

BIOMASS ENERGY ~ FROM FARMS TO FORESTS
AN EMERGING OPPORTUNITY FOR RURAL AMERICA

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DOVETAIL PARTNERS, INC.



Biomass Energy – From Farms to Forests an Emerging Opportunity for Rural America

Introduction

A revolution is taking place within the United States. Driven by rising costs of fossil fuels, a marked shift toward greater use of renewable energy is underway. For example, nineteen states have established targets for renewable energy production. Sixteen states have mounted initiatives to encourage production of ethanol, and seven more have enacted laws to encourage its use. Thirty states have installed wind generated electricity capacity. Many are pursuing possibilities of electricity from various forms of biomass.

A key element of renewable energy development is biomass. To date, bio-energy has largely come from corn starch, soybeans, firewood for residential heating, black liquor from chemical pulping operations, and various forms of waste wood. In the near term corn starch-derived ethanol will increase in importance as an energy source. However, emerging technology is likely to expand bio-fuels options to include energy crops such as switchgrass, agricultural crop residues, and broader applications of woody biomass. Such materials will also become important as a source of industrial chemicals and industrial feedstocks.

The increasing importance of biomass as a source of energy and chemicals translates to a substantial opportunity for the U.S. farm economy, as well as potential for revitalization of the forestry and wood products sector. Diversified and sustainable farm income, long a point of concern, is likely to receive a significant boost, and the forest products industry stands to benefit from expanded product options and increased profit potential.

The opportunity and potential does not come without risk, however. Care must be taken within agriculture to ensure that one critical resource – topsoil – is not sacrificed to obtain another critical resource – energy. On the forestry front, new markets for wood may

The 25x'25 Work Group

Momentum continues to build

The 25x'25 Work Group is an alliance of agricultural, forestry and environmental groups who believe that by the year 2025, America's working lands will provide 25 percent of the energy consumed in the United States.

"The timing is right for Americans to embrace a new energy future and lessen our dependence on foreign oil," says Read Smith, co-chair of the 25x'25 Work Group. "The more people hear about the potential for developing renewable energy and the multitude of benefits it can provide for our country, the more eager they are to sign on. It just makes sense for our national security, for our economy and for our environment."

Montana Governor Brian Schweitzer became the first state leader to pledge his support for the 25x'25 initiative on March 7, 2006. The next day, Pennsylvania Governor Ed Rendell and Indiana Governor Mitch Daniels signed on. And one day later, Minnesota Governor Tim Pawlenty offered a resounding endorsement in his State of the State message: "Let's lead the way and set a strategic goal of "25-by-25"--so that 25 percent of all types of our energy will come from renewable sources by 2025."

For more information on 25x'25, go to: <http://www.25x25.org>

strain increasingly tight supplies, drive up prices of already high-priced wood, and provide an incentive for over harvesting. On the other hand, new markets may provide an incentive for establishment of tree plantations.

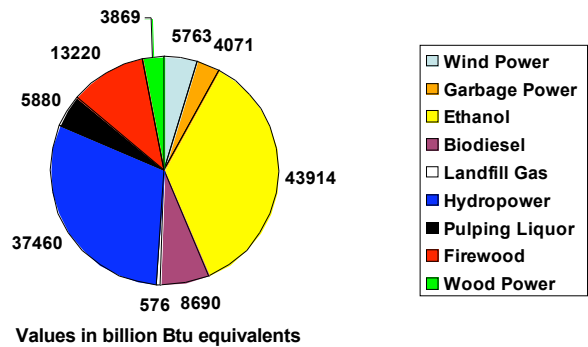
This report explores bio-energy opportunities in Minnesota as a model for both how one state might contribute to renewable energy development and also how one state’s actions could impact energy availability and costs throughout the country.

Bioenergy in Minnesota

Minnesotans consumed about 1,745 trillion Btu of energy in 2001, with energy expenditures of approximately \$12.5 billion. Transportation fuels (gasoline, diesel, jet fuel) accounted for the greatest quantity of energy consumed, followed by coal and natural gas used primarily for electrical generation and home heating.

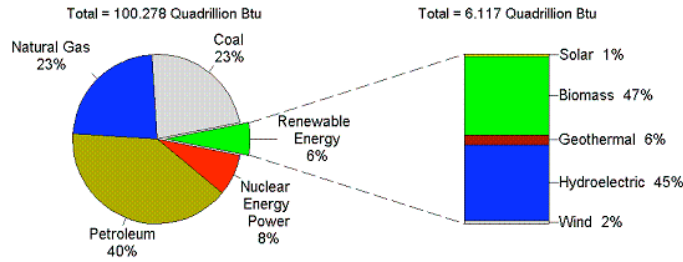
Renewable sources of energy, though still accounting for a relatively small proportion of total energy requirements, are growing. In 2005 renewables accounted for about 86 trillion Btu of Minnesota’s energy production (Figure 1), or about 7.1 percent of total energy consumption; renewable energy production included about 11 percent of electricity, 10 percent of gasoline, and 2 percent of diesel. Nationwide, about 6 percent of energy is obtained from renewables (Figure 2).

**Figure 1
Renewable Energy Produced in Minnesota, 2005**



Source: Derived from Jordan and Taff (2005), with hydropower and energy from pulping liquor (listed in Jordan and Taff as conventional sources of energy) and firewood (from Mouelle et al. (2003) added.

Figure 2
The Role of Renewable Energy in U.S. Energy Supply. 2004



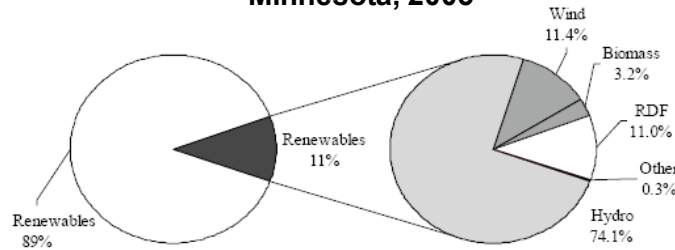
Source: U.S. Department of Energy, Energy Information Administration (2006)

The majority of renewable energy produced in Minnesota in 2005 came from biomass – about 80 trillion Btu in the form of ethanol from corn starch, and biodiesel from soybeans; heat from burning of firewood; and electricity and heat from spent pulping liquor and waste wood. This was equivalent to about 6 percent of the total non-transportation energy consumed in the state and about 15 percent of all industrial energy consumed. In the future, biomass options will expand to include ethanol and/or hydrogen fuels from wood, agricultural crops and residues and other cellulosic materials.

Electricity from Biomass

Biomass accounted for 200,000 MWh, or 3.2 percent of the electricity produced in Minnesota from renewables in 2005 (Figure 3). This figure is expected to rise to 5.5 percent of renewable electricity production by 2015, when renewable electricity will account for about 20 percent of total electricity produced.

Figure 3
Profile of Renewable Electricity Production in Minnesota, 2005



Non-Renewables	50,100,000 MWh
Renewables	6,200,000 MWh
Total Energy	56,300,000 MWh

Source: Minnesota Department of Commerce (2005)

Beyond what is now produced, there is considerable potential for additional production of electricity from biomass. For instance, a 2005 report by the National Renewable Energy Laboratory (NREL) at the request of the Minnesota Department of Commerce and the

Table 1
Biomass Resources in Minnesota by Three Studies

Source of Biomass	Biomass in Resources from ORNL database (tons/year at < \$50/ton)	Biomass Resources from NREL GIS Group (tons/year)	Biomass Resource from 1997 ILSR Inventory (tons/year)	Average of All Biomass Resource Data (tons/year)
Forest residue	874,900	-	-	874,900
Mill residue	1,121,000	1,017,688	571,960	903,549
Agricultural residue	11,935,896	40,709,527	22,040,438	24,895,287
Energy crops	5,783,002	-	-	5,783,002
Urban wood waste	1,532,529	-	-	1,532,529
Total	21,247,327	41,727,215	22,612,398	33,989,267

Source: NREL (2005)

Minnesota Office of Environmental Assistance concluded that available biomass (Table 1) could produce 80 percent of Minnesota's electricity needs assuming energy generation in direct-fired power plants and 99 percent if combusted in plants employing state-of-the-art technology (Table 2).

Table 2
Power Potential from Minnesota Biomass

Source of Biomass	Average of All Biomass Resource Data from Table 1 (tons/year)	Power Potential from the Use of Direct-Fired Biomass Power Plants (aMW)	Power Potential from the Use of Integrated Gasification/Combined Cycle Power Plants (aMW)
Forest residue	874,900	176	220
Mill residue	903,549	182	227
Agricultural residue	24,895,287	5,009	6,252
Energy crops	5,783,002	1,164	1,452
Urban wood waste	1,532,529	308	385
Total	33,989,267	6,389	8,536

Source: NREL (2005)

If only data from the 1999 Oak Ridge National Laboratory (ORNL) study of biomass are used, rather than the more optimistic figures derived by using averaged estimates of biomass availability as in the NREL study, more conservative, but nonetheless impressive, estimates of electric production capacity are obtained (Table 3). The electric generating potential shown in the far right column of Table 3 (<\$50/ton) is equivalent to over 40 percent of current generating capacity. The difference in electric generating potential between the two studies is due to a more conservative estimate of agricultural crop residue availability. Studies of the percentage of agricultural crop residues that can be removed from the land on a sustainable basis have generally shown acceptable removal rates of 60 to 80 percent. A study of corn stover showed acceptable removal rates of 65 to 91 percent¹ in Minnesota, depending upon the tillage practices used (Figure 4).

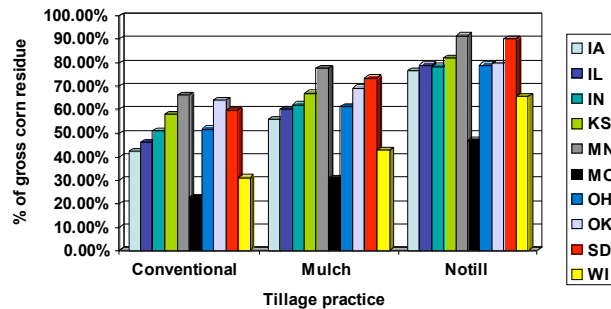
Table 3
Potential Power Obtainable from Minnesota's Plant-Based Bio-Resources,
Based on ONRL 1999 Study and NREL Conversion Factors

Resource	Quantity Available @ (000 dry tons/year)			Electric Potential (aMW)		
	<\$30/t	<\$40/t	<\$50/t	<\$30/t	<\$40/t	<\$50/t
Forest residues	468	682	875	94	137	176
Mill residues (wd)	71	916	1,121	12	149	182
Ag. residues	0	11,936	11,936	0	2,401	2,401
Energy crop pot.	0	427	5,783	0	86	1,164
Urban wd waste	1533	1,533	1,533	308	308	308
Total	2917	15,494	21,348	414	3,081	4,231

Source: National Renewable Energy Laboratory, 2004.

¹ An "acceptable" removal rate is one that is judged to be sustainable over a long period of time without degradation of the productive capacity of the land.

Figure 4
Geographic Variation in Percent of Gross Corn
Stover Supply that Can Be Harvested with
"Acceptable" Erosion Rates



Source: Graham, R. Oak Ridge National Laboratory (2003)

While generation of a large portion of Minnesota's electricity from biomass appears to be technically feasible, economic feasibility appears doubtful, at least given current prices and technology levels. The Minnesota Center for Rural Policy and Development concluded in a 2005 report that electricity production from wood was not economically feasible, except perhaps in specific locations and situations, unless wood could be obtained for less than prevailing prices or if wood-generated electricity would be sold at above-market rates. Wood generated electricity was, in fact, identified, as the least economically attractive option of six alternative energy production systems.

The finding that production of electricity from wood biomass is not economically competitive was underscored by a December 2005 report for the American Forest and Paper Association that examined costs of biomass- vs. coal- generated energy nationwide. Estimated national average costs of producing electricity from wood in 50 and 100 MW plants were estimated to be 80 to 90 percent higher than current retail electricity costs in Minnesota and 26 percent higher than electricity production in new coal facilities. Nationwide, prospects for economic production of biomass electricity are a bit more promising, with estimated differences between wood and coal-generated electricity generally in the range of 1.4-2.2 cents/KWh, but far less than that in several southern states. In those states where biomass generating costs are close to costs associated with generation from coal there is concern that biomass energy development in could soon threaten pulpwood supplies and even sooner should subsidies to encourage biomass energy be enacted.

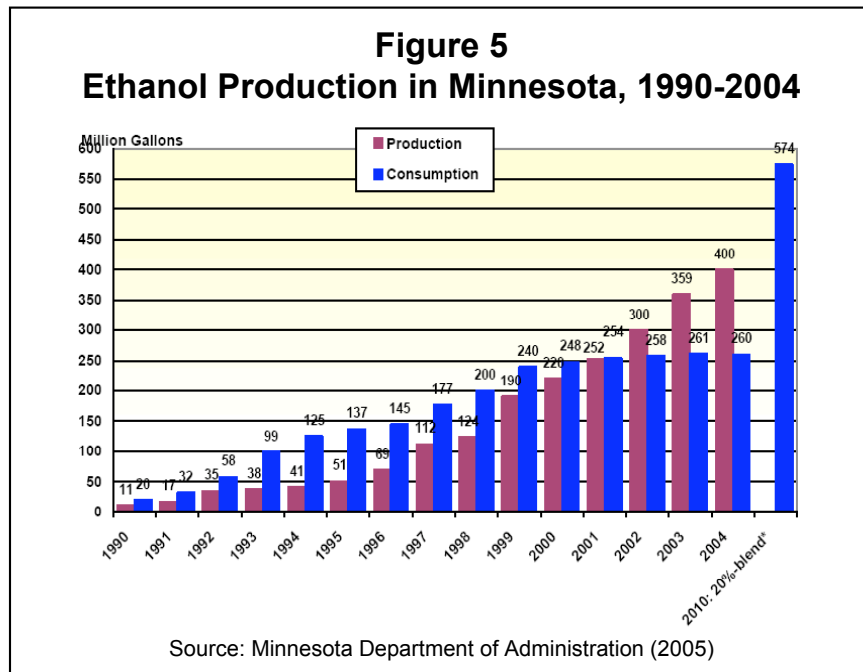
Because of the relatively high costs associated with production of biomass electricity, the U.S. Department of Energy forecasts little to no growth in the U.S. biomass generating industry through at least 2020. Current projections are for about 15.3 billion KWh of biomass generation in 2020, or only 0.3 percent of electric generation nationally. Should regulation of coal-related mercury emissions increase, or increased attention to safety in coal mining increase costs of electric generation from coal, then projections of future biomass electricity production could, of course, change. Biomass energy, including

cogeneration of electricity, is likely to continue to provide a major portion of energy consumed by the forest products industry – over one-half at present.

Ethanol

It is clear that there is considerable potential for generating electricity from agricultural and other forms of biomass in Minnesota given the right economic conditions. However, the potential payoff from production of liquid fuels from biomass is far greater, with the caveat that the technology needed to bring about that payoff is as yet unproven from a commercial standpoint.

In 2004 Minnesotans consumed 2.67 billion gallons of gasoline and additional fossil fuels such as aviation and diesel fuels. All of this was imported. Also in 2004, Minnesota produced over 400 million gallons of ethanol, of which 140 million gallons were exported to other states (Figure 5). The economic impact of Minnesota ethanol production is estimated at \$1.36 billion annually, including 5,300 jobs, with much of this impact in rural areas.



Recently enacted legislation sets a target within Minnesota for a 20 percent ethanol blend in all gasoline sold in 2010 and beyond. Meeting that target will require 574 million gallons of ethanol just to meet state consumption requirements. Using current technology and corn starch as a raw material, the 20 percent ethanol-blend requirement is expected to require the use of some 230 million bushels of corn, or assuming level production of corn, about one-quarter of Minnesota’s corn crop.

Beyond the ability to produce ethanol from corn starch, technology is emerging that will allow economic production of ethanol from the cellulose component of plants.^{2,3} When this technology is commercialized, all forms of biomass will become potential raw materials for ethanol production. As shown in Table 4, production of an additional 1.1 billion gallons of ethanol will become possible within Minnesota with new technology implementation. If the more optimistic biomass availability figures are used in determining ethanol production potential (from the far right column of Table 1), then additional ethanol production potential in Minnesota rises to 1.8 billion gallons annually.

Table 4
Ethanol Production Potential from Minnesota Biomass, Based on ONRL 1999 Study and NREL Near-Term Conversion Factors

Resource	Quantity Available @ (000 dry tons/year)			Ethanol Potential (million gallons)		
	<\$30/t	<\$40/t	<\$50/t	<\$30/t	<\$40/t	<\$50/t
Forest residues	468	682	875	31	45	58
Mill residues (wd)	71	916	1,121	3	42	51
Ag. residues	0	11,936	11,936	0	597	597
Energy crop pot.	0	427	5,783	0	26	347
Urban wd waste	1533	1,533	1,533	70	70	70
Total	2917	15,494	21,348	104	779	1,122

Over the long term the 1.1 and 1.8 billion gallon figures as indicated above are probably conservative, as ethanol production yields are likely to improve as technology develops. For instance, there is a considerable difference today between ethanol yields obtainable in pilot plant operations and theoretical yields of ethanol. Higher yields are forecast in the mid- to longer term (Table 5).

Nationally, ethanol production potential is estimated at about 9 billion gallons if production is based on corn starch only, and up to 50 billion gallons assuming implementation of cost-effective cellulose-to-ethanol technologies. To put this into perspective, gasoline consumption in the United States in 2004 was 138 billion gallons.

² Wood ethanol technology is not new; wood ethanol was used extensively, for example, in the U.S. and Europe during World War II to fuel vehicles. What is currently holding back the commercialization of cellulosic ethanol is the cost of production.

³ Production of cellulosic ethanol is technically feasible, but production costs are about \$2.73 per gallon. As reported by Dr. Arvizu, Director of the National Renewable Energy Laboratory, a goal of reducing production costs to \$1.07 by 2020 has been set by NREL – a goal viewed as attainable within that time frame.

Table 5
Estimated Near, Mid/Long Term, and Theoretical Ethanol Yields
from Various Forms of Biomass

Waste/Residual Biomass Resource Category	Theoretical Yield*, (gal/BDT)	Near-Term Yield**, (gal/BDT)	Mid/Long-Term Yield*** (gal/BDT)
Paper (landfill)	127.8	63	95.3
Field and Seed Crop Residues	102.0	55.1	85.5
Lumber Mill Waste	112.8	59.5	82.5
Forest Slash/Thinnings	112.8	66.5	94.8
Urban Wood Waste	108.2	45.6	66.6
Urban Yard Waste	91.8	45.6	66.6
Food Processing Waste	?	43.6	64.4
Wheat Straw	114.1	57.6	84.2
Corn Stover	113.3	57.2	83.6
Aspen	131.0	77.3	110.0
Ponderosa Pine	112.9	66.6	94.8
Poplar	111.4	65.7	93.6
Switch Grass	97.4	43.6	64.4

Source: National Renewable Energy Laboratory as reported by Mann and Bryan (2001).

* Data compiled by Quang Nguyen, NREL.

** Near-term yields are based on current NREL 2-stage dilute acid experiments and models. See Table 2.4 for yield assumptions.

*** Mid/long-term yields are based on NREL projections for performance of the Simultaneous Saccharification and CoFermentation (SSCF) (1-dilute stage acid/1-stage enzymatic hydrolysis) process.

The figures clearly indicate that bio-energy is largely an opportunity for the agricultural sector, with the potential of only 109 million gallons of annual production (about \$110 million) indicated for forest and mill residues. However, there is an important aspect of woody plants that makes them particularly attractive as a raw material for cellulosic ethanol production: the quantity of fossil fuel energy needed to deliver 1,000,000 Btu to the automobile gas tank is far lower than for the same product made from agricultural crops (Table 6).

The information contained in Table 6 is worth a bit of discussion as it reveals several little known truths about the most common liquid fuel, gasoline, and about the sometimes controversial product, ethanol. Note that the production of all liquid fuels listed, including gasoline, requires the expenditure of greater quantities of energy than is delivered to the vehicle fuel tank. In the case of gasoline the process of obtaining petroleum and then transporting and processing a portion to gasoline requires the use of 1,241,000 Btu of fossil fuel energy for each 1,000,000 Btu delivered to a petrol station in the form of gasoline. The 1,000,000 Btu contained within the gasoline comes from fossil petroleum that is extracted from the ground. No new energy is created in the process. Energy used for exploration or for military action to protect petroleum supplies are not counted in this figure. The production of an equivalent number of Btus in the form of corn starch-based ethanol requires considerably more energy. This product is nonetheless attractive, since only 600,000 Btu of that energy is obtained from fossil fuels, with this used largely to fuel farm machinery and to produce fertilizer. Most of the rest of the energy needed comes from solar energy captured by the leaves of the corn plants and converted to usable form through photosynthesis.

Table 6
Energy Required to Deliver 1,000,000 Btu to a
Vehicle Fuel Tank

Fuel	Total Energy Required (Btu)	Fossil Energy Required (Btu)
Gasoline	1,241,000	1,241,000
Ethanol (corn - starch)	1,587,000	600,000
Ethanol (corn cellulose)	1,250,000	230,000
Ethanol (wood)	2,600,000	10,000

Source: Oregon Department of Energy, 2005.
(<http://egov.oregon.gov/ENERGY/RENEW/Biomass/forum.shtml>)

The commercialization of cellulose-to-ethanol technologies will markedly reduce the need for fossil fuel inputs. Cellulosic ethanol production from corn will require less than 40 percent of the fossil energy now needed per unit of output. Cellulosic production from wood, on the other hand, will require only about 10,000 Btu of fossil fuel per 1,000,000 Btu delivered to the fuel tank, giving a 100:1 gain for petroleum use to fuel gain through ethanol production. Total energy required to produce cellulosic ethanol from wood are higher than for any other raw material source only because of the relatively long growth period and resulting consumption of solar energy.

Low fossil fuel requirements for ethanol production from wood are certain to stimulate interest in woody biomass on the part of policy makers. Low fossil inputs will also translate to increasing economic advantages for the landowner or fiber producer, especially if prices of fossil fuels continue to rise. Increased interest in establishment of

tree plantations is also likely. In the future, conversion of existing pulp and paper mills to integrated biorefineries (see 2005 Dovetail Report *The U.S. Pulp and Paper Industry: A Key Player in the Coming Bio-revolution*) will be driven in part by the availability of cost effective technologies for producing cellulosic ethanol.

Unlike biomass derived electricity, the production of which is not cost competitive with other sources of power, ethanol is close to being competitive with gasoline even without subsidies. The Minnesota Center for Rural Policy and Development study, referred to previously, identified production of corn starch derived ethanol as a profitable enterprise given prevailing energy prices and costs in mid 2005.

A comprehensive assessment of gasoline production costs in California provides an interesting baseline for gauging the economic potential of a non-subsidized ethanol industry (California Energy Commission 2003). As shown in Table 7, average crude oil costs plus refiner costs and profits approximated \$0.91 for the period 1997-2003. By the end of the period (July 2003) the costs had risen to \$1.16, with crude oil costs \$0.70 per gallon. A little over a year later crude oil costs per gallon of gasoline were more than double the mid-July 2003 level (\$1.47) and the price of crude oil plus refiner costs and profits was \$1.93.

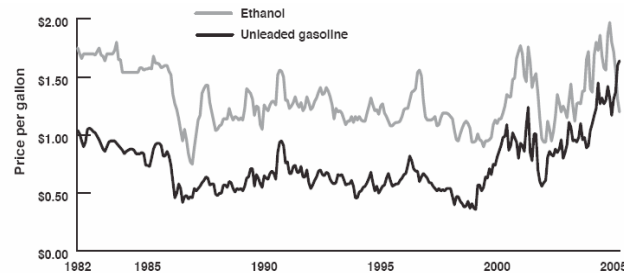
Ethanol prices, in contrast, were about \$1.20/gallon in the fall of 2005, about the same level as the previous March (Figure 6). Even allowing for the fact that it takes about 1.5 gallons of ethanol to provide the same fuel value as gasoline, the price of ethanol was significantly lower than the price of gasoline in October 2005. Moreover, ethanol costs are projected to drop considerably going forward, whereas petroleum and thus gasoline costs are likely to rise.

Table 7
California Gasoline Cost Analysis

	Branded Gasoline			Unbranded Gasoline		
	July 2003	July 2002	1997-Present	July 2003	July 2002	1997-Present
Retail Prices	1.74	1.60	1.49	1.74	1.60	1.49
Federal Excise Tax	0.18	0.18	0.18	0.18	0.18	0.18
State Excise Tax	0.18	0.18	0.18	0.18	0.18	0.18
State and Local Sales Tax	0.13	0.12	0.11	0.13	0.12	0.11
Crude Oil Cost	0.70	0.62	0.52	0.70	0.62	0.52
Refiner Costs and Profits	0.46	0.43	0.39	0.32	0.28	0.34
Distribution Costs, Marketing Costs, and Profits	0.09	0.07	0.11	0.23	0.22	0.16

Source: California Energy Commission (2003)

Figure 6
Wholesale Prices of Ethanol and Gasoline,
1982-2005



Source: Omaha Average Rack Prices: Nebraska Energy Office (2005) as reported by Jordan and Taff (2005)

Hydrogen

Another possibility for producing fuels from biomass involves the production of hydrogen using gasification or other technologies in combination with steam reforming and what is referred to as the water-gas shift reaction. Despite low levels of hydrogen within biomass (about 6 percent by weight) the National Renewable Energy Laboratory recently estimated that hydrogen from Minnesota biomass could replace as much as 89 percent of current gasoline consumption in the State, while also dramatically reducing transportation related CO₂ emissions. Biomass-derived hydrogen is not yet economically feasible, but a goal of economic competitiveness with gasoline by 2015 has been established by NREL scientists. Parallel development of hydrogen fueling stations and vehicles equipped to use hydrogen fuel will be needed to achieve commercialization.

Minimizing Negative Environmental Impacts from Biomass Harvesting

An area of concern with biomass energy development is the potential for negative environmental impacts from the removal of crop residue in agricultural situations or coarse woody debris removal in forest management. Focusing on the forestry situation, the concern is that removal of woody material such as logs and branches will have a number of negative impacts including the potential to deplete soil nutrients, increase soil erosion, or reduce wildlife habitat and biodiversity. Coarse woody debris, including both large standing and downed logs as well as smaller branches and brush, provides important nutrient cycling functions and more nuanced ecosystem services such as moisture retention and suitable conditions for seed germination. For example, recent studies in the Upper Peninsula of Michigan found that hemlock (*Tsuga Canadensis*) and yellow birch (*Betula alleghaniensis*) seedlings were 42 times more abundant on decaying wood than on soil.

To balance societal needs for renewable, less polluting energy sources with desires for healthy and diverse forests, one approach that is being taken in Minnesota is the development of “Biomass Harvesting Guidelines.” Operating under legislative direction, the Minnesota Forest Resources Council (MFRC) and the Minnesota Department of Natural Resources (DNR) are to develop best management practices for “sustainably managed woody biomass” for both forestland and brushland in the state by July 1, 2007. A 12-member interdisciplinary technical committee will develop two sets of guidelines: one for brushland and one for forestland. Both sets of guidelines will focus on the sustainable harvest of biomass while protecting the soil, water, and habitat that are essential to a healthy and sustainable ecosystem. The project also involves a University of Minnesota lead effort to develop and consolidate scientific information regarding the environmental impacts of woody biomass removal from forest and brush lands. Impacts to be evaluated include soil productivity, biological diversity, and carbon sequestration.

The Bottom Line

A great deal of new technology is in various stages of development that has the potential to dramatically transform rural economies within the relatively near term. Both agricultural and forest sectors within Minnesota will be impacted as new products and technology options provide opportunity for entrée to lucrative national and global energy markets via transformation of biomass to energy. With the caveat that care will be needed to ensure that economic opportunity does not result in environmental degradation, biomass energy offers substantial opportunity to owners and managers of Minnesota’s farms and forests. The greatest opportunity is in production of liquid transportation fuels, placing rural areas in the forefront of a movement away from petroleum import dependence.

Dr. Jim Bowyer is a professor within the University of Minnesota’s Department of Bio-based Products (part time) and an Elected Fellow of the International Academy of Wood Science. He is the current Chairman of the Tropical Forest Foundation, Chairman of the Minnesota Bio-fiber Council, Member of the Governance Board of the Temperate Forest Foundation, and Past President of the Forest Products Society (93-94), and of the Society of Wood Science and Technology (87-88).

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