Clean Energy from Wood Residues in Michigan

Michigan Biomass Energy Program
Dulcey Simpkins, Coordinator

Discussion Paper
June 2006

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A Report of the Michigan Biomass Energy Program

The goal of the Michigan Biomass Energy Program (MBEP) is to encourage increased production and/or use of energy derived from biomass resources through program policies, information dissemination, and state and regionally funded research and demonstration projects. Electronic copies of the paper are available on the MBEP website. Comments and requests for copies of this report, or for information concerning biomass energy development in Michigan, may be sent to:

Contact Information

Department of Labor & Economic Growth
Energy Office
Michigan Biomass Energy Program
P.O. Box 30221
Lansing, MI 48909

Phone: (517) 241-6223
Website: http://www.michigan.gov/biomass

Preparation of the Report

Dulcey Simpkins—principal writer, editor, researcher
Nicole Allard—student assistant, researcher
Jan Patrick—program manager, section supervisor

The views expressed in this paper are those of the MBEP staff and do not necessarily reflect the views of the U.S. Department of Energy or the Michigan Department of Labor & Economic Growth—Energy Office.

Acknowledgements

The MBEP staff would like to thank the following agencies and organizations, as well as many individuals not listed, who provided valuable information and suggestions for this report.

Michigan Departments of Environmental Quality
Michigan Department of Natural Resources
Michigan Public Service Commission
Missouri Department of Natural Resources
Ohio Public Utilities Commission/Biomass Energy Program
Southeast Michigan Resource Conservation and Development Council
USDA Forest Service Northeastern Area
Wisconsin Department of Administration
Central Michigan University
Michigan State University
University of Cincinnati
University of Wisconsin-Madison
General*Bioenergy
J.H. Hart Urban Forestry
Primary Power, Inc.
Sigma Capital Investments, Inc.
Weston Solutions, Inc.

We also want to acknowledge the U.S. Department of Energy and the Great Lakes Biomass State and Regional Partnership whose financial assistance supports the operation of the MBEP and the publication of reports such as this.

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Introduction: Renewable Energy on the Policy Agenda

The United States hosts only 8% of the world's population, but consumes almost 25% of world energy production.[1] Due to the energy intensity of modern living in the United States, having a reliable and affordable energy supply is integral to economic stability. However, there is a growing awareness that the energy strategy currently pursued by the United States is not sustainable. Falsified reserve estimates for both oil and natural gas, increased instability in the Middle East and Venezuela, and the Iraq war have highlighted the vulnerability of US energy markets.[2] It is now an increasingly common assertion among American citizens and government officials alike that true energy security lies in reducing dependence on fossil-based fuels and focusing on renewable energy.

The boundaries of the growing debate over an appropriate national energy strategy range from a status quo fossil fuel-based energy portfolio on the one hand, to an efficiency and renewables-based portfolio that promotes investment in solar, wind and biomass energy on the other. Market-based assessments of fossil fuel resources suggest that higher demand will spark technological innovation in reserve identification and extraction, allowing a continual increase in the petroleum and natural gas supply; this cornucopian view urges restraint with regard to state support for a shift to renewable energy. Simultaneously, in these same commercial and finance sectors, there are voices arguing for a different strategy that fosters innovation in renewable energy production and reduces the traditional dominance of fossil fuels in the marketplace. Public opinion echoes these voices: Consistently over the last 20 years, polls demonstrate majority opinions in favor of not drilling for more oil and of increased investment in energy efficiency and renewable energy.[3]

State legislatures are responding to popular opinion, supporting renewable energy portfolio standards, creating tax incentives for renewable energy production and use, and implementing public benefits funds for future investment in renewable energy projects. Success in moving renewable energy closer to center of state and national political debates since 2004 has indeed been an important development. Still, the modest support generated for tax rebates on biofuels and wind energy production remain far less substantial than envisioned by the champions of renewable energy. More far-reaching renewables strategies promote dramatic investments in alternative transportation fuels and a rapid decentralization of energy production to local,

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[1], *Annual Energy Review 2003*, Figure 11-3 World Primary Energy Consumption., US Department of Energy, Energy Information Administration. Online at www.eia.doe.gov.

[2] SEC v. Royal Dutch Petroleum Co., et al. before the US District Court for the Southern District of Texas, Houston Division [http://www.sec.gov/litigation/complaints/comp18844.pdf]; "Report: Investigation targets former El Paso employees," USA Today (Reuters), Posted 8/11/04 [http://www.usatoday.com/money/industries/energy/2004-08-11-el-paso_x.htm]; Jad Mouawad, "With Geopolitics, Cheap Oil Recedes Into Past," *The New York Times*, January 3, 2005; "Natural gas prices not expected to relent: History—EIA"; Projections: Short-Term Energy Outlook, Energy Information Administration, US Department of Energy, August 2004. For more information on oil, see "International Energy Outlook 2004: World Oil Markets," Energy Information Administration, US Department of Energy. Online at http://www.eia.doe.gov/oiaf/ieo/oil.html.

[3] For example, the January 2004 Zogby International survey for the Wilderness Society documented that only 36% of 1,000 likely voters surveyed felt the Arctic National Wildlife Refuge (ANWR) should be opened for drilling, and only 10% felt that drilling more was the answer to our energy problems. "More than 75% of voters in every region of the country and in all education, age and income subgroups choose conservation/fuel efficiency or alternative energy sources as the best way to reduce oil imports. Some of the strongest support comes from Independents (92%), Women (87%), Union households (85%), and NASCAR fans (81%). More than 3 of 4 Republican voters (77%) also choose either conservation/fuel efficiency or alternative energy over more oil drilling (17%)." Online at http://www.zogby.com/news/ReadNews.dbm?ID=789. A December 2005 survey on the question of drilling versus alternatives showed similar results: only 38% of those polled favored opening ANWR, and an increased (but still quite low) 17% felt drilling was a sustainable energy policy. Online at http://www.zogby.com/Soundbites/ReadClips.dbm?ID=10890.

preferably renewable resource bases. Proponents of these strategies warn of dire consequences for mainstream Americans as oil production passes its peak—generally estimated to lie within the next twenty years, if it has not already arrived.[4]

Wood Residue as a Renewable Energy Resource: Outline of Discussion

In this context, it is critical for states to understand their indigenous resources when considering their energy options. This report explores the potential for biomass energy in Michigan by focusing on wood residue as an energy feedstock. Wood residue is a convenient, physically well-understood feedstock. However, despite its abundance, it is difficult to make an argument to modify infrastructure, educate consumers and utilities, and invest in new energy planning and processes without first understanding the cleaner emissions, sustainable renewable capacity, domestic economic benefits, and associated land use and carbon balance benefits that this renewable biomass fuel provides. This paper is intended to provide background on residue wood energy for policy makers, businesses, academics, and citizens interested in exploring alternatives to our fossil fuel-based energy production and transmission system. It provides:

1. an introduction to biomass energy;
2. a background on wood energy in the US and Michigan;
3. a discussion of characteristics of wood energy feedstocks;
4. an explanation of wood to energy pathways with associated harvesting, transport and storage considerations;
5. a presentation of options for energy conversion technology;
6. a comparison of environmental impacts of wood energy versus coal and natural gas;
7. an assessment of potential economic and energy supply impacts; and
8. an outlook for the future of wood energy in Michigan, including a discussion of the role of policies, initiatives and incentives that could advance cleaner, reliable, domestic and renewable resources as part of our mainstream energy portfolio.

This paper also provides policy recommendations based upon the weight of the evidence in current research about the environmental and economic impacts of biomass energy production. No fuel source is perfect, and decision-makers should not approach any energy source as a cure-all, devoid of negative impacts. The Second Law of Thermodynamics tells us that nothing new can be created in the universe, and converting matter into energy always requires some energy to perform the conversion. But how much useful energy is lost, and what sort of byproducts of that conversion we must deal with, are two outcomes that research, policy and investment choices can influence. There are many favorable aspects of wood energy production that should inform state-level policy formation to address our current energy crisis by diversifying our energy resources to include more wood residues.

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[4] Richard Heinberg, *The Party's Over: Oil, War, and the Fate of Industrial Societies* (Gabriola Island, British Columbia, 2003). Heinberg focuses on "Hubbert's Peak" geologists whose research forecasts the world oil production peak in the early 21st century, between 2006 and 2012. Peak oil timing is debatable for a wide variety of methodological reasons (not to mention the difficulty in obtaining accurate reserve numbers), but its inevitability is noted by the US Department of Energy: a 2004 report titled *Long-Term World Oil Supply Scenarios*, by John Wood, Gary Long, and David Morehouse (EIA-DOE) assigns the highest probability of peak oil to the year 2026.

Preview of Findings and Recommendations

- Michigan has ample wood residue resources, and already has some working examples of wood-to-energy facilities.

- Much of the wood residue generated by the forest products industry is utilized on-site to heat and/or power its plants and facilities. However, many of their boilers are nearing retirement age. Upgrading old boilers presents an opportunity for deploying more efficient conversion technologies.

- Research in many states highlights urban tree residues (UTR) as an untapped resource that could more than double the wood residue available for profitable use. For example, more efficient separation of urban wood residue, forestry cuttings, and yard waste from municipal solid waste can lead to creation of a profit center for selling mulch, or a profitable contract from selling an energy feedstock to a local wood-fired plant.[5] Collection and processing infrastructure for UTR will require an investment by cities, counties and industries. Educational campaigns and new regulations may also be necessary to foster an ethic of wood residue recycling in the current environment of dispersed dumping of individual yard waste—an important component of UTR. Increased tipping fees can also help redirect wood residues out of landfills and into more immediately productive uses.

- Wood energy technologies are either well-commercialized (boilers) or entering commercialization (gasifiers, pyrolysis).
    - Caveat: Wood's potential use as a feedstock for *transportation* fuels is not based upon currently commercial technologies. However, in the near- to medium- term, cellulosic ethanol conversion technologies have the potential to help reduce U.S. dependence on foreign oil.

- Wood and other biomass feedstocks are more difficult to transport than liquid fuels, and are more challenging to store than coal. In addition, because wood has a lower energy content than coal, it takes a larger volume of wood to generate the same energy as a given volume of coal. Consequently, biomass feedstocks like wood are best suited to localized energy production.
    - Caveat: Wood residue densification into pellets or briquettes is energy intensive. However, densification creates wood-based fuel with approximately 20% more energy output per unit volume than logs or wood chips themselves. In addition, regularly-shaped densified fuels are much easier to transport and store, which helps overcome the energy costs of creating the denser fuel (see Table 2: Wood Energy Characteristics, Merits, and Technology Options on page 18).

- Wood-fired boiler, gasification, and pyrolysis technologies are cleaner than coal in emissions of most criteria pollutants regulated under the Clean Air Act (e.g. sulfur, particulates), as well as in emissions of mercury and other heavy metals produced by coal combustion.

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[5] St. Paul, Minnesota is home to a 25 megawatt (MW) wood-waste fired facility that supplies 75% of the thermal energy required by district heating and cooling customers. Planning for the system began in 1999, and it opened in 2003. Clean Energy Resource Teams, Community Energy Case Study: "District Energy St. Paul: CHP District Energy Fueled by Biomass," The Minnesota Project, July 2003, online at http://www.cleanenergyresourceteams.org/metro/CS-District%20Energy%20St.%20Paul.pdf.

- Emissions from the production of wood-based energy compare favorably with natural gas emissions—but wood is a renewable resource whereas natural gas is not.

- Wood energy can be managed as a carbon neutral feedstock: replanting trees neutralizes carbon dioxide emitted from wood fuels. However, fossil-derived oil, coal, and natural gas are net carbon producers, increasing greenhouse gases without any possible regenerative offset.

- Distributed generation is desirable as a solution to offset the high degree of centralization of energy production, as well as capacity problems throughout the United States. The 2003 blackout affecting the Midwest and East Coast demonstrated the extreme vulnerability of our state and region to centralized energy's tenuous infrastructure. While wood is difficult to transport to centralized energy plants, coal is similarly difficult to ship in a decentralized context. Because wood is locally abundant in outlying areas as well as in cities, it is a preferred source of energy for distributed generation utilizing smaller, less centralized energy production facilities.

- Economies of scale for large utilities allow them to negotiate a low price for coal. Wood fuels are more competitive choices for smaller power producers—which again could support a more efficient, robust and localized energy distribution system.

- Technology promotion, policy changes and financial tools are needed to help increase the amount of biomass energy produced in Michigan. Michigan policymakers could enable a significant shift in Michigan's energy portfolio toward renewable energy from wood in a variety of ways, such as by incentivizing biomass energy production, and by requiring utilities to integrate wood energy and other forms of biomass power into their production portfolio.

Michigan has tremendous potential to further develop both solid and liquid fuel applications of wood residue. There are clear opportunities for urban areas, industries, and even private citizens to capitalize on potential energy uses of wood residues. In addition, biomass-based ethanol and synthetic liquid transportation fuels (syn-fuels) have the potential to revolutionize the American love affair with their personal vehicles without ending it.[6] This paper focuses primarily on opportunities for biopowered heat and electricity in Michigan, but it also has implications for biofuels.

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[6] In a landmark article linking energy and national security, former CIA chief James Woolsey and Senator Richard Lugar (R-Indiana) explain how ethanol from wood and other organic matter has the potential to significantly reduce our energy insecurity due in part to dependence on foreign oil: "Ethanol has always provided an alternative to gasoline. In terms of environmental impact and fuel efficiency, its advantages over gasoline substantially outweigh its few disadvantages. But until now it has only been practical to produce ethanol from a tiny portion of plant life -- the edible parts of corn or other feed grains. …Recent and prospective breakthroughs in genetic engineering and processing, however, are radically changing the viability of ethanol as a transportation fuel. New biocatalysts -- genetically engineered enzymes, yeasts, and bacteria -- are making it possible to use virtually any plant or plant product (known as cellulosic biomass) to produce ethanol. This may decisively reduce cost—to the point where petroleum products would face vigorous competition." From "The New Petroleum," *Foreign Affairs*, January/February 1999.

Wood as a Biomass Energy Resource

Wood is a form of biomass, and as such can be understood as an energy resource in the context of biomass energy. **Biomass fuels include any organic matter that is available on a renewable basis** including forest residues, wood product residues, agricultural field residues and processing wastes, animal wastes, agricultural and woody crops grown for fuels, and municipal solid waste (MSW). Implicit in this definition is the need not only for the organic energy resource itself, but also for an ongoing feedstock management plan in order to make the renewable aspect a reality.

Biomass fuels produce very low emissions, generate relatively few acid rain- and smog-causing particles, and have a minimal impact on the environment when converted to energy correctly (using proper practices and best available technologies; see Environmental Impacts for detailed information). In addition, all share the characteristic that they can be regenerated relatively quickly to provide a reliable energy feedstock over time. Biomass energy can be derived from almost any configuration of organic components of flora and fauna. Petroleum and coal are also organically derived fuels, but they are derived from fossilized flora and fauna of earlier eras, and consequently are not renewable (in a practical timeframe for our civilization).

Biomass feedstocks are not homogenous, and their physical characteristics vary widely. They may have high moisture content like some animal wastes, or low moisture content like wheat straw; or, any one kind of biomass—like wood—can be green (newly cut from live specimens) and high in moisture, or dried and lower in moisture. The single most important characteristic of biomass feedstocks, from the perspective of energy production, is their moisture content. Biomass heating values are determined by their moisture content, but are consistently lower in energy density than coal or petroleum, which often limits the distance over which biomass can be transported economically. Biomass resources can be further categorized as solid fuels that can be used as they are without modification, or as gaseous fuels such as methane from anaerobic digestion of manure or MSW, and synthetic gas (syn-gas) from gasification.

While there is no universally shared categorization of biomass resources, this paper relies on the eight biomass categories used by the Michigan Renewable Energy Program, which was commissioned by the Michigan Public Service Commission in 2004[7]:

1. Wood and wood residue: The oldest biofuel, wood still provides heat and cooking fuel to the majority of the world's population, and also remains useful for citizens of advanced industrialized countries living in the higher latitudes over cold months. Wood residue (harvesting, urban trees, post-processing, land clearing, demolition, pallets) is also in this category, and has more diverse pathways to energy use than forest-felled wood.
2. Traditional agricultural commodities: Corn and soybeans are the most well-known crops that produce biomass energy, as they are feedstocks for ethanol and biodiesel respectively. Canola, sunflowers, and other oilseed crops are also used.
3. Energy Crops: Certain species of grasses and trees can be utilized specifically as energy crops. Fast-growing willow (*Salix*) and poplar (*Populus*) can be grown as short-rotation woody crops. Similarly, switchgrass (*Panicum virgatum*) and other prairie species like little Bluestem and Indian Grass (*Schizachyrium scoparium, Sorghastrum nutans*), as well as fast-growing *Miscanthus* varieties, serve as excellent sources of "cellulosic" biomass. In addition, traditional food and feed crops can also overlap with

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[7] For more information on the Michigan Renewable Energy Program, and to view annual reports, go to http://www.michigan.gov/mrep/.

energy crops: while corn is viewed as both a food crop and an energy feedstock in the ethanol industry, it can also be used in direct combustion in a corn stove or boiler, a technology currently enjoying tremendous appeal in Midwestern states with cold winters.

4. Animal Waste: Manure is used for fuel in much of the developing world; yet in the United States it has primarily served as a helpful soil amendment despite its use by early settlers as a fuel. Agriculture is taking a new look at anaerobic digestion to help address groundwater resource contamination from an overabundance of manure nutrients in contemporary commercial livestock operations. In addition, mortality, rendering, blood, and other animal parts also can be utilized in anaerobic digestion to produce methane, or to provide grease sources for biodiesel.
5. Landfill Gas-to-Energy (LFGTE): Containment and channeling of landfill methane to energy producing facilities has saved cities, industries, and others millions of dollars while displacing tremendous volumes of greenhouse gas emissions of methane produced by organic waste decomposition in the landfill's anaerobic environment.
6. Municipal solid waste (MSW) and waste water: Anaerobic digestion (AD) of biosolids has great potential for increasing the value of human-produced waste, but concerns about actual methane productivity of the various technologies, and about ammonia and other substances generated by AD processes will need to be addressed. Despite the fact that methane production in anaerobic environments is well proven, many waste water projects simply consider AD as a treatment option and do not design plants to capture the energy potential. Similarly, organics diversion from municipal solid waste for use in a "community" anaerobic digester can give us energy today, as opposed to landfill gas months or years from now. Diversion can also reduce waste volumes enough to prevent increased land use for waste management.
7. Agricultural and industrial residues: Other organics such as corn stover, grass cuttings, tree clearings, food processing and rendering waste are potential energy resources.
8. Tire waste: While viewed only partially as a renewable resource, scrap tires do have an organic component and can serve as an energy feedstock. Using the appropriate emissions control technologies, tire waste used in cofiring helps put unattractive public health threats to work in a function where they have value.[8]

Wood is the most commonly used biomass resource. Wood can be used in solid form or processed and pelletized for use for residential, institutional, and commercial heating. Chipped wood can be utilized as a stand-alone fuel for boilers and gasifiers, or it can be co-fired with coal or other biomass. Modern technologies enable us to extract more energy per unit volume of wood; future technologies will allow wood residues to be processed into a syn-gas for internal combustion engines, fuel cells, or natural gas power plants. Finally, more advanced technologies can generate a variety of liquid fuels from cellulosic materials found in wood.

This paper examines wood-to-energy possibilities in Michigan, focusing on the production of electricity and/or heat. However, the resource assessment and decentralization principles that guide this paper also apply to the potential for wood as a transport fuel feedstock in the future.

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[8] *Culex spp.* mosquitoes carrying the West Nile virus breed in locations where there is ample standing water—such as in piles of waste tires. See "West Nile Virus: Information for Scrap Tire Owners," Emerging Disease Issues, State of Michigan website, 2004; online at http://www.michigan.gov/emergingdiseases/0,1607,7-186-25805_25824-75812--,00.html. Tire piles are also vulnerable to fire, which can spread uncontrolled, unfiltered toxics over a wide area. Tires are also being used to fire cement kilns, partially because the tire-derived ash has value in the cement manufacturing process (Phil Badger, General*Bioenergy, personal communication, October 30, 2005).

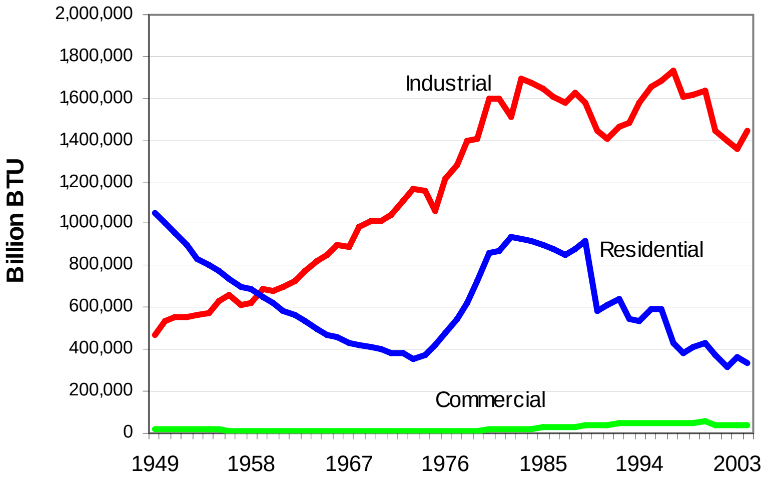
History of Wood Energy in the United States

Wood and wood byproducts are the oldest and most commonly used biomass feedstock in the United States. In 1880, nearly 60% of the energy produced in the United States came from wood. This was soon to change due to technological innovation, the popularization of new energy sources, and political factors.

Economics and regulations enhanced the attractiveness of other fuel sources in the early 1900s. Petroleum monopolies emerged at the turn of the century, and oil products became widely and cheaply available as the United States was the leading oil producer. Furthermore, liquid petroleum was quite easily transported as compared to the irregular bulk of wood products, making it the preferred choice for home heating boilers. Coal had been used since the 1700s for direct heating, similar to the uses of wood. However, the development of steam engines boosted coal use. By the 1880s, coal was used to fire electric power plants, beginning the system of large centralized coal-fired power production system we rely on today.[9]

Figure 1--Changes in Sectoral Wood Use, US 1949-2002

Source: Energy Information Administration at www.eia.doe.gov.



Petroleum and coal have approximately 60-90% more energy stored in each unit of volume than wood.[10] The high "energy intensity" of fossil fuels made them extremely popular, and wood did not remain competitive despite its widespread availability. When coal-fired electrification became cheaper and infrastructure more extensive in the late 1940's, residential use of wood for energy decreased dramatically. Natural gas was popularized when pipelines became commercially viable after World War II. The ability to transport natural gas also helped displace wood and led to a dramatic rise in use for home heating; currently up to 55% of all US households heat with LNG.[11] Its high energy intensity, clean burning properties, ease of use, and domestic abundance also made it a favorite of industry. Figure 1 above details the changes in wood energy use by sector, showing the marked decline of residential wood use after a brief resurgence brought on by the energy crisis of 1973.[12] At the same time, it also documents industry's growing use of wood, which is reviewed in the policy history below.

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[9] Robert Porter, "The History of Coal Use," US DOE Office of Fossil Energy, accessed on February 4, 2005; online at http://www.fe.doe.gov/education/energylessons/coal/coal_history.html.

[10] "Fuel Value Calculator," 5th Edition, produced by USDA Forest Service, Forest Products Laboratory, and the Pellet Fuels Institute; accessible at the US Forest Service website: http://www.fpl.fs.fed.us/documnts/techline/fuel_value_calculator.pdf.

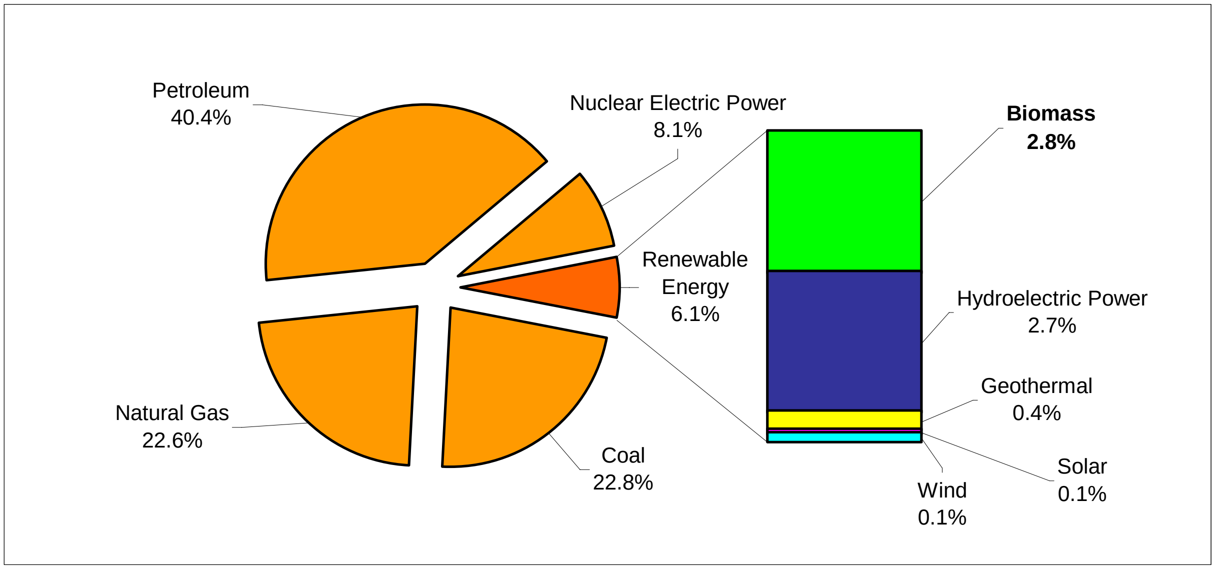
[11] "History," Natural Gas.org website, accessed February 4, 2005, online at http://www.naturalgas.org/overview/history.asp. See also "Natural Gas," Environmental Literacy Council, accessed February 2, 2005, online at http://www.enviroliteracy.org/.

[12] Colin High and Kenneth Skog, "Current and Projected Wood Energy Consumption in the United States," p.232; from Donald L. Klass, ed. Energy from biomass and wastes 23. Proceedings of IGT's conference; 1989 February 13-17; New Orleans, LA. Chicago, IL: Institute of Gas Technology; 1990: pp.229-260.

There has been progress in the development of renewable energy resources in the US. Non-renewable resources such as oil, coal, petroleum and natural gas (fossil fuels) make up the majority of our current energy supply, but now 6% of US energy comes from renewable sources. Traditionally, hydroelectric power supplied the majority of renewable energy, but biomass energy recently surpassed hydroelectric to supply nearly 3% of national energy needs. This is a notable increase from the 1% of total national energy use supplied by biomass in 1994. Of that biomass energy, 83% came from wood residue (Figure 2). Since the mid-twentieth century, wood energy has regained a profile as a significant energy feedstock in certain niche markets—particularly in the forest products industry and some utility-scale facilities. Over the last thirty-five years in particular, major policy changes and economic signals have dictated how wood energy has fared in competition with traditional coal-fired electricity and natural gas power. The impact of these sometimes contradictory influences is discussed below.

Figure 2—US Energy Consumption by Source, 2005

Source: Energy Information Administration at www.eia.doe.gov.



1970s: Clean Air Policies and Renewable Energy Incentives

In the 1970s, OPEC cartel restrictions and natural gas shortages intensified efforts to conserve energy as well as to develop renewable energy sources. Residential use of wood again picked up around the same time, due to the oil crisis and a strong emphasis on conservation and domestic fuels during the Carter Administration (1976-1980). In 1978, passage of the Public Utility Regulatory Policies Act (PURPA) obliged U.S. electric utilities to purchase onsite energy production surpluses at their state regulated avoided cost rate, thereby encouraging the forest products industry's use of wood residue for fuel. In addition, renewable energy tax credits and related financial incentives drove investments on the part of Independent Power Producers (IPPs). Some of the early adopters were industrial facilities that could utilize some of their own residues as fuel for cogeneration systems that also provided steam for industrial process use. Many utilities, including Consumers Energy in Michigan, locked into long term contracts with IPPs, for the purchase of electric power generated from wood and other biomass residues.[13]

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[13] Thomas Stanton, Competitive Energy Division, MPSC, personal communication, March 22, 2005.

Also during the 1970s, environmental degradation caused by emissions from power plants, industry, and transportation prompted the first national attempts to regulate the quality of our energy production. The Clean Air Act, first passed in 1970 and amended in 1990, established mandated quality levels for the criteria pollutants sulfur dioxide, nitrogen dioxide, suspended particulates, carbon monoxide, ozone and lead. These levels were set with reference to ambient levels that would result in harm to humans and the environment.[14] The act was to have a positive overall impact on the long-term growth of biomass energy production despite the short-term vagaries of energy markets: while the cost savings of wood energy rose and fell in relation to fossil fuels, the environmental benefits persisted. In recent years these benefits have been shown to be more valuable than first realized, as the rapidly increasing cost of health care in the United States has paralleled the rising rate of respiratory and other illness associated with air pollutants.[15]

1980s: Incentives Sunset and Fossil Fuel Prices Decline

Both heating oil and natural gas prices had risen steeply in the late 1970s, heightening the appeal of wood. Increased attention to air quality —particularly sulfur emissions responsible for acid rain—had also encouraged business and residential sectors to embrace wood energy. Despite wood's appeal, research on wood energy consumption during that era revealed how promising advances in biomass energy were abandoned when oil prices fell: "The use of wood for energy [had] expanded beyond forest products industries and the residential sector to include commercial and institutional use, industrial steam production, electric cogeneration, and electric utility power production. Research and development work was in progress in both the public and private sectors to commercialize wood gasification, methanol and ethanol production, and synthetic petroleum fuels production. However, the fall in oil prices since 1985 ... significantly reduced commercial interest in much of this work although considerable technical progress has been made in most areas."[16] In addition, renewable tax credits were phased out and avoided cost rates dropped significantly in many states during the Reagan Administration.[17] The decline of PURPA-based incentives, in combination with a steep drop in both natural gas and oil prices, rapidly defused the momentum behind a growing biomass energy sector.

1990s: The Natural Gas Decade

In 1992, the first Gulf War highlighted the insecurity of world oil markets, prompting President George H.W. Bush to initiate the Energy Policy Act (EPAct), which promoted renewable domestic sources of energy. Alternative transportation fuels, for which wood can also be a feedstock, became a focus of government and industry attention. However, as the war's impacts on markets faded, the heightened interest in fuel conservation and security faded as well. Some incentives for transport fuels remained in place, but renewables as a whole were de-emphasized throughout the prosperous 1990s. Under President Bill Clinton, natural gas received considerable attention as prices hovered around $2 per million cubic feet (Figure 3).

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[14] Z. Plater et al, *Environmental Law and Policy: Nature, Law and Society*, St.Paul, MN: West Publishing Co, 1992, p.773.

[15] The US Environmental Protection Agency's website provides comprehensive background on the Clean Air Act. The *Plain English Guide to the Clean Air Act*, posted on EPA's site, is a helpful primer on the role of states, federal government, industry and the public; the problems caused by different kinds of pollutants, the permitting process, air toxics, and mobile sources.

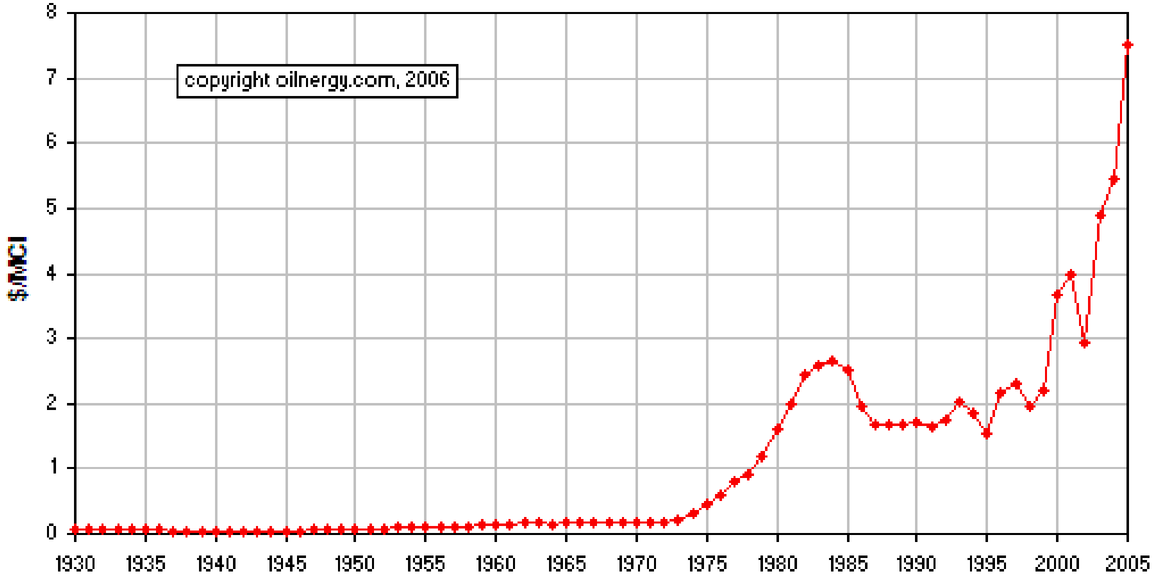
[16] High and Skog, "Wood Energy Consumption," p.232.

[17] Ausilio Bauen, Jeremy Woods and Rebecca Hailes, *Bioelectricity Vision: Achieving 15% of Electricity from Biomass in OECD Countries by 2020*, Imperial College London, Centre for Energy Policy and Technology and E4tech (UK) Ltd, April 2004; *Urban Wood Waste in Michigan* 1994, p.14.

It was also attractive because it was seen as the environmentally friendly solution to the problem of coal due to its clean burning properties and lack of sulfur emissions.

Figure 3—US Wellhead Natural Gas Price, 1930-2005 ($/million cubic feet)

Source: Oilnergy.com.



However, the Clinton Administration also fostered biomass energy. EPAct continued putting attention on biofuels, but more importantly a new executive order placed more emphasis on biomass energy and bio-based products. President Clinton's August 12, 1999 Executive Order on Bio-based Products and Bioenergy authorized new funding for research on biomass energy. It also established the Interagency Council on Biobased Products and Bioenergy, with representation from the heads of the federal Agriculture, Commerce, Energy and Interior departments, the Environmental Protection Agency, the Office of Management and Budget, the National Science Foundation among others.

Partnership between USDA and DOE has generated significant opportunities for research, development and deployment in the biomass field through a biomass grant offered by the two agencies. President Clinton also proposed a five-year extension of EPAct's 1.5-cent/kW hour tax credit for electricity produced from biomass. The measure expanded the types of biomass eligible for the credit to include certain forest-related, agricultural and other resources. In addition, a one-cent/kW hour tax credit would be given for electricity produced by cofiring biomass in coal plants.[18] While the increased attention on the importance of biobased products initiated useful programs that remain in operation today, the level of funding was inadequate, and no PURPA-like incentives were advanced that would promote integration of biomass energy production into utility portfolios.

Wood versus Natural Gas in Michigan

Case studies of Michigan-based wood energy production demonstrate the legacy of PURPA. PURPA incentives had made wood energy popular again after a century of decline (Figure 4). Michigan demand for residual wood rose as new utility scale plants were built in Grayling (1991)

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[18] Dave Block, "Executive Order and Proposed Bill Will Boost Biobased Products and Bioenergy," *Biocycle*, Vol. 40, No. 9, September 1999. Online at http://www.environmental-expert.com/magazine/biocycle/september/article4.htm.

and Flint (1996). The increased demand in turn raised the price of wood fuels. As growing markets increased the value of residual wood supplies, quantities available at zero- or low-cost declined. Plants that were built in the 1980s when wood residue was much cheaper faced new competition for the procurement of fuel supplies.

Yet during the same decade, a significant decline in the price of natural gas made it the new fuel of choice for heating in both residential and some industrial sites. As natural gas is the cleanest-burning fossil fuel given current technology, shifting from biomass to natural gas did not undo the move toward lower emissions instigated by the Clean Air Act—but it did help defuse the momentum towards faster renewable energy development, and eventually began to undermine wood energy production. This was due to both the simple dynamic of pricing for wood, and to the more complex interests of utilities in marketing natural gas to gain larger clients while prices were attractive.

Two case studies of non-utility wood energy plants demonstrate how the changing energy market dynamics, in combination with utility preferences for fossil fuels, influenced the fate of wood-fired power in Michigan. Central Michigan University (CMU) and Dow Chemical of Midland (1982-1996) both invested in wood-fired energy systems for heating in the 1980s. Each had arrangements with various contractors to deliver wood residue. The low- to no-cost resource itself, plus transportation expenses, cost less than natural gas.[19] So long as natural gas remained at or near 1980s prices, wood was a competitive fuel. However, natural gas prices declined through the 1990s from \$5.5/MBtu to \$2.7/MBtu—a drop of nearly 50% (1997 dollars).[20] In addition, the new utility-scale wood-fired plants in Grayling and Flint put upward pressure on wood residue prices. Dow entered into a special contract for electricity with Consumers Energy in order to obtain the stability of a long-term contract price for electricity, but one provision of that contract was a requirement for Dow to shut down its wood energy plant.[21] Dow closed its wood energy system and sold it to a Canadian pulp and paper company. Wood residue that was previously being used close to the source in Midland was then able to supply nearby Flint's Genesee Power facility—a utility-scale wood energy plant enabled by PURPA. However, local wood supplies for CMU did not increase. After opening in 1985, CMU's wood fired plant then shut down in 1990 because wood residue became more expensive than natural gas. Fortunately for CMU, the wood boiler remained functional, and the university's administration decided not to sell it. The buyers' market for natural gas, supported by its low emissions and domestic abundance, has suddenly become a sellers' market in the early 21st century. Natural gas prices moved rapidly to record highs in 2002, and turning back to wood energy has saved CMU over \$1 million per year.[22]

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[19] Wood residues have long been considered "wastes." During the mid-1980s, wood residue was low- to no-cost primarily because there were few local uses for it. Depending on the context, wood residues can be very high cost. Due to a proliferation of uses for it—in addition to the growing attractiveness of renewable energy—wood residue in the 21st century is rarely a "waste" product except in the most remote settings.

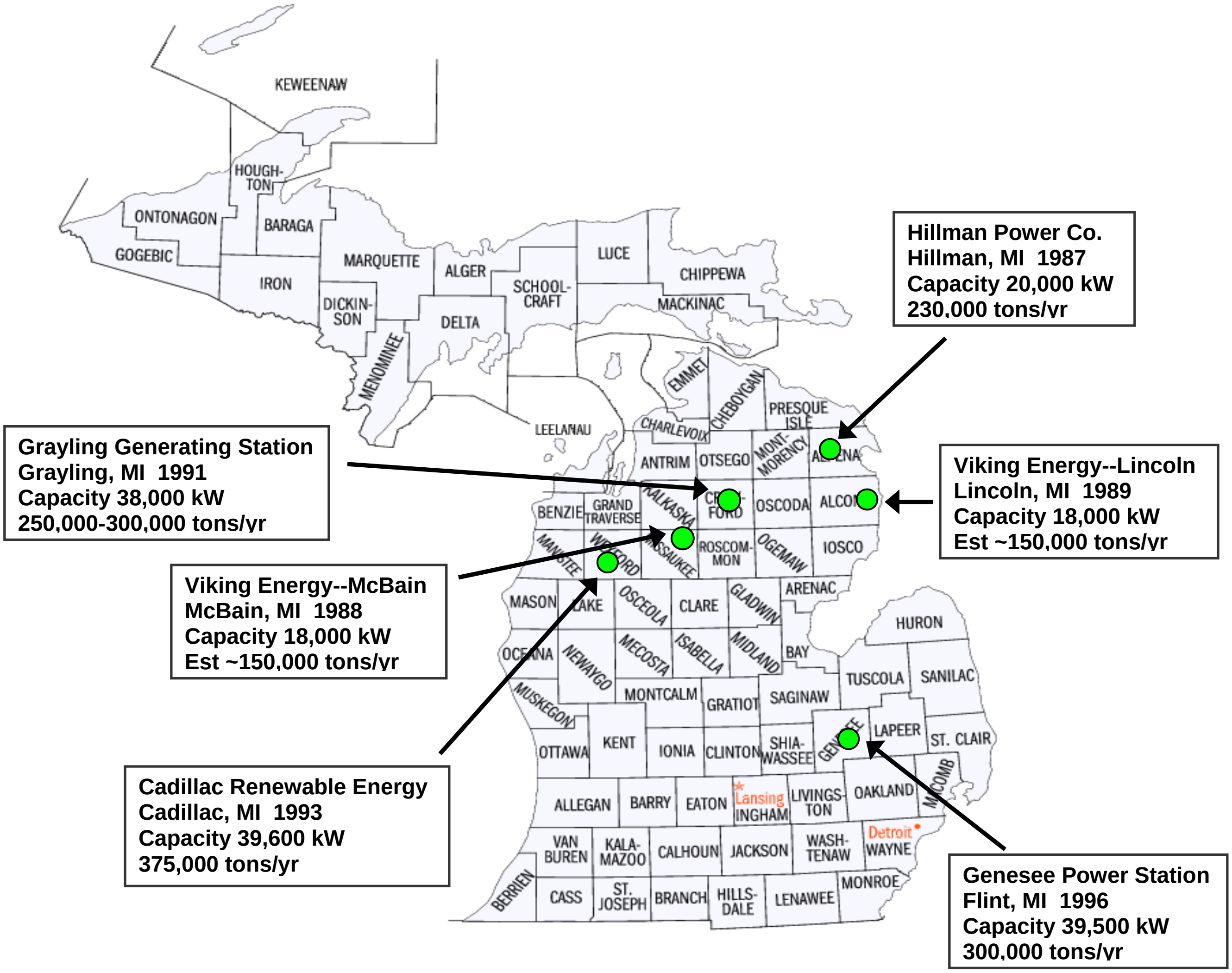
[20] Danny Aerts and Kenneth Ragland, "Case Study of Successful Wood-Fired Co-Generation Power Plant 1982-1996," Mechanical Engineering Department, University of Wisconsin-Madison, no date.

[21] Michigan Public Service Commission Docket No. U-10997: Consumers Power Company, approval of special energy contracts with Dow Corning Corporation and Hemlock Semiconductor Corporation, issued 12/07/1995.

[22] Andy Vajcner, "CMU Wood Fueled Steam Boiler and General Utility Overview," Internal Document, December 21, 2004.

Figure 4— Facilities Producing Electric Power from Wood Fuel in Michigan

Utilities using wood (general location indicated below) have a combined capacity of 173,000 kW, or approximately half of Michigan's wood-based energy. All of Michigan's utility-scale wood energy plants are combustion-based. There are 20 to 30 jobs per plant. No new biomass electric plants have been brought on-line since 1996. Another 195,000 kW are produced by the forest products industries and other businesses using wood for on-site energy production. Data for both types of facilities can be found at the National Renewable Energy Laboratory's Renewable Electric Plant Information System [http://www.nrel.gov/analysis/repis/].



Hillman Power Co.
Hillman, MI 1987
Capacity 20,000 kW
230,000 tons/yr

Grayling Generating Station
Grayling, MI 1991
Capacity 38,000 kW
250,000-300,000 tons/yr

Viking Energy--Lincoln
Lincoln, MI 1989
Capacity 18,000 kW
Est ~150,000 tons/yr

Viking Energy--McBain
McBain, MI 1988
Capacity 18,000 kW
Est ~150,000 tons/yr

Cadillac Renewable Energy
Cadillac, MI 1993
Capacity 39,600 kW
375,000 tons/yr

Genesee Power Station
Flint, MI 1996
Capacity 39,500 kW
300,000 tons/yr

Table 1—Facilities Producing Electric Power from Wood Fuel in Michigan

Source: REPiS, online at http://www.nrel.gov/analysis/repis/.

Type	Capacity (kW)
Michigan Total	368,170
Utility (six sites)	173,100
On-site Upper Peninsula	150,800
On-site Lower Peninsula	44,270

The 21st Century: Energy Diversity through Renewables

Despite success stories like CMU's, the overall story of renewables in Michigan is one of lost opportunities. Both short term price pressures and longer term utility strategies based upon traditional fossil fuels created disincentives for investment in renewable energy production in general. PURPA-based initiatives began to have an impact on Michigan's energy landscape, with some decentralized wood based or wood-coal co-fired plants. However, emphasis on fossil fuels—specifically on natural gas energy production that easily met Clean Air Act standards—defused the movement toward renewables support among policymakers and the public. Both in Michigan and nationwide, lessons about diversification and investment in indigenous renewables that were forced upon the United States in the 1970s did not have the wide-reaching impact they might have had.

The 2005 Energy Policy Act (EPAct) includes some measures to promote biomass energy. Grants were authorized for:

- Rural and remote communities using biomass, landfill gas, and livestock methane,
- Facilities producing electricity, heat, or fuels from forest thinnings,
- Creating valuable products from local, renewable biomass resources, and
- Producers of cellulosic biomass ethanol.

Wood residues are possible feedstocks for each of these funding opportunities. In addition, tax incentives may be offered for cellulosic biofuels, small renewable systems, and gasification projects—all of which could utilize wood.[23] The production tax credit for electricity produced from renewable energy provides a ten-year credit of 0.9 cents per kilowatt-hour for sources including open-loop biomass (like wood residues), and 1.9 cents per kilowatt-hour for closed-loop biomass (like energy crops). However, authorization of these important opportunities has not been followed by appropriation of necessary funding.[24] Environmentalists and fiscal conservatives criticized the new act for directing tens of billions of dollars toward "royalty relief, tax credits, loan guarantees, and other forms of support for the oil, gas, coal, and nuclear industries at a time of high energy prices and record profits."[25] In sum, EPAct authorizes some small steps to help diversify our energy portfolio, but the energy crisis facing Michigan and the United States may require more significant initiatives to resolve.

Despite some promising measures, EPAct 2005 reflects the lack of consistent and adequate funding for renewable energy after the 1970s oil crisis. This inconsistency deterred investors

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[23] "EPAct calls for many incentives programs, including multiple changes to the Internal Revenue Service Tax Code. To reach the goal of producing the first one billion gallons of annual cellulosic biofuels production by 2015 an incentive program will be established at DOE for the production of cellulosic biofuels. Additionally, the DOE may provide loan guarantees to carry out demonstration projects for cellulosic biomass, the construction of facilities for converting municipal solid waste (MSW) into ethanol and other byproducts, demonstration projects for ethanol derived from sugarcane and bagasse, and rebates for a renewable energy system connected to a house or small business. EPAct calls for credits for vehicles capable of operating on a renewable fuel, alternative refueling stations, investments in gasification projects converting product from biomass." From USDA-DOE Biomass Research Development Initiative, "Biomass Provisions in the Energy Policy Act of 2005," September 2005, accessed online at http://www.bioproducts-bioenergy.gov/news/DisplayRecentArticle.asp?idarticle=205.

[24] Despite the promise of closed-loop biomass energy production, no operations in the United States currently utilize this system and claim the higher tax credit (Phil Badger, General*Bioenergy, personal communication, October 30, 2005; Dr. Kenneth Ragland, Emeritus, University of Wisconsin, personal communications, July 2005). The time required to establish energy crops varies from 2-3 years for switchgrass, and 4-10 years for poplar and willow; Kelly Launder, *Energy Crops and their Potential Development in Michigan*, Michigan Biomass Energy Program, August 2002, pp. 3-4. This timeframe deters investors from closed-loop biomass systems, particularly given the more immediate returns of investment in wood-fired heat or electricity, or the emergent market for cellulosic ethanol; Bruce Woodry, Sigma Capital Investments, personal communication, May 11, 2006.

[25] Jennifer Weeks, "National Energy Bill Boosts Bioenergy, But…," *Biocycle,* September 2005, pp. 67-70.

and potential consumers alike, and undermined what was a promising start for renewable energy in the United States. Now, instead of facing price volatility and international instability of oil-producing nations from a position of strength, many states that have not created renewables programs find themselves vulnerable to high prices and volatility in both oil and natural gas markets in the early 21st century. They are now threatened by potential price increases of 50% or more on natural gas use this winter. Furthermore, since the September 11, 2005 terrorist attacks on New York City, and the subsequent invasion of Afghanistan and Iraq, oil prices have become more unstable. The US imports more than half of the oil it consumes, while the price of oil has topped $70 per barrel. The growing insurgency in Iraq has made oil infrastructure protection difficult, and the overall security of petroleum resources in the Middle East less certain. Given that authoritarian or semi-authoritarian regimes govern oil producing countries such as Saudi Arabia, Nigeria, and Iran, and that these regimes either face internal strife or do not favor United States policies, volatile pricing caused by international instability will continue to plague oil markets.

Upward price pressures on all fuels have been intensified by the devastating effects of Hurricane Katrina in September 2005. Prices for oil, natural gas, and propane surged in the wake of infrastructure damage and supply constriction in the Gulf. Even when repairs to supply chains are complete, the need for energy resource investment to repair New Orleans and other damaged areas will continue. Hurricane damage to energy infrastructure in 2005 put a spotlight on our vulnerability to unforeseen natural disasters caused by dependence on energy imports. Climate scientists have linked more intense and therefore more damaging storms to warming oceans. Upcoming temperature increases will generate stronger storms, which increases the likelihood that we will experience more of these disasters in the future. And whether or not we have a national disaster in 2006, or 2007, the finite nature of fossil fuels dictates that their prices will continue to rise over time.

In order to create a flexible energy portfolio to meet our needs throughout this century, as well as to provide ourselves with greater energy security, this discussion paper promotes diversity of fuel sources as the healthiest long-term strategy.[26] Such diversity comes from increased policy focus on and investment in renewable energy production. Federal and state governments are re-investigating how renewable energy from biomass, solar and wind might help their current energy dilemmas, and many states are already implementing policy initiatives to increase renewable energy production and use.[27]

Wood Resources Old and New

When considering wood residue utilization for the production of renewable energy, much of the low-hanging fruit has already been picked. Many sawmills already use their onsite residues for their own energy needs: overall, the industry obtains more than 50% of its electrical and thermal capacity from biomass.[28] The remainder of the convenient centralized wood residue resources not used at forest products industry facilities is being used by utilities.

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[26] Amory and Hunter Lovins, *Brittle Power: Energy Strategy for National Security*, Rocky Mountain Institute, 1982 (www.rmi.org). This report, commissioned by the Pentagon, recommended strong moves toward renewable energy production from biomass, solar and wind. It also promoted the concept of distributed generation on the premise that highly centralized systems, when they fail, fail spectacularly—but networks of self-contained energy production nodes can provide the same amount of energy more efficiently and more securely.

[27] See the Database of State Incentives for Renewable Energy (DISRE); http://www.dsireusa.org. See also Michigan Renewable Energy Program Web site: http://www.michigan.gov/mrep.

[28] DOE figures for the US Pulp and Paper industry report that it uses biomass to create more than 7,500 MW of electricity for its own use. EERE estimates that at least that amount of power could be generated by unused mill wastes and urban wood wastes.

Currently in Michigan there is increased demand for wood residue, due in part to a reduction in available residues from the forest products industry. Foreign competition is impacting the wood products industry. Low priced furniture, furniture component parts, and pulp from foreign suppliers has reduced demand for some Michigan wood products. Decreased production may account for some of the reduction in wood residues from mills. Improved sawmill efficiency and improved utilization of all components of currently harvested trees may also account for some of the reduction in wood residue availability.[29]

While forest products residues have decreased, growing pressure to divert organic materials from landfills has *increased* the availability of some urban wood residues.[30] However, the overall theme of new and improved uses for wood residues also holds true outside the forest products industry: an increased number of uses for these residues have multiplied, and they are frequently higher value uses than energy depending on the local context.

For example, innovation in the construction supply industry has enabled the use of some kinds of wood residue in production of oriented strand board (OSB), now the standard for housing construction. As builders moved to OSB and other products, they were able to make more commercial use of smaller bits of wood. Pellet manufacturing and animal bedding suppliers have also increased demand on wood residues. Finally, landscaping has also become a major competitor for wood residue resources. Over the last five years, landscaping trends turned toward higher end products such as colored mulches. Mulches decompose over time and continue to provide nutrients as well as keep down weeds—two qualities desired by landscapers and homeowners. The mulch industry has grown up to 10% per year in sales volume, continually increasing pressure on wood residue prices.[31]

Given increased reuse and recycling by forest products firms and secondary/tertiary wood products manufacturers, and the growing number of uses for that residue, the value of wood residue is higher than it was in the PURPA era, when wood residuals were frequently thought of as waste. Higher costs require higher value secondary and tertiary uses. Today, residue from the wood-based economic sector is no longer a free byproduct that nobody wants, which is how "waste" is traditionally conceived.

However, there are other wood residues that have not been subject to increasing competition for their use. Because of the cost of intermediary businesses or new city/county functions to retrieve, sort and aggregate it, urban tree residue is a fundamentally different resource than industry or other urban wood residues. Diffuse in nature, these residues sometimes find their way to wood residue processors, but are more often mixed with municipal solid waste or simply dumped. Some localities have yard waste ordinances that ban wood residues in the solid waste stream, but these ordinances are very difficult to enforce. Urban wood residues, if aggregated, could provide fuel for wood energy applications in or near cities throughout the state. The next section highlights important characteristics of wood residue, noting the potential of redirecting urban tree residues toward energy resource pathways.

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[29] The US Forest Service's *National Report on Sustainable Forests 2003* highlights the dramatic increase in recycling in forest products industries since the 1970s (Indicator 33—Degree of Recycling of Forest Products).

[30] "Wood Recyclers Embrace Municipal Market," James I. Miller, *American Recycler*, July 2004, accessed online at http://www.americanrecycler.com/0704wood.shtml.

[31] Judd Hart, CEO of J.H. Hart Urban Forestry, Personal Communication, September 30, 2005.

Characteristics of Wood Energy Feedstocks

Forest Residues: Forest residues include material not harvested or removed from logging sites in commercial hardwood and softwood stands, as well as material resulting from forest management operations such as pre-commercial thinnings and removal of dead and dying trees.[32] Forest residues may include logging residues, rough rotten salvageable dead wood, and excess small diameter trees. At the initial harvest, up to 50% of the tree (leaves, tops, branches, stump) may not be useful to a particular industry.[33] There is potential here for recovering some of the harvesting residue for energy, while still leaving a suitable amount of material to assist in soil recovery and nutrient flows. In fire dependent ecosystems harvest residues can create increased fire hazard and this is reduced if the material is removed. In such fire dependent ecosystems, the elimination of fire from the system and the build-up of understory fuels can also increase fire hazard. Current strategies to lower fire danger focus on reducing these fuel levels through thinning. This “fuel reduction” thinning process could provide an energy resource in some parts of Michigan. However, the specifics of what, when, where and how much is to be harvested remains a matter of intense debate.[34] Most forest residues are suitable for energy conversion, but they may have high moisture content and may require some energy intensive drying (see processing) depending on the conversion system to be used.

Primary Residues: Mill or processing residues are also divided into two categories, primary and secondary. Primary industrial mill residues are wood residues from manufacturing facilities that process logs or roundwood (i.e. pulp, paper, lumber veneer, and board plants). Primary residues are predominantly green, with moisture content between 40 and 50%. These residues take the form of chips, sawdust, and bark. In certain instances these primary residues may include stumps. Unlike secondary industrial mill residues, the creation of primary residues requires the harvesting of trees.[35] Depending on conversion rates and process efficiencies, up to 40% of the primary mill’s inputs may become primary mill residue.

Secondary Residues: Secondary residues, also referred to as dry mill residues, are the by-product of the wood products industries that utilize kiln-dried material or refined fibers to manufacture consumer and industrial goods. They are generally characterized by their cleanliness, relatively low moisture content, freedom from bark and relatively high energy content.[36] Several of the most common types of secondary mill residues are sawdust, chips

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[32] US Department of Energy, Energy Efficiency and Renewable Energy, Feedstock Composition Glossary, online at http://www.eere.energy.gov/biomass/feedstock_glossary.html.

[33] Tom Stanton, “Biomass Energy: It’s not just for breakfast any more,” Michigan Public Service Commission, 1995; Anthony Weatherspoon, Forest Products Technical Services Specialist, Michigan Department of Natural Resources, personal communications, October 2004.

[34] The importance of managing forests simultaneously for biodiversity, non-consumptive uses, and for industry requires a sustainability based approach that considers intergenerational consequences. The publication *National Report on Sustainable Forests 2003* (USDA Forest Service, FS 766, February 2004) presents the case for increased research and program development to maximize sustainable forest management through these considerations. At the same time, mitigating forest fire disasters requires short term action with an eye toward tree removal and industry value-added through that process. These two missions do not share a timeframe, which exacerbates the potential conflict between “forest management” and industry profitability. Western states have more national forest lands than Midwestern states, so they will be a laboratory for experiments in “harvesting” wood for energy uses. Many biomass energy projects using wood have been initiated since the passage of the Healthy Forests Act, particularly in western states which have significantly more forested public lands. The upcoming years will reveal whether and how sustainability practices will influence the increased use of wood as an energy feedstock. However, this paper is primarily concerned with urban wood residues and other residuals outside of forests, based on the premise that large volumes of non-forest wood waste are present and could be harvested with an investment of money and energy in order to reduce organics in our waste streams as well as to reduce our dependence on non-renewable fossil fuels.

[35] *Urban Wood Waste in Michigan*, September 1994, p.8.

[36] Phillip C. Badger, *Processing Cost Analysis for Biomass Feedstocks*, Oak Ridge National Laboratory, 2002.

and shavings. Yet another 30% of the original tree will end up as secondary residue. Most secondary residues are suitable for energy conversion. In the case of Michigan, most of the mill and manufacturing residues have been recognized as energy or other assets and are not considered "available": nearly 98 percent of all mill residues are currently used as fuel or to produce other fiber products.[37]

Urban Wood Residue: Urban wood residue is a collective reference for wood residue present in municipal and commercial solid waste. It includes urban tree residue (UTR—woody yard and right-of-way trimmings, leaves, tree company and municipal/park trimmings), discarded wood products (scrap lumber, pallets, crates, wooden packing material), and municipal solid waste (MSW) such as fencing, poles, cable reels, furniture, toys, cabinets, seasonal trees and brush trimmings.[38] It may also include chips and grindings of clean, non-hazardous wood from construction, renovation, and demolition activities and storm-generated wood.

Historically, most urban wood residue has been buried or dumped. However, the advent of recycling and composting, in tandem with increased tipping fees for landfills and PURPA-inspired biomass burning plants, have raised the value of wood residues, causing more wood to be diverted from landfills to other uses. Not all of these "uses" are productive. In order to avoid tipping fees, burying wood or dumping it on less visible properties are still common practices in places far from any readily available wood using enterprise.[39] In addition, not all urban wood residues are suitable for energy conversion. Some residues are treated with chemicals that are not compatible with typical wood-to-energy conversion systems, and that can produce emissions harmful to public health and the environment.[40]

Table 2—Wood Energy Characteristics, Merits, and Technology Options

Resource	Energy Characteristics	Advantages	Disadvantages	Technology
Wood and wood residue	▪ green wood: 4,800 Btu/lb (45% moisture content, wet basis) ▪ dry mill residue (brown wood): 6930 Btu/lb (13% moisture content, wet basis) ▪ pellets or briquettes: 8000-9000 Btu/lb (8% moisture content, wet basis ▪ wood-to-ethanol life cycle fossil energy ratio: 14-29:1	▪ renewable, locally abundant ▪ dispatchable (storable), not intermittent (solar, wind) ▪ known technology for heating, boilers, co-firing ▪ much cleaner than coal, carbon neutral if harvested sustainably ▪ pollution prevention for wood industry and processing ▪ prevents landfilling of organics ▪ improved forest health, reduced impact of fires, insects, diseases	▪ lower energy content than non-renewable fossil fuels ▪ can be expensive to transport ▪ requires storage space ▪ must be dried for some energy applications ▪ can be contaminated ▪ lack of consensus on sustainability	**NOW** ▪ wood fired boilers ▪ wood and coal co-fired boilers ▪ co-firing with other biomass ▪ pyrolytic oils (bio-oils) **FUTURE** ▪ wood-to-ethanol ▪ syn-fuels

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[37] Marie Walsh et al., "Biomass Feedstock Availability in the United States: 1999 State Level Analysis," Primary Mill Residues section, January 2000, Oak Ridge National Laboratory, online at http://bioenergy.esd.ornl.gov/resourcedata/index.html.

[38] Badger 2002.

[39] Anthony Weatherspoon (MDNR), Thomas Stanton (MPSC) and Sam Sherrill (University of Cincinnati), personal communications, August and September 2004.

[40] Some treated wood, such as creosote-coated railroad ties, can be used for energy in larger plants that have invested in specially designed burner and emissions control systems.

Green and Brown Residues

Another important categorization of wood residues that cross-cuts the categories above is determined by moisture content. Green residues are typically undried (moisture content of 25-45%), and can include primary residues as well as urban tree residues and energy crop cuttings. Brown residues are dried (moisture content 0-15%) and usually processed. Brown residues encompass secondary residues such as shavings, sawdust, trimmings, composites, pallets, crating, and construction and demolition residues (both clean and treated). In addition, urban tree residues can be brown, such as dead trees, downed limbs, and dried trimmings. Urban wood residues in general include furniture, fixtures, and other brown wood products that become residues when consumers have finished using them.

Clean versus Treated/Contaminated Wood Residues

The quality of wood residue going into a combustion or gasification system determines what comes out—in terms of energy, emissions and non-combusted residues/ash. The use of certain waste streams such as sewage sludge, recovered domestic and municipal waste and construction wood residue are particularly prone to contamination.[41] In addition, even small amounts of some contaminants can lead to significant toxic emissions and health hazards, depending on the technology in use.

Treated woods in particular contain chemicals that create dangerous emissions and have other harmful properties to the energy process. Surveys of wood users in Michigan and other states demonstrate that secondary wood users (including wood energy producers) do not accept wood contaminated by treatments. In addition, the simple economics of protecting a major capital investment create incentives to screen wood fuels, because contaminants can adversely affect machinery necessary to keep boilers running.

Urban Tree Residue (UTR) Versus Other Wood Residue

Compared with other forms of urban wood residue, UTR has no particular resonance with socio-cultural norms of preservation. Harvesting trees for energy resonates with incidences of wholesale forest clear-cutting without necessarily preserving or replanting; indeed, energy policies encouraging wood utilization could lead to that outcome. Forests are complex natural systems that people value not only for their material products but also for their recreational or conservation values and other intangibles—forests are valuable for simply existing. The use of UTR for energy presents a sharp contrast with the use of forest residuals: people are “getting rid” of UTR because it is surplus to their needs, and they do it every year because it grows back. “Harvesting” UTR for energy production does not prioritize its energy values over other values, as often there are no other values. If UTR is unclaimed by another use like composting or landscaping chips, then it actually has a negative value because it will be landfilled or dumped on land that could be used otherwise. There are large volumes of UTR entering landfills that could otherwise be useful for energy or other uses; up to 200 million cubic yards of UTR are removed each year in the United States; this figure is approximately 30% of the total of US hardwood lumber supplies.[42]

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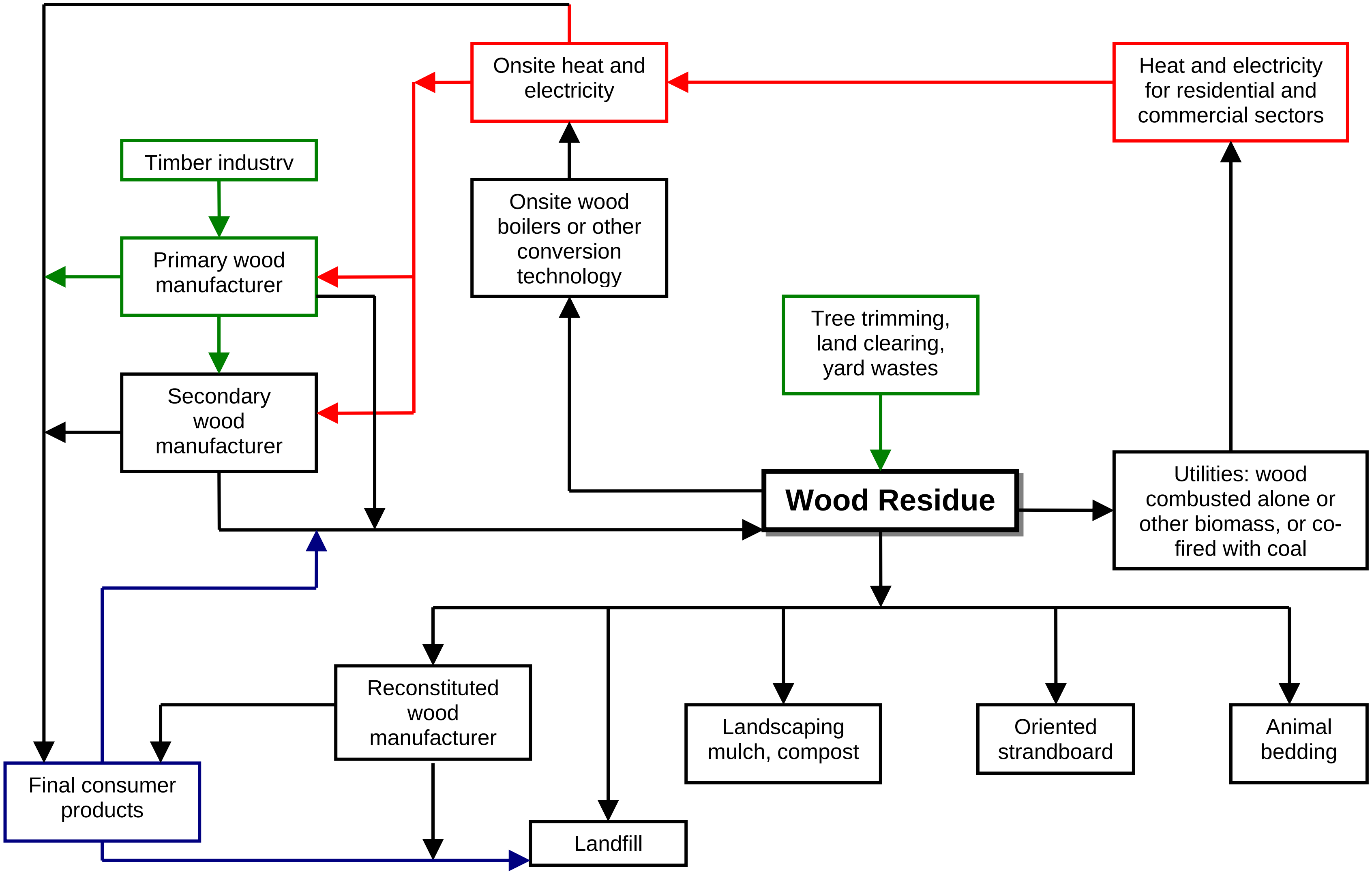
[41] Ausilio Bauen, Jeremy Woods and Rebecca Hailes, *Bioelectricity Vision: Achieving 15% of Electricity from Biomass in OECD Countries by 2020*, Imperial College London, Centre for Energy Policy and Technology and E4tech (UK) Ltd, April 2004, p.33.

[42] Steve Bratkovich, *Utilizing Municipal Trees: Ideas from Across the Country*, Newtown Square, PA: U.S. Dept. of Agriculture, Forest Service, 2001. Available online at http://www.treesearch.fs.fed.us/pubs/11059.

Using UTR is beneficial because it diverts this tremendous volume of organics from landfill spaces, prevents potent greenhouse gases like methane coming from decomposing organics over time, reduces consumption of fossil fuels and production of their associated emissions, and moves communities toward a renewable energy cycle that is locally sustainable and more secure from global economic and political disruptions. The next section explores how we attempt to quantify available wood resources, including UTR, in the United States and in Michigan.

Figure 5—Wood Residue Pathways[43]

Note: Wood and wood products can become wood residue at almost any point on the pathway—just as they can be landfilled at nearly any point. However, all possible paths were not charted in order to maintain the figure's visual clarity. The chart assumes that landfilling occurs when all other options are exhausted, whereas in reality locational variables may determine that there are no options aside from landfilling due to high transportation costs to an alternative user.



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[43] This figure is based in part on wood residue generation and use mapping by Bibhakar Shakya in *Directory of Wood Manufacturing Industry of Ohio*, Ohio Biomass Energy Program, August 1997.

Wood Residue Quantity and Price

Good data on wood residue is hard to find.[44] Oak Ridge National Laboratory (ORNL) has utilized models programmed into its BIOCOST software to generate state level estimates of various biomass feedstocks available at different prices. The feedstocks include Urban Wood Residue, Mill Residue, Forest Residue, Energy Crops, and Agricultural Residue; for the purposes of this report, only the first three categories are relevant.[45] While there are some solid assumptions behind these models, there are also shortcomings. ORNL data relies on estimates provided by other government agencies or generated by other studies. In other words, ORNL's estimates are generated by secondary or even tertiary data, as opposed to estimates derived directly from the field through interviews and surveys. Forest residues are assessed using the 1984 McQuillan model, and then adjusted downward to account for presence of roads, slopes, equipment availability. This model does not account for ecosystem values, soil erosion, or site-specific requirements. It also does not explain how "salvageable" dead wood should be distinguished from dead wood necessary for habitat requirements, nutrient management, and soil protection.[46]

Table 3—Annual Biomass Quantities in Michigan (est. dry tons), by Type and Delivered Price[47]

Biomass Type	< $20/dry ton	< $30/dry ton	< $40/dry ton	< $50/dry ton
Urban Wood Residue	495,734	**826,224**	826,224	826,224
Mill Residue	10,000	932,000	*1,248,000 (est)*	1,564,000
Forest Residue	0	710,000	1,034,000	1,327,900
Energy Crops	0	0	1,154,228	4,179,308
Ag Residues	0	0	680,783	4,265,671

It also does not account for sporadic influxes of large volumes of wood residue created by natural disasters—tornadoes, hurricanes, infestations, and "acts of God." These volumes can be large enough to provide a glut of wood residue at the local level, and at the same time affect national market prices for wood products. We can estimate the wood residue through the demand for replacement wood, but still the actual volume of downed trees and limbs, wood from destroyed homes, and other sources will never be known. These volumes require intensive effort for local processing and utilization, and their unpredictable nature causes price effects to vary, both locally and nationally.

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[44] Wood wastes that are part of urban waste streams suffer from similar problems in quantification: "The absence of hard data, for example, is not just a Michigan problem—it is, in fact, a problem with solid waste and recycling statistics in every state. The EPA, the most quoted source of waste and recycling statistics in the nation, ultimately bases its estimates of MSW generation on initial reports made in the late 1970s. In recent years, updates of the EPA's numbers have been the result of a slow migration of 'best guesses' from the states. Moreover, the states have not devoted enough resources to uncovering what is really going on within their boundaries in the generation, collection and recycling of their waste streams." From *Waste: A Hidden Resource*, Special Report 112: Status and Potential of Michigan Natural Resources (SAPMINR), Michigan Agricultural Experiment Station, MSU, March 2000, p.12.

[45] Energy crops include both grasses and trees, many species of which could thrive in Michigan. However, such crops would not be considered wood waste, as they are deliberately planted and harvested on a regular basis and the markets for these crops would be clearly defined.

[46] Marie Walsh et al., "Biomass Feedstock Availability in the United States: 1999 State Level Analysis," Updated January 2000, Oak Ridge National Laboratory, online at http://bioenergy.esd.ornl.gov/resourcedata/index.html.

[47] Ibid.

More accurate information is available for mill residues. Forest products industries report production data to the USDA as part of the periodic national forest inventory process. Residue production is relatively constant given particular industry practices. Aside from these mill figures, other wood residues including urban wood residue quantities are notoriously difficult to quantify. Many states record or estimate construction, demolition, and solid waste itself differently. Again, quantities were estimated in wet tons, and then corrected to dry tons by assuming 15% moisture content by weight. Similarly, As a result, the ORNL data cannot incorporate the subtleties of the state-specific or feedstock-specific studies.

Since 1994, there have been no Michigan-specific studies of wood residue, nor have there been any Great Lakes regional assessments of the amounts, uses of, or markets for wood residue.[48] However, a notable attempt to use state and regional data to create metrics for national mill residues and wood residue was commissioned by the Northeast Regional Biomass Program and completed by Fehrs in 1999. It aggregates results from seven reports on wood residues from other states and regions, and selects the data about specific waste categories best represented in each study for a summary analysis. This table helpfully breaks out many categories of wood residue that are frequently subsumed under the label "urban wood residue" (which arguably includes woody municipal solid wastes, yard trimmings, UTR, used pallets, and some percentage of land clearing, construction and demolition).

Table 4—Wood Residue Quantities and Prices in the United States[49]

compiled data from 1992-1998 (tons/year)

Wood Residue Type	Total Generation (tons/yr)	Available up to $10/ton (tons/yr)	Available up to $20/ton (tons/yr)	Available above $20/ton [c]
Secondary mill	15,644,000	1,342,000	3,783,000	6,101,000
Construction	16,726,000	2,796,000	7,882,000	12,712,000
Demolition	26,400,000	1,742,000	4,910,000	7,920,000
MSW[a]	11,800,000	1,999,000	5,633,000	9,086,000
Yard trimmings	6,300,000	1,199,000	3,379,000	5,450,000
Urban tree residues (UTR)	51,455,000	9,962,000	28,074,000	45,280,000
Used pallets[b]	6,544,000	230,000	647,000	1,044,000
Railroad ties	1,688,000	na	na	na
Land clearing	na	na	na	na
Used utility poles	na	na	na	na
TOTAL (tons/year)	<136,557,000	<19,270,000	<54,308,000	<87,593,000

(a): Includes used pallets that are disposed in landfills.
(b): Includes used pallets that are repaired, refurbished, or recycled. Used pallets are disposed in landfills are included as MSW wood residue.
(c): The methodology used to estimate quantities and prices equates wood residue available at $20 and above with that that potentially available for fuel. Wood residue potentially available as fuel is defined as the quantity generated less that used by high value markets and that which is commingled, inseparable, or contaminated.
na: Data not available.

This compiled research on various wood residue stocks over the last decade shows that urban tree residues (UTR) from landscaping, yard management, municipal forestry and utility clearing operations have been underestimated by other official sources. Prior DOE estimates put urban

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[48] *Urban Wood Waste in Michigan: Supply and Policy Issues,* Public Policy Associates, 1994. While dated, this is the only existing study of wood residue in Michigan. Later in 2006, a detailed study of wood residues in Southeastern Michigan will be published by the USDA Forest Service.

[49] Jeffrey Fehrs, *Secondary Mill Residues and Urban Wood Waste Quantities in the United States,* prepared for the Northeast Regional Biomass Program, 1999, p. 46.

wood residues in general at 36.8 million tons per year, while the meta-study suggests that only urban tree residues—a subset of all urban wood residue—totaled over 51 million tons, and is at least as abundant as all other wood residue categories combined.[50] Further adding to the confusion, a 1999 *Biocycle* analysis shows a drop in wood available from 42.3 million tons in 1990 to 29.6 million tons in 1999, noting that the drop is almost entirely due to recycling of pallets and a decline in woody yard trimmings.[51] The *Biocycle* study documents 25.2 million tons of woody yard trimmings generated annually, where the Fehrs study provides for only 6.3 million tons—but Fehrs also gives the 51 million ton figure for urban tree residue, some of which might be counted in the *Biocycle* study category for woody yard trimmings.

Taking into consideration the shortcomings of various estimates, and also incorporating the understanding that the amount of urban wood residue is generally underestimated, the ORNL data can be accepted as a conservative estimate of available urban wood residue that could be used to produce energy. The ORNL results for Michigan suggest that at $20 or less per ton, 495,734 tons of urban wood residue is available; at $30 per ton, all 826,224 tons of urban wood residue becomes available.

Energy Potential from Urban Wood Residues

How much energy could this volume of urban wood residues create? In 2000, the State of Michigan consumed over 3,092 trillion Btu's of energy[52], of which 41 trillion Btu's (1.4%) were imported. If all available urban wood residue resources at $30/ton could be converted to energy, Michigan would reduce energy imports by approximately 5.28 trillion Btu's.[53] Substituting 1/8 of our energy imports with domestic wood energy production would increase the amount of money in the Michigan economy, provide job support to renewable energy in Michigan, reduce organics from our waste streams, create a healthier emissions profile for Michigan energy production, provide a better carbon balance, and reduce GHG emissions. These figures only include potential energy production from urban wood residue; there is more surplus wood in construction, land clearing, and even in industry. Harvesting these other wood residue resources could displace more imported energy.

Similarly, an NREL study on urban wood residues that surveyed 30 metropolitan areas found significant local benefits from wood energy production. Diverting wood residues to energy uses could support between 0.4% to 4% of an urban area's electricity needs, simultaneously reducing waste volumes and carbon dioxide emissions from energy production, as well as producing jobs and enhancing the local economy.[54]

Competition for Wood Residue

However, energy is not always the highest value use for wood residues, particularly when the environmental and health benefits of wood energy are not quantified in monetary terms. The phrase "available wood" at any given price implies that some end users will pay more for wood than others. As noted above, the ORNL figures for wood residue show that it is the most available residue type at $20 per dry ton in that analysis. But increased competition would bid the market higher, and available wood residues would then become scarcer. Innovation and

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[50] US Department of Energy, Oak Ridge National Laboratory, http://bioenergy.ornl.gov/papers/misc/resources_estimates.html. Information on secondary mill residues and manufacturing residues was not available at the time of this study; Fehrs, December 2001.

[51] David McKeever, "How Woody Residuals are Recycled in the United States," *Biocycle*, December 1999, pp. 33-44.

[52] US Department of Energy, Energy Information Administration, "Energy Consumption Estimates by Source, Selected Years, 1960-2000, Michigan," online at http://www.eia.doe.gov/emeu/states/sep_use/total/use_tot_mi.html.

[53] Using conversion factor of 6,400 Btu's per pound.

[54] George Wiltsee, *Urban Wood Waste Resource Assessment*, NREL/SR-570-25918, November 1998, pp.3-4.

waste reduction have created other high value markets for these residues. A “high value market” refers to the industries that manufacture specialty goods for secure markets, such as paper, pulping, and composite materials like OSB. Even higher value markets are available for the larger tree portions of urban tree residues, which can be converted into lumber and high-end wood products such as customized cabinets and furniture. Now competition for more readily available wastes has intensified further. All interview sources in government agencies and the energy industry identified the landscaping industry as a major competitor with energy producers for wood residue. Landscaping has become the highest value use for wood residue chips in urban and suburban areas.[55] In light of tightening wood residue markets, any feasibility assessment for a new wood-to-energy or wood-to-fuel must factor in the market environment and other pressures on the wood residue feedstock.

Location, Location, Location: Distinguishing Residues from Wastes

Despite the information just presented about the value of wood residues for various industries including energy, frequently wood “waste” is landfilled. This counterintuitive phenomenon is tied to the locationally specific nature of biomass. As mentioned earlier, biomass is difficult to handle and transport when compared to liquid or gaseous fuels. Biomass fuels like wood are best utilized close to their source. If a major land clearing operation must dispose of wood, but is 150 miles from the nearest wood energy production facility, and the wood is not needed by the local mulch industry, landfilling is the likely course of action. The transportation costs required for moving wood to distant energy production facilities, pellet plants, or other industries are often prohibitive. So while in theory wood has a value, in practice the markets for wood are driven by demand locations and not necessarily by supply sites. This being the case, prices for wood can be very high in some places featuring the competition described above, yet surplus wood volumes are landfilled, burned, or illegal dumped in others. As tipping fees increase, transportation costs become less of a factor, and two related yet contradictory trends may occur: (1) the effective radius of biomass feedstocks become larger—or it is cheaper to transport biomass fuels relative to landfilling, and (2) the desirability of moving wood at all becomes less appealing than creating an industry to take advantage of that feedstock in situ—perhaps by building a small or medium-sized (5-15 KW) wood power plant, or a cellulosic ethanol biorefinery.

Landfills and Tipping Fees

Michigan landfills do not accept the green waste called “yard clippings.” Wood fragments under 4 feet in length and 2 inches in diameter fall into the yard clippings classification. [56] Wood residues that have been chipped or ground technically fall under the definition of yard clippings, but in practice this definition is not strictly enforced. Some landfills even accept chipped wood at no- or low-cost as an alternative daily cover. Most other forms of wood residues are not banned from landfills in Michigan: stumpage, whole trees, and construction and demolition waste are all eligible for landfilling. EPA waste management guidelines allow for wood waste to go into inert landfills, which are less expensive to operate than Subtitle D MSW landfills. However, depending on the state, landfilling can be such a costly option as to encourage residue producers to seek alternative uses for wood residues.

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[55] One source recommended that, if the renewable energy industry in Michigan wants to make wood residues more available for combustion, it should consider hiring consultants to redirect landscaping tastes back to the 1970s and 1980s: “We need to revive interest in those white rocks.”

[56] “Part 115, Solid Waste Management: Statute and Rules Impacting Composting,” Michigan Department of Environmental Quality (DEQ) Web site at http://www.michigan.gov/deq. Legal provisions that apply generally to composting are included in Part 115, Solid Waste Management, of the Natural Resources and Environmental Protection Act, 1994 PA 451 (NREPA).

Most states have legislated a surcharge on waste deposits to landfills in order to encourage diversion, re-use and recycling. Landfills pass along this surcharge with fees and transport surcharges encompassed in what is called a tipping fee. Low surcharges lead to correspondingly low tipping fees.[57] Michigan imposes a very low surcharge of $0.07 cent per cubic yard ($0.21 per ton). Correspondingly, Michigan's low-end tipping fees are around $11 per cubic yard. Midwestern tipping fees are among the lowest in the nation—$15-$16 per ton versus $40-$50 per ton in the eastern US.[58] The fact that most states have much higher surcharges helps explain why Michigan is currently among the top five waste importing states.[59] Both Democrat and Republican state legislators have started initiatives to raise this surcharge, but so far no legislative action has been taken. Without stronger incentives to move wood residues out of waste streams, Michigan landfills will continue to absorb large volumes of wood that has great value as a renewable and clean energy resource.

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[57] Matt Flechter, Recycling and Composting Coordinator, Michigan Department of Environmental Quality, personal communication, September 27, 2005.

[58] Tom Henry, "Trash in, cash out: Landfills want to expand, but garbage imports rankle," *The Toledo Blade*, Environment Special Report, July 7, 2002.

[59] "Economics of Wastes/Residues in Food Processing and Food Service Facilities: Costs of Disposal of Wastes and Residues," Table 4.3—Solid Waste Tipping Fees of Landfills, Incinerators and Waste-to Energy (W-T-E) Plants, and Processing Facilities, December 2001), Kansas State University Online Text Modules, available online at http://www.oznet.ksu.edu/swr/Module4/Costs_of_Disposal.htm.

Wood-to-Energy Markets

The feasibility of energy extraction from any resource base depends not only on the technological efficiency of processing it, but also on extraction and transportation costs. Steps in the conversion of wood to energy include harvest and collection of the residues; transportation to facilities where the residues can be preprocessed (dried or ground) if necessary; and then storage prior to delivery to a plant for energy conversion. The type of processing and storage of any given operation must meet the requirements of the conversion technology in question. Moisture levels of wood fuel in turn will determine the processing specifications and storage dimensions of the biomass energy facility.

Harvesting

Wood is a renewable resource, if it is harvested at a sustainable rate using proper methods.[60] Harvesting, used in the traditional sense of gathering mature crops for human use, is a term more appropriate for the forest products industry or for energy crop plantations. In application to wood residue, it means the method of collecting the wood residues and gathering them at a central facility for processing. Mill and industry wood residue are often used on-site, removing the "harvesting" step from the costs of the fuel. Unlike forest products industry residues, urban wood residues are often dispersed, of varying quality, and erratic in flow. At the same time, yard waste, and urban tree trimmings—a significant portion of urban wood residue—grow back, so a reasonable estimate of a sustainable medium-term flow of the feedstock can be identified with enough detailed information of the local area. However, knowing how much UTR is available does not solve the problem of actually designing and implementing a harvesting strategy.

The problem of harvesting urban wood residues is similar to the problem that faced early recycling policies: the most effective way to get dispersed wastes organized and diverted is to encourage individuals to value them.[61] This educational strategy eventually worked with recycling newspapers, aluminum cans, glass and finally plastics. Incentives for cans and from "bottle bills" encouraged people to participate in recycling for material rewards, but not everyone requires that motivation. People are, in fact, willing to spend some of their time and/or money for a cleaner environment, which bodes well for the future of urban wood diversion from the waste stream to energy uses. However, there will still be a need for outreach, which will likely fall to various levels of government to meet.

Other mechanisms for encouraging diversion of wood residue from the solid waste stream include penalties. As noted earlier, tipping fees help raise the value of wood residues. Rather than pay for disposal of "waste," residue producers must consider how it might otherwise be used to avoid that fee. For large wood residue producers, penalties and tipping fees do have an

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[60] "Harvesting" can mean removal of wood residues from primary and secondary wood processing waste reserves: power plants cannot be built for a particular capacity if the waste wood to fuel them cannot meet the demand. Harvesting also can mean forest thinning of deadwood or of specific species. Finally, harvesting can also mean planned rotational cutting of dedicated energy crops such as poplar and willow. Oak Ridge National Laboratory (ORNL) data demonstrate that there are prices at which energy crops will displace traditional crops on some agricultural lands.

[61] In *The Tipping Point* (Back Bay Books, 2002), Malcolm Gladwell studies watersheds of behavior change in US policy settings. His work is designed to help explain questions such as "Why did recycling become mainstream?" What was the pivotal event, or when was critical mass of opinions reached, that led to shared norms and understandings about a new definition of waste? It is important for renewable energy to consider studies like his. The needed shift away from standard ingrained patterns of energy use will require similar outreach to that which went into changing individual/household/municipal waste management processes and institutions so that they normalized recycling behavior.

effect. Construction and clearing operations need to find a taker for their wood residues or face the costs of landfilling tremendous volumes. Organics diversion has helped wood disposal companies, cities and other organizations value wood residues and take notice of energy producing facilities that might pay them for it. The emerald ash borer (EAB) infestation in Michigan has created tremendous volumes of wood residues which will only increase over the next five years at least, prompting wood disposal procedures that simplify harvesting. EAB residues disposal needs have already improved the reliability of supply to wood fired electrical generation in Southeast Michigan.

Transportation

The feasibility of energy extraction from any resource base depends not only on the technological efficiency of processing it, but also on how much it will cost to get it to the efficient technology, how much of the resource there is, where it is, and, and the cost of extracting it from that location and delivering it to the end user—in the desired useful form. Because biomass has a relatively low energy density compared to conventional fuels such as oil or coal, it is best used as a local resource. Transportation distances from the resource supply to the power generation point must be minimized, with the maximum economically feasible distance being less than 100 miles round trip. Transporting more than 50 miles is usually not cost effective because more energy is expended to transport the wood to the facility than the wood can generate, although this general rule can vary based upon local conditions and the availability of backhaul commerce for the delivery company.[62]

There are some exceptions to this rule: depending upon the ability of parties involved to creatively merge different shipping needs on the same routes, wood residue delivery trucks do not necessarily have to drive back empty. Wood residues from manufacturing in southern Michigan are hauled to Alpena's wood-fired power plant, but other products are loaded onto the empty trucks for the backhaul. Similarly, Genessee Power in Flint receives shipments of emerald ash borer and other residues from a Detroit area marshalling yard, and delivery trucks recoup transportation costs on return deliveries.[63] However, in general, the most economical conditions exist when the energy use is located at the site near where the biomass residue is generated or aggregated, such as a wood product manufacturing site, or a municipal organics collection site.[64] Densification of woody biomass into pellets or briquettes can make transportation over longer distances affordable due to the higher energy content of smaller volumes, and due to the ease of packing these regularly-shaped feedstocks (see Wood Residue Densification below). However, densification is only cost effective in cases where the wood residues have been previously reduced in particle size by other wood processing processes.

Handling and Storage

The necessity of on-site processing and storage of wood residue requires careful planning and attention to spatial considerations not normally applicable to traditional fuels. Handling and storage can be a major portion of the expense of a biomass energy system (20-40% of total

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[62] Techline, Wood for Biomass Energy, USDA Forest Products Laboratory, online at http://www.fpl.fs.fed.us/documnts/techline/Wood_Biomass_for_Energy.pdf; M.K. Mann and P.L. Spath, "A Life Cycle Assessment of Biomass Cofiring in a Coal-Fired Power Plant," *Clean Production Processes 3* (2001), p.84.

[63] Jessica Simons, SE Michigan Resource Conservation and Development, personal communication, September 9, 2005; Anthony Weatherspoon, MDNR, personal communication, September 23, 2005.

[64] *Lessons Learned from Existing Biomass Power Plants,* Appel Consultants, prepared for NREL, EPRI, and Western Regional Biomass Program, No Date, online at www.westbioenergy.org/lessons/les01.htm; see also http://www.eere.energy.gov/biomass/biomass_feedstocks.html.

costs), so it is important to integrate these steps into the overall design of a biomass energy system.[65] Incoming wood must be weighed, offloaded, stored for processing, screened for size reduction and metals/non-wood materials removal, stored longer term, metered as fuel, and conveyed into the conversion system. There are generally two ways of storing wood residue: covered storage such as open sided buildings, bins or silos; and outdoor storage in piles on concrete or gravel pads.[66] The specific type of storage will depend on required moisture content, frequency and reliability of deliverables, climatic conditions, and the on-site volume of wood residue required by the design and function of the conversion system itself. An optional step in handling between offloading and energy production is drying, which would be located just before the boiler or gasifier to treat the wood immediately before conversion.

Wood Residue Densification

There are ways to increase wood's energy density and thus make each transported pound worth more, while at the same time making the shape of the biomass fuel easier to transport in bulk. In some places where the economics of energy and relative abundance of wood have created a market for wood residue products that can be transported over long distances, it has proven worthwhile to expend energy to densify wood. Densification is the process of taking wood residue and/or by-products and processing them into a product that has a higher Btu content per unit of weight or volume. This can be done by processing wood residue into uniformly sized particles that are then compressed into pellets or briquettes; or it can be done by processing these particles into a liquid through a pyrolysis process.

When wood residues are densified, their Btu content is enhanced and handling, transportation and feeding of combustion systems are also improved.[67] One benefit of densification is shown in residential pellet systems where densified fuels has enable the conversion technology to dramatically reduces emissions as compared to standard fireplace and stove technology (see Table 4).[68] The cleanliness and efficiency of pellets and briquettes indicates their potential utility in small scale bioenergy for businesses, local governments, public institutions (schools, hospitals, universities), and small industry.

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[65] Phillip C. Badger, *Processing Cost Analysis for Biomass Feedstocks*, Oak Ridge National Laboratory, 2002, p.15.

[66] C.H. Murray, *Energy Conservation in the Mechanical Forest Industries*, Food and Agriculture Organization of the United Nations, Forestry Department 1993, online at http://www.fao.org/docrep/T0269e/t0269e08.htm.

[67] "Wood Densification," Publication No. 838, West Virginia University Extension Service, Southeastern Regional Biomass Energy Program, 1988; "Heating your home with wood pellets," Wisconsin Focus on Energy, 2002, online at www.focusonenergy.com.

[68] David Broderick and James Houck, *Emissions Inventory Improvement Program (EIP) Residential Wood Combustion Coordination Project*, OMNI Consulting Services, Inc., prepared for Mid-Atlantic Regional Air Management Association (MARAMA), October 13, 2003.

Table 5—Wood Combustion Emissions by Technology[69]

Wood Burning Equipment	Emissions Factors (pounds per ton burned)					
	PM10[d]	NO_x	CO	VOC	SO_2	NH_3
Fireplaces; Outdoor Equipment[a]	34.6	2.6	252.6	229	0.4	1.8
Non-Catalytic Woodstoves: Conventional[b]	30.6	2.8	230.8	53	0.4	1.7
Non-Catalytic Woodstoves: Low-Emitting[b]	15.4	2.0	123.9	13.5	0.4	0.9
Non-Catalytic Woodstoves: Pellet-fired[c]	**4.2**	**13.8**	**39.4**	**N/A**	**0.4**	**0.3**
Boilers and Furnaces	28.8	2.6	252.6	229	0.4	1.8

[a] Includes masonry heaters. Masonry heaters were not broken out from fireplaces in the survey. Includes all outdoor wood-burning equipment (e.g. fireplaces, chimneys, barbecues, fire pits). Emission factors for fireplaces are used.

[b] These source classification codes are proposed for non-certified and certified woodstoves, respectively.

[c] These include both certified and exempt pellet stoves. PM10/PM2.5 and CO emission factors are for certified pellet stoves based on the review by OMNI (1998). Emission factors for NO_x and SO_2 are taken for certified pellet stoves (emission factors for exempt stoves not available).

[d] This study equates particulate matter emissions at the 10 micron and 2.5 micron level. However, most transport studies distinctly separate them, and Clean Air Act regulations require measurement of both types separately to determine compliance (attainment).

Pelletizing wood and other biomass feedstocks is a technique widely used in Japan, Scandinavia, and parts of Europe that has helped overcome the barriers to transportation of wood fuels.[70] Other countries have greenhouse gas and pollution taxes that are far more restrictive than in the United States, creating incentives to embrace biomass fuels that might seem too expensive in our domestic context. However, as long-term patterns in US pollution policy tend to mimic European standards, it is instructive to note that affordability is not inherent in the feedstock itself, but in how energy itself is regulated and valued at the local, state and national levels. In addition, changing markets for heating oil and natural gas have inspired changes in energy use: pellet manufacturers in the US have grown at over 30% per year, and pellet stove sales soared over 50% in 2005.[71]

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[69] Megan Schuster and Stephen Roe, "Survey of Residential Wood Combustion Activity and Development of an Emissions Inventory for the MANE-VU Region," prepared for the National Emissions Inventory Conference, June 10, 2004 (www.marama.org).

[70] Matthew Griffiths, "Pellets appeal," *Renewable Energy World*, February 3, 2005.

[71] Paula Tracey, "Jaffrey firm puts mills' byproducts to good use," *New Hampshire Union Leader*, May, 9, 2005; Katharine Webster, "Wood pellet stoves selling fast as home heating oil prices rise," Associated Press, September 13, 2005.

Conversion Technologies

Plants convert solar energy into chemical energy via photosynthesis. In order to animate the various appliances, machinery, and amenities of their daily lives, humans design methods to convert that stored chemical energy into power—also defined as the ability to do work. Conversion processes release the energy locked inside organic materials through the use of heat and pressure, making it available for human use. There are several processes for converting biomass to energy including direct combustion, co-firing, gasification, and pyrolysis. Moisture content of the fuel has implications for how much of the energy embodied in biomass can be converted to useful work. The following section briefly explains the role of moisture content and provides an overview of conversion technologies.[72]

Moisture Content and Energy Content

The ease with which different types of wood residues are processed and converted to energy varies depending on the type of residue and its moisture content. Moisture content affects handling costs and conversion efficiency. Moisture content (MC) is the percentage of wood mass that is water. Vaporizing water to steam requires a heat input of 1000 Btu's per pound. This means that a portion of the energy in the wood is used to eliminate the water. Consequently, lower moisture content implies higher energy content. Freshly cut wood can have a moisture content of almost 50% and significantly lower energy content per unit of weight.[73] Green chips (45% MC) have a gross heating value of 4,800 Btu's per pound. Dry sawdust (13% MC) has a gross heating value of 7,000 Btu's per pound. Dense and/or wet wood weighs more than dry wood, and consequently is more costly to transport. Densified fuel such as wood pellets normally contains about 8,000 Btu's per pound (8% MC). Unless otherwise mentioned, the report uses a 20% moisture estimate as a standard wood fuel condition.

Direct Combustion

Direct combustion—the burning of biomass materials—is the primary process used to convert biomass into useful energy. A furnace and heat exchanger together make a boiler system; wood fuels combusted in the boiler create heat. The heat itself can be used in cooler climes, such as with water pipe indoor heating. Alternately, steam produced during the combustion process can be used to turn a turbine and generate electricity.

The surplus heat escaping from the process can be used for space heating of associated plant spaces, used to power industrial processes, or directed to turn a turbine for electricity generation.[74] These systems that both produce electricity and capture waste heat are called combined heat and power (CHP) systems. While there are methods for boosting energy conversion efficiency to 40%, actual boiler efficiencies typically range around 20-22% efficiency for electricity.[75] However, when used in a CHP application, wood-to-energy systems can have conversion efficiencies of over 60%.[76]

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[72] This section draws on J. Aabakken, *Power Technologies Data Book, 2003 Edition*, National Renewable Energy Laboratory Publication TP-620-36347, June 2004.

[73] "Fuel Value Calculator," 5th Edition, produced by USDA Forest Service, Forest Products Laboratory, and the Pellet Fuels Institute; accessible at the US Forest Service website: http://www.fpl.fs.fed.us/documnts/techline/fuel_value_calculator.pdf.

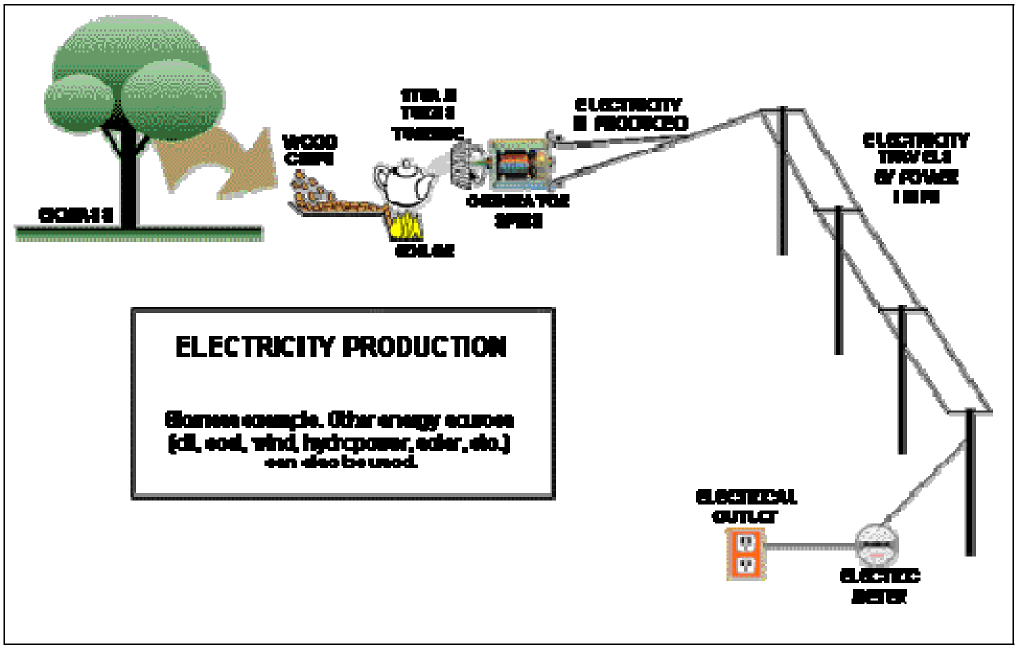
[74] Biomass Energy Technology, Wood Energy Data, Regional Wood Energy Development Programme in Asia, online at http://www.rwedp.org/d_technodc.html.

[75] Renewable Energy Technology Characterizations, EPRI Topical Report # TR109496, December 1997, "Direct Fired Biomass" and "Gasification-Based Biomass"; online at www.eere.doe.gov/consumerinfo/tech-reports.html.

[76] Lew McCreary, USDA Forest Service, personal communication, September 30, 2005.

Figure 6—Electricity from Wood Combustion

Source: State of Hawaii, Department of Energy.



The four major burner types associated with combustion are described below[77]:

Pile burner: Used in boilers burning wood with up to a 65% relative moisture content, pile burners are fed as biomass is dumped down a chute onto a pile. The biomass is dried in the heat in the refractory-lined chamber. Biomass is partially burned by underfire air, and the volatile gasses are driven off to be burned in a secondary chamber by an overfire air injection.

Grate burner: In this most common type of burner, combustion takes place, combined with stokers, on a grate. The types of grates used to support fuel beds include reciprocating, stationary, sloping, and moving grates. The thin pile of fuel on a grate burner allows more uniform air distribution compared to a heaped pile. In this situation, combustion rates can be increased more rapidly, eliminating particulate problems related to fuel dropping onto the fire. There are four main types of stokers: spreader, underfeed, traveling grate, and sloped grate stokers – the spreader stoker being most commonly used. As biomass is fed into the furnace, some of it burns in suspension while the larger pieces fall onto the grate where it burns. The ash on the grates and air blowing through the grate keeps the grate cool.

Fluidized bed: Fluidized bed burners burn the wettest and dirtiest fuels and can take fuels with a wide variety of particle sizes. The bed is comprised of an inert material like sand or limestone. The biomass is injected into the bed (which was initially preheated) where it is ignited by contact with the hot bed.

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[77] Appalachian Hardwood Center, "Overview of Wood-Fired Boiler Use in West Virginia," Fact Sheet 16, April 1998; online at http://www.wvu.edu/~agexten/forestry/fact16.pdf.

Combustion air is added to the furnace under pressure greater than the pressure required to cause the bed to levitate, which forces the bed into a fluidized motion. Provided combustion temperatures are kept low, this system prevents the production of NO_x. Exhaust gases, however, still contain more particulate matter than other types of furnaces. Fluidized bed burners are rapidly becoming the preferred technology for plants >10MW because of their clean and efficient combustion characteristics.[78]

Suspension burner: Combustion occurs when biomass particles are suspended pneumatically in air. Biomass will have to be passed through a hammer mill, reducing particle size, in order to use densified biomass. Wood chips and green mill residue must be dried and sized, as particle size of biomass is crucial. A pinhole grate may be installed to catch biomass that falls to bottom of the furnace without being burned. Suspension burners usually burn at 80 percent efficiency.

Co-firing

Co-firing involves the simultaneous combustion of different fuels in the same boiler. While the capacity of the boiler does not change, the amount of emissions generated by creating the same amount of energy decreases. Biomass substitution usually ranges from 10-15% of required fuel supply.[79] Because clean biomass feedstocks like wood are relatively low in sulfur and other harmful materials, they have often been mixed with coal firing to reduce sulfur dioxide emissions that contribute to acid rain. In addition, because biomass grows through the utilization of carbon dioxide, the (sustainable) use of biomass feedstocks is considered carbon neutral and does not contribute to greenhouse gas emissions.[80] Biomass co-firing has been successfully demonstrated in the full range of coal boiler types, including pulverized coal boilers, cyclones, stokers, and bubbling and circulating fluidized beds. Co-firing biomass feedstocks, such as wood residue, with more traditional fossil fuels, such as coal, assists in emissions reduction for the fossil fuel. Fluidized bed combustors can achieve emission factors of half or less than grate burners for all monitored pollutants in a co-firing scenario.[81] The energy conversion efficiency of biomass-coal co-firing ranges between 33-37%.

Gasification

Gasification systems operate differently than boilers in biomass-only or co-firing systems that directly burn the biomass. Gasification requires the use of high temperatures [yet below that required for combustion] and an oxygen-starved environment to convert biomass into a gaseous mixture of hydrogen, carbon monoxide, and methane). The product gas can be used to generate heat and electricity by direct firing in engines, turbines and boilers after it is “scrubbed” to remove particulates and problem chemicals. Alternatively, the product gas can be reformed to produce fuels such as methanol and hydrogen for fuel cells.[82] The cleaned gas can then be used to fuel combined cycle (IGCC) power generation systems, which are up to three times more efficient than combustion systems (60% conversion efficiency for combined cycle versus

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[78] *Bioelectricity Vision*, 2004, pp.5-6.

[79] Renewable Energy Technology Characterizations, December 1997, “Biomass Co-firing.” Online at www.eere.energyh.gov/consumerinfo/pdfs/bio_co_fire.pdf, p.2-35.

[80] M.K. Mann and P.L. Spath, “A Life Cycle Assessment of Biomass Cofiring in a Coal-Fired Power Plant,” *Clean Production Processes 3* (2001), p.81-2.

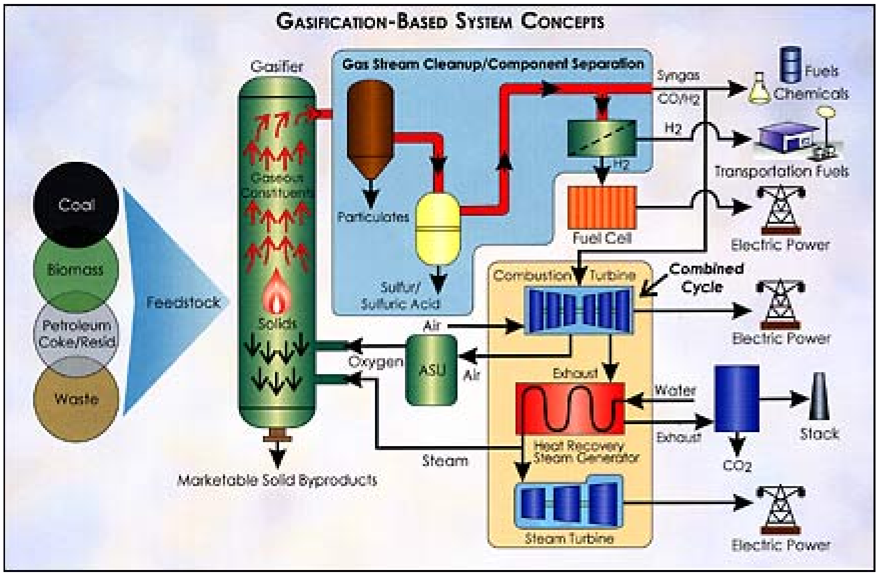
[81] G. Morris, “The Value of the Benefits of US Biomass Power,” Green Power Institute, Berkeley, CA; NREL, 1999.

[82] *Bioelectricity Vision*, 2004, p.6

20% for combustion).[83] Gasification-based systems may present advantages compared to combustion in terms of clean and efficient operation and economies of scale.

Figure 7—Gasification System Process Flow

Source: US Department of Energy.



Internationally, gasification has provided hope for clean energy systems based on biomass. As reported in WWF *Bioelectricity Vision*: "Hundreds of small-scale fixed bed gasifiers are in operation around the world, in particular in developing countries. Recent gasification activities, mainly in industrialised countries, have focused on fluidised bed systems, including circulating fluidised bed systems. Larger systems coupling combined cycle gas and steam turbines to gasifiers (biomass integrated gasification combined cycle, BIG/CC) are at the demonstration stage. BIG/CC systems could lead to electrical efficiencies of about 50%."[84] With such successes worldwide, in combination with significant investment in gasification technologies by the US Department of Energy, gasification seemingly should be more prevalent in the United States. However, investment does not necessarily lead to deployment: Few gasification systems operate commercially in the US.

One notable example is the Vermont Battelle/FERCO project. This installation employs the low-pressure Battelle gasification process in which the biomass is converted into a gas and residual char at a temperature of 850°C, and a combustion reactor burns the residual char to provide heat for gasification. Circulating sand between the gasifier and combustor provides heat transfer between the reactors. This project has proved reliable, but the overall reliability of gasifiers has not been consistent enough at large-scale facilities to encourage more investment.

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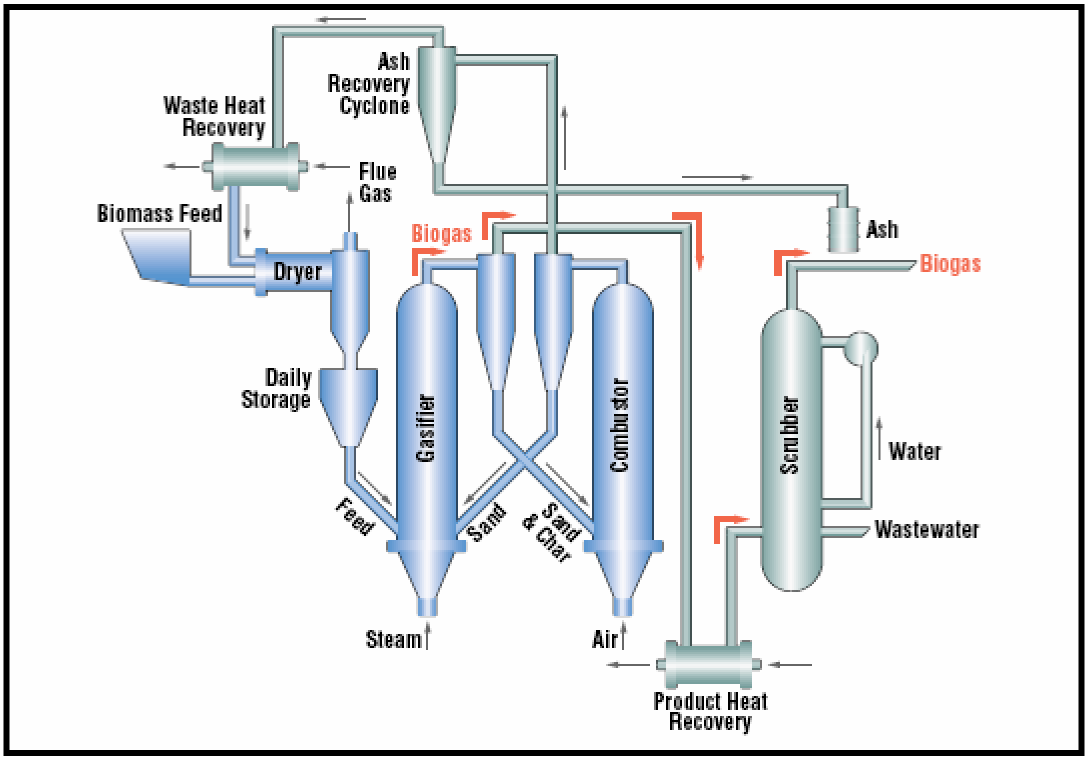
[83] The same quantity of biomass utilized would create nearly twice as much energy (10-20% boiler efficiency vs. 25-40%+ gasifier efficiency; R. Sims and J. Gigler, "The Brilliance of Bioenergy," *Renewable Energy World*, Jan-Feb 2002.

[84] *Bioelectricity Vision*, 2004, p.6.

Figure 8—Vermont Battelle/FERCO Gasifier

Source: National Renewable Energy Laboratory.



Pyrolysis

Like gasification, pyrolysis is thermal decomposition occurring in the absence of oxygen. The processes are similar enough that the reaction temperature and the composition of the byproducts are the main indicators of difference. Lower temperatures and a short vapor residence time in the processor define the “fast pyrolysis” reaction, which produces bio-oils that can be used for heating or transportation. Conversely, higher temperatures and long residence times characterize gasification. Fast pyrolysis for liquids production is of particular interest currently as the liquids are transportable and storable. These features allow biomass to be converted into bio-oil at one location and used for energy or chemicals in another location, something that gasification or direct combustion processes cannot do.

Table 6—Typical yields from different modes of wood pyrolysis (dry wood basis)

Source: IEA Biomass Pyrolysis Network.

Mode	Conditions	Liquid	Char	Gas
Fast pyrolysis	moderate temperature, short residence time (particularly vapour)	75%	12%	13%
Carbonization	low temperature, very long residence time	30%	35%	35%
Gasification	high temperature, long residence times	5%	10%	85%

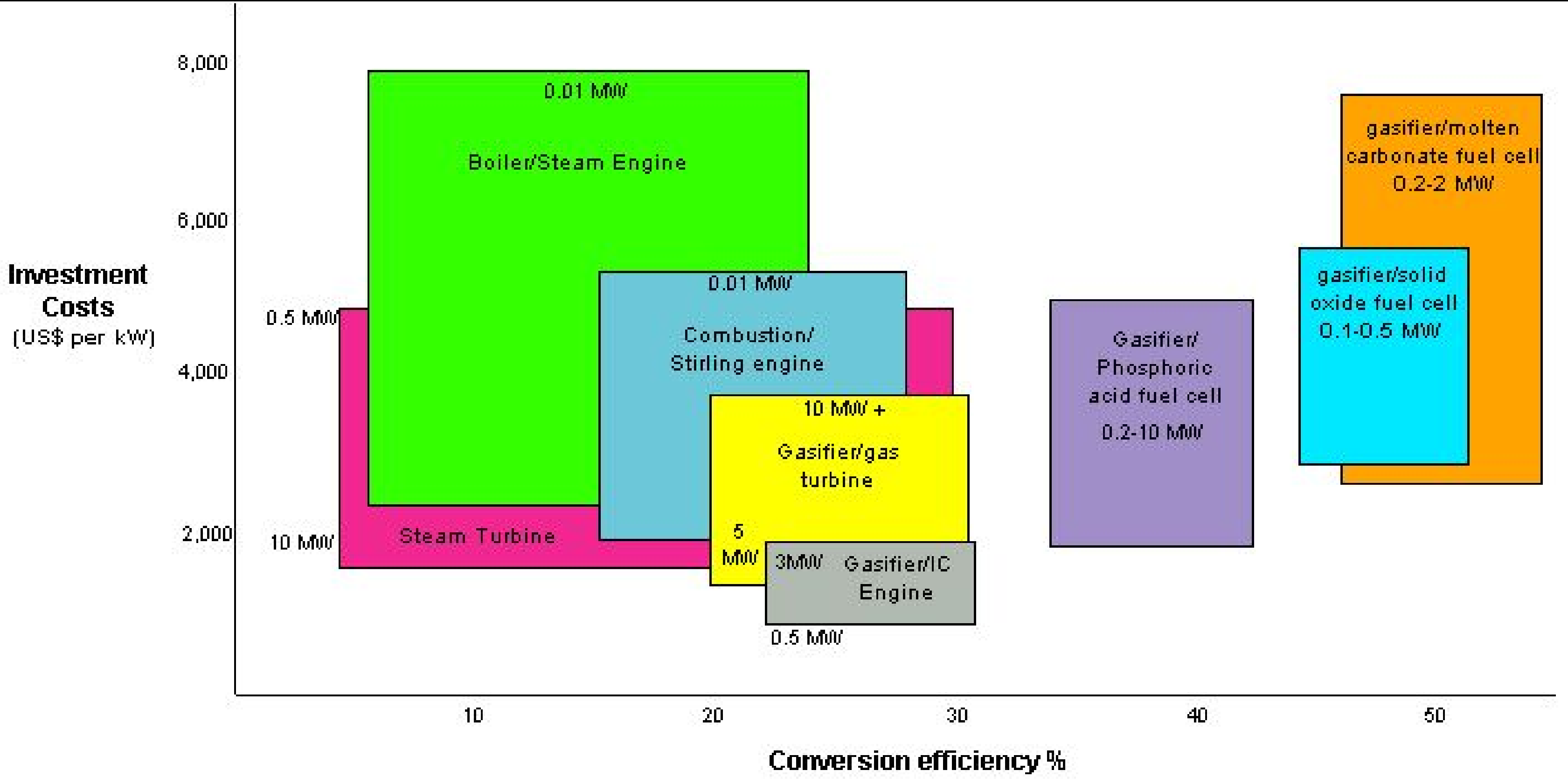
Pyrolysis requires finely ground, very dry feedstocks. While most work has been carried out on wood due to its consistency, virtually any form of biomass can be considered for fast pyrolysis. The ability of mobile pyrolysis units to convert wood residues to a densified bio-oil while operating in the field makes it an excellent prospect for addressing invasive woody species removal or reducing the wood processing burden caused by pests like the emerald ash borer.

Economies of Scale and Economies of Efficiency

Technology choices require assessment of available capital and equipment cost, combined with specifications for the appropriate size. In general, steam turbines and boilers have been the most popular mechanisms for converting wood to energy. These technologies both benefit significantly from economies of scale. Figure 9 displays the costs of various conversion technologies over a range of conversion efficiencies, focusing on small scale bioenergy (<10MW). At this scale, small boilers can be incredibly expensive per kilowatt investment. However, gasifiers are not subject to strict economies of scale. Figure 9 also shows that at any efficiency, gasifier prices increase with size. Therefore, while boilers are well-tested and versatile, returns to scale can make smaller boilers expensive. Gasifiers can be economically justified in a variety of sizes, making them more modular and ideal for less centralized energy production throughout cities or rural areas.

It is also important to note that scale and capital cost are not the total determinants of the cost of energy produced. This figure clearly shows that gasification technology has higher conversion efficiency on average than boiler technology, although the two technologies do overlap in price and efficiency options. While a 10MW steam turbine system can be built for less than $2,000/kw, the conversion efficiency on such a technology might be at the lower end of boiler technology options—less than 10%. At the same time, a 10MW gasifier could cost twice as much, but may have double or more the conversion efficiency, making the difference between the options less obvious without more information about other factors such as fuel options and availability.

Figure 9—Comparison of cost, efficiency, and size for a range of small-scale bioenergy technology systems



Source: R. Sims and J.Gigler, "The Brilliance of Bioenergy," *Renewable Energy World*, Jan-Feb 2002.

Benefits of Wood Residue versus Standard Fossil Fuels

Environmental impacts

The potential environmental benefits that can arise from utilizing well-managed biomass energy feedstocks as opposed to fossil fuels include:

- lower emissions of certain criteria pollutants compared certain fossil fuels;
- lower emissions of criteria pollutants and greenhouse gas emissions compared to other wood residue uses;
- CO_2 neutrality.[85]

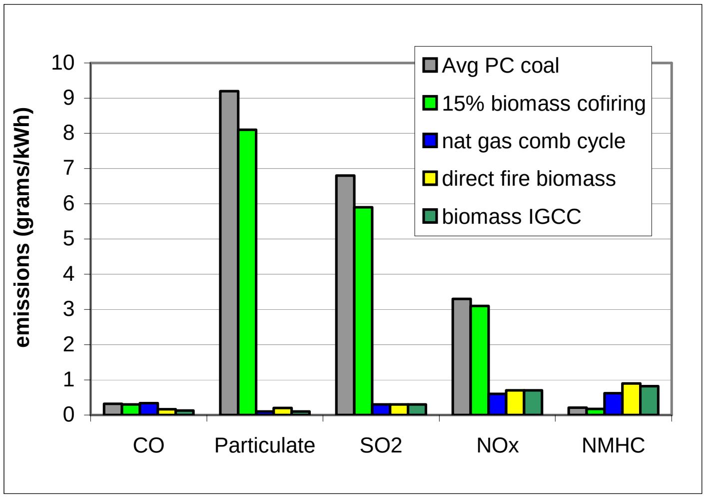
This section explores each of these benefits in turn.

Air pollution: Wood Residue versus Fossil Fuel Feedstocks

The actual "greenness" of biomass fuels such as wood is frequently called into question due to perceptions of biomass energy emissions. In some cases, the negative perception that using biomass for fuel is highly polluting are well-founded: open burning and residential firewood use have exacerbated smog in many cities and prompted no-burn days announced by local weather stations. Clearly, biomass energy technologies do not involve open burning. Nevertheless, combustion of any material creates some quantity of harmful emissions. Given this reality, the questions we need to ask about wood residue energy to assess its impact on the environment are: (1) what is the life-cycle emissions profile of biomass energy production in comparison to the coal or natural gas energy for which it would substitute; and (2) are there remedies for emissions generated by biomass energy production?

Figure 10—Biomass Energy Life Cycle Emissions

Source: Mann and Spath, 2004.



With regard to the first question, biomass energy resources like wood residue compare quite favorably with coal and natural gas in terms of their contribution to criteria pollutant emissions regulated by the Clean Air Act. NREL research demonstrates that, with the exception of non-methane hydrocarbons, biomass combustion or dedicated biomass IGCC dramatically decrease emissions criteria pollutant emissions when compared to a coal emissions baseline.[86] In fact, in all criteria pollutant categories, the biomass energy technologies are almost identical to the emissions for natural gas, which is touted as the cleanest fuel available today. Replacing coal with biomass nearly

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[85] *Bioelectricity Vision*, 2004, p.35. The use of forestry residuals and select debris can reduce forest fire risk; in addition, if energy crops are utilized on degraded or partially agricultural lands, other benefits include soil and watershed protection, and enhanced habitat to protect biodiversity

[86] Margaret Mann and Pamela L. Spath, "A Comparison of the Environmental Consequences of Power from Biomass, Coal and Natural Gas," Presentation at the Energy Analysis Forum (Golden, CO, May 29-30, 2002); online at www.nrel.gov/analysis/pdfs/m_mann.pdf.

eliminates particulate and sulfur emissions. Co-firing only 15% biomass with coal can reduce emissions of coal-fired power plants between 6 and 20 percent.[87]

Table 7—Co-firing and Biomass Combustion Emissions *Reductions* compared to Pulverized Coal (grams/kWh)

Source: Mann and Spath, 2004.

Technology	CO	Particulate	SO_2	NO_x	NMHC
15% biomass cofiring	6%	12%	13%	6%	19%
100% biomass	50%	98%	96%	79%	-329%

Other data from advanced industrialized countries demonstrate some variation from these findings in that NO_X and CO emissions from biomass are greater than that of coal, depending on the technology used. European cases suggest that well managed biomass plants tend to hold close to coal-fired emissions in NO_X and CO, however, and the overall pattern of low particulates, very low sulfur, and low volatile organic compounds still holds.[88]

With regard to the second question of emissions unique to woody biomass, there are valid concerns regarding non-regulated pollutants from any form of combustion. Wood that contains certain preservatives or that contains certain contaminants from industrial processes can cause environmental risks if added to the combustion process. When exposed to heat, the contaminants volatilize into toxins harmful to human health. These materials also prevent the processing and use of ash, char, and other combustion products that may have commercial value.[89]

For clean and efficient energy production, the best practice is to prevent contaminated materials from entering the wood residue-to-energy supply chain. There are also strong short-term, direct incentives to energy producers and their suppliers for careful oversight of feedstock supply: Treated wood materials can also transform into chemical compounds that corrode or otherwise damage the conversion facility itself. Wood energy facilities in Michigan and nationwide have well-established practices of manual inspection at offloading, in which even a very small amount of a suspicious substance can merit turning away contaminated loads.[90] There are also metals screening techniques that remove nails and other contaminants as the wood residue is sorted by size and processed before conversion. Finally, most wood energy facilities will not accept any sort of demolition wood, and often bar generally cleaner construction residues as well.[91]

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[87] "Wood energy can compete well with oil, natural gas and coal. The prices paid by fuel users invariably do not reflect society's total cost of production and consumption. These additional costs, known as externalities, include the costs of air and water pollution and hazardous and non-hazardous waste disposal. When these externalities are counted in energy costs, wood fuel becomes even more inexpensive. Estimated environmental costs from wood were less than 1 cent per kilowatt hour, higher only than solar and wind energy." *Waste: A Hidden Resource*, Special Report 67: Status and Potential of Michigan Natural Resources (SAPMINR), Michigan Agricultural Experiment Station, MSU, January 1995, online at http://www.msue.msu.edu/msue/imp/modsr/03239567.html.

[88] *Bioelectricity Vision*, 2004, p.36-7.

[89] Lew McCreary, USDA Forest Service, personal communication, September 30, 2005.

[90] Andy Vajcner, Central Michigan University Plant Manager, personal communication, December 2004; Westbioenergy, *Lessons Learned from Existing Biomass Power Plants*, Appel Consultants, prepared for NREL, EPRI, and Western Regional Biomass Program, No Date, online at www.westbioenergy.org/lessons/les01.htm; Badger 2002.

[91] Some large recycling companies have the capital and workforce to accept C&D residues. Tierra Verde Industries (TVI) helps smaller California municipalities meet California's 50% waste diversion goals (50%). While its primary feedstock is green residues from land clearing, landscaping, and residential wastes, it also has high-technology screening equipment that makes

Ultimately, the efficiency of the conversion technology used determines emissions levels. When the biomass fuel is combusted most thoroughly given the optimal air flow and temperature, fewer emissions result.[92] In addition, large-scale biomass energy production facilities include best available technologies such as scrubbers in order to capture particulates and other pollutants that do result from combustion.

Gasification technology is not commercially deployed in Michigan at this time. However, information from gasification projects in other states and countries demonstrate that emissions from gasification are lower than from combustion of fossil or biomass fuels.[93] Specifically, the lower temperatures needed for the initial stages of gasification prevent the formation of nitrous oxides, and the conversion of biomass to gaseous form allows more complete combustion.

Air pollution: Wood Residue-to-Energy versus Other Waste Outcomes

The above examples compare emissions by energy conversion technology and feedstock. However, in considering wood residues and biomass residues more generally, it is important to consider the pollution consequences of **not** using these residues for energy. In a 1999 study for the National Renewable Energy Laboratory, extensive data from the large California biomass energy market demonstrated that using biomass for energy diverts wastes from more polluting fates in landfills or even open burning.[94] This includes pollution from forest fires compared to capturing and using the understory fire load to fuel a boiler that has good emission controls.

Greenhouse Gases and Carbon Balance

Burning both biomass and fossil fuels causes carbon dioxide (CO_2) emissions. However, unlike fossil fuels, biomass fuel feedstocks grow back and absorb about the same amount of CO_2 emitted. Sustainable biomass resource production through residuals processing or energy crops production will produce few, if any, CO_2 emissions above that which are taken in during the biomass life-cycle.[95] As a result, biomass co-firing has been embraced by many industries as a voluntary means for reducing their greenhouse gas emissions.[96] This could create tax credits for power plants if legislation is passed for CO_2 and/or other greenhouse gas emissions.[97]

Another less frequently mentioned benefit aside from reducing coal-based greenhouse gas emissions is the diversion of biomass from other end uses that produce even more greenhouse

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C&D residues an acceptable input to some of their products; Larry Trojak, "The Many Shades of Green," *Biocycle*, September 2005, pp.27-28.

[92] The exception to this rule is emissions of nitrous oxides (NO_x). Higher temperatures can combust biomass more thoroughly, but are also conducive to NO_x formation.

[93] "Biomass Gasification," DOE-EERE, online at http://www1.eere.energy.gov/biomass/gasification.html.

[94] G. Morris, *The Value of the Benefits of Biomass Power*, NREL/SR-570-27541, November 1999.

[95] "A major benefit of substituting biomass for fossil fuels is that, if done in a sustainable fashion, it would greatly reduce emissions of greenhouses gases. The amount of carbon dioxide released when biomass is burned is very nearly the same as the amount required to replenish the plants grown to produce the biomass. Thus, in a sustainable fuel cycle, there would be no net emissions of carbon dioxide, although some fossil-fuel inputs may be required for planting, harvesting, transporting, and processing biomass. Yet, if efficient cultivation and conversion processes are used, the resulting emissions should be small (around 20 percent of the emissions created by fossil fuels alone). And if the energy needed to produce and process biomass came from renewable sources in the first place, the net contribution to global warming would be zero." From "Environmental Impacts of Renewable Energy Technologies," Union of Concerned Scientists, updated 2002, online at www.uscusa.org.

[96] *Renewable Energy Technology Characterizations*, December 1997, "Biomass Co-firing," pp.2-37, online at www.eere.energy.gov/consumerinfo/pdfs/bio_co_fire.pdf.

[97] "Fossil CO_2 reductions are currently being pursued voluntarily by utilities in the U.S. through the federal government's Climate Challenge program. These utilities may be able to receive early credit for their fossil CO_2 emission reductions for future use in the event that legislation is passed which creates market value for CO reductions." Ibid.

gases than using them for energy.[98] As with other emissions mentioned above, overall greenhouse gas emissions from biomass fuels are less than from other transformations of that same biomass. In the short term, biomass used for fuel will add more atmospheric CO_2 than if it were buried in landfill, but over time the landfill will out-gas CO_2. In addition, landfills also emit methane (CH_4), and its greater radiative effectiveness as a greenhouse gas creates a more serious long-term burden.

Employment Impacts

As noted earlier, wood residue feedstocks are ideal for smaller, decentralized systems where conversion facilities are located near the biomass resource itself. Biomass energy facilities utilizing wood residue can help bolster jobs in rural areas with resource-dependent economies, which are usually characterized by slow economic growth. An analysis of biomass energy potential in OECD countries suggested that a shift to biopower would help rural economies:

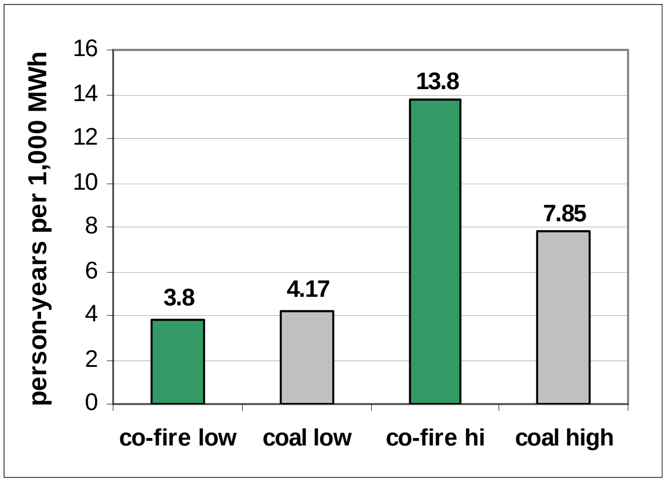
> *"…the use of biomass energy has some employment benefits over using fossil fuels at a national level if there is a substantial employment generation effect from producing the biomass fuel, especially if it substitutes imported fuels. But, the greatest value of bioelectricity schemes with regard to employment lies in the fact that quality jobs could be generated where there is great need for them, in particular in rural areas where job maintenance and creation and economic growth are of issues of concern."*[99]

Recent studies using only data from the United States show that both power plants and fuel production operations provide rural jobs with good comparative wages and benefits. In addition, there are almost twice as many supporting jobs than in the plants themselves, with total employment equal to 4.9 fulltime jobs per each megawatt of net plant generating capacity.[100]

Despite the fact that co-firing uses biomass feedstocks with coal requires far less biomass feedstock than coal, the utilization of up to 10-20% biomass also enhances local economies. Figure 11 compares biomass co-firing needs with coal mining needs, since both require essentially the same plant type and job functions after the fuels are processed. The low labor scenarios for biomass co-firing include mill residues and some types of urban wastes; high labor scenarios include biomass plantation operations involving larger-scale and more frequent transportation and processing. One study also notes that labor-intensity of coal production dropped 39% from 1988 to 1998, and is estimated to fall another 36% by 2008.[101]

Figure 11—Biomass Co-Firing vs. Coal Mining, Low and High Labor Scenarios

Source: Singh and Fehrs, 2001.



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[98] Margaret Mann and Pamela L. Spath, "A Life Cycle Assessment of Biomass Cofiring in a Coal-Fired Power Plant," Clean Production Processes 3, (2001) pp. 81-91; the authors highlight that cofiring biomass prevents the methane formation that would otherwise occur if that same volume of wood underwent decomposition in mulch applications or in a landfill.

[99] *Bioelectricity Vision*, 2004, p.26.

[100] Morris 1997.

[101] Virinder Singh and Jeffrey Fehrs, *The Work That Goes Into Renewable Energy*, Renewable Energy Policy Project Report #13, November 2001; labor figures p. 21.

Consequently, the numbers in Figure 11 are likely to shift more in favor of biomass co-firing. Finally, coal mining is a dangerous industry whose regulations are poorly enforced. Death on the job, long-term respiratory illness, and destruction of community water supplies and ecosystems are the hallmarks of coal extraction.[102] In terms of quality of life, biomass clearly benefits local communities and workers more than coal.

While more attention has been focused on the need for steady jobs in rural areas, there are also opportunities for some urban jobs. Utilization of UTR could help provide a boost to employment to urban areas which are also host to unemployment problems. Municipalities and counties that design and implement UTR collection systems and support locally-based power production can also increase their employment figures while addressing landfill and energy problems.

Efficiency and Reliability Impacts

Employment is only one economic benefit provided by investing in biomass energy from wood residue. Local biomass feedstocks actually help produce cheaper energy for rural areas, creating a locally shared economic benefit. As energy production becomes less centralized, overall production becomes more labor intensive—but also more reliable and efficient in transmission.[103] For example, coal-based electricity costs run higher to remote areas due to the extra expense of transmission lines and infrastructure. It is also more expensive because the further electricity travels, the more is lost in transmission--which means **all** customers are paying the price for wasted energy. Up to 70% of electricity can end up as line losses—energy lost in transmission. Localized energy production in rural areas using biomass can help overall economic health of a region or state by enhancing systemic energy efficiency. Using locally based systems that complement highly centralized standard energy production is called distributed energy (DE) or distributed generation (DG).

A 1999 study of 275 DG systems found that electricity supply needs and deferral of transmission/distribution system upgrades were the two primary reasons for supporting distributed energy.[104] DG is also an excellent opportunity for integrating locally based biomass energy systems into the overall energy infrastructure. The shortcomings of biomass fuels due to transportation difficulties and being more closely “tied to the land” are much less of an issue when viewed from the perspective of the need for decentralized infrastructure that lets customers get what they pay for, instead of paying the majority of their bill for energy lost in transmission. Basing power on locally based biomass energy plants in this fashion would contribute to better power reliability and quality, lower energy costs, more choice in energy supply options, and greater predictability of energy costs (lower financial risk) with renewable energy systems.[105]

Such transformations will not be seamless. A shift toward biomass energy raises the prospect of dramatic structural shifts in fuel consumption patterns. Rural areas will take on a larger energy load, and centralized energy producers must adapt to new patterns of load and consumption in the overall system.[106] Yet over the longer term, significant use of renewable technologies would relieve fuel supply challenges with cleaner biomass feedstocks.

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[102] Jeff Goodell, “Cooking the Climate with Coal,” *Natural History*, May 2006, online at www.naturalhistorymag.com.

[103] Tom Stanton, Michigan Renewable Energy Program, MPSC, personal communications, January 2005.

[104] “Distributed Energy Basics: The DE Solution,” Energy Efficiency and Renewable Energy, Department of Energy, online at http://www.eere.energy.gov/de/basics/der_basics_dersol_bene_major.shtml.

[105] Ibid.

[106] “Executive Summary,” *Distributed Energy: Towards a 21st Century Infrastructure*, p. 7, Consumer Energy Council of America, accessed February 9, 2005 online at http://www.cecarf.org/Publications/MiscPub/DEExecSummary.pdf.

Outlook for Wood Energy in Michigan

Barriers to Wood Energy

If wood energy has so many potential benefits, the natural question is why isn't everyone using it? The more widespread adaptation of wood energy has been limited by certain physical properties of the wood itself, as well as by political and economic factors.

Energy Content: The primary conversion technologies currently used to extract energy from solid wood only reach 15-20% conversion efficiency. Newer technology is more efficient, and gasification shows even more promise. However, people will continue to view fossil fuels as a better investment because they can produce tremendous amounts of energy per volumetric unit conveniently and (at least until recently) cheaply.

Market accounting versus social accounting: Not all costs and benefits are incorporated in energy's costs. The cost of fossil-based electricity could be taxed to reflect higher public health costs imposed on society. Conversely, the cost of wood energy could be subsidized to reflect the need to continually replenish wood resources for a sustainable energy system.[107] The perception of fossil fuel energy as the most efficient and effective may change when environmental and public health costs can be incorporated into the price of energy and cease being considered externalities whose cost is displaced onto society.

Tastes and Preferences: People do not have to change any of their standard operating procedures to use fossil fuels even if they do cost more. In economic terms, demand for fossil fuels is somewhat inelastic, such that when prices increase people still will pay for that product because there are no substitutes. This can mean there really are no substitutes physically existing, or it can mean that there are no products that are considered substitutes because they are unacceptable for some reason in the eyes of consumers. These reasons can include simple inconvenience. This is true both of consumers, who are not actively seeking substitutes for fossil fuel-based heat or electricity, and of utilities, who are not actively prospecting wood resources to establish wood energy production facilities. Neither utilities nor consumers need change their standard operating procedures to use fossil fuels, even if they do cost more than wood systems will—once established. Change in itself is perceived as highly costly, and this perception helps explain why more effort has not been directed toward renewables by utilities that have specialized in non-renewables for decades.

Centralization: By their very nature, biomass fuels (excluding liquid fuels) are difficult to transport. Given our highly centralized and inefficient energy production/distribution systems, it is difficult to integrate biomass energy without higher transport and storage costs. Biomass fuels are by their nature more suitable to distributed generation systems. Transporting wood fuels over long distances is generally not economically prudent. Because of its handling and storage requirements, the initial cost of a wood biomass energy system is approximately 50% higher than that of a fossil fuel system, making a renewable energy system a more daunting investment prospect. Consequently, most wood energy systems require a systems approach to their design as an accessory to another function. In their daily operations, forest industries produce enough wood residue to fuel their own operations by installing wood-fired boilers or gasifiers. They thus avoid both higher energy costs as well as the time and costs associated with disposal of a "waste" product. Aside from forest products industries that often use wood

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[107] Robert Costanza et al., "The value of the world's ecosystem services and natural capital," *Nature* 387: 253-260, 1997; Reid J. Lifset, "Full Accounting: Where Industry Meets Ecology," *Journal of Industrial Ecology*, New York Academy of Sciences May/June 2000, online at http://www.greenbiz.com/toolbox/howto_third.cfm?LinkAdvID=23883.

on-site, many potential wood energy users are far removed from potential sources of waste or surplus wood that they might use. Decentralization of wood resources presents challenges to an effective supply chain, and in turn innovation and demand are depressed when obstacles seem too great to overcome.

Burden of the Past: Historically, there have been grave environmental and public health consequences from free wood burning, including dangerous particulate and air toxics emissions. Newer boiler technologies can prevent the majority of harmful emissions, and high-temperature gasification almost completely combusts wood feedstocks, leaving only small quantities of ash for disposal. While new combustion systems are cleaner and gasification is cleaner still, there is still a perception that wood energy might not be “clean enough” to be green. There is also the argument for natural gas. Despite clear emissions benefits over coal, there are still more emissions from wood as compared to natural gas. Natural gas is an abundant resource that does not contribute to our dependence on foreign oil, and that emits far fewer harmful substances than coal. Yet it is a still non-renewable resource whose price has become quite volatile. In northeastern and Midwestern states we see institutions with boilers switching to wood as a replacement for natural gas.

Unsustainable practices: If not harvested sustainably, wood feedstocks could erode and worsen the carbon balance. For wood energy to be truly renewable, sufficient planning and timing must accompany harvesting and processing in order to maintain or reduce greenhouse gas emissions. Without management, harvesting will cause further decline of forested areas that play a critical role in moderating climate change. In addition, the role of trees as part of functioning natural ecosystems maturing under particular local conditions must be respected if wood is to become a more useful energy feedstock in the United States without the destruction of valuable existence values of forests as whole entities that preserve biodiversity, atmospheric quality, critical landscape buffers against heat, wind and erosion, and as greenhouse gas sinks.

Benefits of Wood Energy

Despite the drawbacks, this report argues for the investment of time, money, and planning effort in policy development to support of wood residue-to-energy projects. Why should we invest in this form of biomass energy?

Energy security: International instability and volatile petroleum prices have raised questions about the wisdom of reliance on foreign energy resources. Wood is relatively plentiful in the United States, is suited to local energy production in a secure distributed generation framework, is available at low cost or no cost in urban areas as waste, and can also be made more plentiful through deliberate plantation planning as an energy crop.

Climate change and environmental quality: Standard fossil fuels generate carbon dioxide emissions that contribute to global climate change, but wood fuels emit less than 90% of the carbon dioxide than petroleum or coal. If wood replacement rates are correctly applied, wood energy can be carbon neutral. As for criteria emissions, newer technologies have reduced emissions from wood firing dramatically, and in the case of gasification, most emissions are nearly eliminated. Furthermore, wood and energy crop resources are relatively sulfur-free.

Sustainability: Wood can also be managed as a carbon-neutral renewable energy resource—otherwise known as closed-loop biomass fuel. Management considerations include a sustainable rate of harvesting forest scrub or damaged trees, as well as replanting to maintain carbon cycling at the pre-harvest rate. “Energy crop plantations” of poplar or willow have been successfully deployed outside the United States as closed loop biomass resources that extract as much carbon as is released by wood combustion or gasification. Ecosystem values, which are less quantitative but more critical in terms of species diversity and long-term forest health, are often considered a criterion for renewable resources.

Ecosystem Health: Distributed biomass markets can help provide local markets for woody biomass removed from forests to improve forest health. Removal of woody biomass can reduce hazards associated with wildfires, can make forests more insect and disease resistant, and can enable the removal of invasive species. Removal of this biomass material can also improve growth rates and increase removal rates for greenhouse gases.

Socio-cultural compatibility: Wood is the oldest and most well understood biomass resource next to manure. Both have been used for home heating cooking in pre-industrial societies worldwide, from ancient tribes in Europe and Africa, to early American settlers during the great Westward expansion, to rural settlements in Asia and Latin America today. Today, many citizens of industrialized countries still understand wood as a fuel, and some even use it regularly for heating and cooking in more remote areas or colder climes. They are disposed to accept wood (as opposed to manure, another traditional fuel) as a viable fuel option in lieu of petroleum or coal-based energy sources.

On-demand: Wood is a dispatchable energy resource, meaning it is available on-demand from a physical storage site, like gasoline and coal. Other renewables such as solar and wind energy are not dispatchable but intermittent. Some solar and wind energy may be stored in batteries, but the energy sources themselves cannot be controlled or stored. In other words, they are more of a “use it or lose it” source of energy, whereas wood and other forms of biomass can be set aside and protected for use in the future.

In summary, there is no silver bullet for our energy crisis. Yet despite the drawbacks, there are many compelling reasons to invest in wood residue-to-energy projects. Based upon its clean, renewable, and reliable energy characteristics, Michigan decision makers need to understand what wood residue resources we have, and what steps we can take to make them easier to use. The next section provides recommendations for growing the contribution of wood residues to Michigan’s energy portfolio.

Recommendations

Given the benefits illustrated above, combined with the presentation of proven and near-market technologies that can produce clean energy from biomass, what actions could foster increased biomass use in Michigan’s energy portfolio? In order to take concrete steps to increase biomass energy in Michigan, we must first assess Michigan’s level of wood energy readiness through resource and facility inventories and target market identification.

1. Michigan Wood Residue Inventory

While many studies of wood residue quantities have been conducted nationwide, Michigan does not have a recent study. For estimating renewable energy resource potentials, clearly there is a need for a more recent inventory of wood residues in Michigan. It would be even better to create a system for gathering this sort of information on a routine basis. Initial investment in information gathering will also help educate producers and consumers about alternative uses, and clarify the importance of energy conversion as part of an overall wood recycling program.

More importantly, a well-designed, replicable study of wood supply is necessary to support increased interest and investment in wood as an energy resource.

The response to the emerald ash borer infestation currently plaguing Southeast Michigan provides an opportunity for such a study. With money from USDA-USFS, the Southeast Michigan Resource Conservation and Development Office, in collaboration with MDNR, MDEQ, and MBEP, announced a request for proposals for study of urban wood residue with a focus on the dramatic growth in wood residue supply due to the emerald ash borer epidemic. This study will further the work done in *Urban Wood Residue in Michigan* (1994). However, due to resource constraints, this report will not be able to comprehensively establish wood residue market information throughout the state, as interviews and surveys only covered quarantined counties in southeast to middle-lower Michigan. Ongoing efforts to work with DNR and to conduct research through the Michigan Biomass Energy Program will be necessary to extract information about markets, prices and supply dynamics in more detail. This detail will hopefully create opportunities for brokers to aggregate and extract energy or other uses from hitherto undervalued wood residues. The SEMI-RCD wood residue assessment is expected in fall 2006. See Appendix B for more details.

2. Boiler Inventory

Boiler replacement is an ideal time for inserting biomass-ready technologies. An inventory of existing boilers in Michigan would identify boiler age and type. Some facilities have the types of boilers (under-fire stoker, traveling grate) that can use biomass fuels like wood with no or minimal modifications. Alternatively, more advanced technologies might replace the wood-to-energy systems dominated by these older boilers. Replacing them with advanced boiler systems, modern turbines, or even gasification- or pyrolysis-based power systems would nearly double energy production capacity from the same volume of feedstock. In these replacement scenarios, financial assistance from grants, loans, tax credits or bonding could be invaluable.

3. Wood Energy Target Markets

Looking at wood residue not primarily as a source of electricity, but as an opportunity fuel for replacement of heating oil and natural gas, specific energy users with long time horizons are prime candidates for conversion to wood energy systems. Schools, hospitals, prisons, cities, and other non-profit organizations do not operate on a three- to five-year payback mentality. Because they have a longer time horizon than business, they can look out fifteen or twenty years and appreciate the life-cycle costing and price stabilization that biomass energy systems can provide. They also have more to gain by investing in their communities. The Biomass Energy Resource Center of Montpelier, Vermont, helped Vermont schools pioneer the “Fuels for Schools” program 15 years ago; currently 10% of the state’s students are warmed by wood heat—and wood chip prices have increased less than 1% per year.[108] The program has expanded to five Rocky Mountain States as well. The model for institutional use of wood energy exists. In the current context of volatile gas and oil prices, many Michigan institutions could capitalize on the Fuels for Schools experiences in pursuit of stable prices with a renewable energy supply. The Michigan Biomass Energy Program can provide outreach and grant funding to help demonstrate the feasibility of institutional wood boilers. Incentives such as tax credits for biomass heating/cooling or “green” bonding of biomass boilers could advance such wood energy projects on a larger scale.

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[108] “School Wood Energy Programs,” Biomass Energy Resource Center, online at http://www.biomasscenter.org/services/school-wood-heat.html.

These first three items identify what Michigan already has—the ingredients, the existing technology, and target markets for small- and medium-scale wood use. The next six recommendations highlight processes, policies and incentives that can make conversion of wood residues to energy more feasible in Michigan.

4. Green Permitting

Some US cities allow for quicker building permitting if the project has a green component. For example, Chicago, IL and Madison, WI have streamlined “green permitting” processes that move such projects to the front of the permitting line. The State of Michigan might consider a similar sort of permitting shift for renewable energy projects. Specifically, if a boiler will be using renewable energy feedstocks like wood, and it is a proven technology with adequate emissions testing as approved by the DEQ-Air Quality Division, such projects could be promoted to a fast track, or be processed within a given timeframe, in order to provide incentives to would-be wood energy project developers in both the public and private sectors.[109] Some of the precursors to such a process, including the aggregation of testing information on biomass combustion technologies, are currently underway as part of a collaborative effort between MBEP and MDEQ begun in 2006.[110]

5. Higher Tipping Fees and Banning Wood from Landfills

Urban wood residue is the most underutilized and least understood category of wood residue. At the same time, urban wood residue/UTR has the most potential, and is conveniently located within jurisdictional boundaries of cities that already have waste management systems. The development of recycling systems for paper, glass, plastic and other materials took time, and was not free, yet recycling has become so popular and important to communities that people support it even at times when it loses money, as in New York. Similarly, some communities have initiated urban organic residue collection such as curbside leaves in autumn and grass clippings/yard trimmings in summer. However, such programs require a variety of education, incentives and penalties to achieve compliance before they become self-sustaining. This more comprehensive approach to recycling requires more time and money from the average citizen: recycling bags cost money, the service itself adds a fee to their waste management costs, and gathering the organics requires work—although perhaps not more work than it would take to put them into a dumpster or landfill.

One way to motivate communities and waste management concerns to re-use and recycle in productive uses like energy is to raise the state’s surcharge on landfilling, which would in turn raise tipping fees. Higher disposal costs will inspire innovation and redirect resources to higher value uses; ultimately, some communities, schools and institutions may even start their own wood energy projects in order to take advantage of wood residues in a context where they are too expensive to dump. In addition, banning wood from landfills altogether has been done in some states. Michigan could follow suit in order to target wood residues more specifically for diversion from the waste stream.

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[109] Thanks to Derek Price at Weston Solutions, Inc. for this concept.

[110] Randy Telesz, Michigan Department of Environmental Quality—Air Quality Division, personal communications, April and May 2006.

6. Net Metering

The production of energy by local facilities with abundant natural resource feedstocks can be fostered by net metering. A net metering consent agreement (Case No. U-14346) was filed with the Michigan Public Service Commission, and comment period closed on February 1, 2005. Net metering tariffs for some of Michigan's state-regulated electric utilities have already been accepted by the Commission Staff, and work is proceeding to finalize tariffs for the rest.[111] However, the resulting value of net excess generation (approximately three to six cents per kilowatt-hour) in combination with restrictions on production size to less than 30kW, and lack of assistance for integration of independent generation to the grid make this provision far less powerful than net metering rules in other states. In order to incentivize independent power production with clean, renewable biomass resources, six to seven cents has been the standard for net metering elsewhere. Michigan can learn from states that have been successful in diversifying their energy production, and a higher value on avoided costs of energy production for utilities is an important ingredient in the recipe for renewables.

7. Production Tax Credits

Renewable energy production tax credits provide incentives to developers that help buy down the cost of excess capital for new technologies. In the case of biomass, other special investments for fuel and ash handling fuel/ash handling must also be undertaken, and credits can reduce the burden of transitioning to biomass energy from wood residues. Tax credits have been pivotal to the establishment of the wind industry in the United States, and the continual battle to have the credits extended created instability and unwillingness to invest in the wind energy market periodically over the last 17 years since the credit was first established at the federal level by the Energy Policy Act of 1992. A long-term tax credit at the state level for biomass and other renewable energy projects is a low-cost incentive that legislators could authorize, that would help generate jobs, cleaner air, and energy security in Michigan.

8. Renewable Portfolio Standard (RPS)

An RPS is a market standard requiring the production of a set amount of renewable energy. While it is a form of mandate, the role of government is not to dictate who shall produce what energy, but only to provide the means for certifying that it is in fact produced. Renewable Energy Credits are tradable forms of proof that renewable energy has been generated; "The RPS requires all electricity generators (or electricity retailers, depending on policy design) to demonstrate, through ownership of Credits, that they have supported an amount of renewable energy generation equivalent to some percentage of their total annual kWh sales."[112] Investors and energy generators make decisions about how to comply with the RPS, and because it applies to all energy generators it is not an anti-competitive measure.

An RPS is a mandate, but the state's role is merely to certify production of renewable energy, and enforce penalties for non-compliance with renewables requirements. Some states have set parameters for which sorts of energy (biomass, wind, solar, hydro) will qualify and under what conditions, but aside from setting the ground rules there is little bureaucratic role in the renewable energy credits market once established. The state does not engage in dissemination

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[111] Michigan Public Service Commission, "Case No. U-14346—Net Metering Consensus Proposal," online at http://www.michigan.gov/mpsc/0,1607,7-159--105908--,00.html. The Michigan Renewable Energy Program also has a Net Metering section at http://www.michigan.gov/mrep.

[112] "The Renewables Portfolio Standard: How It Works and Why It's Needed," American Wind Energy Association 1997, online at http://www.awea.org/policy/rpsbrief.html#What.

of funds or promote any particular project, but the establishment of the credits market provides long-term security for project planning and investment. This long-term feature of Michigan's energy markets will attract large-scale energy producers to biomass energy production as they seek to improve their market position and develop an interest in driving down the cost of renewable energy through their own investment patterns and partnerships.[113]

Renewable portfolio standards focus on electricity generation, but creative arrangements could also be made to require a certain percentage of thermal energy be produced from renewables as well. Wood and other biomass are well-suited for heating since they have a stable price relative to fossil fuels and they can be stored more effectively than wind and solar energy. A thermal component of Michigan's RPS would provide tremendous incentives for collaboration on wood energy projects between utilities and larger consumers who are seeking ways to avoid the tremendous price risks of the volatile natural gas market.

9. Distributed Generation

Identifying the best applications of wood energy brings home the importance of "acting locally." Biomass resources are intimately linked to their local area. Precisely because oil and natural gas are easier to move, modern society broke the historical link with local energy production in the industrial age. We now have an overburdened and somewhat incoherent centralized energy infrastructure dominating all our productive activities in the United States. Our energy infrastructure is not very flexible, not responsive to local resource endowments, and not manageable in a modular way— in other words, vulnerable to accident or attack.[114] However, our federal system is based in part on the fact that lower levels of government are good at addressing tasks that require maximum flexibility. Similarly, many smaller units of energy production would add up to a large quantity of energy production, but being "distributed" among localities would make that energy more responsive to local conditions. In addition, local energy production is more "democratic" in that costs and benefits of that energy system are linked more closely to the service area itself. We need to reconceptualize energy in order to take advantage of a wealth of resources currently undervalued at these local production levels, and develop the security and flexibility of distributed generation.

There has been discussion of distributed generation (DG) and localized energy production in the Michigan legislature and at the Michigan Public Service Commission, yet there has been little in the way of policy changes to date, to stimulate the growth of DG installations.[115] The work of the Capacity Need Forum to identify indigenous energy resources and document available and emergent technologies that could assure adequate capacity in Michigan is a step toward the "inventory" requirement recommended earlier.[116] However, legislators could empower the Michigan Public Service Commission to support the development of a more robust decentralized energy production and distribution system in Michigan through funding programs or regulatory measures.

Establishing requirements for decentralized energy should not be viewed as uneconomic simply because these requirements would entail new investments. The prospect of making investments

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[113] Ibid.

[114] *Brittle Power*, 1982.

[115] Thomas Stanton, Competitive Energy, MPSC, March 3, 2005.

[116] The Michigan Public Service commission authorized the collaborative work of the Capacity Need Forum (CNF) to project Michigan's electrical generation capacity needs over the short and long term. "The goal is to provide policy recommendations within the current scope of the Commission's jurisdiction and under currently existing legislation, in order to assure that additional generation could be built if needed." CNF report online at http://www.cis.state.mi.us/mpsc/electric/capacity/cnf/.

in biomass energy production are often argued unaffordable, usually without incorporating the relative cost of a new biomass plant as opposed to a new coal, nuclear, or natural gas plant. Comparing new biomass facilities to existing facilities is erroneous, however, as electricity and natural gas industries are already established, and their capital costs already sunk. Policy makers need to consider the question: “Per kilowatt, how much is the investment in a **new** plant of each type?” In addition, they should also consider the costs of not investing in biomass energy: what are the costs of pollution, especially in terms of lost worker productivity and higher medical costs? Finally, as noted in Economic Impacts, investing in local energy production systems based on biomass such as wood residue would help address Michigan’s economic woes through both the use of local resources that can create local jobs, and through the confidence businesses and citizens would have in reliable energy supplies.

10. Future Options: Energy Crops and Ethanol

Fast-growing trees and grasses can be managed to enrich degraded sites such as mining areas, degraded pastures, and formerly cropped fields—and can also be harvested as energy crops. The opportunity of some value-added to farmers or rural communities who engage in carefully planned wood management regimes for energy purposes could help sustain local biomass energy systems and provide income support in traditionally more depressed rural sectors. Michigan can benefit from the demonstration projects for energy crops in Iowa, Wisconsin and other states, and capitalize on lessons learned to integrate energy cropping into domestic agriculture and energy practices.

Ethanol production from cellulosic materials like wood residues (as opposed to corn) is approaching maturity in Canada and in the European Union.[117] Michigan, as the automotive design, engineering, and manufacturing capital of the world, should seriously consider the possibilities of being on the cutting edge of transport fuel technology and processing. Cellulosic biomass as transport fuel feedstock is not highly commercialized yet, but it is coming soon. Investing in systematic identification and collection of biomass residue feedstocks like wood wastes further both the near-term goal of making ethanol from cellulose, and the longer term goal of moving to renewable fuels. As with using wood residues for heat and electricity productions, using wood for biofuels reduces our dependence on high emission, nonrenewable, carbon dioxide-emitting fossil fuels that take money out of the Michigan economy.

Michigan’s auto industry itself should also consider the tremendous potential of the flex-fuel vehicle market, and of the “plug-in flex fuel” movement gaining momentum throughout the United States. Some vehicles already exist that can be plugged into the electric grid to charge their battery for backup power—and at the same time rely on liquid fuels for their primary power. However, a vehicle that is able to run on biofuel and to plug in to the electric grid could theoretically be operated on entirely domestic resources. Furthermore, wind, solar, and biomass resources can all be utilized to create electricity, creating a context where plug-in flex-fuel hybrid vehicles could run entirely on renewable domestic energy.[118]

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[117] Iogen Corporation of Ottawa, Ontario, owns the world’s largest cellulosic ethanol demonstration plant. Iogen’s process makes ethanol from wheat straw: www.iogen.ca.

[118] David Morris, founder of the Institute for Local Self Reliance, commonly promotes plug-in flex-fuel hybrids as an industrial revolution that could revitalize Michigan and re-invest in American communities by growing the renewable fuels and renewable energy sectors. He spoke on this topic at Michigan’s First Annual Harvesting Agri-Energy Conference, March 15, 2006. Proceedings available online at http://www.michigan.gov/deq/0,1607,7-135-3585_4129_4183-140646--,00.html. More resources are available at www.newrules.org.

Michigan Energy Policy Today: Prospects for Renewables

Unlike many other states, Michigan has yet to develop a renewable portfolio standard, public benefits fund, or green credits to facilitate a shift toward renewable energy: Michigan has only three of twelve possible policy incentives recorded by the Database of State Incentives for Renewable Energy, and only three of ten types of financial incentives.[119] Nor has it invested in education, outreach or institution building to enhance consumer interest and participation in whatever renewables programs do exist.

There are positive policy trends, however. The Michigan Renewable Energy Program has engaged in ongoing efforts to inventory renewable energy options and make recommendations to the Michigan Public Service Commission. A Net Metering Order was issued by the Michigan Public Service Commission in March 2005. The Capacity Needs Forum commissioned by MPSC completed a report in late 2005 which assessed the need for more electrical production capacity in Michigan, and highlighted the availability of renewable energy options for preventing that shortfall.[120] And perhaps most surprisingly, given the overall lack of a coordinated energy strategy and a related lack of organized demand for one from the public, the Michigan State House of Representatives convened a special committee to examine the possible impacts of a renewable portfolio standard in 2005 and continuing through 2006. However, more concerted policy efforts and public mobilization will be required to help Michigan go past leaning toward renewables and actually move toward embracing them and integrating them more fully into Michigan's energy profile.

New developments in statewide energy planning may change Michigan's static position of dependency on non-renewable energy imports. Governor Jennifer Granholm's Executive Directive 2006-2 provides guidance and authorization for the Michigan Public Service Commission to design a renewable portfolio standard and an entire "21st Century Energy Plan," both of which will actively pursue some of the recommendations described above.[121]

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[119] For a full listing of all state initiatives concerning renewable energy incentives, by type, see the Database of State Initiatives for Renewable Energy (DSIRE) at www.dsireusa.org.

[120] See the Capacity Needs Forum report online at http://www.cis.state.mi.us/mpsc/electric/capacity/cnf/.

[121] Governor Granholm's Executive Directive 2006-2 charges MPSC Chairman Peter Lark with creating a comprehensive energy plan that can meet Michigan's capacity needs with renewable energy and energy efficiency strategies. A report on this "21st Century Energy Plan" is due December 31, 2006. For more information, see the MPSC's website at www.michigan.gov/mpsc.

Appendix A: Tools for Understanding and Using Wood for Energy

Technical Tools

U.S Forest Service Fuel Value Calculator
http://www.fpl.fs.fed.us/documnts/techline/fuel_value_calculator.pdf

Wood Fueled Boiler Financial Feasibility Program
http://www.forest.wisc.edu/extension/boilermanual.htm

Michigan Forest Products Industry Directory
http://www.michigandnr.com/wood/

2004 Michigan Recycled Materials Market Directory
http://www.deq.state.mi.us/documents/deq-ess-recycle-rmmd-pallets.pdf

U.S. EPA Wood Recycling Resources
http://www.epa.gov/epaoswer/non-hw/recycle/jtr/comm/wd-info.htm

RET Finance http://analysis.nrel.gov/retfinance/
Calculates cost of energy of renewable electricity generation technologies.

RETScreen® International http://retscreen.gc.ca
Free software from Natural Resources Canada that provides tools for evaluating energy production, life-cycle costs and greenhouse gas emissions reduction for various renewable energy technologies (RETs).

Real Options Analysis Center http://www.nrel.gov/realoptions/
Information center, modeling environment and virtual community for research related to the advanced financial valuation of renewable energy technologies.

BIOCOST http:// bioenergy.ornl.gov/papers/misc/biocost.htm
An Excel-based program designed by Oak Ridge National Laboratory. Allows the user to select a region and specify values for several variables including expected yields, land rents, labor costs, and chemical, fertilizer, fuel, and planting stock prices. Several key management options also available.

Pellet Fuels Institute (US) http://www.pelletheat.org/2/index/index.html

European Pellet Centre http://www.pelletcentre.info/CMS/site.asp?p=878

Renewable Energy Websites

Michigan Biomass Energy Program http://ww.michigan.gov/biomass

US Department of Energy Biomass Program http://www.eere.energy.gov/biomass/

USDOE/USDA Biomass Research & Development Initiative http://www.bioproducts-bioenergy.gov/

International Energy Administration “About Bioenergy” http://aboutbioenergy.org

Renewable Energy Policy Project http://www.repp.org

Great Lakes Biomass State Regional Partnership http://www.cglg.org/biomass/index.html

Database of State Incentives for Renewable Energy (DSIRE) http://www.dsireusa.org

Renewable Energy Glossary of Terms http://egov.oregon.gov/ENERGY/RENEW/glossary.shtml

Appendix B: Emerald Ash Borer Infestation Overview

The emerald ash borer (EAB) is an invasive beetle that preys on North American ash trees, which have no natural resistance to this exotic insect from Asia. It is estimated that the insect arrived in North America in untreated wood packing materials from China in the early to mid-1990s. The EAB was first identified in Michigan in the summer of 2002. By 2006, an estimated 15 million ash trees had been identified as dead or dying in twenty counties in the southeastern portion of the state (the primary quarantined area). In addition, approximately 30 small outlier quarantines have been established in other areas of Lower Michigan, with another 20 sites soon to be designated. Regions of Ohio, Indiana, and Ontario have also reported significant EAB outbreaks. In June 2006 the first outbreak in Illinois was reported in the one of Chicago’s suburban communities. A small amount of affected nursery stock was transported to Virginia and Maryland, but was intercepted before infestation could occur in the New England states.

The widespread destruction caused by the EAB has resulted in enormous costs for local communities (due to the expense of removal, disposal, and replanting efforts) and has produced large quantities of ash wood residues in need of disposal. According to the Michigan Department of Agriculture, in a one-year period from June 2004 to June 2005, nearly 300,000 tons of ash tree residues had been processed at state-run disposal sites alone. [300,000 tons is equivalent to 35,000-45,000 KW, depending on the conversion technology used.] This amount of ash residue does not account for dead or dying ash trees still standing due to lack of funds for removal. It also excludes ash wood residue that is being dumped, landfilled or buried in order to avoid transport and processing costs.

The Michigan Department of Agriculture (MDA) is primarily responsible for implementing the state's EAB eradication program. This program mandates that the movement of all ash woody material be regulated and prohibits the movement of untreated/unprocessed items from inside the quarantine area to outer regions. Numerous state and federal agencies throughout Michigan and neighboring areas, non-profit organizations, and research universities have formed collaborative partnerships to address the EAB issue. Extensive research programs have been implemented, addressing EAB biology (host selection, dispersal range, natural enemies), eradication strategies (monitoring, trapping, live tree and log treatments), and utilization alternatives.

MBEP has partnered with MDNR, MDEQ, the Southeast Michigan Resource Conservation and Development Council, and other state agencies as well as federal research labs in order to aggregate the best available information on wood residue market dynamics and technological advances, in order to make itself a resource for economic development and long-term energy planning at the state level. This team of partners, through funding from the USDA Forest Service, coordinated a study of wood residue generation in Southeast Michigan. This inventory includes wood residues from EAB-related removals, other urban tree residues, and wood wastes from manufacturing and other industrial sectors. The results of this survey are expected in fall 2006.

For more information: www.emeraldashborer.info.

Clean Energy from Wood Residues in Michigan (Discussion Paper MBEP-3)
Printed June 2006
Cost of printing 150 copies: $1581.92 or $10.55 per copy.