.

Biomass Energy Crops

Biomass energy crops include perennial grasses, trees, and annual crops that are grown specifically as bioenergy feedstock. Grasses and small diameter woody energy crops are typically high in ash content.

The Billion-Ton Study Update uses POLYSIS to estimate county-level production of dedicated energy crops. The model accounts for changes in land use from crop production and pasture to energy crop production.

Forest Biomass

Three types of primary forestry biomass, logging residue, thinnings, and other removal residues, as well as one secondary source, mill residue, were considered. Logging residues are defined as the limbs, tops, cull trees and cull tree components, and downed trees from harvesting operations. Thinnings are the non-merchantable components of stands that are thinned as part of fuel treatments and restoration projects; they do not include urban tree or right-of-way removals in this dataset. Other removal residues are those associated with pre-commercial thinning operations and the conversion of timberland to non-forest land use (residential or commercial development). Mill residue includes currently unused wood and bark residue resulting from milling operations. Consequently, all forest biomass considered is tied to industry activity.

Logging residue and thinnings estimates were collected from the U.S. Forest Service's Timber Product Output (TPO) database. The analysis excluded administratively reserved forestlands which are not open to timber production as well as inventoried roadless areas. Logging residues were limited to 70% of available feedstocks to ensure sustainability. A more thorough discussion of the assumptions on technically retrievable residue is included in *Biomass Resource Assessment for Farmers Cooperative Supply and Shipping Association* (Energy Center of Wisconsin 2010). That study assumed a 65% removal rate for illustrative purposes. Forest thinnings that were more than one-half mile from the nearest road were excluded because of the high cost of removal. Mill residue estimates were obtained from the TPO database. Forest biomass is priced at the roadside, mill residue at the millgate.

10. The Midwest Biomass Inventory Assessment

The Midwest Biomass Inventory shows that there are significant amounts of biomass feedstock in the region. The quantities vary greatly as differences in land use and crop production vary. In this section, data compiled from the Billion-Ton Study Update is presented. Biomass by feedstock, year, and county is included as an appendix.

Many of the feedstocks included in the inventory have valuable uses other than the production of thermal energy. Mill residue is used for livestock bedding and combined heat and power (CHP) applications. The vast majority of crop residue is left in the field with the exception being small amounts of straw used for animal bedding. The price of each of these feedstocks is determined in part by alternative uses. Consumers and businesses will seek high value, low cost fuel sources. The use of shelled corn for home heating has waned as higher commodity prices have made it less competitive with other fuels.

10.1 2012 Midwest Biomass Inventory

Table 6.1 presents the amount of biomass available by state and feedstock for 2012. Corn stover is the largest source of biomass among crop residues making up 46 million of the 52.5 million tons of material available in 2012. Each state has considerable agricultural biomass resources available. Corn producing states have the largest amount of biomass available.

No perennial grasses or woody energy crops are expected to be produced in the seven-state region in 2012. Forest biomass and mill residue make up less than 2% of the total biomass available and about 10% of non-grain and oilseed biomass. However, these feedstocks are most likely to be used for biothermal applications. Michigan, Minnesota, and Wisconsin have the largest amounts of forest biomass available in part because each state has large quantities of removal residue.

Table 10.1 2012 Midwest Biomass Inventory (1,000 tons)

Agricultural Biomass	Illinois	Iowa	Michigan	Minnesota	North Dakota	South Dakota	Wisconsin	Total
Crop Residue								
Barley Straw	-	-	-	43	701	-	-	744
Corn Stover	9,496	20,777	1,070	6,998	1,366	4,960	1,563	46,229
Oat Straw	-	-	-	-	-	-	-	-
Wheat Straw	862	8	832	420	229	3,009	232	5,592
Total	10,358	20,785	1,902	7,460	2,295	7,969	1,795	52,564
Hay	2,016	4,319	1,753	4,602	4,286	6,753	5,513	29,240
Total	12,374	25,104	3,655	12,062	6,581	14,722	7,308	81,805
Dedicated Energy Crops								
Perennial grass	-	-	-	-	-	-	-	-
Woody Energy Crops	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-
Forest Biomass								
Logging Residue & Thinnings	276	102	898	873	7	68	1,130	3,353
Other Removal Residue	234	62	294	656	15	14	1,049	2,324
Total	510	164	1,191	1,528	22	82	2,179	5,677
Secondary Biomass								
Mill Residue	24	9	9	12	2	0	41	98
Total	12,908	25,277	4,855	13,602	6,605	14,804	9,528	87,579

Source: Billion-Ton Study Update, 2011

Figure 6.1 presents forest biomass by county for the seven-state region. The vast majority of forest biomass resources are available in Minnesota, Wisconsin, and the upper peninsula of Michigan. There is currently considerable forest biomass utilization in Michigan's lower peninsula.

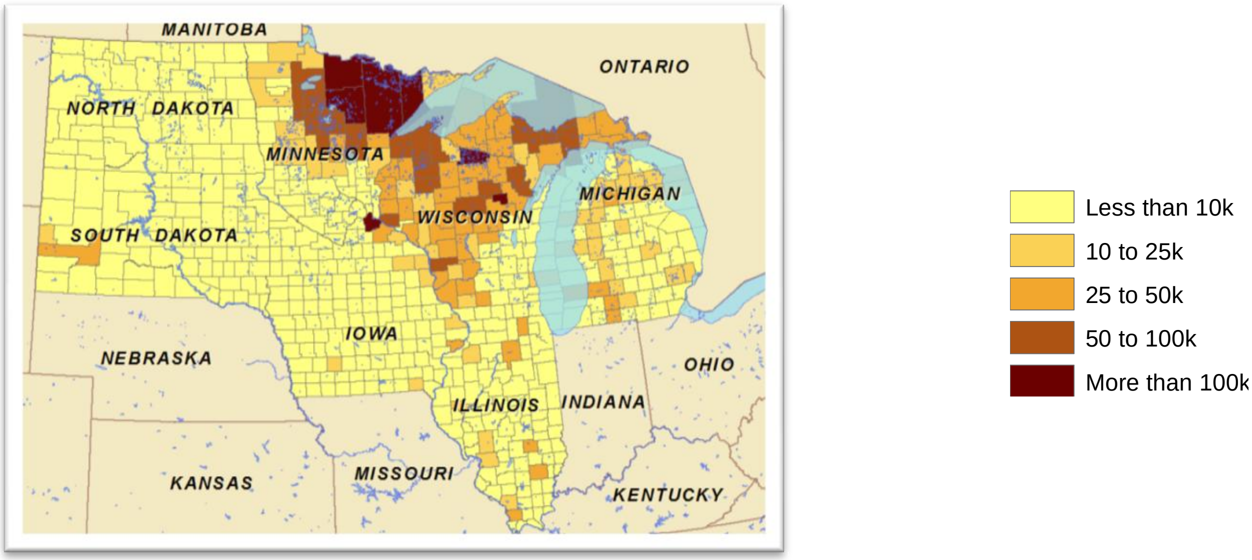

Figure 10.1 2012 Forest Biomass by County (Tons)

Corn stover is available in large quantities across the Corn Belt which extends across much of the region from the eastern Dakotas, southern Minnesota, Iowa, Illinois, and southern Wisconsin. 2012 Corn Stover by county is presented in Figure 6.2.

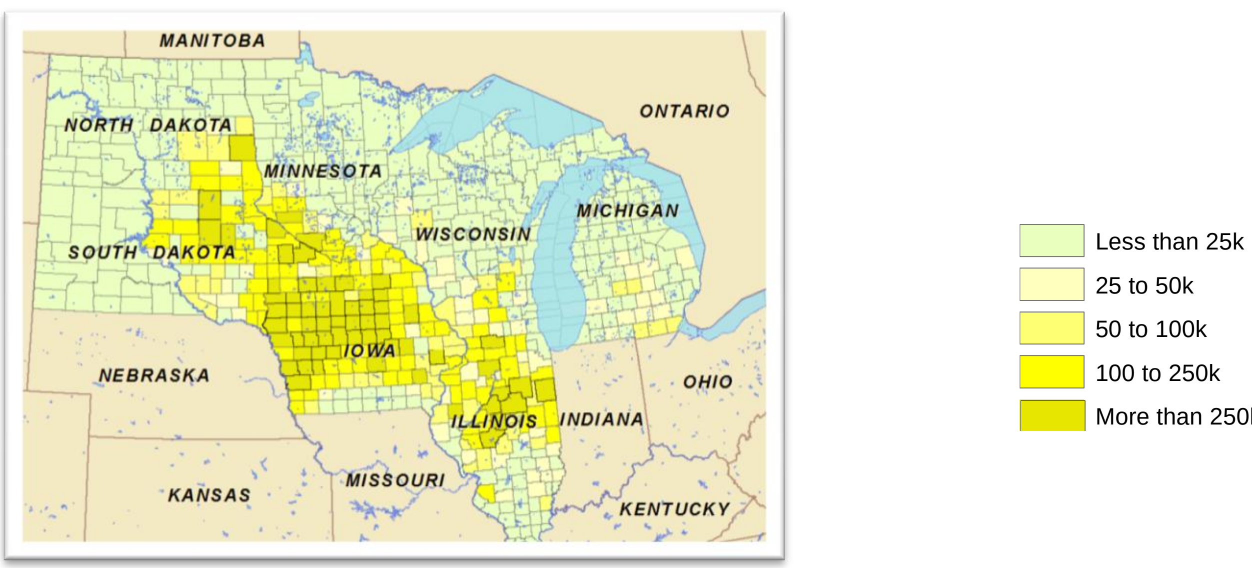

Figure 10.2 2012 Corn Stover by County (Tons)

While corn stover is the dominant regional source of biomass, inclusion of other crop residues provides a more complete picture of biomass for areas with diverse production practices. Figure 6.3 presents crop residue by county for 2012. The map displays higher levels of biomass in the central Dakotas and Michigan where relatively large amounts of wheat straw are available.

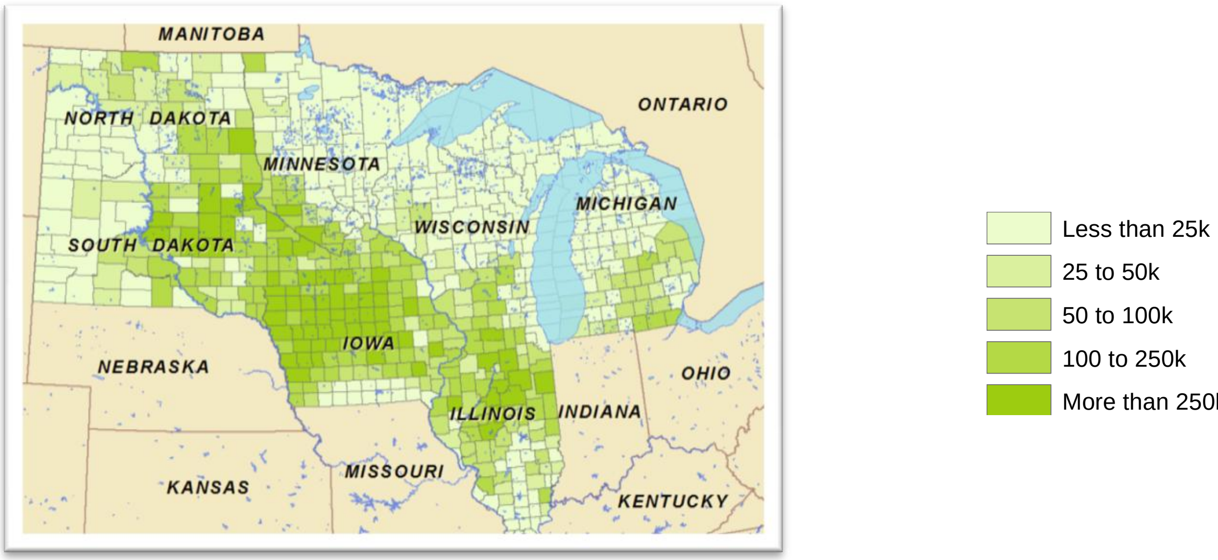

Figure 10.3 2012 Crop Residue by County (Tons)

10.2 2025 Midwest Biomass Inventory

Biomass in the Midwest is estimated to increase dramatically between 2012 and 2025. Most of the increase results from an increase in crop residue yield. Crop residues are estimated to increase more than 60% to 75 million tons per year. Hay production is expected to decrease as land is diverted to other uses including the production of perennial grasses and woody energy crops which are expected to provide nearly 5 million tons of feedstock in 2025. Forest biomass resources are expected to increase only slightly from 5.7 million tons in 2012 to 5.8 in 2025. Biomass in 2025 by state and feedstock is presented in Table 6.2.

Table 10.2 2025 Midwest Biomass Inventory (1,000 tons)

Agricultural Biomass	Illinois	Iowa	Michigan	Minnesota	North Dakota	South Dakota	Wisconsin	Total
Crop Residue								
Barley Straw	-	-	-	82	1,038	-	-	1,120
Corn Stover	14,621	33,242	1,844	10,579	3,299	8,260	3,306	75,151
Oat Straw	-	-	-	-	-	-	-	-
Wheat Straw	1,223	15	1,124	1,014	1,315	3,961	338	8,989
Total	15,844	33,257	2,968	11,675	5,652	12,221	3,644	85,260
Hay	1,862	3,842	1,621	3,916	3,829	5,662	5,097	25,829
Total	17,707	37,098	4,589	15,591	9,481	17,883	8,741	111,089
Dedicated Energy Crops								
Perennial grass	29	-	-	-	-	583	-	611
Woody Energy Crops	-	-	1,501	934	-	-	1,854	4,289
Total	29	-	1,501	934	-	583	1,854	4,901
Forest Biomass								
Logging Residue & Thinnings	280	103	915	898	7	76	1,155	3,433
Other Removal Residue	238	63	298	666	16	14	1,064	2,357
Total	518	166	1,212	1,564	22	90	2,219	5,790
Secondary Biomass								
Mill Residue	27	11	10	12	2	0	43	104
Total	18,279	37,275	7,312	18,100	9,505	18,556	12,857	121,884

Source: Billion-Ton Study Update, 2011

10.3 Conservation Reserve Program Changes

The Conservation Reserve Program compensates landowners that retire highly erodible and other environmentally sensitive cropland. Only land with a documented cropping history is eligible.

The Billion-Ton Study Update assumes that the amount of land enrolled in the Conservation Reserve Program (CRP), approximately 32 million acres, which is the current authorized acreage, will remain fixed into the future. However, enrollment is expected to decrease due to a reduction in program funding and high commodity prices. The ten-year county-level acre average is presented in Figure 6.4.

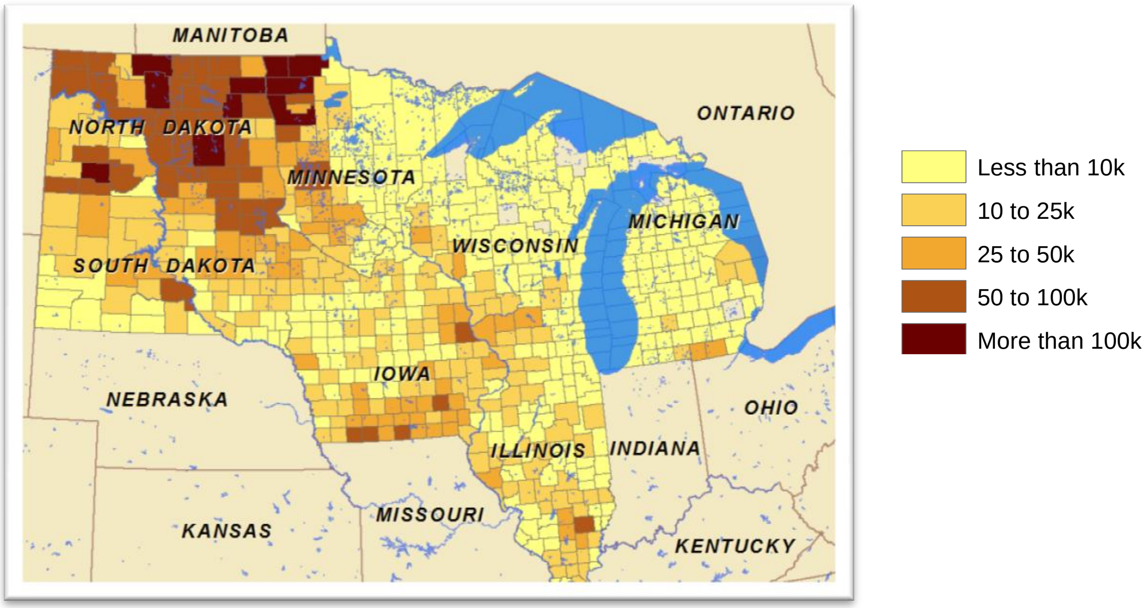

Figure 10.4 Average CRP Enrollment 2000-2011 (Acres)

The 29 million acres currently enrolled in CRP, along with other conservation lands, represent a meaningful untapped biomass resource. A limited and managed harvest of these lands could provide a biomass stream without compromising conservation values. USDA rules provide for managed harvest of hay on many grassland practices. This harvest is limited to one harvest every three years (or one third of a field every year). USDA rules also provide for some timber management practices on many forest practices. Many CRP contracts are under-managed and could be improved by appropriate harvest practices. However, further research is necessary to assess this resource in light of its variability and environmental sensitivity.

Other conservation lands are comprised of those participating in federal, state, and privately managed programs. These programs include the Wetlands Reserve Program (WRP) and Grasslands Reserve Program (GRP) managed by the National Resources Conservation Service (NRCS) of the USDA that had 272,000 and 335,000 acres under management in 2010 respectively. State programs such as Minnesota's Reinvest in Minnesota (RIM) program, which has more than 200,000 acres enrolled, also work to restore marginal and sensitive agricultural land. The U.S. Fish and Wildlife Service has more than 2 million acres under easement, which are concentrated in the duck producing areas of North and South Dakota. As most of these lands are in easement, they are not likely to be converted to cropland in the near term.

10.4 Summary

The biomass assessment includes projections of sustainable levels of biomass for the years 2012 and 2025. The amount of residue will increase significantly by 2025 as crop yields increase. Perennial grasses are also expected to be produced in sizable quantities in 2025. The expected reduction of acres enrolled in the Conservation Reserve Program is expected to have a noticeable impact on crop residue production. In the next section, the results of our assessment will be compared with those of previous studies.

11. Findings and Implications

Knowledge of current and future biomass feedstocks is necessary for the development of biomass markets. Assessments can serve as a starting point for local developers and other stakeholders to investigate the feasibility of new solid biofuel enterprises as well as to inform lawmakers working to create or modify existing energy policy. Site-specific analyses are necessary to verify the economic supply of biomass in their area as many factors including feedstock availability and fuel demand are local.

In this study, data on energy use for heating needs in the Midwest was compiled and an economic assessment of biomass feedstock was conducted. The intent was to highlight information that would provide an initial, high-level estimate of the percentage of current energy used for heating that can be replaced with biomass. Given the small size and preliminary nature of our project, the assessment relied on data and assumptions from the recently completed Billion-Ton Study Update report instead of starting with more preliminary data. As with other assessments, the accuracy of our work depends on the realism of our assumptions. While data and model assumptions are realistic, they will not align with those of all users of the data. Hopefully, many individuals will still find value in our work and make amenable caveats or modifications as needed. Most importantly, all users of the assessment should understand its mechanics and shortcomings. Work to develop new biomass businesses or enterprises must validate the data contained in this assessment.

This report is a companion effort to others made by the Heating the Midwest Inventory Working Group. In the course of the group’s work, a regional biomass inventory database was developed comprised of existing datasets. The information was also uploaded to the Knowledge Discovery Framework Bioenergy Library. The databases contain existing biomass literature and datasets. Together these resources are expected to further the state of understanding of solid biofuels especially in the Midwestern States that are currently participating in the Heating the Midwest initiative.

11.1 Findings

The study assembled data on Midwestern energy use for heating and calculated the county-level biomass in order to estimate the percentage of energy that biomass can potentially provide for heating purposes in the region. Unfortunately, differences in geography make direct comparisons impossible. At the same time biomass is difficult to transport, in general. Consequently, markets will likely be smaller in dimension than Midwestern states. Efforts to develop new biomass markets will require an understanding of local heating energy needs, markets, and technology.

Large amounts of energy are used for residential, commercial, and industrial heating in the Midwest. Natural gas is currently the primary fuel for heating needs across industries and states. Given its currently low price and sizeable beds in the United States and Canada, this is unlikely to change in the near-term. While natural gas prices are low at the current time, fuel oil and propane have both become more expensive in recent years as petroleum has risen in price. Many of the same customers that use propane and fuel oil may find biomass to be an economic alternative in the absence of natural gas service.

Despite the dominance of natural gas as heating fuel, more than 300,000 homes in the seven-state region use wood as their primary heating fuel saying nothing of those residences that can or do use it as a secondary heating source. Biomass is currently used as a heating fuel particularly in residential and industrial applications.

There are large quantities of biomass across the Midwest. This includes agricultural biomass in the form of crop residue and hay. Forest biomass includes logging and removal residue. That being said, it is important to note that much of this biomass is currently used for food, feed, or fuel. Diverting its use to thermal applications will require bidding with these uses which may not be successful in all cases as many existing applications have a higher value than heating.

The estimated number of Btus available from biomass by feedstock and state is presented in Table 7.1.

Table 11.1 Estimated HHV by State and Biomass Feedstock, 2012 (Trillion Btus)

Agricultural Biomass	Illinois	Iowa	Michigan	Minnesota	North Dakota	South Dakota	Wisconsin	Total
Crop Residue								
Barley Straw	-	-	-	0.6	10.0	-	-	10.6
Corn Stover	134.1	293.4	15.1	98.8	19.3	70.0	22.1	652.8
Oat Straw	-	-	-	-	-	-	-	-
Wheat Straw	11.8	0.1	11.4	5.7	3.1	41.2	3.2	76.5
Total	145.9	293.5	26.5	105.2	32.4	111.2	25.2	739.9
Hay	28.8	61.8	25.1	65.8	61.3	96.6	78.8	418.1
Total	174.7	355.2	51.6	276.1	126.2	319.0	129.3	1,897.9
Dedicated Energy Crops								
Perennial grass	-	-	-	-	-	-	-	-
Woody Energy Crops	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-
Forest Biomass								
Logging Residue & Thinnings	2.2	0.8	7.2	7.0	0.1	0.5	9.0	26.8
Other Removal Residue	1.9	0.5	2.3	5.2	0.1	0.1	8.4	18.6
Total	4.1	1.3	9.5	12.2	0.2	0.7	17.4	45.4
Secondary Biomass								
Mill Residue	0.2	0.1	0.1	0.1	0.0	0.0	0.4	0.9
Total	**179.0**	**356.6**	**61.2**	**288.5**	**126.3**	**319.6**	**147.1**	**1,944.2**

Changes in the Conservation Reserve Program are expected to result in a reduction in enrolled acres in the next few years. The amount of land removed from the program is not known with certainty, but it is likely that much of it will be used for crop production given high commodity prices. Some CRP lands may be used to produce energy crops, especially perennial grasses. Regardless of its use for production of traditional or energy crops, an increase in available biomass in the form of crop residues or energy crops is likely.

A biomass fuel supply assessment within a specific procurement area is necessary when evaluating development of a new biomass facility. High-level assessments, such as this report, do not provide adequate information to make a site-specific decision. Neither Heating the Midwest nor the authors of this report are responsible for any decisions made using this data. The data relies on assumptions developed under guidance of the Heating the Midwest Inventory Working Group which may not align with prevailing conditions. Data presented have not been verified to be correct. The report can serve as a starting point for the siting of a solid biomass aggregation or conversion facility; however, the inventory does not replace the need for on-site visits, discussions with producers and owners of biomass. Other firms may be working to secure the same supplies simultaneously. Detailed local analysis by bioenergy professionals is a must.

11.2 Future Research

The Midwest Biomass Inventory provides a snapshot of biomass feedstocks in the seven-state region. There are many related issues where further consideration would benefit the development of biomass thermal activity in the region. These include thermal biomass market potential, co-product marketing, feedstock development, land use change, sustainability, best practices, biomass availability, technological challenges, and infrastructure requirements.

New thermal biomass fuel enterprises must secure currently unused supply, outbid current users, or access future expanded production. Competition for supplies on the basis of price depends on buyers' willingness-to-pay and biomass feedstock owners' willingness-to-accept. These in turn are a function of broader market forces and require knowledge of the determinants of biomass and heating fuel demand and supply. Research is underway to identify the willingness of crop producers and loggers to supply biomass feedstocks, work that is fundamental to quantifying economically available supplies.

Combustion of biomass feedstocks produces ash, a co-product that has value as a soil amendment. A market assessment of ash produced from the combustion of biomass as well as handling and logistics would be helpful. Breeding of dedicated energy crops for traits desired for thermal energy is underway. The production of dedicated energy crops will cause a shift in land use which may have significant environmental impacts.

Sustainability is fundamental to the accurate estimation of current and future biomass availability. Biomass collection impacts the soil erosion, soil organic matter and carbon content, water quality and availability, wildlife habitat, ecosystem function, recreational opportunities, climate, and human health. Forest biomass harvesting guidelines are in place in Michigan, Wisconsin, and Minnesota.

Research to identify and disseminate best practices as they relates to biomass removal, sustainability, carbon balance, and emissions generated from the combustion of these materials would further the industry. This might include documentation of current and promising combustion technologies including cogeneration, combined heat and power (CHP), tri-generation, and district heating alternatives as well as recent development work related to collection, densification, and handing technology. Densification may make use of physical processes as is the case with pelletizing or briquetting or a thermochemical process such as torrefaction.

Infrastructure that supports a regional biomass industry including traditional forest resources should be identified. Opportunities provided by agricultural and dedicated energy crop feedstocks would complement these activities.

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