

HEARTLAND PAPERS

Harnessing the Power of Biomass Residuals: Opportunities and Challenges for Midwestern Renewable Energy

By Steve Brick

With contributions by Tyler Strom



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ON GLOBAL AFFAIRS

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Senior Fellow on Energy and Climate,
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The views expressed are strictly those of the author.



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Foreword

With proposed legislation on national energy policy stalled in Congress, states and regions have been drawn into the debate on their energy futures. All realize that a forward-looking energy policy underlies economic vitality, job creation, the promotion of new energy, and a reduced reliance on imported carbon fuels. The region that seizes the lead on energy policy will have taken a giant stride into the twenty-first-century economy.

No region needs this stimulation more nor is better placed to benefit from it than the American Midwest. This report focuses on one source of renewable energy—biomass—and how it can be harnessed to help power the Midwest's future.

The Midwest has always been rich in national resources. It used those resources to build the agricultural and industrial economies that underlay American prosperity in the nineteenth and twentieth centuries. But those days are past. Neither farming nor traditional manufacturing can provide the mass employment the region needs. Much manufacturing is going or gone. The Midwest's population is declining. Its industries are being outsourced. Both cities and towns suffer unemployment and falling standards of living. Above all, the Midwest's energy policy is negative, not positive. The region is a major energy consumer and greenhouse gas emitter and is dependent on energy imports.

This report looks to residual biomass, specifically waste from agriculture and forestry, as one potential resource to be explored. The Midwest landscape is rich in these underused by-products. On the one hand, the waste needs to be properly disposed of to avoid soil or water contamination. But more positively, the Midwest can harness the biomass residuals as a new source of energy and, in so doing, set an example for future energy initiatives that will hopefully someday be a feature of broader U.S. energy policy discussions. Other nations around the world have been working with residual biomass technologies for decades, and we believe they also deserve closer examination in our country.

In 2008 The Chicago Council on Global Affairs launched its Global Midwest Initiative to examine the relationship of the region to the global economy since the heartland of America is so vital to the nation's global competitiveness. Making best use of the rich resources our region offers, while also promoting energy security, economic vitality, and environmental awareness, is the focus of this fourth installment of the *Heartland Paper* series.

The Chicago Council has been interested in the link between the Midwest and national energy policy since 2009 with the release of the task force report *Embracing the Future: The Midwest and a New National Energy Policy*. That report, drafted by thirty-two experts and stakeholders from political, business, academic, and civic sectors, brought a regional perspective to the national debate on climate and energy policy. The report included recommendations for building, transportation, and industrial energy efficiencies; emissions offsets; and low-carbon supply technologies. It is our hope that this *Heartland Paper* will continue to provide a path forward for sensible energy legislation.

Acknowledgments

I would like to extend my sincere appreciation to the report's author, Steve Brick, The Chicago Council's senior fellow on energy and climate, whose vision for this study and dedication to energy policy are invaluable. Perhaps nobody was more qualified to undertake this endeavor than Steve, a Midwesterner who has been working with energy and environmental policy for over thirty years. He has been working to foster greater midwestern regional cooperation on energy and climate policy despite the numerous setbacks we have seen at the national level. He also authored a Chicago Council *Global Midwest Policy Brief* in 2009 entitled "Climate and Energy—The Midwestern Stake," which outlined the Midwest's vital role in the national energy and climate debate.

Steve was provided immense support by Tyler Strom, an outstanding research assistant who collected data, tracked current events on biomass, created charts and maps, organized meetings of the advisory committee, and contributed to all aspects of the report production.

This report was drafted with the input of an experienced advisory committee, members who touch different aspects of energy policy in our nation, from industry to advocacy, from policy to practitioner. We are very grateful to all of the members who took time out of their busy schedules to participate in our workshops and provide feedback to early drafts of the report. See Appendix I for a listing of the advisory committee members.

The Chicago Council's Global Midwest Initiative team is also responsible for driving this project to completion. I especially want to thank Juliana Kerr Viohl, director of Global Chicago/Global Midwest, and Mia Arter, program coordinator, for their guidance and

management of the *Heartland Papers* series and the Global Midwest Initiative. Richard C. Longworth, the Council's first senior fellow, whose book led to the vision of the initiative and these reports, continues to serve as an inspiration for our Global Midwest projects. I also want to thank Catherine Hug, our editor, for her time and attention to detail.

Lastly, this report would not have been possible without the support and partnership of the U.S. Department of Agriculture (USDA) Rural Development Agency. I especially want to recognize Judith A. Canales, administrator of USDA Rural Development Business and Cooperative Programs, Curt Wiley, chief of staff of USDA Rural Development Business and Cooperative Programs, and Todd Campbell, confidential assistant, USDA Rural Development Business and Cooperative Programs, for their engagement. They helped frame the relevance of this topic and shape the final product. We are delighted to have had the opportunity to continue to work closely with such an important institution to our nation's future.

Rachel Bronson
Vice President, Studies
The Chicago Council on Global Affairs

November 2011

Executive Summary

As the United States and countries around the world search for alternatives to the economic, political, and environmental challenges of conventional energy sources, debates are raging over the positive and negative aspects of various bioenergy technologies and feedstocks. The introduction to a recent National Academies report perfectly sums up the challenge of bioenergy systems:

“Biofuels are complicated. Biofuels are controversial. There are very strong advocates for and political supporters of biofuels. There are equally strong sentiments against biofuels.”¹

Food grains used for biofuel, especially corn-based ethanol, and dedicated energy crops have come under increased scrutiny for their environmental impact, including increased land use and lifecycle greenhouse gas emissions. Corn-based ethanol is also increasingly controversial because of its potential competition with growing global food needs. This study, which looks at the potential for advancing the residual biomass industry in the Midwest, is premised, in part, on the hope that residual biomass resources can be less controversial bioenergy feedstocks than either food grains or dedicated energy crops. Produced as by-products of existing activities such as agriculture, residuals represent potentially attractive opportunities for the Midwest. The following examples illustrate this potential.

- Livestock agriculture—dairy, in particular—is an important component of the Midwest economy. Economic forces have driven producers towards larger herds. Modern dairy operations can involve more than 1,000 animals. These animals produce a lot of manure that can create objectionable odor, pathogen contamination, and water pollution. None of these impacts are good for the public or the producer. Anaerobic digesters can help eliminate odors, manage pathogens and nutrients, and produce bioenergy—four benefits from one process.

- The region’s corn farmers produce a lot of stover (cobs, stalks, husks, and leaves) in addition to the grain. If technologies for producing ethanol from the cellulose in stover can be perfected and commercialized, a portion of that stover can be used as a biofuel feedstock, reducing food-fuel competition and providing an additional source of farm income.

The key findings of this study are highlighted below. One finding, in particular, is critical to the development of the residual biomass industry. In order to design bioenergy systems that are compatible with agricultural and environmental goals, it is essential that we adopt a “landscape-based” perspective for our analysis. Too often, agricultural or forestry feedstocks are considered in a narrow context as if these resources were coal or oil. A landscape-based perspective recognizes the ecological interactions that affect farming and forestry and seeks to balance them against various production goals. In addition, capturing the ecological value of these feedstocks can help improve their overall cost competitiveness in the market. A landscape perspective can be used to guide development of residual biomass resources today, and this experience can help inform the development of other feedstocks down the road.

Key findings include:

- Ecologically sustainable residual biomass resources could be used to produce around 17 percent of the region’s gasoline needs or 14 percent of the region’s electricity.
- Residual biomass resources are concentrated in certain areas of the region, and these concentrations can guide development.
- A landscape-based framework is needed to evaluate the agricultural, energy, and environmental trade-offs inherent in bioenergy systems.
- Nonenergy benefits may be as important as energy benefits in the economic evaluation of these resources.
- The technology exists now to manage animal manure and produce bioenergy.

1. National Research Council Committee on Economic and Environmental Impacts of Increasing Biofuels Production, *Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy* (Washington, DC: The National Academy Press, 2011).

- Technology to produce ethanol from corn stover and other cellulosic feedstocks is evolving, but is not market ready.
- Most bioenergy systems using residuals are currently uncompetitive and will need subsidies and other public policies to move forward.

In light of these findings, this study offers the following recommendations:

- Utilize the region's manure resource by:
 - Increasing the penetration of on-farm anaerobic digesters.
 - Developing and testing watershed-based nutrient trading schemes.
- Prepare the region's corn farmers to participate in a market for cellulose by:
 - Increasing research to determine acceptable levels of stover harvest.
 - Increasing research to better understand logistical issues of stover harvest, transport, and storage.
 - Increasing research on the impact of different tillage systems on grain and stover production.
- Embrace a landscape-based perspective for analyzing biofuel feedstock pathways by:
 - Developing and employing interdisciplinary teams to integrate the research described above and to produce integrated assessments of feedstock costs and benefits.

Introduction

As the economic, political, and environmental costs of conventional energy resources mount, so does interest in renewable energy sources. From solar to wind to hydropower to biomass, renewable energy development is growing rapidly throughout the world. According to the International Energy Agency (IEA), renewable electricity is projected to grow from around 19 percent of global supply to around 33 percent by 2035.² IEA predicts that global biofuel use will quadruple during the same period. Biomass energy—or heat, electricity, and vehicle fuel generated from organic matter such as corn, switchgrass, sugarcane, wood, and farm and municipal waste—is a significant pillar of the renewable energy market mix.

Bioenergy has played a prominent role in U.S. energy policy debates since the 1970s. The oil supply and price shocks of 1973 and 1979 spurred the call for alternatives to conventional fuels, especially imported petroleum. The notion that we can replace Middle Eastern oil with homegrown, renewable biofuels has endured through most of four decades. Biomass-powered electricity and natural gas substitutes have likewise been consistently represented in U.S. energy policy discussions.

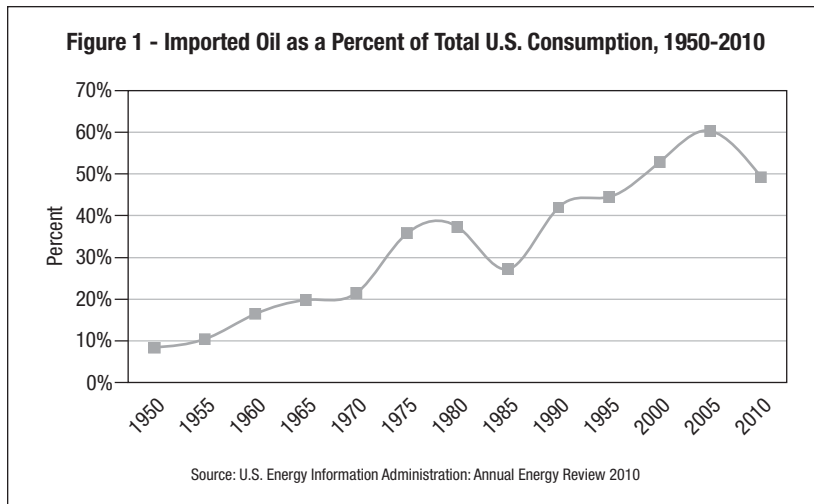
The arguments for promoting bioenergy, including biofuels, are generally threefold. First, bioenergy can strengthen national security by replacing imported petroleum. Second, bioenergy can stimulate U.S. domestic economic development and reduce the flow of dollars offshore. Third, bioenergy is better for the environment than fossil fuels.³ The environmental argument has become especially pronounced as the debate over climate policy has heated up in recent years.

The U.S. political response has involved financial support for research and development, a range of production subsidies, and various state and national mandates. Claims can be heard from across the political spectrum about bioenergy's potential contribution to energy independence and economic prosperity.⁴

2. International Energy Agency, "World Energy Outlook 2010 Factsheet: What Does the Global Energy Outlook to 2035 Look Like?" (Paris: International Energy Agency, 2010).

3. "About RFA," Renewable Fuels Association, accessed November 15, 2011, <http://www.ethanolrfa.org/>.

4. Wisbusiness.com, "Gov. Walker: Accelerates bioenergy assessment to speed up investment in Wisconsin," press release, May 26, 2011; Wisconsin Department of Commerce, "Governor Doyle Announces Biofuels Grant in Milwaukee," press release, July 27, 2007.



In spite of prolonged and consistent public and political support, the role played by biomass in the overall U.S. energy mix has remained small. As of 2009, according to the U.S. Energy Information Administration, all forms of renewable energy (hydroelectric power, geothermal, solar, wind, and biomass) accounted for about 8 percent of U.S. supply. About half of this comes from various forms of biomass.⁵ In the same year biofuels supplied about 5 percent of U.S. fuel volume.⁶ In 1973 imported petroleum made up about 35 percent of U.S. consumption, peaking at 60 percent in 2005 and accounting for 49 percent in 2010, marking the first time since 1997 that America's foreign oil addiction fell under the 50 percent threshold, according to a May 2011 *Reuters* article.⁷ Without biofuel production, this figure might have edged towards 55 percent. Because of costs and limited production, the role biofuels have played in promoting energy security have, to date, been limited.

5. U.S. Energy Information Administration, "Renewable Energy Annual: 2008 Edition," http://www.eia.gov/cneaf/solar.renewables/page/rea_data/rea_sum.html.

6. Because the energy content of biofuels is lower than that of petroleum, the contribution measured on an energetic basis would be around 3 percent.

7. Tom Doggett, "U.S. Relies Less on Oil Imports to Meet Fuel Demand: Government," *Reuters*, May 25, 2011.

Biomass Power Generation: A Global Trend

Currently, over fifty countries have biomass power plants that supply an increasing share of electricity. These countries have been identifying technology-based opportunities for utilizing abundant residual resources to grow economies while protecting the environment and encouraging energy security and quality of life. Germany, France, and Sweden produce the most biomass and renewable waste energy in Europe, accounting for over 4 percent of biomass production in 2009. These same three countries represented over one-third of Europe's renewable energy production. Finland's Alholmens Kraft power station is currently the world's largest biomass-fired power plant, with an installed capacity of 265 megawatts. Other countries are also beginning to bring online more biomass energy production. The United Kingdom, with currently less than 3 percent of total energy derived from biomass, has two biomass power plant proposals under way—the Port Talbot Power Station (350 megawatts) and Tees Renewable Energy Plant (295 megawatts). To be completed by 2012, these plants will greatly support the UK's renewable energy capacity. National Bio Energy Co., Ltd., China's leading enterprise in the biomass power industry, currently has nine projects under construction with the potential capacity of 108 megawatts. If oil prices remain high and economic competitiveness and energy security continue to push renewable energy development, biomass energy adoption is likely to remain an accelerating trend across the globe.

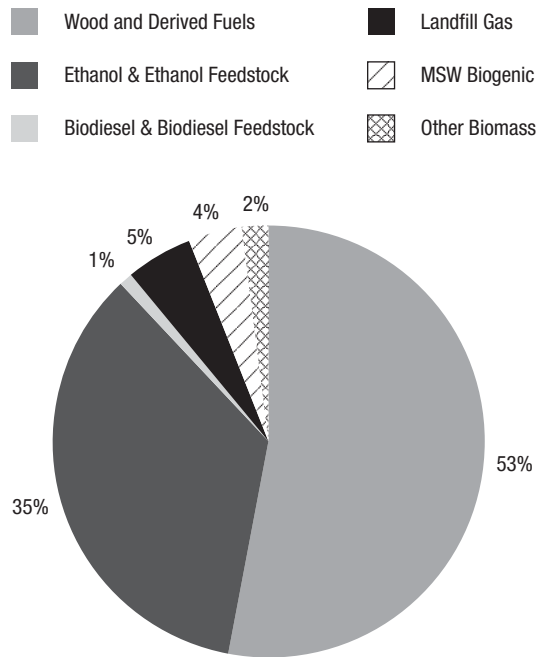
The biomass landscape

Biomass energy sources can be divided roughly into three categories: primary crops such as corn, soybeans, and sugarcane; dedicated energy crops such as switchgrass and *Miscanthus*; and residuals. Residual biomass is material that is left over from other processes, some of it currently used and useful, some of it waste material that must be managed in some way. Residuals include crop and forestry residues, animal manures, food processing waste, sewage treatment biosolids, urban and suburban yard and forestry waste, and the organic component of municipal solid waste. Today, a significant share of American bioenergy comes from corn ethanol.

Corn-based ethanol has enjoyed continuing federal subsidies and, recently, substantial growth. Since 2000 U.S. production of corn-based ethanol has increased almost tenfold.⁸ Economically, the biofuels industry has had a positive impact. The Renewable Fuels Association (the country's biofuels trade organization) takes credit for creating around 70,000 direct jobs and another 400,000 indirect jobs in the United States and claims that the industry adds about \$6

8. "Statistics," Renewable Fuels Association, accessed November 15, 2011, <http://www.ethanolrfa.org/pages/statistics#B>.

Figure 2 - Percentage of U.S. Biomass Energy Consumption by Source Type, 2008



Source: U.S. Energy Information Administration: Renewable Energy Annual, 2008

billion to household income annually. If current federal crop production subsidies of about \$3 billion per year are subtracted from this total, the net addition to income would be about \$3 billion. Some experts suggest this number should be higher. High corn and soybean prices recently—driven in part by high biofuel demand—mean that federal subsidies have been lower than they otherwise might have been. When this reduction in subsidy is taken into account, the net addition to income is higher. Federal mandates have helped the bottom line of our region’s corn farmers and have helped cushion the Midwest farm economy from the recent recession.

At the same time, however, the environmental consequences of corn-based ethanol have become increasingly controversial. This controversy is not new, but it has become more heated in recent years. The most recent debate centers on the lifecycle greenhouse gas emissions of corn-based ethanol, including emissions released through land use change outside the United States. This debate is

both analytically complex and politically controversial. Simply put, the argument is that incremental demand for corn in the United States (stimulated by federal policy) leads to new land being brought under the plow in places outside the United States and that the emissions associated with this land clearing and tillage must be tallied and counted as part of corn ethanol’s lifecycle greenhouse gas emissions. According to some studies, corn ethanol is worse from a climate standpoint than conventional petroleum. According to the U.S. Environmental Protection Agency (EPA), corn ethanol barely meets the environmental threshold required by the law (a 20 percent greenhouse gas emissions reduction from gasoline), although there is some valid concern about the EPA’s analytic procedures that call this conclusion into question.⁹ As has become all too common in such cases, this controversy is about to be sorted out in the courts. Whatever the outcome, the environmental halo of corn ethanol has been tarnished, and the likelihood that other biofuels will be similarly scrutinized is high.

Beyond the concern about greenhouse gas emissions is worry that demand for primary crops for biofuel competes with food needs. In view of rapidly growing global populations and concern over agriculture’s ability to keep up with food demand, the diverting of food crops to produce fuel becomes ever-more controversial. The potential interactions between demand for food, fiber, and fuel have therefore clouded the overall economic picture for grain-based biofuels and strengthened the push for developing other feedstock sources.

The Energy Independence and Security Act of 2007

The Energy Independence and Security Act of 2007 (EISA) and the beefed-up Renewable Fuel Standard (RFS2) it mandates provide a significant push to the biofuel industry. EISA commits the nation to produce a total of 36 billion gallons per year of biofuels by 2022. If the RFS2 goals are met, by 2022 biofuels will supply about 15 percent by volume of our projected liquid transportation fuel needs.

At the same time, EISA limits incentives for conventional ethanol to 15 billion gallons per year—just a 1.5 billion increase over 2010 levels—and requires a minimum of 16 billion gallons per year from cellulosic resources. Cellulosic resources include wood, grass, and the nonedible parts of plants such as corn stover (the leaves,

9. U.S. Environmental Protection Agency, “Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis,” EPA-420-R-10-006, February 2010.

stalks, husks, and cobs left in the field after harvesting corn). The cellulosic feedstock is assumed to be split in some proportion between energy crops and crop residuals. Thus, the question of how much corn stover (and other crop residuals) can be mustered and under what circumstances is more than academic. It is an unavoidable step in carrying out and achieving current policy mandates.¹⁰

As production closes in on the 15 billion gallon-per-year cap for corn ethanol, attention is shifting to dedicated energy crops and crop residuals. For two years running, the EPA has revised downward its forecasts for the contribution made to the RFS2 by advanced biofuels. New production has come online more slowly than expected and cellulosic technologies still face significant technical challenges. Assuming that these challenges are met and the courts sustain the RFS2 policy, there will be guaranteed demand for at least 16 billion gallons per year of cellulosic biofuel by 2022.

Why Study Biomass Residuals?

Biomass residuals have a number of advantages over other bioenergy feedstocks. First, as a waste, by-product, or residue from other processes or activities, these feedstocks do not compete with fuel as a source of food. Focusing on residuals can also help reduce the land demand and environmental consequences associated with primary crops such as corn.

To be sure, energy and other products alone are unlikely to provide sufficient economic justification in the current environment for new investment in biomass residuals. However, the important benefits beyond energy production of using residuals as bioenergy feedstocks make them an attractive alternative. Residuals such as animal manures, food processing wastes, sewage treatment biosolids, and urban yard and forestry wastes can be environmentally hazardous if not properly managed and must be disposed of appropriately. The economic and environmental costs of these residuals can be mitigated by converting them into energy and other products. In most of these instances, the primary benefit of conversion is cost-effective and environmentally sound management of the waste stream, while energy and other products are helpful add-ons. In other words, the reason we should study these resources is that we may find better ways to manage them and produce a modest amount of energy to boot.

10. National Academy of Sciences, "Liquid Transportation Fuels from Coal and Biomass: Technological Status, Costs, and Environmental Impacts" (Washington, DC: National Academies Press, 2009).

Crop and forestry residuals, which are by-products of farming and forestry activities, have received attention as potentially low-cost, environmentally benign feedstocks. Converting such feedstocks into energy is more complicated than would first appear and will require sustained, crossdisciplinary thinking to sort it out. Corn stover, in particular, has already garnered a good deal of attention as the feedstock of choice in our region for producing so-called ethanol from cellulose. The straightforward arithmetic of "x" corn production equals "y" stover appears to translate into a considerable quantity of ethanol, assuming that economic and technical hurdles can be overcome. However, a host of agronomic and environmental questions need attention before we can confidently say how much stover is available for energy production and under what circumstances. The same is true for forestry residuals, which have received less attention because the resource is relatively smaller and more localized. This study attempts to better define and understand the inherent tradeoffs of producing energy from residual biomass and to lay a sound foundation from both an agricultural and environmental perspective for the development of the residual biomass industry in the Midwest.

Study Purpose

The research reported here considers the residual biomass resource of six states in the upper Midwest: Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. The following questions guided the effort:

- How much of this resource is produced in the region and how much can be used to produce energy and other products?
- Which technologies are available or under development for converting these biomass streams into energy and other products?
- What are the obstacles preventing expanded use of this resource?
- Which government policies could help promote responsible use of this resource?
- How might expanded use of this resource contribute to the economic health of the rural portions of the region?

The initial list of residuals included in this analysis were crop and forestry residues, animal manures, food processing waste, sewage treatment biosolids, urban and suburban yard and forestry waste, and the organic component of municipal solid waste. The framing questions set forth above quickly led us to narrow our focus to crop and forestry residuals and animal manures as the most abundant and important regional resources. Appendix II provides a listing of sources for the analysis.

Chapter I

Economic Potential of Residual Biomass

This chapter examines the current state of the industry for residual biomass, including its economic potential. Because of economic and technological factors, the present economic potential for utilizing biomass residuals is very small. The next chapter will examine how current challenges may be overcome to help advance the development of the market for biomass residuals.

The following factors affect the economic potential of residual biomass:

- The cost of competing alternatives (oil, natural gas, and coal)
- The availability and cost of conversion technologies
- The cost of biomass collection and transportation
- The willingness of producers to embrace unfamiliar practices
- The existence of public subsidies, incentives, and regulatory policies

The next sections provide an overview of each of these factors in the current environment.

The cost of competing alternatives (oil, natural gas, and coal)

Fossil fuel incumbents currently have a significant competitive edge over new market entrants that is not likely to disappear soon. First, most bioenergy technologies tend to be both smaller in scale and less efficient than fossil counterparts. For example, the large BP oil refinery at Whiting, Indiana, produces 15 million gallons of product per day. A large cellulosic biorefinery would perhaps produce 200,000 to 300,000 gallons per day. A typical biomass power plant is in the 25 to 50 megawatt range. A typical new coal-fired power plant would be in the 600 to 1,000 megawatt range. A biomass power plant is expected to have a heat rate (a measure of production efficiency) of around 13,000 Btu/kilowatt hours. A modern coal plant would be substantially more efficient, around 9,000 Btu/kilowatt hours.

While economies of scale create a strong competitive advantage, they also come at a cost. For conventional technologies, the capital investment and corresponding risk are high. A new conventional coal plant would require around \$5 billion in capital, and a new oil refinery would require at least \$10 billion. In addition, the permitting and construction processes for such facilities can extend to between five and ten years. Finally, because these facilities are added in such large increments, it is more difficult to match the more gradual upward trends in energy demand that occur. The advantage for residual biomass production is that its smaller installations entail less capital, can be permitted and built more quickly, and can match growing energy demand more smoothly.

In addition to process efficiencies and economies of scale, incumbents enjoy other important advantages. Much existing energy infrastructure is already depreciated—in some cases significantly—and its cost basis is a fraction of that for new technologies. Owners of depreciated plants can produce at prices that are very close to operating costs, whereas new entrants need to recover their capital investment as well as operating costs. Many energy markets are monopolies or oligopolies, and access to these markets is not easy for new entrants. Incumbents with significant market power are unlikely to welcome upstarts. Transportation infrastructure—rails and pipelines, in particular—grew up with the existing energy industry, and bioenergy projects have transportation needs that are not well addressed by the existing transportation system.

In short, the price of competing energy alternatives is too low to support the development of biomass energy projects without subsidies or regulatory incentives. Although prices for all fuels have increased in recent years, the level has been insufficient to propel bioenergy aggressively forward. Historically, price movements have been erratic, with brief upward swings followed by price moderation. Higher prices must be maintained if they are to stimulate investment. Energy demand has dropped and supplies have increased during the recent recession, so it is probably imprudent to depend on significant price increases to drive the market for bioenergy and give investors confidence in making long-term capital investments.

The availability and cost of conversion technologies

The roster of technologies for biomass conversion is a relatively short one. The following table outlines the main options, commercial status, and typical outputs.

Technology	Status	Primary Outputs
Anaerobic digestion	Mature	Biogas, bedding
Combustion	Mature	Steam, electricity
Gasification	Mature	Synthesis gas
Transesterification	Mature	Biodiesel
Cellulosic fermentation	Developing	Ethanol
Pyrolysis	Developing	Bio-oil, synthesis gas, biochar
Hydrothermal liquefaction/ carbonization	Lab	Bio-oil, synthesis gas, biochar

As the table indicates, some bioenergy conversion technologies are well understood and mature, while others are still in development.

Mature technologies

Four technologies are commercially available and have been widely deployed: anaerobic digestion, combustion, gasification, and transesterification.

Anaerobic digestion

Anaerobic digestion is used to reduce a variety of organic substrates—manures, food processing wastes, sewage treatment biosolids, organic components of municipal solid waste—to biogas and digester solids. Biogas can be burned to produce heat or electricity. Biogas can also be further refined and comingled with pipeline quality natural gas or used to power compressed natural gas vehicles. Digester solids are most commonly used as bedding for farm animals. Digester effluent can substitute for fossil-based fertilizer.

According to the EPA, the United States is home to 169 digesters, fifty-two of them—almost one-third—are found on farms in the six-state Midwest region, all but two of them large dairy operations. Although the Great Lakes has almost one-third of the nation's digesters, the contribution to regional energy supply is small, with total installed electric capacity of 33 megawatts, or 2 percent of the total installed electric generating capacity in the region. The market penetration of anaerobic digestion is likewise small, with only about

1 percent of the region's cattle manure managed through digestion. Digesters are found on about 10 percent of the region's largest dairy farms (greater than 500 head). The Innovation Center for U.S. Dairy and the Wisconsin Bioenergy Initiative both work to increase the use of digesters on Midwest dairy farms.¹¹

Combustion

Various biomass streams can be burned in conventional boilers or gas turbines to generate steam or electricity. These technologies are well established. Pelletization (compressing biomass feedstock into small pellets) is being tested on dedicated energy crops (*Miscanthus*, for example) and may have applicability to various residues. The region's pulp and paper industry burns most of the mill waste and forestry residues it generates to provide heat and power. There is some use of biomass by the region's electric utilities. Methane captured from landfills is burned to generate electricity, which is most commonly sold back to the grid. In total, biomass generation in the region amounts to about 1,300 megawatts, or about 1 percent of the regional total.

Gasification

Gasification is a long-established technology, with roots going back almost two centuries. The synthesis gas produced can be burned for heating, burned in a turbine to generate electricity, or used as a feedstock for chemical manufacture. Gasification's recent application has been mostly limited to the utility and chemical sectors, although an increasing number of projects to gasify biomass are being developed and proposed. Gasification is a highly flexible technology, as almost any biomass resource can be used as a feedstock. Gasification is capital intensive and relatively complex to operate. The Canadian company Nexterra and U.S.-based Coal Tech offer smaller gasifiers that are well adapted to biomass feedstocks. A Coal Tech gasifier is now being used in West Virginia to gasify poultry litter. The University of Montana and Catawba County, South Carolina, have both ordered biomass gasifiers from Nexterra.

Adjusting to Walmart: The U.S. Dairy Industry's Story of Innovation

Meeting the world's increasing demand for energy will take innovative solutions, including developing renewable energy sources that are safe, reliable, affordable, and environmentally responsible. Anaerobic digestion of manure is a promising technology that holds great potential to meet these needs. However, adoption of manure digesters in the United States has been inhibited by technology application, high capital outlays, regulatory barriers, and limited financing programs. As of September 2011 the EPA estimates that 169 anaerobic digester systems were operating at commercial livestock farms in the United States (Germany has 6,800). Technology adoption of digesters has, however, been accelerating in recent years, in part due to retailer initiatives focusing on sustainability to meet consumer demand.

With more than 9,230 retail units, 2.1 million associates worldwide, and 2010 sales of \$405 billion, Walmart is the largest grocer in the United States. As companies of this scale adjust to market demands by changing purchasing practices and standards, a direct, quantifiable impact is made along the food supply chain. In October 2005 Walmart launched its sustainability program with three clear, straightforward goals:

- Be supplied 100 percent by renewable energy.
- Create zero waste.
- Sell products that sustain people and the environment.

After conducting a waste characterization study, Walmart determined that organic materials accounted for the top waste stream in each of its sectors. As a result, Walmart designed an organic materials diversion program that redirects organic waste streams toward useful energy conversion technologies, primarily anaerobic digestion. This has accelerated the development of industry-wide changes in U.S. food production, particularly in the U.S. dairy industry.

In 2008 the Innovation Center for U.S. Dairy was established to provide a forum for the dairy industry to "work precompetitively to address barriers to and opportunities for innovation and sales growth." By creating convergence up and down the supply chain, the Innovation Center helped the dairy industry develop sustainability benchmarks of its own that aligned with Walmart's new market strategy. The center's first goal was to reduce greenhouse gas emissions for fluid milk by 25 percent by the year 2020, particularly the 51.5 percent contribution milk production makes to the total carbon footprint of a fluid gallon. Because methane from cow manure is one of the most potent greenhouse gases (twenty-one times more than carbon dioxide), the Innovation Center has been supportive of anaerobic digesters to help control emissions. In May 2011 the Innovation Center, along with the Dairy Research Institute and Idaho's Center for Advanced Energy Studies, announced plans to have 1,300 digesters operating across the country by 2020. This ambitious goal will be a necessary, fundamental shift in order for the U.S. dairy industry to remain competitive in Walmart's retail market.

Transesterification

Transesterification is the chemical process whereby fats are converted into biodiesel. The process is widely used for biodiesel production from various seed oils and animal fats. In terms of residual

11. Innovation Center for U.S. Dairy, <http://www.usdairy.com/Pages/Home.aspx>; Wisconsin Bioenergy Initiative, <http://www.wbi.wisc.edu/>.

biomass feedstocks, waste grease would be the main candidate for producing biodiesel through transesterification.

Developing technologies

Two other technologies are in the developmental stage, not fully demonstrated at commercial scale.

Cellulosic fermentation

Cellulosic fermentation is the principal technology being pursued to produce ethanol from a wide range of plant feedstocks. If the technology can be technically proven and made commercially viable, producing ethanol from a wide range of plant material will be possi-

“Cow Power”: A Community Initiative

Three family-run dairy farms in southern Wisconsin are participating in the state's first cluster manure digester project. Dane County's “Cow Power” initiative, launched in 2010 under a Clean Energy and Clean Lakes Resolution to build a community digester, is also the first U.S. community digester built specifically to help farmers reduce biomass runoffs into surrounding freshwater bodies. In the Lake Mendota watershed, cow manure has been a primary source of phosphorous, leading to increased algae blooms and weed growth. The digester project is helping to eliminate this problem by diverting manure from 2,500 cows into three, 1.25 million gallon digesters, reducing the potential for the manure to pollute surface and groundwater through land application. Collecting over 3 million gallons annually, the facility is estimated to generate around \$2 million per year in electricity, roughly the equivalent of powering 2,500 homes. Alliant Energy, a public utility holding company headquartered in Madison, Wisconsin, purchases electricity from the facility, adding to the 3.71 megawatts of electricity the company receives from anaerobic digesters in its service territory.

Not only does this facility reduce total phosphorus from manure by up to 70 percent and produce ample amounts of green electricity, it also allows farmers to better address nutrient management issues and control nuisance odors, a great benefit to a region seeing recent residential and business subdivision expansions in the area. Additionally, anaerobic digesters are recognized for their contribution to reducing greenhouse gases by reducing methane emissions and as a source for job creation, both during construction and operation. Over twenty-five subcontractors and 200 workers built the “Cow Power” facility.

Citing the success of this community digester, four additional family farms in Dane County have proposed to build a second “Cow Power” facility. This manure digester will also contain the same phosphorous removal technology and produce the same \$2 million worth of electricity to be sold to Madison Gas and Electric. Due to the unique nature of these community cooperation initiatives and the benefits they yield socially, economically, and environmentally, these facilities will likely serve as a model for future digesters on farms across the Midwest and nation.

ble. There are two technical barriers to overcome before the process is ready. The first involves reducing the complex carbohydrates that make up the cellulose and hemicellulose found in residual biomass into fermentable sugars, so-called C5 and C6 sugars (because of the number of carbon atoms in the molecule). A variety of chemical and mechanical means are being tested to accomplish this. The second entails designing and producing the enzyme cocktails that can efficiently ferment both the C5 and C6 sugars found in the resulting mix. Both issues have been addressed and resolved to some extent at the lab scale and are now beginning to be demonstrated at the pilot scale. In addition to addressing the technical aspects of enzyme production, it is also important that enzymes be produced cost effectively, at scale. Successful demonstration and commercialization of cellulosic fermentation is essential to tapping the Midwest's significant crop residue resource for liquid fuel production.

Pyrolysis

Pyrolysis technologies are likewise in the developmental stage. Pyrolysis involves thermochemical decomposition of various feedstocks in an oxygen-free environment. Products include synthesis gas, most of which is consumed to sustain the pyrolysis reaction; bio-oil, which can be burned to generate electricity or heat or be further refined to produce transportation fuel; and biochar, which can be used as a soil amendment. There is some evidence that biochar application can improve nutrient retention, enhance cation exchange capacity, and encourage healthier soil microbe communities. However, additional field research is needed to verify such claims. In addition, the biochar may also be a cost-effective means of establishing stable, long-lived pools of soil carbon, which could give it a valuable role in mitigating global climate change. The residence time in the pyrolysis reactor vessel determines whether the process is considered slow or fast. Fast pyrolysis favors the production of bio-oil, and slow pyrolysis favors biochar. The capital and operating costs of commercial-scale pyrolysis systems are poorly understood. The combination of uncertain costs and higher technological risk means that pyrolysis systems are difficult to finance.

Two additional technologies, hydrothermal liquefaction and hydrothermal carbonization, are being studied at the lab scale and may hold some promise for converting very wet feedstocks such as dairy and swine manure into fuels and products.

All of the technologies described could find application in the Midwest. Given the inventory of residual biomass resources and the dominance of manure and corn stover, anaerobic digestion and cellulosic fermentation are especially important to the Great Lakes states. Yet high capital costs make it difficult to finance these technologies without subsidies or regulatory incentives.

The cost of biomass collection and transportation

The logistical challenges of harvesting, transporting, and storing biomass are considerable. Because most biomass has fairly high moisture content, cost-effective transportation distances are limited. Moisture can also affect biomass quality in storage. Storage is of particular concern for crop residues, which are harvested in a narrow time window even though a large biorefinery requires supply year-round. The questions of how to best manage and preserve feedstock quality over that storage period have not been adequately answered and need further investment in long-term research.

The delivered price for residual biomass resources will be an important factor in determining the regional economic potential. This is especially important for crop and forestry residuals. Biomass that is already concentrated—such as animal manure and urban forestry waste—can avoid the transport cost dilemma and will have an advantage over those that are widely dispersed. Natural geographic concentrations, as described in Chapter III, can be guideposts for siting new bioenergy facilities so transportation costs are minimized.

The DAM Project

Since 2008, three agricultural leaders have collaborated to identify and address complexities with the collection, storage, and transportation of crop residue for feed and fuel production. Archer Daniels Midland Company, Deere & Company, and Monsanto Company have been coordinating research efforts to explore technologies and processes to turn crop residues into feed and bioenergy products in an environmentally, agronomically, and economically sound way. Over the past three years, stover from approximately 12,000 acres has been collected for research. The companies are addressing a number of complexities and challenges in their work, including stover collection rates to reduce soil erosion and moisture levels that can affect transporting and storing biomass residues. Part of their aim is to identify areas and establish information where technology developments will have a significant cost reduction impact on stover harvesting. Determining environmentally safe and cost-effective means for harvesting, storing, and transporting biomass will allow farmers to produce more products without the need to farm on more acres, thus increasing the value derived from each acre.

The willingness of producers to embrace unfamiliar practices

Tillage and harvesting practices will also affect the success and failure of bioenergy projects. Tradition is an admirable characteristic of American agriculture. Farms have been worked across the generations by single families, and practices are passed down this line. New activities are often suspect—especially if they are at odds with the basic work of planting, tending, harvesting, and getting product to market. For example, corn stover, the most promising residual biomass feedstock for the Midwest, is also important for adding organic matter to the soil and protecting it from erosion. Recent survey work conducted with Iowa corn farmers showed a degree of interest but also a great deal of caution about the possibility of going into the business of selling stover.¹² Corn ethanol has been a success in part because it involved an expanded market for a core product. Farmers did not need to be persuaded to do anything differently other than plant more corn. And farmers are deeply familiar with the economics of raising corn based on many years of data and experience, so the economic risk/reward calculus was understood. If such a clear calculus cannot be presented for changing farming practices, the farmer is unlikely to be persuaded. In some areas the value of corn stover as a soil amendment may exceed what could be earned by selling it as biofuel feedstock. Additional long-term research is needed to understand and document these complex relationships.

Current patterns of cultivation suggest that only about one-third of the region's corn stover could be used for bioenergy without undermining soil quality. If these patterns changed—if conservation tillage, no till, and winter cover cropping (which reduce the need for corn stover) were more widespread—the amount of available stover could increase substantially. In the current environment, however, encouraging farmers and forest owners to change long-established practices, even with favorable economics, is a challenge.

The existence of public subsidies, incentives, and regulatory policies

Because of the economic challenges and current competitive disadvantages of an industry still in development, public subsidies,

12. John C. Tyndall, Emily J. Berg, and Joe P. Colletti, "Corn Stover as a Biofuel Feedstock in Iowa's Bio-Economy: An Iowa Farmer Survey," *Biomass and Bioenergy* (2010): 1-11.

economic incentives, and regulatory policies will play a pivotal role in helping new technologies emerge and gain a market foothold. These interventions are discussed in more detail in the next chapter. The value of such interventions is proven and certainly not without precedent. Examples include current subsidies for corn ethanol and production tax credits for wind power. Current economic conditions and budgetary limits will make finding new federal or state support for residual biomass energy a challenge and may limit its growth potential.

In the Wake of a Crisis: Japan Turns to Biomass

In the aftermath of Japan's Fukushima nuclear power plant incident, a result of the massive earthquake and subsequent tsunami that crippled northeastern Japan on March 11, 2011, the country has plans to abandon nuclear energy in support of renewable energy pillars, including biomass. Japan's nuclear power industry, which includes fifty-four nuclear reactors that provide 30 percent of the country's electricity and is ranked third in world production, had plans to develop at least fourteen new reactors over the next twenty years. In light of the recent crisis, however, policymakers have accepted that this will likely be impossible. Two months following the disaster, Prime Minister Naoto Kan touted that Japan's energy policy must "start from scratch" and that it is "necessary to move into the direction of promoting natural energy and renewable energy such as wind, solar, and biomass." Japan currently imports nearly 80 percent of its energy needs, mainly due to the extremely dense population, high electricity demands, and lack of natural resources. However, with a dense population comes an abundant supply of municipal solid waste (MSW), a promising residual additive in energy generation. Japan is the world's largest user of thermal treatment of MSW in the world, consuming 40 million tons per year at 190 MSW power generation facilities. The country also has seventy other biomass power plants and fourteen that burn both coal and biomass. In 2009 they together represented 1 percent of the country's total electricity and approximately one-third of the renewable sources. However, there is vast potential for growth, as 1,900 incineration facilities can still be outfitted with generators, and 14 million tons of food crop residue from rice, corn, and wheat go unused each year.

Chapter II Advancing the Market for Biomass Residuals

If residual biomass is to play a larger role in supplying the nation's energy needs, four pieces of a complex puzzle must be in place:

- Conversion technologies must be commercially demonstrated and readily available.
- Products produced from biomass feedstocks must be competitive with prevailing alternatives.
- Viable business strategies must be devised for developing, financing and operating new technologies and for marketing outputs.
- Behaviors of producers must be analyzed and areas where behavioral change is needed identified and addressed.

The first two pieces of this puzzle typically receive the most attention, and indeed both are crucial. All of the points in this chapter will contribute to putting these first two pieces together. Business strategy and behavior are also key factors for success, but to date they have received less attention than they deserve. The last two sections of the chapter examine these two pieces individually.

Adopt a "landscape vision" for analyzing bioenergy feedstocks.

It is tempting to analyze potential biofuel pathways in the same way as coal or petroleum, using a straightforward formula based on cost of resource inputs and conversion and the value of energy outputs. However, biomass resources are inherently different from other energy resources, and especially different from fossil fuels. First, the natural endowment of fossil fuels is fixed. In other words, we cannot do anything to increase the amount of the available resource. We can develop more efficient extraction methods to get more of the resource out of the ground, and we can encourage consumption efficiency to prolong the expected lifespan of the resource, but the basic endowment cannot be changed. In addition, the basic endowment

of fossil fuels is independent of the physical context in which it is found. To be sure, fossil fuel extraction occurs in specific landscapes and creates environmental impacts, many of them severe. But generally speaking, there are no other costs and benefits associated with the resource beyond fuel production.

By contrast, biomass feedstocks are renewable energetic streams. Production occurs in a biophysical context, in specific ecological settings as part of a web of complex interactions that occur over time and space. Biomass production is dependent on and, in turn, affects the surrounding soil, water, and atmospheric complex. Decisions about how these interactions are managed dictate future biomass productivity and touch on a wide spectrum of social concerns.

Soil, water, and air impacts have a potentially broad reach. For example, agricultural practices in the Upper Mississippi basin are tied to seasonal hypoxia in the Gulf of Mexico—the so-called dead zone. A similar phenomenon is observed in the Chesapeake Bay, also tied, in part, to regional agriculture. The international land use change and associated greenhouse gas emissions arising from U.S. corn demand was highlighted earlier. It seems likely that environmental impacts associated with the global macroeconomic consequences of local actions will continue to demand consideration. It is feared that potential increases in the demand for bioenergy crops will reduce the acreage set aside in response to various federal conservation incentives and that this, in turn, will affect habitat for a wide range of plants and animals, ultimately reducing biodiversity.

Because of these differences, it is important that a different framework—a landscape framework—for evaluating bioenergy be adopted. The landscape perspective takes into account the full range of impacts (both positive and negative) that biomass resources and products have on the natural resource system. A landscape-based perspective is needed if we are to devise ecologically suitable ways to increase the role played by biomass energy in the United States, including preserving soil quality and protecting surrounding natural resources. Using a landscape perspective will not only help avoid costly mistakes, but increase the total value of biomass energy by taking into account its benefits beyond the simple production of energy.

There are three challenges to adopting a landscape perspective:

- A landscape perspective demands consideration of a web of interactions (air, water, soil, biota), not all of which can be equivalently described or quantified. Even where quantification is

attempted, it may be difficult to find consensus on the “right” number. Among other things, this requires a very high degree of interdisciplinary thinking and cooperation.

- A landscape perspective requires incorporation of difficult-to-monetize factors alongside those that are more easily monetizable.
- A landscape perspective imposes a perspective of longer-term ecosystem protection and improvement on an economic calculus that tends to be more short term in nature.

Manure management on large farms can help illustrate these challenges. Concentrated Animal Feeding Operations (CAFOs) are growing in number and are expected to play an increasing role in supplying the nation’s meat, dairy products, and eggs. CAFOs yield large amounts of manure that create objectionable odors and methane (a potent greenhouse gas) and that potentially threaten both surface and ground water through nutrient and pathogenic contamination. Anaerobic digestion, as discussed earlier, is one option for managing manure. The resulting biogas can be burned to generate electricity, which can then be sold back to the regional electricity grid. Digester solids can be used for animal bedding, which creates a second value stream. However, revenues from electricity and bedding are rarely sufficient to justify the investment, and the number of digesters in the region remains well below the full potential.

A landscape-based accounting of manure management by anaerobic digestion would include energy generation, greenhouse gas reduction, odor management, animal bedding, nutrient cycling, and pathogen management. All of these attributes can be described, and some can be quantified. Yet only the value of electricity and bedding can be readily captured in the market today. The exercise of describing and quantifying all ecosystem impacts involved requires calling on the expertise of many disciplines: engineering, agronomy, water quality, air pollution, environmental markets, and utility economics. All of these and probably several others have something to contribute to the overall system analysis. In order to bring value to currently nonmonetizable attributes, these disciplines would need to bring their expertise into the policy and business realms to create value—either through new markets or through regulatory policies.

In a world dominated by short-term economic concerns, readily monetized factors tend to receive the most weight. However, such

The Landscape Vision

The landscape vision was incorporated into the “America’s Energy Future” report by the National Academy of Sciences. The report recognized that sustainable development requires a broader focus that extends beyond single issues. Land-use decisions for bioenergy feedstock must simultaneously be evaluated for their impact on air quality, water quality, soil quality, wildlife habitat, carbon sequestration, rural development, and all other issues affecting the natural resource system.

The National Laboratory for Agriculture and the Environment (NLAE), a transdisciplinary laboratory of the USDA Agricultural Research Service, focuses on integrating the fundamental principles of the landscape vision. NLAE’s mission is to integrate soil, water, and air processes into animal, cropping, and watershed systems to enhance environmental quality, sustainability, and agricultural system efficiency. Its mission requires a blending of diverse expertise between producers and other decision makers across a number of scientific disciplines.

Soil, Water, and Air Resources, a research unit under NLAE, has a primary focus on the basic soil and air components of agricultural and environment systems. Dr. Doug Karlen, research leader of the research unit, acknowledges that the key for implementing a landscape vision is to recognize that today’s complex problems have multiple solutions: “In addition to providing multiple sustainable feedstock supplies of biomass, we must continue to explore multiple conversion platforms (i.e., biochemical, thermochemical, catalytic) and account for all impacts and tradeoffs (intended and consequential) of each decision.”

an analysis omits critical factors. From a societal perspective there is good reason to support a landscape-based analysis despite its complexities. Supportive policies and subsidies are needed to encourage practices whose benefits are clear but currently unrecognized by markets. At the same time, markets for these attributes must be created as soon as possible to ensure that appropriate economic signals are in place for socially beneficial behavior.

Adopt an incremental approach.

Energy resource estimates have a long history of inspiring passionate debate among advocates for competing resources and technologies. These debates often involve oversimplifications of complex and uncertain issues and are generally not very useful for advancing efforts to solve our energy problems, however we may conceive this job. Moreover, these debates usually overlook the incremental and slow rate of change that characterizes global energy systems. So, for example, we are unlikely to appropriate a significant portion of the Midwest’s agricultural residue for energy production in anything less than a decade. Yet assessments based on rapid and complete appro-

priation have a tendency to dominate our current policy debates. In reality, change in energy systems is almost always incremental, and it would be wise to apply incremental thinking to the questions of how and where residual biomass resources can best be used. An incremental approach recognizes the need for experimentation, technology development, environmental monitoring, and, importantly, adjustment.

Capture the true costs and benefits of conventional and bioenergy production by including environmental impacts.

Because energy markets are unlikely to do this on their own, economic and environmental regulations could be better fashioned to capture the costs and value of ecological outcomes. This would add value to resources that do not degrade the environment and that actually contribute to environmental sustainability and enhancement. Among the most important areas for biomass resources are greenhouse gas (especially carbon) emissions and water pollution.

Carbon emissions

Many academic studies have considered the impact of various greenhouse gas regulations (and the pricing of carbon) on bioenergy technologies.¹³ The studies come to the unsurprising conclusion that pricing carbon is good for bioenergy. In addition, credits for terrestrial carbon sequestration could create an incentive for conservation tillage systems, which help offset greenhouse gas emissions. At present, no federal climate policy exists and state policies are limited in their reach. It is therefore not yet possible for bioenergy technology developers to include potential greenhouse gas revenues in project *pro formae* in the financing process. Until a national program is in place, it will be difficult to reap this benefit. Interestingly, some bioenergy advocates—the U.S. Farm Bureau chief among them—are on record as opposing mandatory carbon limits, so legitimate concern over the total cost of greenhouse gas regulation may trump any upside that could accrue to others. This is especially true given that the greenhouse gas footprint of biofuel production is coming under increased scrutiny, moving the discus-

13. For example, see David Philip, Martin Zaks, and others, “The Contribution of Anaerobic Digesters to Emissions Mitigation and Electricity Generation Under U.S. Climate Policy,” *Environmental Science & Technology* (2011).

sion from one in which bioenergy was assumed to be carbon neutral to one in which every project is examined under a microscope. Nevertheless, taking greenhouse gas emissions into account as part of the cost of energy production would promote the development of the most environmentally friendly solutions and help make biomass residuals a viable alternative.

Water pollution

Nutrient trading schemes and watershed-based approaches to water quality permitting may allow some forms of bioenergy to capture value for reducing water pollution. For example, economic incentives for reducing nitrogen and phosphorous runoff could help add value to technologies that use animal manure for bioenergy. If anaerobic digestion can be shown to prevent nutrients and pathogens from contaminating ground and surface waters, innovative regulatory programs may allow the digester owner to capture this value. Watershed-based permitting pilots are under way in Wisconsin and Ohio, and Pennsylvania has launched a nutrient trading market.

Nutrient Trading and Sustainability Standards

Producing biomass feedstocks and bioenergy as economically, socially, and ecologically as possible while maintaining multistakeholder consensus among power plants, farmers, national and state agencies, environmental groups, and others is no easy task. Water quality trading, however, is considered an innovative market-based approach that meets these sustainability goals. Nutrient trading also encourages stakeholder involvement while protecting and improving watersheds to ensure safe, clean water for the benefit of the public and environment.

The Ohio River Basin Water Quality Trading Project is a first-of-its-kind northeast interstate trading project that includes coordination and collaboration across a diverse set of stakeholders to design and develop credit markets for nitrogen and phosphorus. Led by the Electric Power Research Institute, the proposed trading program will allow farmers to earn water quality credits by implementing agreed-upon conservation practices to support biomass production. By selling these credits to pollutant dischargers, farmers will receive money to apply and maintain new management practices.

In another effort to ensure a balance of economic, environmental, and social imperatives while engaging a diverse set of stakeholders, the Council on Sustainable Biomass Production (CSBP) was initiated to develop a voluntary sustainability standard for biomass growers and bioenergy producers. Formed in 2007 by a group of companies, conservation organizations, academics, government agencies, and growers, CSBP set out to develop a voluntary standard—to be adopted December 2012—that will provide guidance to biomass producers and bioenergy companies on sustainable production methods for biomass-based bioenergy in the United States.

Create economic and regulatory incentives to stimulate demand for bioenergy and bioproducts.

State and federal economic incentives (grants, loans, loan guarantees, production incentives, tax credits) and various regulations (renewable electricity standards, renewable fuel standards) have so far been the single most important driver of biomass conversion technologies and have been responsible for propelling many bioenergy projects forward. State renewable electricity standards can create demand for biomass electricity projects. Five of the six states in the Midwest have some form of renewable electricity standard (Indiana is the exception). To date, these quotas have been dominated by wind projects because they are cheaper to build than most biomass electricity projects.

Low carbon fuel standards, which could create additional demand for biofuels, have been debated, but not enacted in our region. California has adopted a standard requiring a 10 percent reduction in carbon intensity by 2020. Biofuels are expected to play a major role in achieving this target. However, because of the significant controversy over the lifecycle greenhouse gas emissions of some biofuels, the carbon benefit of biofuels has been diminished and in some cases zeroed out.

Nevertheless, if fully implemented, the RFS2 legislation described previously will provide significant impetus to cellulosic fermentation. Indeed, by itself the policy would create demand for 16 billion gallons of cellulosic biofuels and drive the construction of many large biorefineries. Demand of this magnitude could use up all of the Midwest's corn stover resource and more.

State public benefit funds such as the Wisconsin Focus on Energy program have provided grants for bioenergy projects. Federal programs provide both grants and loan guarantees for bioenergy projects. Successful projects most frequently involve a combination of funding sources.

Develop viable business models.

Sound technology, favorable economics, and supportive policies are not sufficient to bring projects to fruition. Viable business models are needed. Key strategic questions include who will own and finance the project, how the costs and benefits are shared when third parties are involved, and how markets are accessed.

Who will own and finance the project?

The producer of the feedstock may not be the best candidate to finance and operate a project. Today, many digesters are developed and financed by third parties, in part because some of the earliest projects, which were farmer owned and operated, failed. Operating responsibility is best lodged with those having appropriate expertise. Generally, farmers want to farm and not act as energy engineers. Third-party participation can help insure that operational responsibility sits with an entity that can manage it.

The grain farmer may not be the best party to harvest and sell the corn stover, although many analysts assume that this is the model to pursue. Because the grain will be the most valuable part of the corn plant, the farmer will focus his attention first on that and possibly contract with third parties for removal of the stover after the corn harvest is complete. This will require a sharing of the economic benefits as well as a great deal of operational clarity and coordination on the part of both parties.

How are the costs and benefits shared when third parties are involved?

Financial benefits usually flow according to financial risk. This does not mean that the feedstock producer will not share in project benefits, but it is important that expectations are realistically calibrated and understood. This goes for investment risk in projects as well. There are many advocates for farmer-owned-and-operated bioenergy facilities, and it is potentially alluring to get a piece of the action. It is good to remember that the rate of failure for energy projects is high (greater than 50 percent) and that downside risk and associated loss of capital is possible. The recent recession saw the failure of many bioenergy projects, and this lesson should be born in mind when considering investment.

How is access to markets gained?

Much of the work of gaining access to markets involves activity and expertise in the regulatory and political spheres. Third-party developers can be better suited to this work, especially if they have completed multiple projects and are familiar with existing regulations and laws. Working with state and federal agencies to obtain grants and loan guarantees, negotiating interconnection agreements with

electric utilities, certifying electrical output for eligibility as renewable energy, and certifying the carbon content of fuels are all steps to gaining market access for biofuels.

Encourage farmers to adopt new practices that would increase residual biomass industry potential.

As stated in Chapter I, current patterns of cultivation suggest that only about one-third of the region's corn stover could be used for bioenergy without undermining soil quality. If these patterns changed, the amount of available stover could increase substantially. The behavioral obstacles to new agricultural practices, however, should not be underestimated. What would need to happen to change the prevailing patterns? Economic signals will be important, and a thorough and convincing analysis of the costs and benefits of proposed alternatives will be needed to open the discussion. If a basic bottom-line case cannot be made, then the chances for success are slim. Even so, the economic argument by itself may not be enough. Existing patterns will need to be examined carefully to understand their deeper underpinnings. If these can be better understood, then the search for positive, respectful ways to encourage behavior change can begin. This will require engaging different disciplinary expertise—psychology and sociology, in particular—than is typically brought to bear on questions of the bioeconomy and will require working with producers in new ways.

Chapter III Tapping the Midwest's Potential

This chapter addresses the following questions:

- What types of residual biomass does the region produce?
- In what amounts?
- To what extent are these resources available for producing bioenergy and bioproducts?
- Where are these resources concentrated in the region, and how can these concentrations guide the development of bioenergy projects?

Various estimates for regional supplies of agricultural crop residues, animal manures, forestry residues, primary paper mill wastes, urban wood wastes, and sewage treatment sludge are presented. Other resources such as food processing wastes and secondary wood processing wastes may be important locally, but are a very small portion of the regional resource.

Energy resource estimation

Various approaches to quantifying energy resources can lead to widely divergent estimates and correspondingly different conclusions about what the estimates imply. The most extreme example involves calculating the total amount of solar radiation reaching the earth's surface during the course of a year. It can easily be demonstrated that this level exceeds society's total needs by a considerable margin. Physics, economics, and behavioral factors conspire to reduce the amount of solar energy that can realistically be captured to levels far below the theoretical potential.

In the case of the biomass resources studied here, the following assessments are considered:

- **Total resource:** For example, all of the corn stover, manure, or forestry residue produced in a given area.

- **Ecologically available resource:** The quantity of material that could be used for bioenergy without compromising the ecosystem services that the resource also provides. For example, agricultural crop residues play an important role in soil health as measured through physical, chemical, and biological properties and processes. Crop residues reduce the potential for soil erosion by wind and water, increase nutrient cycling efficiencies, and increase water entry and retention, thereby improving water quality if properly managed.
- **Natural concentrations:** Is the resource concentrated in particular ways that should be considered when devising regional resource strategies and policies?

The analysis must also consider the economically available resource, which comprises the portion of the resource that would be used, given a particular set of economic, engineering, and behavioral assumptions. Analyses of economic availability usually start with a base case (i.e., current fossil fuel prices, environmental regula-

	(10 ⁶ dry tons)	(%)	Source
Crop residues			2000-2009 production averages, USDA NASS: Data and Statistics
<i>Corn stover</i>	106		
<i>Soy straw</i>	64		
<i>Wheat straw</i>	7		
Total	177	81	
Animal manure			2007 Census of Agriculture
<i>Cattle</i>	14		
<i>Swine</i>	4		
<i>Poultry</i>	2		
Total	20	9	
Forestry residue	11	5	Milbrandt, 2005
Primary mill residue	5	2	Milbrandt, 2005
Urban wood residue	6	3	Milbrandt, 2005
TOTAL	219		

tions, and known technologies) and various alternative scenarios (high fossil fuel prices, high carbon prices, viable nutrient trading markets, new technologies). A comprehensive economic analysis is not attempted here, as considerable uncertainty attends the estimation of both ecological and economic availability. The information in Chapter I can help guide such an analysis. Crucial policy questions can best be understood by varying assumptions and testing the sensitivity of conclusions to these changed variables.

Total resource

Agricultural residues and animal manures dominate the total resource picture, constituting 90 percent of the total resource available in the region.

The energetic content of these resources can be expressed in a number of ways. The heat content of the dry biomass contained in each of these streams allows them to be compared on an equivalent basis. (Animal manures are almost always used in their wet states,

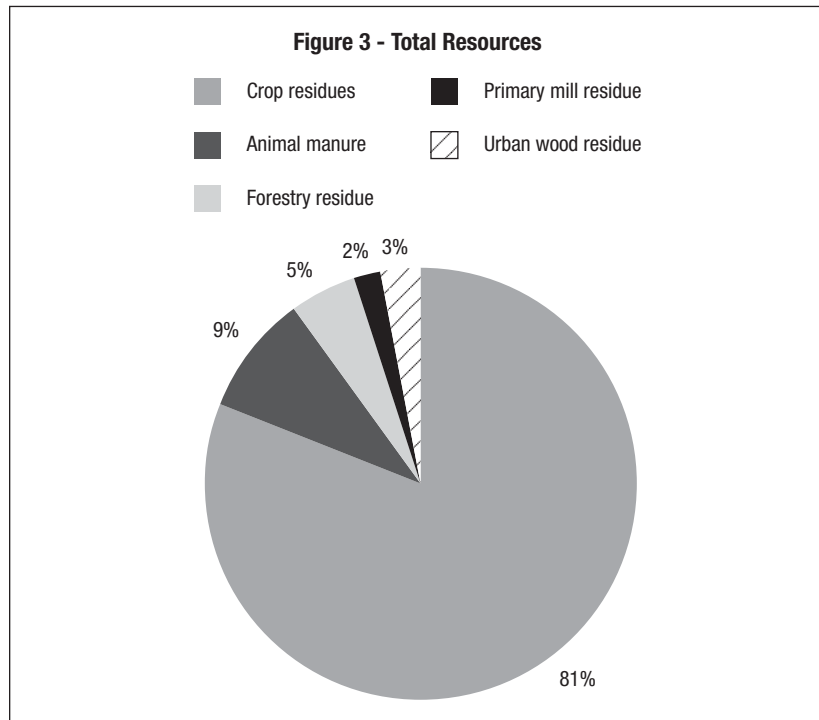
	Dry biomass energy content (10 ⁶ MMBTU)	Ethanol (EtOH) (10 ⁶ gallons)	Electricity (10 ³ MWH)	Digester gas energy content (10 ⁶ MMBTU)
Crop residues	3,540	15,434	354,000	
Animal manure	400	N/A	N/A	64
Forestry residue	220	959	22,000	
Primary mill residue	100	436	10,000	
Urban wood residue	120	523	12,000	
TOTAL	4,380	17,352	398,000	64
Percent of regional demand	25	46	61	2

so the dry data are mainly presented for comparison purposes). For agricultural and forestry residuals, the volume of ethanol (EtOH) that might be produced from the feedstock can be estimated. The amount of electricity the dry biomass would produce if burned can also be determined. Finally, the energetic content of the digester gas that could be produced from animal manures can be estimated. Table 3 presents total regional resource potential, not ecological or economic potential.

Ecologically available resources

Our ability to estimate ecological potential for these various resources is uneven. Properly managed, animal manures can provide crop nutrients that reduce the need for purchased fertilizers. Bioenergy production can help reduce the volume of odors associated with manure by converting a portion of the carbon into methane and still return many of the nutrients to crops when the residual material is applied to the soil. For this analysis it is assumed that 100 percent of the region's animal manure is ecologically available.

Forestry residue—the tops and branches from harvestable timber left in the forest—provides habitat for various species, stabilizes soils, and can replenish soil nutrients. Perlack (2005) assumes that 65 percent of forestry residue is available for bioenergy, and the same assumption is made here. Milbrandt (2005) reports that 80 percent of primary mill residue is already utilized. For this analysis the



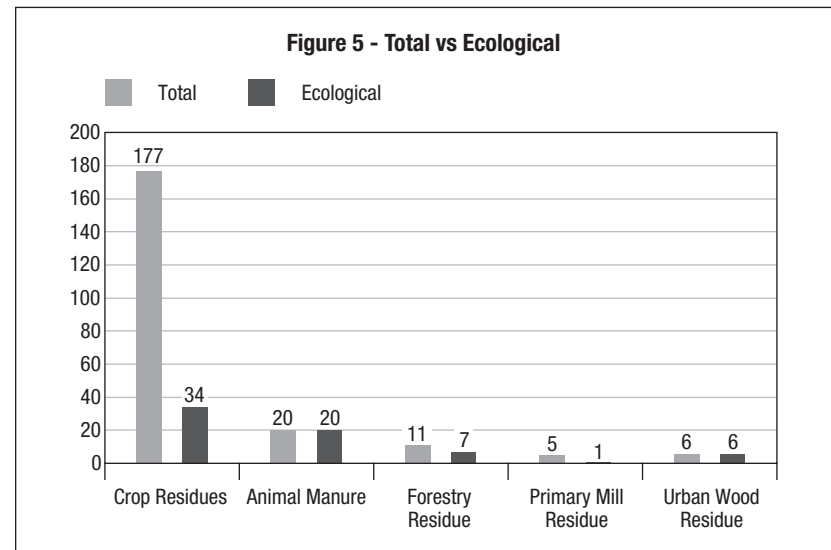
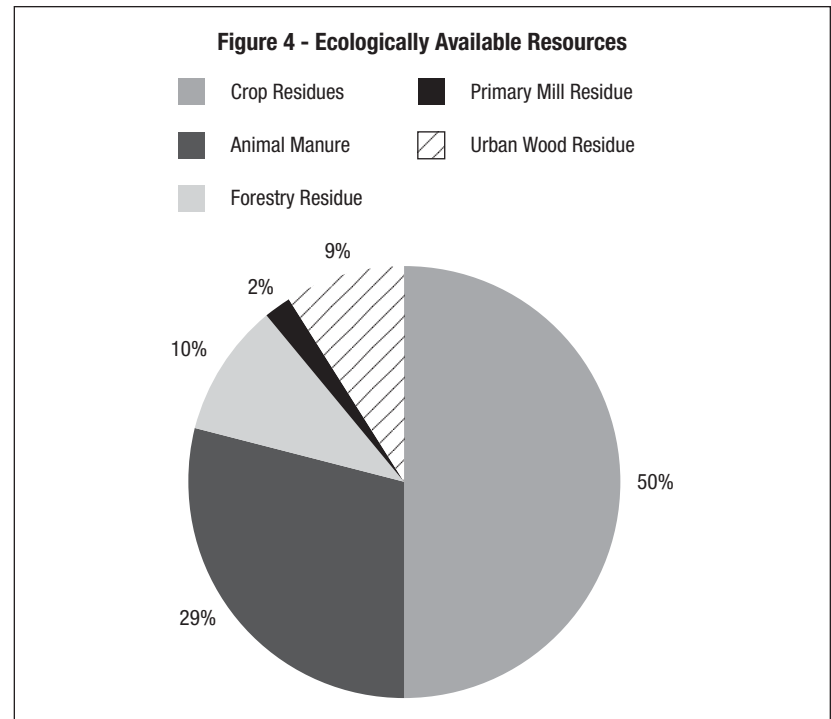
available portion has been reduced accordingly (although this is not strictly an ecological constraint).

Urban wood residue is assumed to be 100 percent available, in spite of the fact that there are a few projects in the region that do use this waste. These projects are not sufficiently large, in total, to reduce the estimate.

It is currently assumed that all soybean residues must be left in farm fields to prevent erosion and maintain nutrient levels. Soybean cultivars with greater nonseed biomass have been developed, but are not in widespread use. If these become more common, some soybean residue could become available for bioenergy and bioproducts.

Some effort has already been devoted to estimating acceptable levels of corn stover and wheat straw removal, although the research community has yet to reach consensus on what these levels are. Important factors include tillage systems (conventional, reduced, or no-till), whether a winter cover crop is used, soil type, field slope, and year-to-year climate conditions. A review of recent academic research reveals a range for stover removal from zero (where conventional tillage is applied) to 100 percent (where no-till and winter cover crops are employed). Milbrandt (2005) pegs the ecologically

	(10 ⁶ dry tons)	(%)
Crop Residues		
<i>Corn stover</i>	32	
<i>Soy straw</i>	0	
<i>Wheat straw</i>	2	
Total	34	50
Animal manure		
<i>Cattle</i>	14	
<i>Swine</i>	4	
<i>Poultry</i>	2	
Total	20	29
Forestry Residue	7	10
Primary Mill Residue	1	2
Urban Wood Residue	6	9
TOTAL	68	



recoverable resource at 37 percent of the total resource. Nelson (Biomass and Bioenergy, 2002) estimates the ecologically recoverable portion at 17 percent. This analysis uses 30 percent. This figure is an arithmetic simplification and is not intended to represent a scientifically defensible point estimate. Table 4 presents a revised list of ecologically available resources based on the data presented in Table 2.

The ecologically recoverable resources are about 19 percent of the total resources. This is due to dropping all soy as well as 70 percent of corn stover and wheat straw from the inventory and reducing available forestry residue to 65 percent of the total resource. Table 5 presents a revised energetic analysis based on the data presented in Table 3.

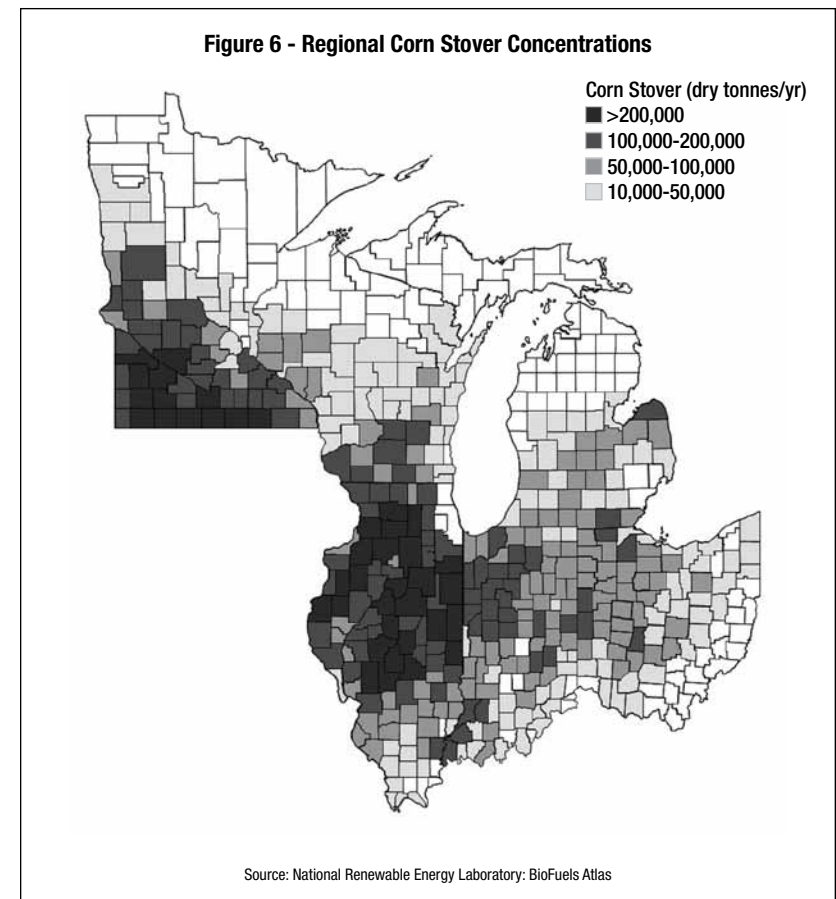
How might the ecologically available resource change? Crop residue harvest rates could increase if different tillage practices are adopted more widely than at present. One recent study (Wilhelm, et. al., Industrial Biotechnology, October 2010) suggests that up to half of the corn stover produced could be harvested in no-till situations and all of it could be reclaimed if no-till is employed in concert with winter cover cropping. Perlack, et. al. (2005) assume that residue harvest rates will increase as yields increase, and this frequently cited study includes scenarios that have average yields rising dramatically. Yields have, in fact, increased regularly for the past several decades. However, the scientific basis for assuming that this trend will continue at the same rate is uncertain, especially when consid-

	Dry biomass energy content (10 ⁶ MMBTU)	Ethanol (EtOH) (10 ⁶ gallons)	Electricity (10 ³ MWH)	Digester gas energy content (10 ⁶ MMBTU)
Crop residues	700	3,000	68,000	
Animal manure	400	N/A	N/A	64
Forestry residue	140	610	14,000	
Primary mill residue	20	90	2,000	
Urban wood residue	120	520	12,000	
TOTAL	1,480	4,220	96,000	64
Percent of regional demand	8	17	14	2

ering all soil types and conditions found throughout the Corn Belt. In addition, changing climate conditions and increased spring runoff can also significantly impact the length of corn growing seasons and harvest times on an annual basis, making the availability of corn stover seasonally difficult to predict.

Natural concentrations

The region's biomass resources show some natural degree of concentration, and these concentrations can offer some guidance about the location and size of potential projects.



Crop residuals

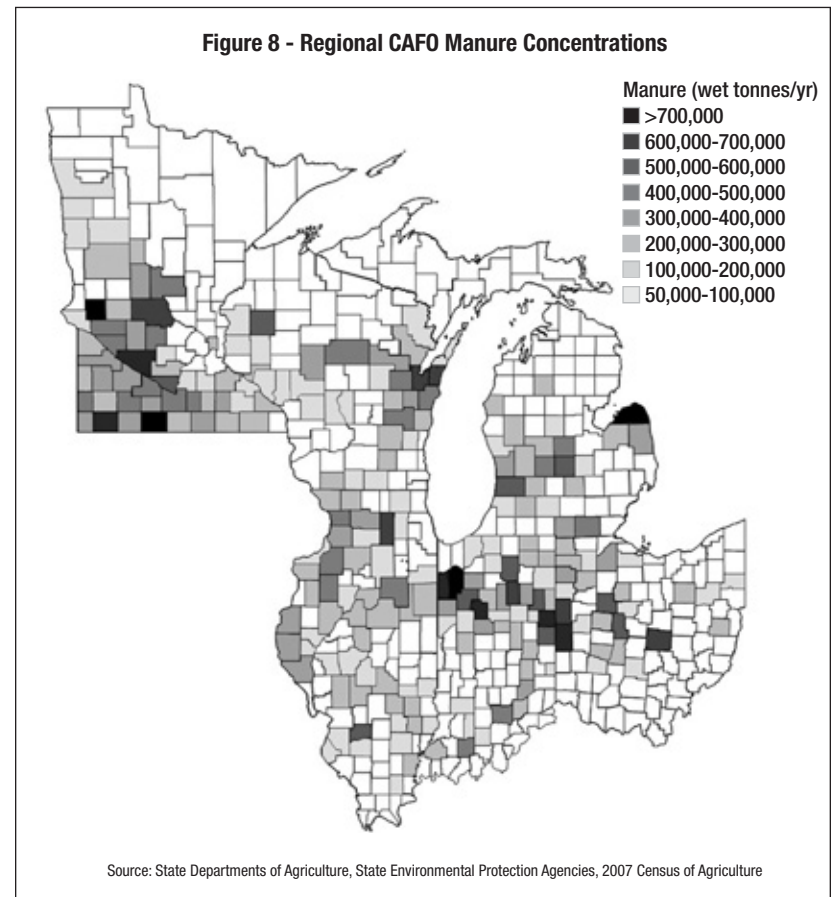
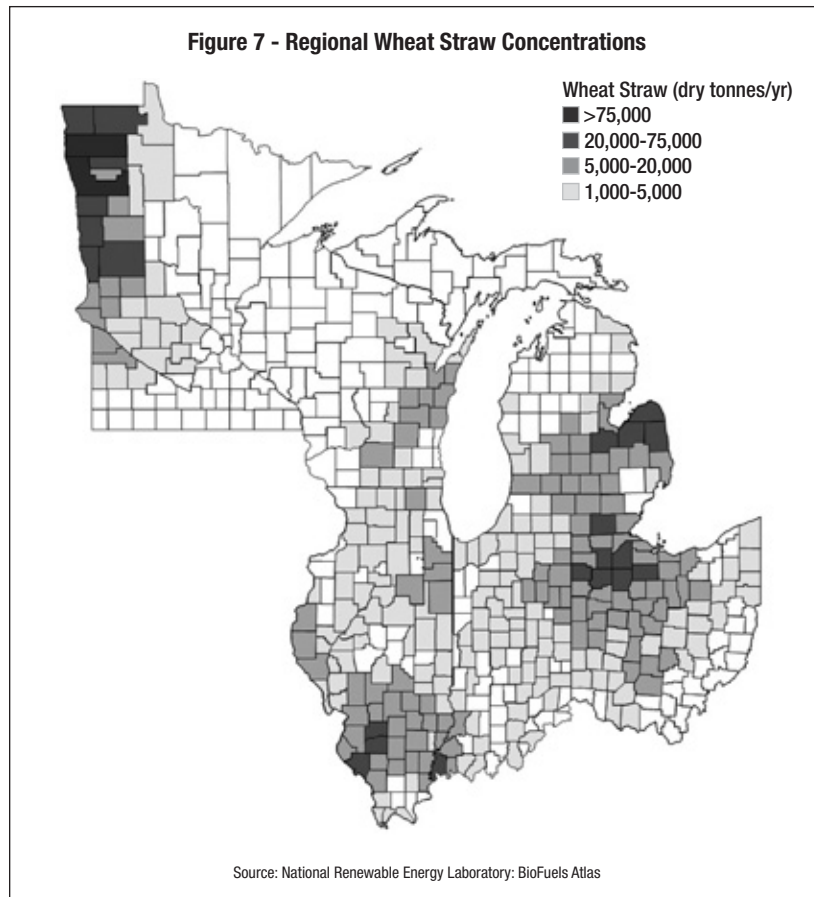
Corn stover production is concentrated in eight areas—southwestern Minnesota, southeastern Minnesota, south-central Wisconsin, northern Illinois, east-central Illinois, central Illinois, northwest central Indiana, and northwest central Ohio (see Figure 6). Each of these regions has a central point around which more than 1 million tons of stover is produced within a fifty-mile radius annually. Counties in these areas generally produce more than 200,000 tons of stover per year. Each of these eight regions could support one large biorefinery, while minimizing stover transport costs.

The most significant areas of concentration of wheat straw are found in northwest Minnesota, east-central Michigan, and north-

west Ohio (see Figure 7). It is unlikely that wheat straw production by itself could justify bioenergy project development, although wheat straw could supplement other feedstocks to supply projects.

Animal manures

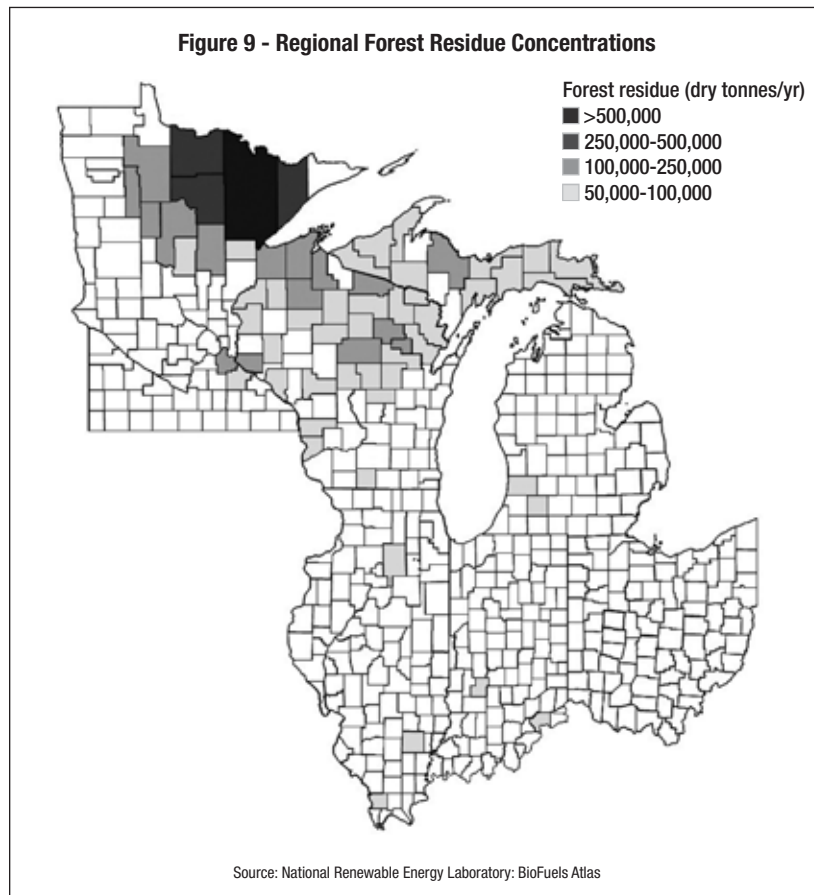
The region is home to almost 200 million cattle, swine, and poultry. Many of these animals are dispersed in small numbers across the agricultural landscape, and the manure they produce is probably not collectible for bioenergy production. However, the region has a significant number of concentrated animal feeding operations (CAFOs), which are probably the best candidates for bioenergy projects.



More than 137,000 farms report having cattle in the region. There are only about 2,800 with more than 500 head, and just over 700 with more than 1,000 head. These farms represent about a quarter of the cattle population.

More than 20,000 farms report swine, with 2,800 (about three-quarters of the total population) reporting more than 2,500 animals. Poultry is even more concentrated. Around 28,000 farms report more than 80 million birds in the region. Seventy-three million (90 percent) are concentrated on 136 farms.

In total about one-third of the region's manure is found in CAFOs. Figure 8 highlights manure concentrated in CAFOs.



Forestry residues

Forestry residues are concentrated in northeastern Minnesota, north-central Wisconsin, and Michigan's Upper Peninsula (see Figure 9). Each of these regions could probably support one or more bioenergy projects utilizing forestry residue.

Urban wood residues

Significant concentrations of urban wood residue can be found in Chicago, Milwaukee, Minneapolis and the surrounding counties, Akron, Cincinnati, Columbus, Detroit, Indianapolis, St. Louis, and Toledo.

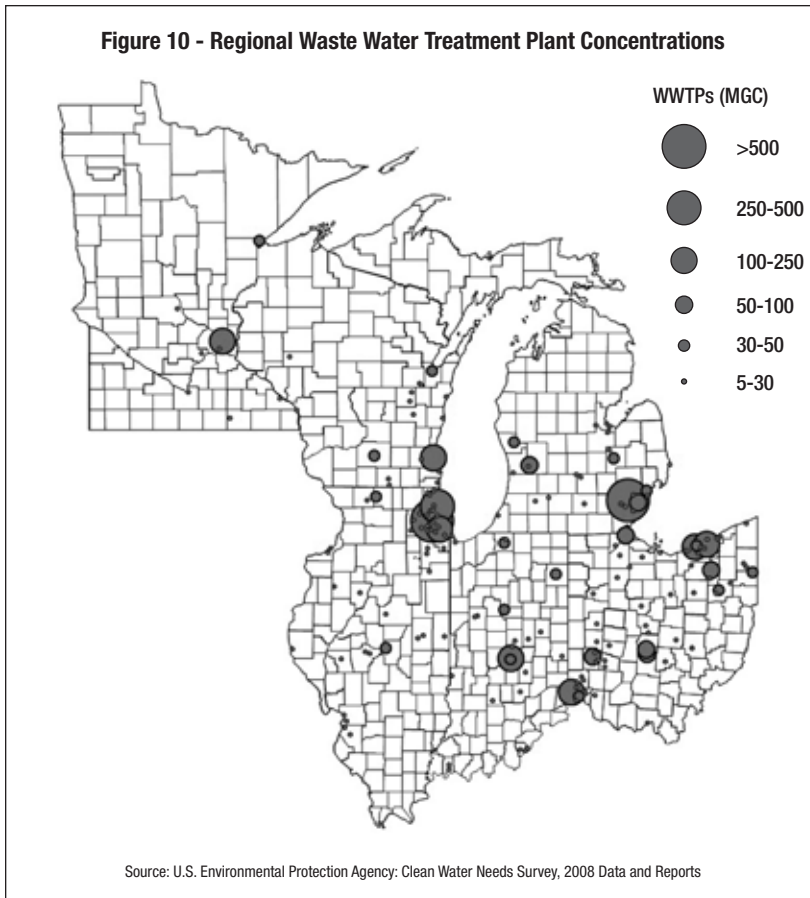
Sewage sludge

Municipal wastewater treatment plants (WWTPs) treat raw municipal sewage and separate wastes into a liquid effluent stream and solid-liquid streams comprised of debris and sludge. Sludge is further treated to form biosolids using mainly anaerobic digestion techniques. A good rule of thumb for a biosolid production rate in a typical treatment plant is one dry ton per million gallons of wastewater treated. Biosolids are most frequently disposed of by land filling, land spreading, or composting, but there is potential for energy production using these solids.

WWTPs are concentrated in urban and suburban areas. There are seven cities in the region with facilities treating over 100 million gallons per day: Chicago, Cincinnati, Cleveland, Detroit, Indianapolis, Milwaukee, and St. Paul (see Figure 10).

The vast majority of WWTPs treat wastewater flows equal to or less than one million gallons per day. Facilities treating less than five million gallons per day typically do not produce enough biogas to make electricity generation feasible or cost effective and were therefore not included in this study.

The energy numbers in Table 6 assume that all WWTPs treating at least five million gallons per day within the region utilize anaerobic digester technology and incinerate their biosolids for electricity generation.



Summary

Crop and forestry residues and animal manures offer the largest opportunity for bioenergy development in this region. The resources are naturally concentrated, and these concentrations can be used to guide project development. For crop residue eight high-production regions have been identified where projects could be located. For forestry residue, three high-production regions have been identified. For animal manures, CAFOs are the logical focus for project development. CAFOs themselves show a tendency to concentration, with higher numbers found in southwestern Minnesota, east-central Wisconsin, northwest Indiana, and east-central Indiana/west Ohio.

Table 6 - Energetic Analysis of Wastewater Treatment

	Electricity (10 ³ MWH)	Digester gas energy content (10 ⁶ MMBTU)
Sludge treatment		3
Incineration of biosolids	2,000	

Source: Stillwell and others, 2010; U.S. Environmental Protection Agency: Clean Water Needs Survey, 2008 Data and Reports

Chapter IV

Policy Recommendations

To promote bioenergy in the Midwest as a way to diversify energy security, create economic growth, and reduce environmental impacts, focus should be placed on the most abundant resources first. This is not to gainsay the opportunity presented by smaller residual streams in the region, but if policies to increase the use of bioenergy are to be devised and promoted, they should have the maximum impact. This said, care should be taken to insure that smaller residual streams benefit from the policies aimed at exploiting the more abundant resources whenever possible. Overall, however, the small streams are not the main focus of this report.

Make manure management a high priority

Responsible manure management—especially at the region’s concentrated animal feeding operations (CAFOs)—should be a high priority. The technology for managing manure to produce biogas and other products is mature, widely available, and well known. The economics are currently unfavorable, and projects generally need financial subsidies to propel them forward. If we define the immediate market as CAFOs with more than 500 animals (in the case of dairy), only about 10 percent of the regional market has been tapped. The percentage is even smaller for swine and poultry. What is the outlook for increasing that number?

The energy side of the digester equation is pretty well understood, with the total potential energy value of regional digesters being modest, at best. If the full potential represented by dairy CAFOs were tapped, the total electricity generated would be worth about \$150 million to the region, a drop in its \$33 billion electricity bucket. While various energy subsidies are in place, given the current sluggishness of the economy and consequent tightness of all forms of public funds, these subsidies are not likely to be increased soon. In addition, despite the well-understood potential for digesters to reduce greenhouse gas emissions, the wrangle over climate policy is likely to be protracted, and larger forces than the community interested in anaerobic digestion will drive the outcome, leaving developers unable to capture the value of such reductions.

In view of this, digester technology projects might be expected to plod forward at about the present rate, if not experience an actual

Food Waste to Food Energy

Food waste is America’s second largest waste stream after paper and paperboard and represents the single largest component of municipal solid waste reaching landfills and incinerators. Landfilling food waste can have significant economic, societal, and environmental consequences, including the release of methane, a greenhouse gas twenty-one times more potent than carbon dioxide. Landfills in the United States accounted for 17 percent of all methane emissions in 2009. In an effort to reduce detriments, waste aggregators and food processors have been developing waste-to-energy projects to create more value out of residual organic materials and divert waste from landfills.

The Energy Center of Wisconsin published in March 2011 the Great Lakes Region Food Industry Biogas Casebook profiling operational anaerobic digester projects at food processing facilities. The casebook provides detailed case studies of six types of biogas systems and various feedstocks used by twelve food processing companies in Illinois, Indiana, Minnesota, New York, and Wisconsin. The publication is the first of its kind to compile data from Great Lakes region food companies that use digesters and illustrates how these technologies can create opportunities for producers to reduce both energy intensity and emissions while creating a renewable fuel that helps reduce fossil fuel purchases.

Waste Management, Inc., has also shown recent interest in increasing value from their waste streams by investing in new and emerging processing and conversion technologies. The leading North American provider of comprehensive waste and environmental services has developed a number of proactive corporate sustainability goals, including to:

- Double energy generation to power the equivalent of 2 million homes by 2020;
- Triple the amount of material recycled to 20 million tons annually by 2020;
- Increase fleet fuel efficiency by 15 percent and reduce emissions by 15 percent by 2020.

Organic waste diversion is a critical component to Waste Management’s success in reaching these goals. In 2010 Waste Management estimated that their waste-based energy production potentially avoided over 3.5 million metric tons of carbon dioxide equivalent and powered more than 1 million homes. Committed to continuing its capital investment in green technologies, Waste Management is prepared to invest in emerging opportunities for managing waste that will help increase earnings and growth margins while enhancing society and the environment.

decline. This would leave a substantial resource untapped for some time to come. This would also continue to expose the region’s surface and ground waters to nutrient and pathogen contamination and some of its residents to objectionable odors. Since these effects can be reduced by broader application of manure digesters, the nutrient management/watershed protection side of the equation is where supporters should look to provide additional impetus for digester projects at this time. In other words, anaerobic digestion should be promoted for its total value as a solution for odor control, nutrient management, and watershed protection, not just energy production.

State and federal regulations are gradually driving better manure management practices, including anaerobic digestion, in the region. Creating economic incentives for watershed protection activities may be a promising incremental strategy for promoting anaerobic digestion. In certain watersheds in our region, regulated entities, mainly wastewater utilities, may be able to pay for “nonpoint” source (pollution from diverse sources rather than from a single point) reductions in nutrients (including those created by digesters on CAFOs) in lieu of adding more pollution control equipment to existing treatment facilities.

A pilot to test this proposition, spearheaded by the Milwaukee Metropolitan Sewerage District (MMSD), is under way at the present time. MMSD’s hypothesis is that it can achieve the required environmental outcome (cleaner water) by paying for nonpoint source pollution reductions throughout the watershed and save consumers money in the bargain. To the extent that this can be demonstrated and all of the various complications of measurement and enforcement worked out, it will create a tangible economic value that could accrue to anaerobic digestion owners.

Some of the smaller residual streams present in the region (food processing waste, organic components of municipal solid waste) can add value to digesters on farms, and partnerships with waste haulage companies could provide an economic boost to well-situated digesters.

The work of key organizations supporting the effort to increase the penetration of digesters on farms in the region deserves continued support. As mentioned previously, the efforts of the Innovation Center for U.S. Dairy and the Wisconsin Bioenergy Initiative are prominent examples.

Cultivate the cellulosic biofuel industry

Preparing the region to participate in the evolving cellulosic biofuel industry is also a major priority. Cellulosic biofuels represent a potentially substantial economic opportunity for the Midwest and could also have a larger impact on the U.S. energy supply mix.

First, the technical and economic challenges to cellulosic fermentation must be overcome. This effort is under way and reasonably well funded. No other incremental steps have been identified that could hasten progress. As with all new energy technologies, the outcome of this work is uncertain. It is reasonable to assume that the technical barriers can be overcome with time and continued

research. However, it is less certain that the final technical configuration will necessarily be a cost-competitive one. This concern is offset somewhat by the mandates for advanced biofuels now embodied in federal policy. However, if the subsidy inherent in the mandate is too costly, political support for changing or abandoning the policy will clearly grow, and the industry could suffer as a result.

Second, the many complexities of supplying feedstock to the cellulosic fermentation industry must be addressed. From the standpoint of corn stover and wheat straw, this boils down to two big questions: (1) How large is the potential resource given the competing needs of protecting soil and water resources and sustaining grain harvest? (2) Can the logistical challenges of harvesting, transporting, and storing large quantities of cellulosic biomass be met cost effectively?

If unchanged, current tillage practices will limit the region’s harvest of crop residuals to about 30 million tons per year. If the farmer realized \$10 of cash income per ton for this residue, this would mean a \$300 million increase in net farm income on a regional total of about \$15 billion, a 2 percent increase overall. Although this figure is speculative, it is probably reasonably illustrative of the potential regional benefit. Some research suggests that changed tillage practices could double the figure to \$600 million or more, which would represent a 4 percent boost to the rural economy of the states in our region. We need a better understanding of grain stover production interactions and a strategy for persuading more farmers to change tillage practices before this increase can be realized.

Given that cellulosic fermentation technologies are not ready for widespread application, stover production and harvest field trials should continue to study and clarify production and logistical issues. Work under way at Iowa State University’s New Century Farm is a good example of the type of research that is needed to better address these questions.¹⁴ Similar research should be replicated in the six-state Midwest region, perhaps focusing on the stover concentration areas described earlier. Research should focus on testing the economic and ecological feasibility of different tillage practices, and a close look at behavioral factors involved is also needed. The same soil management practices that would allow higher stover harvests would also reduce erosion and water pollution and potentially increase soil carbon levels. These benefits should be studied, tallied, and included in the case for change.

14. United States Department of Agriculture, “New Century Farm,” <http://www.reeis.usda.gov/web/crisprojectpages/214501.html>.

Projects that utilize forestry residue should also be considered in three geographic areas: northeastern Minnesota, northern Wisconsin, and Michigan's Upper Peninsula. All of the issues outlined for the use of crop residues apply to the use of forestry residue, although the logistics of harvesting forestry residue are markedly different and challenging. Much of the potential acreage involved is found in our national forests, and the management plans prepared for these forests and the process used to develop them are the context in which a discussion over feedstock availability and ecologically safe harvest should occur.

Develop pyrolysis projects

The development of several pilot-scale, slow pyrolysis projects should be undertaken without delay. The suite of benefits from this technology—and especially the potential multifaceted benefits of biochar as described earlier—have gained a great deal of attention in the press and are the focus of academic research. For all of the economic reasons described above, however, slow pyrolysis technology is not advancing at an acceptable rate. Among other things, this has created a chronic shortage of biochars for use in field trials, slowing the study and confirmation of the potential benefits. A longer assessment on this topic, “Biochar: Assessing the Promise and Risks to Guide U.S. Policy,” prepared by the author for the Natural Resources Defense Council, provides further analysis.¹⁵

Explore hydrothermal technologies

Hydrothermal technologies deserve a harder look (meaning, at this point, more research support) because of their potential ability to handle very wet feedstocks. These technologies could prove very helpful in managing such problematic wastes such as hog manure.

Begin the process of collaboration

Adopting the landscape vision described in Chapter II is the surest way to balance economic and environmental concerns as we look to agriculture and forestry for new energy feedstocks. This is a complex

tangle. The best way to sort it out is to gather the various parties who have an interest—farmers, academics, environmental advocates, politicians, and others—and begin the process of collaboration to forge a common understanding and consensus. Such collaboration is perform messy and demands that participants cross disciplinary barriers for the sake of a greater good. Vigorous interdisciplinary thinking and debate is the only way to insure that the full suite of costs and benefits of bioenergy systems are considered and given appropriate weight. Without such a perspective, bioenergy systems will be considered on too narrow a basis, and society will be short-changed. Although a landscape perspective might, at first, seem to be a way to limit bioenergy potential, it is, in reality, the best way to responsibly maximize it and to guarantee its viability over the long term.

15. Stephen Brick, “Biochar: Assessing the Promise and Risks to Guide U.S. Policy,” Natural Resources Defense Council Issue Paper, November 2010, http://www.nrdc.org/energy/files/biochar_paper.pdf.

Conclusion

This report is premised on the idea that by studying residual biomass resources, better ways can be found to manage these resources and a modest amount of energy can be produced to boot. The findings generally support this hypothesis. The principal conclusions of this study are emblematic of energy and environmental problems more generally:

- The biomass resources identified in the regional inventory can make a modest contribution to the energy supply in the region but cannot by themselves “solve” our energy supply problems. The lesson here is that complex social challenges are almost always addressed incrementally. The potential contribution of incremental solutions should not be gainsaid. Furthermore, the financial and technical risk of pursuing incremental steps is lower than the “long-bomb passes” favored by large, single-solution pathways.
- The potential to exploit residual biomass resources is complicated by a host of positive and negative factors. A narrow analytic framework is apt to yield misleading conclusions and should be avoided. A suitably complex framework is more challenging to develop and understand, but is likely to produce more useful insights. Most critically, a landscape perspective—examining these resources in their native biophysical context—is the single most important recommendation of this study. Only by adopting such a view can the complex web of environmental and economic consequences be untangled.
- Focus should be placed on the most promising opportunities first. Midwest farms produce a lot of manure, which could be much better managed. Known technologies can produce energy and help protect the environment. Midwest farms also produce a lot of corn stover and—in spite of many potential limitations—use of this resource as a fuel feedstock could provide extra farm income. While the technical aspects of producing ethanol from cellulose are worked out, the important issues of how much stover can reasonably be harvested and how this harvest can best be accomplished can be studied and resolved.

The Midwest can help shape national energy and agricultural policies to improve the region’s environmental and economic future. By embracing a landscape perspective, taking incremental steps with new technologies and practices, and expanding cost/benefit analyses to include a broader range of impacts, we can support the effort to develop ecologically viable energy alternatives, while reaping the benefits of improved residual biomass resource management.

Appendix I Advisory Committee Members

Advisory Committee members met two times in Chicago to discuss regional inventories of residual biomass resources, energy conversion technologies and production economics, and policy development. The Committee also reviewed early drafts of the final report and provided essential feedback.

Jerry Bingold, Director of Renewable Energy, Innovation Center for U.S. Dairy

Colleen Callahan, Illinois State Director of Rural Development, U.S. Department of Agriculture

Todd Campbell, Confidential Assistant, Business and Cooperative Programs, U.S. Department of Agriculture

Karen Chapman, Great Lakes Regional Director, Environmental Defense Fund

Leon Corzine, Past President, National Corn Growers Association

Tim Diehl, Hydrologist, U.S. Geological Survey

Molly Flanagan, Program Officer, The Joyce Foundation

Stan Gruszynski, Wisconsin State Director of Rural Development, U.S. Department of Agriculture

Alan Jirik, Vice President of Governmental and Environmental Affairs, Corn Products International

Brendan Jordan, Director of Bioenergy and Transportation Programs, Great Plains Institute

Doug Karlen, Supervisory Research Soil Scientist, National Laboratory for Agriculture & the Environment, U.S. Department of Agriculture—Agricultural Research Service

Joe Kramer, Senior Project Manager, Energy Center of Wisconsin

Dave Loos, Technology and Business Development Director, Illinois Corn Growers Association

David Miller, Director of Research and Commodity Services, Iowa Farm Bureau Federation

Chris Pierce, President, Solution Management LLC

Adele Simmons, Senior Executive, Metropolis Strategies

Appendix II

Sources of Analysis

A number of national assessments of biomass availability were consulted as the regional estimate was developed. The three most important are:

Perlack, Robert D., Lynn L. Wright, Anthony F. Turhollow, Robin L. Graham, Bryce J. Stokes, and Donald C. Erbach. "Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply." Oak Ridge, Tennessee: Oak Ridge National Laboratory, April 2005. http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf.

Milbrandt, Anelia. "A Geographic Perspective on the Current Biomass Resource Availability in the United States." Technical Report NREL/TP-560-39181. Golden, Colorado: National Renewable Energy Laboratory, December 2005. <http://www.nrel.gov/docs/fy06osti/39181.pdf>.

Biomass Research and Development Board. "The Economics of Biomass Feedstocks in the United States: A Review of the Literature." Occasional Paper No. 1, Biomass Research and Development Board, October 2008. http://www.usbiomassboard.gov/pdfs/7_Feedstocks_Literature_Review.pdf.

The National Renewable Energy Laboratory has developed an online biomass mapping tool, which was also used in the analysis (<http://maps.nrel.gov/biomass>).

The EPA Office of Wastewater Management conducts the Clean Watersheds Needs Survey (CWNS) every four years, collecting information on publicly owned wastewater collection and treatment facilities. The *2008 CWNS Report to Congress* was used to evaluate sewage sludge and biosolids concentrations (<http://iaspub.epa.gov/apex/cwns2008/f?p=115:2:184938905786209:::RP::>).

A case study analyzing energy recovery from wastewater treatment plants was also cited:

Stillwell, Ashlynn S., David C. Hoppock, and Michael E. Webber. "Energy Recovery from Wastewater Treatment Plants in the United States: A Case Study of the Energy-Water Nexus." *Sustainability* (April 2010): 945-962.

Annual agricultural statistics collected and published by the USDA have been used to develop state-specific estimates of biomass resources. Data collected by various state agencies in the region have supported the analysis of concentrated animal feeding operations (CAFOs) and sewage treatment facilities.

In reviewing biomass technologies, the National Renewable Energy Laboratory biomass energy website is a good place to start (http://www.nrel.gov/biomass/national_bioenergy.html), with a range of technical papers and publications for a more general audience.

The Energy Center of Wisconsin has an online resource aimed at promoting biorefinery opportunities in the Midwest. The website has a great deal of solid technical information (<http://www.biorefine.org/>).

In 2009 the National Academies issued a report on liquid transportation fuels from coal and biomass that contains a wealth of technical information. A free PDF of the book can be downloaded at http://www.nap.edu/catalog.php?record_id=12620.

About the Authors

Steve Brick, senior fellow on energy and climate, joined The Chicago Council on Global Affairs in 2009, providing broad experience from his thirty years of work at the intersection of energy and environmental policy. From 2005 to 2009 Mr. Brick was manager of the environment program for the Joyce Foundation in Chicago. He directed a \$6 million per year grant portfolio focused on energy and water issues in the Great Lakes region. Prior to his work at the Joyce Foundation, Mr. Brick worked as associate director of research for the Energy Center of Wisconsin, where he was responsible for a wide range of studies on energy efficiency, renewable energy, and the environmental impacts of energy systems. His previous positions include director of environmental affairs for PGE National Energy Group, science and policy director for the Clean Air Task Force, and cofounder and vice president of the energy consulting firm MSB Energy Associates. Mr. Brick received his B.A. and M.S. from the University of Wisconsin-Madison, where he studied at the Gaylord Nelson Institute for Environmental Studies.

Tyler Strom, program officer, Global Chicago/Global Midwest, joined The Chicago Council on Global Affairs in 2011 and has served as the research assistant for the senior fellow on energy and climate. Tyler grew up on an Illinois farm outside of Chicago. Tyler has a B.S. in agricultural business and economics with a focus on international agriculture from Iowa State University and an M.S. in environmental studies and sustainability science from Lund University in Sweden. His master's thesis analyzed local food systems as they related to sustainable development.

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Brick, Stephen. "Biochar: Assessing the Promise and Risks to Guide U.S. Policy." Natural Resources Defense Council Issue Paper, November 2010. http://www.nrdc.org/energy/files/biochar_paper.pdf.

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