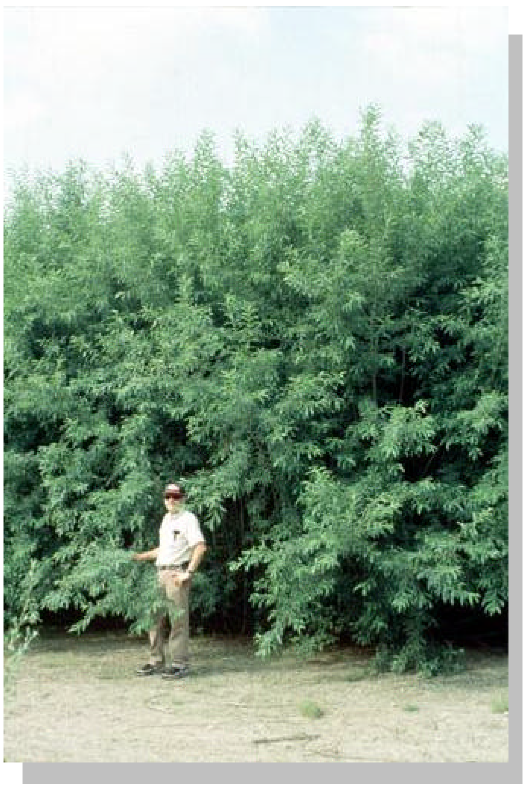
Co-Burning Biomass Opportunities in Wisconsin
A Strategic Assessment



Final Report for Contract No. 80081

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1 Need for Biomass Fuels

The environmental costs of our entrenched energy infrastructure are growing. We need to engage these challenges and develop new sources of energy. Renewable energy holds the promise of a sustainable energy foundation for our society. We may be able to integrate our industrial society more with natural processes and forces.

Biomass is solar energy, captured by plants.

Biomass energy is one such renewable form of energy. "Biomass energy" describes a broad array of energy products derived from animal and plant material. The biomass refers to the actual living matter, be it trees, fast-growing trees or gas from decomposing landfill waste. Biomass is solar power, trapped by plants through photosynthesis.

Energy from wood is one of the oldest forms of energy used by humankind. Wood energy has served us well over the millennia. The modern age has brought many other ways to produce the different types of energy- heat and electricity - that we require. Wood energy still has an important place in our electrical generating mix because of the value it delivers today, and the potential it holds for the future.

The carbon emitted from wood burned today was only absorbed in the recent past. The carbon in coal and natural gas, on the other hand, was absorbed from the atmosphere when dinosaurs roamed the Earth. We return this ancient carbon to the atmosphere when we burn fossil fuels, and, in the process, are tipping the climate out of balance through global climate change.

Wood is one of the few energy options available to us today that allows us the potential to eliminate greenhouse gas emissions from energy production. The fuel can be replenished from new tree growth. When wood fuel is replaced with new energy crops, the carbon loop is closed, just as in nature.

Wood can come from industry residues, from logging, from urban tree trimmings, or from old pallets. It can also come from fast-growing energy crops developed to provide biomass energy. Energy crops can include trees and grasses and could be grown by farmers, taking land out of agricultural commodity production and providing more diversified income to farmers. Energy crops would support rural development.

As a renewable source of energy, wood has the added advantage of being dispatched, or available on-call. This gives wood energy an added advantage not shared by other renewable energy sources, such as wind or solar.

Wood is burned in special wood-fired powerplants around the country. New and more efficient technologies are on the horizon that can use energy crops. But development of technologies and markets may require a more piecemeal approach to establish markets, crops, new business relationships and practices. Cofiring wood with coal provides an incremental approach toward developing energy crops as an energy alternative.

1.1 What is cofiring?

Most electrical generating plants use a single fuel - coal. The boilers are even designed to use a specific type of coal. However, it is possible to modify the boiler and the fuel processing equipment to blend wood or some other biomass into the fuel mix. This is described as "cofiring." Cofiring basically means that more than one fuel type is used simultaneously. For this report, we address the cofiring of coal and biomass.

Cofiring can work in several different ways, depending on where the fuels are blended. In some cases, the fuels are blended before entering the boiler. In other cases, the fuels are processed separately and injected into the boiler separately, but burn together. Cofiring substitutes biomass for coal in existing capacity - it does not expand existing capacity.

There are several reasons for cofiring wood with coal. Coal is a finite fuel, while wood is renewable. Cofiring coal with wood leads to lower emissions and may provide a more economical means to reduce emissions. The wood is, sometimes, available at less cost than coal. And, burning the wood provides an alternative to landfill disposal.

Cofiring is discussed in greater depth in "Cofiring Biomass with Coal," on page 10.

1.2 Developing technologies for biomass energy

New technologies are under development that will increase efficiencies in the conversion of biomass to electricity. One question is whether the energy crops will be available when these new technologies are available. It is especially daunting to develop a fuel source while simultaneously launching a new technology. Any progress toward developing the fuel source will aid the introduction of new technologies such as biomass gasification and Whole Tree Energy.

Cofiring is a bridge strategy until new fuels are available. Cofiring with energy crops will allow us to establish new fuel supply techniques and relationships to reduce the risks and obstacles of introducing advanced technologies in the future.

1.3 What are the Biomass Fuels?

Biomass fuels can come in many different forms and from different sources. Although these fuels can be used for space heating, process steam, ethanol production or electricity, this analysis only focuses on electricity generation. The most common type of fuel in use for power generation today is wood waste. Another option under development are energy crops.

Wood wastes (also referred to as "wood residues") are available from a wide variety of sources. One can categorize them by considering the supply, manufacture and use of the wood and forest products.

The **primary forest products industry** consists of those industries that take round logs and produce lumber and cut wood of different dimensions for use by different customers and industries. Although this industry generates as little wood waste as possible, they still must generate some residue in the manufacture of their product. Often, they will have their own wood-fired boilers on site to provide heat and, occasionally, electricity. These residues typically include sawdust and sanderdust, bark, chips and cuttings. The residues are centralized at the mills. These residues are not chemically treated.

The **secondary forest products industry** consists of those industries that take the lumber and make it into finished products. These residues typically include sawdust and sanderdust, chips, shavings, and edgings and cuttings. These residues are generally not chemically treated.

Post consumer wastes come from the final users of the forest products. In many cases, that includes pallets, other containers and packing materials. These have a limited life and create a disposal problem. Providing a use for the materials as fuel at the end of their product life creates a lower cost disposal method and a means to get more value from the use of this renewable material.

Urban Tree Trimmings are the waste left over from tree trimmings by municipalities and utilities and their contractors. There is a surprisingly higher level of these materials available and it is a resource worth looking at.

1.3.1 Energy Crops

The term "energy crop" refers to any crop grown specifically for its high yields and suitability for conversion to energy. In Wisconsin, promising energy crops include fast growing trees, harvested on a four to ten year rotation, and grasses harvested once or more per year. These energy crops are grown on lands not used for food, feed, or fiber. To date, most of the midwestern energy crop research has focused on hybrid poplars and switchgrass.

These fuels could be used for either electricity or ethanol production. It is also possible that they could be used for other higher value products than energy - such as paper, or new products (Olsen and Moran).

Energy crops could be grown in large plantations or in many small plots in a region. Harvesting could be done by the energy producers, contract loggers, or the farmers or landowners. Under the best circumstances, energy crops would be grown on land converted from agricultural row crops (Olsen and Moran).

Energy crops can be grown on land which is set aside under the federal Conservation Reserve Program (CRP). Currently, the federal governemnt rents highly erodible lands from farmland owners to compensate for keeping the land out of production. With energy crops, subsidies can be reduced while the farmer generates additional income from the land with low erosion crops (Olsen and Moran).

Table 1 : Cropland potentially available for energy crops within 50 mile radius of select plants

Plant	Study area in Wisconsin (acres)	Land in Agriculture (acres) in study area	Percentage of study area in agriculture
Blount Street	4,740,166	3,672,085	77%
Pulliam	3,728,646	2,349,264	63%
Milwaukee	2,952,410	2,153,529	73%
Weston	5,072,935	2,116,341	42%
Rock River	2,586,959	2,086,972	81%
Valley	2,623,862	1,881,341	72%
Alma	2,713,880	1,684,527	62%
French Island	3,102,249	1,385,080	45%
Nelson Dewey	1,778,974	1,183,499	67%
Bayfront	2,907,486	220,647	8%

Source: Wisconsin Energy Bureau. Transmittal letter from Mr. Don Wichert to Mr. David Tillman, July 15, 1997.

1.3.1.1 Herbaceous Crops

Herbaceous crops for electricity include tall-growing prairie grasses of many varieties. The leading variety is switchgrass, a grass sometimes used for forage. The grasses are harvested, dried and stored until transferred to the generating plant.

Grasses can also be planted as buffers along stream banks. This filters farm runoff and reduces surface water pollution.

Photo from U.S. Department of Energy Biopower Program.

The grasses are perennials with strong root systems, the same type of grass that built the rich soils of the Midwest. Land disturbance is minimized once the prairie grasses are established in a plot. Grassy crops could be harvested once or twice per year.

The grasses increase biodiversity, the diversity of life. Grasses provide rare habitat for birds, which have declined in number under corn and alfalfa cropping. Herbaceous energy crops can mimic native prairies and provide new habitat for species declining in numbers (Bartelt, et al).

Current costs at the Chariton Valley project at the plant gate are $50-60 per ton (Cooper, Braster, & Woolsey). This translates to $3.18 to $3.81 per million Btu

(MMBtu). The Oak Ridge National Laboratory has assembled a database, *The Oak Ridge Energy Crop County Level Database*, for estimating energy crop production costs for counties across the United States (Graham, Allison, and Becker). The costs for Wisconsin counties from this database of estimates and data varies from $32 to $60 per dry ton at the farmgate, which would range from $2.03 to $3.81 (Graham, Allison, and Becker).

Cost of production are affected by land rents, productivity, energy crop yields and other production costs. Growing these grasses for fuel is a very young concept. Grasses have not been widely grown as commodity crops, besides for hay and forage. Much room yet remains to improve practices and reduce costs. Production costs for corn have steadily dropped for a number of years. Many researchers expect that we can develop new hybrids and techniques to improve the practice, increase yields and lower production costs.

In addition, switchgrass as an energy source is a superior product to coal in many ways. Switchgrass has better environmental, social and economic development impacts than coal. Unfortunately, the coal industry is a mature industry with large resources and subsidies. The excluded costs of environmental pollution from coal help make coal an even cheaper option.

1.3.1.2 Tree Crops

Fast-growing trees are also under development as energy crops or "Short Rotation Woody Crops." These trees are grown more like an agricultural crop. Tree species under consideration and development include hybrid poplars, willows, black locust, and silver maple.

Energy crop trees would be grown in rows. Cuttings are planted on a variable spacing, depending on crop rotation (harvest cycle) plans. For some species, such as willow, the plant is cut after the first year to create a "coppice," or multiple shoots from the cut location. Coppiced trees will produce more wood. Trees are harvested on 3 to 8 year cycles. Research, testing and field trials are being conducted to determine the optimal approach to improve yields.

Trees are harvested with existing logging or cropping harvesters. Specialized equipment is being designed and tested on a small scale.

The development plans for tree energy crops entail converting existing farmland to tree crops. In this way, standing forests are not converted. This represents an improvement over traditional agricultural row cropping in reduced fertilizers, soil disturbance and improved and more diverse habitat. These tree plantations will not provide the same level of environmental restoration as native, uncropped forests.

The Oak Ridge Energy Crop County Level Database, provides a range of prices for woody crops at the farm gate from $36 to $65 per dry ton, which translates to a range of $2.12 to 3.82 per MMBtu[1] (Graham, Allison, and Becker).

As with grasses, there is room for innovation to improve practices and reduce costs. Production costs are expected to decrease with expanded field trials, plantings and research and development.

1.4 Benefits of Energy Crops

Economic Benefits of energy crops include:

- **Increased income** to farmers and landowners.
- **More jobs** in rural communities.
- **Reduced subsidies** for erosion control in the Conservation Reserve Program (CRP)
- **Crop diversification** for farmers
- **Stabilized farm income** with long-term contracts

1.5 Environmental Impacts

Wood as a fuel has several environmental advantages over coal. These advantages can be seen in that coal is a very impure fuel, whereas wood is much simpler. Coal contains many elements which, nationwide, are emitted to the atmosphere in quantities of millions of pounds per year: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chlorine, chromium, cobalt, copper, fluorine, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, selenium, silver, sulfur, titanium, uranium, vanadium, and zinc.

Whereas coal contains heavy metals and other complex compounds, wood is made of simpler stuff. Basically, wood is the building blocks of the tree, the cellulose and lignin. However, certain wood wastes can carry other materials with treatment and use.

1.5.1 Air

The electric power industry is a significant contributor to air pollution of all forms. If we are to ever reduce these emissions, we must have substantial modifications to existing practice by this industry. The National Resources Defense Council has estimated that, nationwide the industry accounts for 28% of NOx emissions, 67% of SO2 emissions, 36% of CO2 emissions and 33% of mercury emissions (National Resources Defense Council). As air emissions have impacts across state borders, it is not possible to provide such precise levels of impacts for the State of Wisconsin.

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[1] Based on 9,000 Btu/pound, as per Foster Wheeler

1.5.1.1 Greenhouse Gases: CO2

Modern electric power generation is one of the single largest sources of greenhouse gas emissions. The Wisconsin Department of Natural Resources has found that the electric utility industry accounted for 33% of Wisconsin's greenhouse gas emissions in 1990 (Wisconsin Department of Natural Resources). Given that the electric generation industry consists of a smaller number of larger emitters than transportation or other sources, it provides more opportunity to control emissions.

Because wood is trapped solar energy, another environmental advantage of wood fuel over coal is the reduction in greenhouse gas emissions. Carbon dioxide is the major greenhouse gas of concern in fuel combustion. Both wood and coal emit carbon dioxide and carbon monoxide during combustion. However, carbon emissions should be considered in light of total fuel cycles, including fuel creation and production.

Wood is created through the natural process of photosynthesis. The mass of wood is captured from the carbon in the atmosphere and water in the air and soil. This is shown in the chemical equation for photosynthesis (and combustion), as shown in .

Figure 1: Simplified chemical equation for photosynthesis

$$CO_2 + H_2O + \text{light} + \text{chlorophyll} \rightarrow (CH_2O) + O_2$$

Following the equation from the left, we see how the building blocks of wood - cellulose, hemicellulose and lignin - are formed. Carbon dioxide (CO2), water (H2O), light and chlorophyll combine to form wood (represented as carbohydrates - CH2O - which actually occur in many variations) and release oxygen (O2).

In combustion, an opposite process takes place. A simplified diagram is given in Figure 2.

Figure 2: Simplified chemical equation for combustion

$$(CH_2O) + O_2 + \text{energy} \rightarrow CO_2 + H_2O + \text{light} + \text{more energy}$$

The combustion process roughly reverses the photosynthesis process. The carbohydrates are consumed and the mass released as CO_2. Reviewing these two equations it is apparent that wood energy forms a cycle of carbon sequestration and release. It is this cycle that provides the opportunities to develop a closed loop energy system that does not add to the accumulation of greenhouse gases.

Carbon is trapped from the atmosphere through photosynthesis, whereby it becomes plant material. Coal is material formed from the accumulation of biological materials over many eons. The carbon in coal was captured from the atmosphere many millions of years ago. When these materials were sequestered in the earth's crust, they were removed from the atmospheric carbon cycles.

When coal is burned the carbon emitted is from ancient reserves. This carbon is returned to the atmosphere after being interred for many millions of years and makes net additions to the levels of greenhouse gases in the modern atmosphere.

Carbon from the combustion of wood, on the other hand, was removed through photosynthesis relatively recently from the atmosphere. Emissions from combustion of this wood does not result in a net increase in greenhouse gases, or only small increase relative to coal. The greenhouse gas balance is much better with sustainable forestry practices, by replacing harvested trees. What's more, carbon is also stored underground in the plants' root systems.

1.5.1.2 Nitrogen Oxides: Urban Air Pollution

Nitrogen oxides, or NOx, are formed in combustion. NOx leads to formation of low-level urban ozone when it reacts with other pollutants in the low level atmosphere. (This is the undesirable location for ozone, as opposed to ozone in the upper atmosphere, which provides a key function in screening out harmful ultraviolet rays). Low-level ozone is a health hazard that leads to respiratory problems. NOx can travel great distances to contribute to ozone pollution.

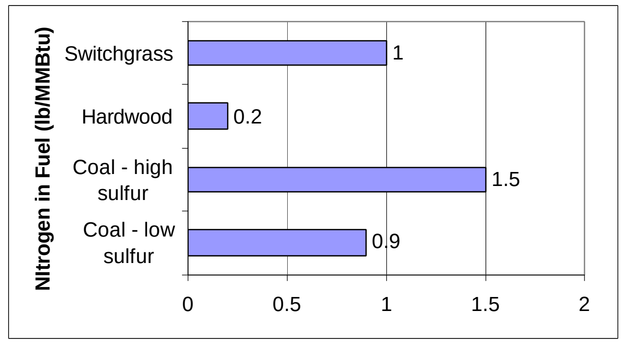

Figure 3: Nitrogen content of different fuels.

Biomass fuels are inherently lower in nitrogen, which may lead to less formation of NOx as there is less nitrogen to start with (Energy Efficiency and Renewable Energy Network). Furthermore, wood ignites at a lower temperature than coal, which leads to less formation of NOx from nitrogen in the air. Tillman, Hughes, et al have concluded that biomass cofiring at a 10% rate, by mass, leads to reductions in NOx of about 9%. Figure 3 shows the varying levels of nitrogen in different fuels.

1.5.1.3 SO2: Acid rain

Sulfur within coal is emitted to the air after combustion as sulfur dioxide (SO2). This SO2 is collected within rain where it forms acid compounds that are returned to the surface. (Nitrogen oxides [Nox] also form acid compounds, but to a lesser extent). The Acid is returned both through rain and in dry form. The more precise, but less popular, term is "acid deposition".

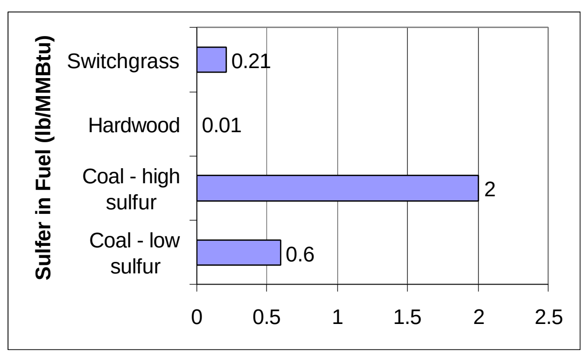

Figure 4: Sulfur content of different solid fuels.

Acid deposition damages streams and lakes by making them inhospitable for many plants and fish. Forests are also damaged through acid rain. Acid rain has also been known to damage the paint on automobiles! Finally, buildings and monuments are gradually eroded by the acid deposition.

Biomass has significantly lower amounts of sulfur than coal. Of course, coal comes in many different varieties, but wood has even much less sulfur than the lowest levels for coal. Figure 4 shows the levels of sulfur in different fuels.

Many utilities - especially Wisconsin utilities - have already reduced their sulfur emissions by switching to lower sulfur coal. Because Wisconsin was a leader in regulating sulfur dioxide, we reduced our pollution from sulfur and Wisconsin utilities benefited when the rest of the nation followed suit. However, even these plants can reduce their SO2 emissions further by cofiring with wood.

Wisconsin led in regulating and reducing sulfur dioxide pollution.

1.5.1.4 Mercury and other heavy metals

A recent problem that has become increasingly apparent is the emission of mercury from combustion of coal. Coal combustion is the single greatest contributor to mercury found in the more than 260 lakes and more than 350 miles of Wisconsin rivers, as of 1996 (Izaak Walton League of America). Coal contains mercury in small amounts, but enough to add up after combustion of a few million tons - the scale used in powerplants.

Untreated wood doesn't contain mercury. To the extent that wood is substituted for coal, the mercury problem is eliminated.

Mercury is released to the atmosphere during combustion and returned to the ground with rain. The mercury settles in streams and rivers. With fish eating the mercury, it continues to accumulate within the fish, especially in older, larger ones. Other animals eat the fish. At the top of the food chain are humans - US! (Izaak Walton League of America).

Mercury is a neurotoxin, or a poison. Health effects include nervous system damage, gastrointestinal disturbances, kidney problems, infant brain damage, mental retardation, loss of sensation in finger and toes, slurred speech, loss of coordination and more (Wisconsin Department of Natural Resources, Bureau of Watershed Management).

In addition to mercury, there are other heavy metals and elements of concern in coal. These include lead, cadmium and arsenic. We don't yet know all the specific impacts the release of these chemicals has on the environment and public health. However, it would seem useful to reduce the emissions by substituting fuels and technologies that don't release the substances.

1.5.2 Radioactivity

Another, often overlooked issue with regards to coal combustion is the emission of radioactive material. Coal is a very impure fuel, which contains thorium and uranium. Thorium and uranium are released in the gases and ash from coal combustion[2]. Some researchers have concluded that persons living near coal plants are exposed to higher levels of radioactive emissions than those living near nuclear power plants[3].

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[2] http://www.ornl.gov/ORNLReview/rev26-34/text/colmain.html

[3] McBride, J. P.., Moore, R. E. , Witherspoon, J. P. and Blanco, R. E. "Radiological Impact of Airborne Effluents of Coal and Nuclear Plants," *Science* December 8, 1978.

1.5.3 Effects on Wisconsin waterways

Combustion of wood does not lead to sulfur dioxide emissions (SO_2) that can cause acid rain. This advantage leads to greater value for wood as a component of a sulfur dioxide reduction strategy. However, most Wisconsin utilities have switched to low-sulfur western coals that have also allowed them to reduce SO_2 emissions.

Sulfur dioxide and mercury pollution lead to reduced fish populations and vitality in northern Wisconsin. This reduces the capacity of the environment to sustain life. Further, there are real economic impacts when fishery populations are affected. Anglers spend over $1 trillion directly in Wisconsin, generating taxes of $61 million (Izaak Walton League of America).

1.5.4 Solid Waste

Ash from wood combustion is produced in much lower quantities than ash from coal combustion. Ash from coal ranges from 10 to 18% on a weight basis. Various woods range from 0.3 to 6%[4]. Ash from wood combustion can often be applied to land, recycling nutrients. Land recycling is not available when cofiring with coal, however.

1.6 Economic Impacts

Wood fuel has many benefits for the local economy. Wood fuel is typically produced locally. Therefore, payments to fuel producers remain in the local economy. Low sulfur coal, on the other hand, is produced primarily in western states, so that the value of those purchases leaves our local economy.

Analysis by the Wisconsin Energy Bureau has shown that development of 380 megawatts (MW) of wood energy capacity would lead to increased benefits to the local economy. An additional net 43,000 job-years would be created, and an additional 870 million dollars in earnings, in 1994 (Clemmer and Wichert).

In addition, increased use of wood for energy would lead to lower disposal costs for many firms that now dispose of wood residues.

2 Cofiring Biomass with Coal

Cofiring biomass with coal has been practiced for decades. Here in Wisconsin, we have two successful cofiring projects, both owned by Northern States Power. The Bayfront plant is located in Ashland and the French Island Plant is in La Crosse.

The Bayfront plant was converted to cofiring in 1979. The plant was modified to allow for blending wood with coal fuels in a stoker boiler. The system can accept any blend of wood and coal, up to 100% wood. However, NSP modified the boiler operation in the late 1990s due to problems with slagging. Slagging is the buildup of hard, glassy materials in boilers the reduces heat transfer and efficiency. NSP determined that the slagging was caused by the Eastern bituminous coal, which had an acidic ash, reacting with alkali in wood.

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[4] Electric Power Research Institute, *Strategic Analysis of Biomass and Waste Fuels for Electric Power Generation*, December 1993.

The plant consumes approximately 220,000 tons of wood waste per year, receiving fuels from mills throughout northwestern Wisconsin. Bay Front has burned nearly 1.8 million tons of wood waste from 1980 to 1994. The mill provides an alternative to disposal of the wood residues and mills ship well over 50 miles to Bay Front. It provides Bay Front with their lowest cost fuel by a "factor of two".

The French Island Plant is another wood-fired plant operated by Northern States Power. This 29 MW plant is located in La Crosse, on the Mississippi River. In 1980, the plant was refurbished with fluidized bed boilers to burn wood. Now, it burns wood along with refuse-derived fuel and shredded railroad ties (Ellis). The fluidized bed boiler is a more flexible boiler configuration than other coal boilers.

2.1.1 Cofiring Demonstrations and practice

Cofiring wood with coal has been investigated on a sustained and intensive basis for at least the past 10 years. The utility industry has actually taken leadership on this matter through the Electric Power Research Institute (EPRI). EPRI initiated a testing and commercialization program ten years. They focused, first, on using existing wood residues. Then, as the technology is proven, the infrastructure is in place for longer-term use of energy crops (Tillman, Hughes & Plasynski).

EPRI's testing program, led to testing at numerous facilities involving the whole gamut of boiler technologies. Biomass cofiring has been successfully demonstrated with pulverized coal, stoker, and fluidized bed boilers. However, circumstances do vary, plant by plant (Tillman, Hughes & Plasynski).

Table 2: Utility Testing of Cofiring Biomass With Coal

Utility	Generating Station	Cofiring Approach	Boiler Capacity	Coal Type	Biomass Type
TVA	Allen (cyclone)	Blending biomass & coal; 5-20% by mass	272 MW	Illinois basin, Utah bituminous	Wood waste
TVA	Kingston (T-fired PC)	Blending biomass & coal; 1-5% by mass	190 MW	Eastern bituminous	Wood waste
TVA	Colbert (wall-fired PC)	Blending biomass & coal; 1-5% by mass	190 MW	Eastern bituminous	Wood waste
GPU Genco	Shawville (T-fired & wall-fired PC)	Blending biomass & coal; 3% by mass	190 MW 138 MW	Eastern bituminous	Wood waste, hybrid poplar
GPU Genco	Seward (wall-fired PC)	Separate injection of biomass	32 MW	Eastern bituminous	Wood waste
NIPSCO	Michigan City (cyclone)	Blending biomass & coal; 10% by mass	469 MW	PRB, Shoshone	Urban wood waste
MG&E	Blount St. (wall-fired PC)	Separate injection of biomass; 5-20% by mass	50 MW	Midwest bituminous	Switchgrass
NYSEG	Greenidge Station (T-fired PC)	Separate injection of biomass; 10-20% by mass	104 MW	Eastern bituminous	Wood waste
Southern	Plant Hammond (T-fired PC)	Blending biomass & coal; 5-14% by mass	120 MW	Eastern bituminous	Wood waste
Southern	Plant Kraft (T-fired PC)	Separate injection of biomass; 20-50% by mass	55 MW	Eastern bituminous	Wood waste

From Tillman, Hughes & Plasynski.

There are other examples. Not included here is the King Station, a cyclone boiler owned by Northern States Power (NSP) in Minnesota, Tacoma Public Utilities' Tacoma plant with a fluidized bed boiler, and others.

2.1.2 Cofiring System Design Considerations

Retrofitting an existing coal plant to accept wood fuel requires adding additional infrastructure. These modifications typically include fuel receiving and storage, fuel handling and flow controls, and boiler modifications. Of course, this is a general review. Each one of these sections includes several pieces of equipment, such as truck tippers, conveyor belts, fuel grinders (hoggers and/or hammermills), fans, blowers, scales and valves.

Fuel is received at the plant from either trailer truck or rail. Truck is the predominant method of shipping biomass. However, rail may be useful if cooperatives are used to process and store fuels off-site. For example, an agricultural cooperative already has rail sidings, materials handling equipment and institutional administrative capacity for handling commodities. They might accept biomass, process on site to plants specifications, and then ship boiler-ready fuel by rail to facilities at the plant. When rail is used, the increased shipping distance lowers per-mile costs. On the other hand, adding the extra handling steps can add costs, as well.

Once received, the fuel may need to be further reduced in size and screened to reduce tramp metals. After it is processed, it is then stored for use by the boiler. Different methods are used to do the size reduction, depending upon fuel blending rates, available equipment and boiler type. Size reduction is a significant factor in the economics of wood energy and provides an opportunity to reduce costs with optimized systems.

Pulverized coal boilers already have pulverizers that crush and grind the coal. In some cases, the wood is fed into the fuel stream before the pulverizers, so that it is reduced in size there. However, wood is a fibrous material while coal is friable. Therefore, it is difficult to reduce wood and biomass to the same small particle size required by pulverized coal boilers. The fuel size should be .25" and smaller for pulverized coal boilers (Energy Efficiency and Renewable Energy Network).

For other boilers, the wood particles can be larger in size. Stoker and fluidized bed boilers can accept fuel in sizes ranging up to 2-4 inches in size.

Boiler modifications vary. Modifications may not be needed at all. In some cases, new fuel injector nozzles need to be added (Energy Efficiency and Renewable Energy Network). Another option in use at the McNeil Generating Station in Burlington, Vermont, is to use a gasifier to convert the biomass fuel to gas. This fuel can then be injected into the boiler in gas form.

2.1.3 Capacity impacts of Biomass Cofiring

A concern often raised by utilities is that the lower energy content of biomass results in lower energy produced by the boiler. This has been addressed by several experts in several papers on the subject.

Tillman, Hughes and Plasynski find that biomass cofiring can often result in losing a portion of the energy rating of a plant - a derating. However, they find that there are times when the biomass results in an increase in the capacity of a boiler. These occasions arise when boilers are being fired with wet coal. In EPRI tests at the Seward Generating Station, a 6% cofiring rate resulted in increased capacity. They stress that the results need to be evaluated for individual plants. The controlling factors are "the characteristics of the biofuel, the feed mechanisms for the biofuel, the relationship of the operating coal to the design coal, and the specific features of the fuel preparation and combustion system of any given boiler" (Tillman, Hughes and Plasynski).

2.1.4 Impacts on Boiler Performance

One concern of adding biomass fuel to coal boilers is "slagging". "Slagging" is the buildup of hard, glassy materials in boilers that reduces heat transfer and efficiency. This occurs when the alkali in certain biomass materials glassifies at high temperatures. This tends to be more of a problem with herbaceous crops. Further research and testing is being done on this matter. However, tests at the Ottumwa Generating Station using switchgrass as the biomass have not shown slagging problems (For more information, see the section "Views of Alliant Energy Personnel" on page 32).

2.1.5 Fuel costs

A key consideration for the economics of cofiring projects are the comparative costs of coal and the biomass alternative. In cases where an abundant supply of wood residues is available, the fuel is often available at low cost. Fuel savings can offset the extra investment in infrastructure. Table 3 provides a comparison of fuel costs. It should be noted that all costs must be considered in evaluating a project.

Different coal customers face different prices for coal fuel. When a large utility boiler is constructed, the coal supply is often negotiated up front from a given coal resource. These large, long-term contracts allow the utility customers to pay less for their coal supply than other, smaller users. The effect of this is that wood fuel is a more price competitive option for these smaller users than for the utilities.

Table 3: Breakeven prices for Wood vs. Coal

Comparing only fuel costs

Cost of coal ($/MMbtu)	$ 0.85	$ 1.00	$ 1.25	$ 1.50
Wood Btu/lb	4,250	4,250	4,250	4,250
The Price to beat ($/ton wood delivered)	$ 7.23	$ 8.50	$ 10.63	$ 12.75

Cost of coal ($/MMbtu)	$ 0.85	$ 1.00	$ 1.25	$ 1.50
Wood Btu/lb	4,700	4,700	4,700	4,700
The Price to beat ($/ton wood delivered)	$ 7.99	$ 9.40	$ 11.75	$ 14.10

Cost of coal ($/MMbtu)	$ 0.85	$ 1.00	$ 1.25	$ 1.50
Wood Btu/lb	5,550	5,550	5,550	5,550
The Price to beat ($/ton wood delivered)	$ 9.44	$ 11.10	$ 13.88	$ 16.65

3 Government Mandates and Incentives for Biomass Energy

3.1 Production Tax Credit

The Production Tax Credit provides a tax credit of 1.5¢ per kilowatt-hour for ten years for qualifying renewable electricity generation. The credit was passed in the 1992 Energy Policy Act and extended to new projects started before December 31, 2001. (Inflation adjusted to a present value of over 1.7¢ per kilowatt-hour).

The credit is only available for "closed loop biomass," which are energy crops "planted exclusively" for the production of electricity. This restriction is so tight that no-one has used the tax credit for wood or energy crops. Cofiring of energy crops is not a qualifying use for this tax credit, however.

Legislative efforts from both sides of the aisle continue to modify and extend the credit. The Bush Administration has signaled support for the credit. This credit is a small percentage of the amount given away each year through the fossil fuel depletion allowances.

3.2 Renewable Energy Production Incentive (REPI)

The Renewable Energy Production Incentive (REPI) is a federal incentive program established under the Energy Policy Act of 1992. This program provides payments of 1.5¢ per kilowatt-hour for qualifying renewable electricity generation to entities that are not subject to taxation. The payment is only available for "closed loop biomass," which would include energy crops, but not wood wastes[5]. Cofiring of energy crops may not be, at present, a qualifying use. Conversations with program administrators indicate they have not reached a decision on the applicability to cofiring energy crops.

3.3 1997 Wisconsin Act 204

Under Wisconsin Act 204, mandates for the implementation of 50 MW of new renewable energy capacity were created. These mandates would apply to biomass power, including cofiring. The allotments from the Public Service Commission of Wisconsin are as follows; Wisconsin Electric Power Company, 27 MW; Wisconsin Public Service Corporation, 9 MW; Wisconsin Power and Light Company, 11 MW; and Madison Gas and Electric Company, 3 MW. Renewable energy sources are defined as solar energy; wind power; hydropower; and biomass, including waste derived fuel other than fossil fuel-based waste.

This mandate led to several contracts for biogas from landfills and wind farms. However, no contracts or additional capacity were realized for biomass. (It is worth noting that a given amount of capacity for wind power, with it's lower capacity factor (amount of time generating at full output per year) generates lower levels of energy than the same amount of biomass capacity.

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[5] Section 451.2 of the Federal Register, July 19, 1995, Vol. 60, No. 138.

3.4 Renewable Portfolio Standard

Far-reaching reform of Wisconsin's electric utility industry was tucked into the last budget bill, passed in October of 1999. In addition to the authorization of a statewide transmission operator, the bill introduced a Renewable Portfolio Standard. The Renewable Portfolio Standard is a requirement on electricity providers that a minimum amount of their electricity sales come from renewable sources.

The Renewable Portfolio Standard (RPS) applies only to renewable electricity in service after January 1, 1998. If the energy source was in service before January 1, 1998, it may still be counted if it is less than .6% of the total electricity sales from an electric provider. Electric utilities are allowed to recover these costs through the rate-setting process. Furthermore, capacity in place to comply with the Act 204 mandate, described above, may also be counted toward this requirement.

The RPS applies only to the "eastern utilities", excluding Northern States Power. Hydroelectric power is only included if it is under 60 MW.

Biomass cofiring is specifically allowed. The amount of cofiring counted is the fraction of the energy provided to the boiler, applied to the total energy produced .

The legislation also specifically allows green pricing programs to be used to recover costs of energy resources under the RPS. An electricity provider can use energy produced outside of the state to meet these requirements.

One-half of one percent of electricity sales for every electric provider in the state for 2001 and 2002 must come from new sources of renewable energy. In following years, that percentage increases, as shown in the schedule for the Renewable Portfolio Standard (RPS), provided in Table 4. The table also provides information, based upon 1999 electricity sales, to illustrate the approximate level of this requirement in terms of installed baseload capacity, a more common measure.

Table 4: Wisconsin Renewable Portfolio Standard

Year	Percent of total retail electric sales.	Amount based on 1999 electricity sales (Million kWh)	Equivalent baseload capacity[6], based on 1999 electricity sales (MW)
2001	0.5	320	46
2003	0.85	544	78
2005	1.2	767	110
2007	1.55	991	142
2009	1.9	1,215	174
2011	2.2	1,407	201

Electricity sales data from Wisconsin Energy Statistics, 2000, Wisconsin Department of Administration.

An electricity seller may also meet their obligation under the RPS by purchasing a "Renewable Resource Credit" from other providers who exceed their obligation. In addition, a provider may bank their Renewable Resource Credit and use them in subsequent years to meet their obligation, in lieu of actually producing renewable energy.

Act 9 is a beginning step to developing renewable energy, borne of secret negotiations during the budget process. It has also been hailed in some quarters as one of the best approaches in the country. Even with several loopholes and some lax requirements, the RPS still provides an incentive for power producers to install cofiring capacity.

Adding and using cofiring capacity may be a competitive way for utilities to meeting RPS requirements.

Wisconsin Electric Power Company (WEPCO) has elected to voluntarily exceed the levels of the Renewable Portfolio Standard by 50% as a part of their "Powering the Future" program. This is a hopeful sign that more Wisconsin utilities are looking for successful ways to implement renewable energy.

4 "Green Power" Marketing

Green Power programs provide consumers the opportunity to pay a premium price for power with the understanding that the premium is used to provide environmentally superior energy. It is essential to the success of these programs that customers have confidence in the credibility of environmental claims.

Green Power customers want to know that the premium they pay makes a difference. The compact with these customers states that the power produced with their

[6] Baseload capacity based on a powerplant operating at 80% capacity factor.

investment is cleaner and greener than existing power sources and that new capacity is created by benefit of the program.

Several observers have noted the potential for abuse of green power programs. Christian Demeter of the Antares Group refers to practices dubbed "greenwashing." Under greenwashing, existing renewable energy plants are used, or power is transferred from other existing plants. (Demeter and Lindsey). Ben Paulos refers to the risk of undermining legitimate green power programs by selling power from existing industrial biomass units at a premium, which he refers to as a "mock transaction" (Paulos).

Some "green power" programs have faced controversy in recent years as to how "green" these sources truly are. These concerns have lead to formation of certification programs. The Center for Resource Solutions has established the "Green-E" standards for determining when sources are suitably described as "green." The standards and process are useful for increasing consumer confidence and assuring environmental advocate groups who have led criticism of early shaky programs.

The standards specifically allow for use of biomass (including waste-to-energy and land-fill gas). The only cofiring that is separately discussed is cofiring landfill gas with pipeline gas, for which they require a separate meter and means of verification.

The standards used by Green-E to determine if an energy sources is "green" follow:

- "The product must contain 50% or more renewables content averaged over one year."
- "The fossil portion (if any) of an eligible product must have equal or lower air emissions (SOX, NOX, and CO2) than an equivalent amount of system power."
- "Air emissions from a renewable energy generator using waste materials for fuel must be equal to or less than the emissions that would otherwise be produced from the most common alternative disposal of the waste."

4.1 Green Power Programs in Wisconsin

Wisconsin has been a national leader in the development of Green Marketing programs. Here in Wisconsin, the first green power program was launched by Wisconsin Electric Power Company (WEPCO). A summary of Wisconsin programs is provided in Table 5.

Table 5 Wisconsin Green Pricing Programs

Utility	Program Name	Green Power Assets	Comments
Alliant Energy	Second Nature	Four wind turbines, one contract with a landfill gas company.	2¢/kWh or about $13 a month for an average household; the 50% and 25% options will be priced proportionally
Dairyland Power	Evergreen	Share in Great River Energy 2.0 MW project	Offers wind power to its 27 member distribution cooperatives
Madison Gas & Electric	MGE Windpower	Windfarm: 17 turbines totaling 11.22 MW	$15-million project. Customers get some or all of power from wind. Annually eliminate 16,000 tons of CO2 and 70 tons of SO2
WEPCO	Energy For Tomorrow	Two wind turbines, small WI hydro, landfill gas in WI.	Purchase 25%, 50% or 100% of electricity from renewable resources. Adds $1 to $20 per month.
WI Public Power	(in development)		
Wisconsin Public Service Corporation	Solarwise for Schools	Rooftop solar systems on school roofs	50¢, $1 or $2 per month goes to a tax deductible, non-profit, foundation.
Wisconsin Public Service Corporation	Renewable Electric Rate	Solar electricity	Built if enough people sign up (bold!)
Wisconsin Public Service Corporation	Round up for renewables	Renewable energy	Customers round up and it goes to renewables

The response to green energy programs has been strong across Wisconsin. The Wisconsin utilities have taken a step towards renewable and the experience seems to be profitable and widely applauded.

With all of this green marketing occurring, is there any way for electricity from cofiring energy crops with coal to be accommodated?

4.2 Is Biomass Cofiring Green?

First, we must address the question, "*Is Biomass Cofiring Green*?" Green power is renewable energy providing a sustainable energy source of energy for society. The goal of green power is to reduce or eliminate the environmental damage from fossil fuels and nuclear power.

As seen above, in the "Environmental Impacts" section, biomass leads to lower emission of smog-producing emissions, lower greenhouse gas emissions, and lower sulfur compound emissions.

When considering the impact of energy crops and biomass energy, it is important to consider the incremental change. For example, energy crops may be compared to row crop agriculture. In this sense, they require fewer chemical inputs, and provide greater habitat for other species. Comparing to coal on the electricity production side, we have lower emissions of many different pollutants.

It is important to consider how an effective green cofiring program might be structured. The only premium customers would pay would be for the renewable portion of the electricity. There should be no inclusion for the coal portion of cofiring. Only the incremental cost of retrofitting boilers or purchasing fuel (if any net cost) would be included.

Selling any coal-generated power as green is not advised. The case cannot be made, and the claim will undermine good will toward all green power claims.

Under the first Green-E criterion described above (under ""Green Power" Marketing"), the renewable resource portion is 100% and the criterion is satisfied. Fuel standards may need to be put into place to assure that the wood used was replaced with new plantings, thereby assuring a renewable status.

The second criterion does not apply, as there is no fossil fuel portion with cofiring.

The third criterion gets tricky and may require further analysis. Wood waste that is not sold is often disposed of by either landfill disposal or open burning. Wastes in a landfill do generate emissions as they degrade, although over a longer period of time. These emissions include higher levels of methane, a greenhouse gas.

For energy crops, there is no waste product. The purpose of the crop, from the beginning, is to produce energy.

Biomass energy does qualify as a green source of energy. Unfortunately, many of the benefits and impacts are misunderstood.

4.3 Views on biomass energy

The key question regarding the desirability of energy crops as a renewable energy resource must be answered repeatedly by numerous people. Some ingrained attitudes, against anything involving combustion, say, may need to be challenged.

To flush out the views held on energy crops, a side by side comparison of arguments is useful. This approach can be used in subsequent educational materials.

Pro	Con
• Reduction in greenhouse gases. • Reductions in acid rain. • Reduction in ozone (NOx reduction) • Reduction in solid waste. • Reduction in mercury emissions. • Builds a pathway to closed loop energy system. • Provides new crops to farmers - takes land out of production while diversifying farm income. • Aids rural development. • Controlled combustion in a boiler is much better than open air burning of wastes. • Biomass harnesses solar power. • Replaces coal.	• Greenhouse gases not reduced under all circumstances, such as deforestation. • Still a "smoke stack" industry. • Still emits pollutants, even if less than coal. • Biomass may take market from solar and wind - too cheap and dispatchable. • Wood is not always renewable - dangers if standing forests are used and/or converted to energy crops. • "Utilities try to pass off existing generation as new capacity". • "Energy crops are not renewable because they rely on traditional row crop agriculture, with it's high chemical use.

4.3.1 Sierra Club

The Sierra Club has recently considered energy crops. The focus of their attention is on prairie grasses. The habitat and water preservation benefits of prairie grasses grown as crops has strong appeal for environmentalists concerned about biodiversity and degraded surface water quality. Improvements in air quality from energy crops are also appealing.

The Sierra Club is considering an energy reserve program to augment the Conservation Reserve Program. An energy reserve program would meet soil erosion control goals while providing a cash crop. It marries the goals of renewable energy with farmland preservation.

4.3.2 Perspectives on green power programs

4.3.2.1 RENEW Wisconsin

No discussion of green power in Wisconsin would be complete without the views of RENEW Wisconsin. RENEW has taken leadership in resolving problems with the pioneering Green power programs and removing the confusion, uncertainty and risk from future Green Power initiatives. They have worked with the Center for Resource Solutions to establish green pricing program criteria for Wisconsin.

RENEW's Executive Director Michael Vickerman has laid out these benefits to green pricing programs.

- Programs Present Low Financial Risk to Utilities

- Helps Legislature Gauge Appeal of Renewables
- Engages People Reluctant to Act Politically
- Empowers Customers to Exercise Personal Responsibility
- Breaks Passive Utility-Customer Relationship
- Sets High Bar
- Channels Utility Rivalry Positively
- Invests Advocates in Success of Green Pricing

4.3.2.2 Criticisms of Green Power Program

David Morris, of the Institute for Local Self-Reliance, is a critic of Green Power marketing programs. Morris' arguments, as reported in a 1997 issue of *Sustainable Minnesota*, may be summarized as follows:

- Premiums are too steep. With lower premiums, surveys show there would be higher participation rates.
- Green power only provides small amounts of renewable energy capacity.
- Green consumerism is being pushed while green citizenship is being abandoned. We should all pay for cleaner energy sources, reducing the premium to a minimum.
- With green power, a small percentage of company pays a steep price for a small amount of power. The alternative is for all ratepayers to pay a small increase to provide a significant amount of renewable energy.
- "Wherever a majority favors renewable energy they should exercise their authority as citizens rather than simply as customers."

In Minnesota, in 1994, the state legislature required the largest utility, Northern States Power (NSP), to purchase at least 550-MW of renewable electricity by 2002, 425-MW of that being wind energy. The rate impact for the wind turbines is estimated at 1/20th of a cent per kWh, as the costs are spread among a much larger pool of customers.

4.4 Cofiring and Green Power Rates

Green power rates are generally derived from the *added* costs to provide the renewable power source. This is usually a straightforward procedure as the plants, such as wind farms and landfill gas plants, are separate facilities. Cofiring adds a new wrinkle, however, as the plant's infrastructure is part of a larger fossil fueled plant. Green power customers would not want their funds to flow to coal power.

Therefore, the premium for wood co-fired with coal should reflect only the incremental costs to provide the renewable fuel. This would include the added costs for equipment and the fuel. Likewise, the benefits should be measured by the incremental improvement due to the wood fuel replacing the coal fuel.

Demeter and Lindsey have provided a framework and methodology for determining premiums for green pricing for biomass cofiring (Demeter and Lindsey). The approach can be summed up in the following equation:

Equation 1: Generalized green pricing cost elements

Green Pricing Premium = (Annual Cost of New Green Gen.)
- (Levelized Cost of Equivalent New Fossil Gen.)
- ((Emission Credits; SOx, NOx, CO2) + (Green Marketing Admin Costs))

Demeter and Lindsey apply the principle that the green power customers pays only for the premium cost for the renewable energy, and not for the new capacity, itself. Furthermore, financial benefits due to the use of the green technology flow to those who are investing in the technology. Finally, the program costs are not included, as this is an investment on behalf of the utility for which they will receive a return in higher rates.

Their model includes other factors used to set a green pricing premium. This includes the customer participation rate in the program and the distribution of the program among various customer classes (residential, commercial, industrial), as well as average production costs. There are so many permutations of these factors that it is not feasible to set a green pricing program for a given amount of cofiring capacity.

Therefore, we will report the figures for the example used by Demeter and Lindsey. For their example, they use a hypothetical plant with 100 MW of total capacity, and consider cofiring at 3% and 10% levels. Following are the inputs used in this model:

Factor	Level
Cofiring, amount biomass	3% and 10%
Capacity factor	85%
Heat rates	10,451 and 10,360 Btu/kWh
Coal costs	$1.40/MMBtu
Residue costs	$.50/MMBtu
Energy crop costs	$2.84/MMBtu
Fixed O&M costs	$10.43/kw-year
Capital costs	$100/kW for 3% $271/kW for 10%

Following are the results from the model, for residential customers only and marketing across customer classes:

Equation 2: Green pricing wood co-firing for residential customers only

Biomass output: 3% - 3 MW Biomass output: 10% - 10MW			Incremental Cost ($/month/customer)	
Case Name	Participation Level	# Customers Enrolled	Residues	Energy Crop
Co-firing at 3%	10%	22,267	$(0.33)	$1.69
Co-firing at 10%	10%	74,222	$0.31	$2.35

Source: Demeter and Lindsey

Equation 3: Green pricing wood co-firing across customer classes

Biomass output: 10% - 10MW			Incremental Cost ($/month/customer)	
Case Name	Participation Level	# Customers Enrolled	Residues	Energy Crop
Residential	10%	51,956	$0.31	$2.35
Commercial	10%	2,235	$2.06	$15.64
Industrial	10%	43	$53.94	$409.12

Source: Demeter and Lindsey

In this hypothetical case, the impact on rates are slight. Of course, the hypothetical case is very favorable, as compared to Wisconsin circumstances. For example, the coal fuel costs are higher than utilities pay under long-term coal contracts for large boilers and the wood fuel costs are low. However, there is still reason to believe that the lower costs and higher amounts of energy produced overall can make a biomass cofiring an attractive addition to a green power portfolio to help reduce overall program costs and enlist more customers.

Plasynski, Hughes, Costello and Tillman estimate that the incremental costs for $3 to $30 for a megawatt-hour of energy from the cofiring production. This is 0.3 to 3 cents per kWh (Plasynski, et al).

5 Wisconsin Utilities Evaluate Wood Co-Firing

The Public Service Commission of Wisconsin in Advance Plan 7, Order Point 5.2[7] ordered Wisconsin utilities to conduct studies of constructing cofiring facilities. In addition, many utilities have done their own investigations over the years which are not published. Many utilities are members of the Electric Power Research Institute, or other trade associations, which conduct investigations, research and tests.

In this section, we will review the utility studies and present results of conversations with utility employees with involvement in evaluating, designing or implementing biomass cofiring.

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[7] The Public Service Commission of Wisconsin (PSCW) used to engage in a process known as "Advance Planning." Under this process, different alternative energy demand and supply measures were considered and the Commission would order or recommend various investments or actions. This power was rescinded in 1997 Wisconsin Act 204.

5.1.1 Wisconsin Electric Power Company

Valley Power Plant Renewable Energy Generation Study, Revision 1, October 1998, Black & Veatch for Wisconsin Electric Power Company.

Wisconsin Electric Power Company (WEPCO) responded to the PSCW order by studying six power plant configurations. For all cases, they considered building a new plant at a greenfield site, and building a new boiler adjacent to the existing Valley Plant in the Menomonee Valley, Milwaukee. WEPCO investigated burning wood only, wood with high carbon content fly ash, and wood with Powder River Basin coal.

This is not a cofiring plant in the strict sense of the term. However, utilizing the existing site provides a different approach to cofiring. Typical cofiring utilizes the same equipment for fuel transfer and combustion simultaneously for two different fuels. WEPCO's Valley Plant option approach utilizes the same site only and involves a lesser degree of infrastructure-sharing.

This offers benefits, however. It provides for fewer fuel handling problems and provides added generation capacity. Economies of scale may be realized in reduced operating costs through the use of the same personnel, materials and facilities as the larger plant. Small wood-fired plants often suffer from higher per unit operating costs. However, the investment will be larger than for only adding a new coal stream to an existing boiler.

Another benefit -- from the company’s perspective – is that building at the existing site would make permitting easier since this is a brownfield site rather than a greenfield.

Scenarios at the Valley Plant were considered using the waste heat in the winter months in an existing district heating system. Using the biomass for steam allows more of the steam, from the existing coal boiler to be used for electric power, so the connection between fuel combustion and electric power production is less direct. These designs might also provide steam to the existing turbines at certain times. The boilers would be sized to replace the steam capacity for the other four boilers lost as a result of a switch to low sulfur Powder River Basin coal, thereby making fuller use of the existing turbogenerator.

The wood-coal option provides the highest level of cofiring. On a mass basis, the plant would burn a much higher 60% wood and 40% coal. On an energy basis, that translates to 52% coal, and 48% wood. This option is chosen for comparison to other plants as it is the closest to a plant retrofit as used in other studies. Summary data for the project s provided in Table 6

Table 6: WEPCO Cofiring Retrofit Plan

Cofiring Level (mass basis)	Tons wood per year	Boiler Type	Biomass Power Capacity (MW)	Investment ($000)	Capacity cost ($/kW)	Year $
60%	295,181	Fluid bed				

The report provides a pre-feasibility level assessment of the alternative scenarios. The assessment includes capital and operating cost estimates, layouts, and performance figures. The discussion of emissions is limited to consideration of likely emission control requirements and permitting that would be required. No quantitative emissions are provided for alternate scenarios. It is noted that development of a green field site would require more permitting than expansion of an existing plant. There is no discussion of emissions of greenhouse gases.

A summary of key information is provided in Table 7.

Table 7 Summary of WEPCO Wood Plants Studied

	Wood – existing site	Wood – Greenfield site	Wood / Fly Ash – existing site	Wood / Fly Ash – Greenfield site	Wood On site (Combined Heat and Power)	Wood/Coal On site (Combined Heat and Power)
Net plant output (MW)	35	36	35	36	11	11
Boiler type	Stoker	Stoker	Fluid Bed	Fluid Bed	Stoker	Fluid Bed
Fuel Burn rate (tons/year)						
Wood	286,735	298,817	249,219	259,720	301,248	295,181
Ash / Coal	0	0	62,306	64,932	0	218,178
Net plant heat rate	12,274	12,648	11,968	12,333	55,752	54,362
Total Capital Cost ($1998)	66,177,504	65,173,416	73,168,208	72,164,787	47,717,000	91,449,000
$/kW (based on net kW)	1,891	1,862	2,091	2,062	D.N.A.	D.N.A.
Annual Operating & Maintenance ($1998)	7,004,568	7,507,414	8,569,183	8,108,327	6,896,425	13,521,003

The wood fuel sources were thought to include urban wood waste; used pallets, construction waste, and tree trimmings. 300,000 tons per year is assumed to be available within a 50-mile radius of the plant from these sources. Other sources they have may not have considered include edgings and cuttings from the secondary forest products industry. Experience shows that the forest product industry is willing to ship wood residues much further than 50 miles. The wood fuel supply would appear to be adequate. However, the location does not appear to be suitable for energy crops.

Construction waste would be a concern for the environmental community. Construction waste can contain chemical treatments, paint and metals which would be emitted in combustion.

The wood analysis used includes a 23% moisture content, and wood with a heating value of 5,950 Btu per pound. Wood particle size would need to be three inches and less. This fuel size is greater than the requirements for cofiring in other coal boilers and offers a more economic way to prepare the fuel. Impurities, such as from chemical treatment, would introduce new requirements for permitting.

As may be seen, this represents two different fuel approaches to co-firing. In both cases, the fluidized bed offers fuel flexibility not found in other boiler configurations. Using fly ash utilizes a coal waste product with remaining heating value. The fly ash would come from the Valley Plant (40,800 tons per year generated), the Port Washington Plant (42,500 tons per year generated), and the Oak Creek plant

(187,000 tons per year generated). The coal would be Powder River Basin coal, which is relatively low in sulfur.

5.1.1.1 Views of Wisconsin Electric Personnel

Carl Siegrist, Senior Project Strategist, Office of Research & Innovation, for Wisconsin Electric Power Company (WEPCO) provided answers to several questions regarding WEPCO consideration of cofiring.

Siegrist pointed out that WEPCO has committed to exceed the requirements of the Renewable Portfolio Standard by 50%. Such a higher commitment to renewable energy increases the potential for cofiring projects, as well as more wind power, fuel cell, and solar projects. Their commitment under the RPS will rise to 1.0% in 2001, 1.7% in 2003, increasing to 3.3% of total retail electric sales in 2011, if their "Power the Future" program is approved by the Public Service Commission.

WEPCO has engaged in a building plan for 1,700 MW of generation capacity. This includes two 600-MW coal plants, one or more 500 MW combined cycle natural gas plants and, apparently, additional renewable energy capacity. New biomass and other renewable capacity could be a part of this building plan.

With the construction of new coal plants, WEPCO has the opportunity to design and build in new cofiring capacity from the start of the projects. One way to accomplish this would be to use fluidized bed boilers, which can accept fuel in larger sizes and of more variety. Siegrist said WEPCO is still evaluating all options for their proposed coal plants.

Siegrist said WEPCO needs a demonstrated economic success. The plant must be financially sustainable. Examples of other successful projects also helps increase the prospects for project development.

The designs considered for the Valley Power Plant are still under consideration. An uncertainty exists, however, in how certain scenarios would be treated. Specifically, the option to use a biomass boiler to produce steam for the district heating is at question. This steam would replace steam from the current coal boiler, allowing it to produce more electricity.

How would this incremental electricity be treated under the RPS program? The added electricity would not be there if not for the new coal-wood cogeneration system. However, the electricity is, in reality, produced by coal. It's not clear how this would be interpreted under the RPS program, let alone federal incentive programs.

Fuel costs are an obstacle. Coal is currently purchased at about $1.00 per million BTU. However, in their investigations, Siegrist says WEPCO has found wood fuel costs of approximately $3-4.00 per million BTU for wood residues. That translates to $19 to $38 per ton.

The idea of selling cofiring under green pricing programs has not been previously considered by WEPCO. They are not clear what would be included in the green pricing program. They'd like to hear opinions from environmental groups.

Siegrist said there is a clear need for more information on cofiring to inform forecasts. No doubt, building plans could also benefit from more information about biopower options.

5.1.2 Madison Gas & Electric

Madison Gas & Electric initiated biomass cofiring investigations prior to the PSC order. MG&E had partnered with Ken Ragland and Dany Aerts at the UW Mechanical Engineering Department. Ragland and Aerts pursued a project conceived at a brainstorming session of the Great Lakes Regional Biomass Energy Program (GLRBEP).

Madison Gas & Electric has a history of developing alternate fuels. In 1979, Madison Gas & Electric worked with the City of Madison to develop the capacity to burn Refuse-Derived Fuels (RDF). An RDF fuel preparation plant was set up on Olin Drive just to the north of the Dane County Exposition Center. Boiler modifications were made during this time to handle alternates to coal. Two of the boilers at MG&E's Blount street station were modified to burn alternate fuels. These are identical pulverized coal boilers.

The project was stopped when falling fossil fuel prices made the plant non-competitive. More recently, MG&E has been burning paper derived fuels and some plastic films. General Fuels processes the fuels onsite to the requirements for use in the MGE boiler.

In 1996 and 1997, MG&E hosted the nation's first cofiring tests using switchgrass as a blended fuel. Switchgrass is a prairie grass that is often grown for forage or to build soils. Switchgrass is considered a favorable crop compared to annual row agriculture, as switchgrass is a perennial plant that develops a strong root system that hold soils together. The switchgrass used in these tests came from Chariton Valley, Iowa and Iowa County, Wisconsin.

The MGE switchgrass cofiring test used an 8 to 15% blend of switchgrass to coal (by mass). Tests showed that the fuel handling system would operate trouble-free at a maximum of 3 tons per hour to each boiler (8 & 9), which is equivalent to an 8% cofiring rate, by heat.

5.1.2.1 Test Results

A few problems were encountered during the tests. The existing machinery was not adequate to reduce the large round bales of switchgrass. As a result, these bales had to be taken apart by hand, or offsite with a tub grinder in a later test, to fit into the existing shredding equipment. MG&E suggests that this problem could be overcome by replacing the shredders and hammermills with those capable of handling the large bales. Another problem at the processing stage was dust propagation. Researchers felt a baghouse would eliminate the dust problem.

Another problem was the lack of fuel storage area for a switchgrass. This could be overcome by either just-in-time delivery or from off-site storage.

The boiler efficiency fell off during the tests, from 87.44% to 86.48%. Researchers attributed this to the grate and injection air not being preheated, as in coal-only operation. It was not clear if this would necessarily have to be the case with coal-biomass cofiring.

The costs for switchgrass used in the tests were not competitive with coal costs. The total costs for harvesting, drying, baling, and shipping the Wisconsin switchgrass baled on this experience were estimated at $23 per bale, or $4.44/MMBtu. This compares poorly to the coal costs of $1.20 per MMBtu. Researchers expected that costs could be reduced for a larger scale project.

Emissions tests showed that nitrogen oxide emissions were reduced by 31%, and opacity was reduced by 62% when cofiring at 10% mass replacement. Despite the fact that switchgrass contains 30% of the sulfur of coal, there was no noticeable difference in sulfur dioxide emissions.

Carbon dioxide emissions from biomass combustion were more complicated. Switchgrass contains 35% less carbon than coal on a mass basis, but 4% more on a heat basis. Therefore, carbon dioxide released from boilers increases slightly with increasing use of switchgrass. However, the carbon dioxide from switchgrass is from a renewable source, recently removed from the atmosphere and, therefore, not a net reduction to global warming. Therefore, the emissions reduction of nonrenewed CO2 from cofiring combustion would be around 7%.

5.1.2.2 Views of Madison Gas & Electric Personnel

Several MG&E employees were contacted for this report. These employees include Randy Popp, Laura Williams, and Greg Bollom. Madison Gas & Electric has been a leader in green pricing programs, with their untitled wind power program. They have conducted extensive market research and customer education efforts. Their program has quickly become one of the most successful in the nation.

Madison Gas & Electric have not explored cofiring beyond the switchgrass testing that they conducted. Many MG&E employees report that the fuel handling was difficult, messy and labor intensive. Switchgrass capacity would require special handling or silos to reduce the fugitive dust problem. (Pneumatic conveyance from silos may address their concerns). In addition, space is at a premium in downtown Madison and MG&E doesn't have a large fuel storage area available for the biomass fuel.

The mechanics of fuel supply would need to be addressed. MG&E needs to know what farmers to approach and how. In response to a question regarding a cooperative, that was defined as a "key piece" to the fuel supply puzzle. The MG&E Blount Street station is located on Madison's isthmus, so there is not extra real estate available.

A low moisture content fuel was used in analysis because field crops dry adequately in the field. Given one harvest per year, the fuel would need to be stored afterwards. On field harvesting addresses both the storage and fuel drying issues. The Blount Street Station is located along a railroad and fuel could, potentially, be transported in by rail. Transporting large amounts of biomass by truck to downtown Madison may otherwise introduce some challenges.

The MG&E study focused on test results, but did not generate information on ways and costs to convert the plant. Therefore, conversion costs are unknown at this time and it is difficult to know what the rate impacts would be. Once these costs are determined, a rate study could be conducted. Financially, MG&E would need to be made whole on any such project.

MG&E employees considered energy crop cofiring marketing as a difficult sell for a green power product. To many people, it is not clear that this counts as a "renewable fuel." If it does count as renewable, there's the question of whether it is "dark green" like wind and solar or more of a "light green" renewable energy. They have discussed this option somewhat with the Sierra Club.

A large obstacle to MG&E employees was the skepticism regarding energy crop viability as a renewable energy strategy. Introducing energy crops as a green power option would present a "more significant marketing hurdle" than wind power and require more consumer education. Greg Bollom indicated that it would be "hard to impress the public that it is renewable."

5.1.3 Wisconsin Public Service Corporation

Co-firing Wood Residue Report RENEW-WPS Collaborative Study for Selected WPW Powerplants, February 23, 1999. Wisconsin Public Service Corporation.

To fulfill requirements of the PSCW order, Wisconsin Public Service Corporation (WPS) revisited an earlier study it had done of the wood cofiring with coal at it's Weston station powerplant, located to the east of Wausau. The previous study was conducted by Al Andersen for RENEW Wisconsin through a contract with WPS. That study considered using the Weston Station boiler number 1 rated at 60 MW and constructed in 1954, and the Pulliam station boiler number 6, rated at 62.5 MW and constructed in 1951. The analysis focused on Weston #1, expecting that the results could apply also to Pulliam #6.

The study addressed wood cofiring at 10% on a Btu basis. At this rate, the plant would consume 66,640 tons of wood per year. The study assumed that the wood residues would be delivered to the plant at design specifications of no greater than ¾ inch, and low moisture content. This particular study addressed the possibility of a central "wood refinery" at an offsite location that would process wood to several uses, including fuel. The coal fuels costs were $.94 to $1.01/MMBtu from 1996 to 1998.

This study addressed wood fuel supply in greater depth than the other studies. Several assessments performed by a variety of firms and agencies were used and compared. Sources for wood waste supply include the primary (round log to lumber) and secondary (lumber to finished product) industries.

In addition, they addressed the economics of wood wastes more than the other reports. This area is one of the core challenges of developing wood energy systems. One table provides a breakdown of costs per ton for fuel at two different Btu levels. That table is reproduced in Table 8.

Table 8: Wood residue costs per million BTU at various costs per ton

Cost/Ton	$ 5.00	$ 6.00	$ 7.50	$10.00	$12.50	$15.00	$17.50
Btu/lb	4700	4700	4700	4700	4700	4700	4700
Cost/Mbtu	$ 0.53	$ 0.64	$ 0.80	$ 1.06	$ 1.33	$ 1.60	$ 1.86
Btu/lb	4250	4250	4250	4250	4250	4250	4250
Cost/Mbtu	$ 0.59	$ 0.71	$ 0.88	$ 1.18	$ 1.47	$ 1.76	$ 2.06
Cost/Ton	$20.00	$22.50	$25.00	$27.50	$30.00	$32.50	$35.00
Btu/lb	4,700	4,700	4,700	4,700	4,700	4,700	4,700
Cost/Mbtu	$ 2.13	$ 2.39	$ 2.66	$ 2.93	$ 3.19	$ 3.46	$ 3.72
Btu/lb	4250	4250	4250	4250	4250	4250	4250
Cost/Mbtu	$ 2.35	$ 2.65	$ 2.94	$ 3.24	$ 3.53	$ 3.82	$ 4.12

This study found that the cofiring scheme would lower emissions of several pollutants, as follows, based on cofiring at 10% on a mass basis:

- Particulates: estimated to be reduced by about 8%.
- Sulfur oxides: estimated to be reduced by about 10%
- Nitrogen oxides: estimated to be reduced by about 15%

- Chlorine compounds: estimated to be reduced by about 6%

The study did not address CO2 emissions. The results were calculated for the Pulliam plant, but considered to be applicable to the Weston boiler #1.

The total costs for conversion of the system are estimated at $2,312,679. The highest cost item is for the boiler retrofit at $910,000, followed by the storage silo at $714,000, and the hydraulic trailer dumper at $400,000. Maintenance costs for the new equipment are estimated at $16,900 per year. Apparently, all costs are in 1999 dollars.

This is one of the few studies to address energy crops. The analysis relied entirely on the assessment performed by David Tillman for Wisconsin utilities. The analysis was pretty negative towards energy crops, focusing on low yields, crop conversion, and fuel costs. It was short on suggestions for overcoming challenges and did not provide any other perspectives.

In the conclusions, the report’s authors determine that co-firing is feasible, based on using wood residues. Their analysis considers using wood residues that would otherwise be landfilled, with a value equal to the cost of transportation. The feasibility includes utilizing the wood residue refinery concept.

The incentive for WPS as a cost-effective way to implement co-firing was suggested to be the reduction of emissions. However, the evaluation used a low cost for fuel to reach an overall project savings. The fuels cost at which WPS could save funds was between $7.50 and $10.00. There was no further benefit calculated in terms of decreased emissions.

5.1.4 Alliant Energy / Wisconsin Power & Light

Coal-Wood Co-firing Plant Opportunities and Conceptual Assessments, December 14, 1998, Alliant Energy-Wisconsin Power & Light.

Alliant Energy evaluated the Edgewater plant in Sheboygan. The Edgewater plant has five coal-fired boilers, and a total generation capacity of 800 MW. The studied focused on Unit #3, which is a 70-MW cyclone boiler that utilizes 200,000 tons of coal per year.

The study assessed using wood in a 10%, by weight, blend with coal. This would result in a demand of 20,000 tons of wood per year, or 55 tons per day. Wood fuel cost is estimated at $1.50/mmBTU for 5,000 btu/pound wood (this translates to $15 per ton, which is almost twice the price paid at Northern States Powers' Bayfront Plant in Ashland). They project using wood waste, although the actual sources are not discussed.

The plant has space limitations due to previous expansions. Therefore, they would require Just-in-Time delivery of the wood fuel. As cofiring can reduce boiler capacity, wood fuel use would be shut off during peak times to produce more energy. The plant already cofires Tired Derived fuel (TDF) with coal.

The wood fuel would need to be reduced to ¼” in size. Alliant emphasizes the need for maintaining high fuel quality in terms of size and quality. Impurities often found with bark include alkalis, which can cause slagging in coal boilers. Therefore, bark is excluded from the fuel specification.

The total electrical generation capacity from wood energy would be 5.4 MW. Alliant says they would need to derate the plant by 1.6 MW due to lower efficiency. They estimate the fuel cost impacts of this efficiency loss at $12,900. The boiler operation has been previously modified to switch from high-sulfur to low-sulfur coal. Previously, sulfur content was at 2.5% to 4.5%, and coal blends are now about 0.3% sulfur. Because the lower sulfur coal also has lower energy per pound, the fuel feed systems have already been augmented to increase flow rates.

The study addressed only the sulfur emissions reduction. The sulfur reduction would be 146 tons per year. At a market value of $125 per ton, value, the total annual savings in reduced sulfur emissions would be $18,250.

Capital costs for the plant retrofit were estimated at $2,703,000. Operating costs were estimated at $363,900, of which $220,000 is for increased fuel costs and $50,000 for labor.

5.1.4.1 Views of Alliant Energy Personnel

The focus of Alliant's cofiring efforts have shifted from the review of options at the Sheboygan plant to planning and testing for a switchgrass cofiring system at their Ottumwa plant in Iowa. The Ottumwa project is one of the most developed biomass energy strategies in the country. The Ottumwa project is also known as the Chariton Valley project, for its location and for the local agricultural groups involved. Bill Morton, Lead Engineer, Projects, leads the Ottumwa cofiring efforts. Mr. Morton provided significant information on the progress of the project.

The plans are to modify the 750 MW coal plant to fire switchgrass at a 5% co-fire rate. This will require 50,000 acres of land and 200,000 tons per year to provide the dedicated biomass energy supply for the plant. The boiler is a pulverized coal drum type boiler. The switchgrass is reduced to 1" to 1.5" size, transported pneumatically and then injected into the boiler. To maintain the cofiring rate, 25 tons (50 bales) of switchgrass per hour must be delivered to the boiler (Cooper, Braster, & Woolsey). One concern is slagging from the alkali content of prairies grasses.

Alliant conducted test burns in 2000. They burned 1,250 tons of switchgrass at a rate of 12.5 tons per hour, or 2.5%. At this rate, they were able to reduce the amount of coal added to the boiler. Following the test, the boiler was shut down and inspected for routine inspection. Alliant employees could not find evidence of slagging within the boiler. Alliant performed stack tests for emissions, however, those results are not fully interpreted yet.

Morton indicated the fuel should have a maximum moisture content of 15%. The fuel as delivered is within this limit, so no drying is needed. The costs for the fuel, now is $50 per ton ($3.18/ MMBtu) at the farm gate. Transportation and processing brings costs to about $60-65 per ton ($3.80/MMBtu).

Economics are a key consideration. As mentioned earlier, cofiring does not qualify for the Production Tax Credit. Iowa Senator Charles Grassley has introduced legislation to modify the tax credit to relax the restrictions that make it useless for energy crops.

Future plans include testing at a larger scale. 6,000 acres are available for growing switchgrass for the test program. Employees engaged in the cofiring tests have not yet discussed the program with Alliant's Second Nature green pricing program. So, Alliant has not yet evaluated including energy crop cofiring in a green pricing program.

6 Strategy

Developing energy crops as a reliable and economical fuel source is a challenging prospect. A chicken and egg dilemma exists. Establishing energy generation capacity requires an affordable supply of the fuel. However, no energy crop fuel supply now exists because there is no market to sell to. As a result, there is less development of skills, equipment and planting stock to lower the fuel costs and increase reliability.

Other obstacles remain. The Biomass Energy Infrastructure Workshop, held in 1994, resulted in identification of numerous barriers (Olsen & Stevenson).

The public has very low awareness of biomass energy. "Biomass" is hardly a term in common parlance. What awareness exists is often negative, due to the image of trees being cut or of smokestacks used by the generators. Therefore, including energy crops as an energy source under green pricing programs is problematic due to the public perception (Olsen & Stevenson).

The increasingly competitive electric power industry places less and less value on environmental performance of energy sources. Fossil fuels, though more costly in environmental terms, are significantly less expensive in a financial sense. State and federal policies do not make substantial difference to alter that calculation. It is also worth noting that the lowest prices for coal are paid by the biggest plants, who often have long-term contracts. What's more, entrenched subsidies, such as depletion allowances, tilt the field even more so toward fossil fuels (Olsen & Stevenson).

Using energy crops as a fuel is more difficult than simply contracting with a supplier or two for coal. Supply contracts must be arranged with numerous fuel growers. This is not typical utility practice (Olsen & Stevenson).

Education was noted as a great need. This education applies to all stakeholders in the process. Environmentalists can stand to learn more about combustion and cropping techniques and standards. Farmers can learn more about the crops. Utilities need to learn more about ways to make project design and economics work.

6.1 Goals for cofiring program

A strategy must begin with a goal. Otherwise, there is insufficient direction to guide the strategy. A useful goal would be to establish the practices, markets and resources to integrate closed loop biomass into the existing generation system. Cofiring is an integral part of this plan, as it offers an incremental path to develop the energy resource. As cofiring helps us develop the crops, we come closer to dedicated and highly efficient biomass plants generating power from dedicated biomass crops.

6.2 Development strategies

6.2.1 Dialogue, Dialogue, Dialogue

The Biomass Energy Infrastructure Workshop brought in many individuals new to the conversation over energy crop development. In other regions of the country, "roundtables" have been formed to work through the many issues of energy crop development and use. These roundtables involve individuals from many different types of groups; utilities, farmers, environmental groups, regulators, policy makers and advocates.

The creation of a Wisconsin Biomass Roundtable would provide opportunity to air issues and try to come to agreement. This group could make recommendations for biomass development activities to be funded by Public Benefits funds. The group should be facilitated by a trained facilitator and structured to focus meetings and efforts. To assure participation by not-for-profits or farm groups whose budgets are often stressed, compensation should be included.

6.2.1.1 Workshops

The roundtable process should be inclusive. Including more people leads to a richer variety of ideas and views. However, meetings do not always lead to useful results. Therefore, occasional workshops should be conducted to relay the results and progress of the roundtable to a wider audience. These workshops should be patterned along the successful Biomass Energy Infrastructure Workshop (BEIW).

One of the biggest drawbacks of the BEIW was the lack of follow-through. Energy and excitement was generated, along with action recommendations. It is important that resources for follow-through are provided as the workshops are planned.

6.2.2 Establish guidelines for green energy crop development and use

Many of the concerns of various parties regarding energy crops can be addressed through the development of standards and guidelines for energy crop development and use. These standards would address, for example, the cutting of natural forests for boiler wood by banning the practice. On the other hand, it may be worthwhile at some point to consider the means and guidelines to remove residues left after logging (although this is an expensive proposition, new equipment may reduce costs).

6.2.3 Utility buy-in

Utilities are key to expanded biomass cofiring. Many Wisconsin utilities have responded well to mandates for renewable energy and have made renewable energy work within their business enterprises. In order for them to pursue biomass cofiring, they need to know that their investments will earn a reliable return. Furthermore, the views of the utilities should help guide biomass program development.

Several utilities contacted had not considered cofiring, due to limits on staff time. At the same time, they have raised many concerns. Several of the elements presented here will be of value to utility planners. In addition, a continuing dialogue with utility representatives will help address their concerns. This dialogue should be augmented with technical expertise to adequately address the concerns raised by utility representatives.

6.2.4 Rate studies

No utilities contacted have seriously considered including biomass cofiring in their green pricing programs. A useful approach may be to hire an independent consultant to prepare green rate studies for several utilities. The utilities can provide the basic assumptions and data to be used by the consultant.

6.2.5 Cofiring and green pricing

Most new green pricing programs consist of wind power projects. The next most common technology is landfill gas. Wind power is a clean and popular means of generating electricity with a common perception that it is environmentally beneficial. The same cannot be said of biomass energy. Many potential green power customers are alienated from combustion of any sort. In addition, there is a tendency to see progress only in terms of advancing by leaps, while not appreciating incremental improvements.

The fact is, while biomass energy provides a cleaner alternative to coal, it still entails emissions. To the undiscriminating, it makes for a hard case that a combustion process is cleaner. These views may shift as people become more aware of the potential for a greenhouse gas neutral system that can provide power on demand. Biomass energy is a natural complement to the intermittent renewable sources of solar and wind. However, this case has not been aggressively made.

On the other hand, there are certain market segments that will welcome biomass energy. Agricultural constituencies will appreciate the positive impact on new uses for farm products and rural development. Biomass energy may actually provide a way to broaden the customer base for green pricing programs.

6.2.5.1 Green advocate buy-in

Promoting biomass energy as a green pricing option will require the early support of green power advocates. Groups such as RENEW Wisconsin (dominated by wind and solar interests with little activity on behalf of biomass) and Environmental Decade have played an important role in criticizing or supporting green pricing programs in the past. These opinion leaders should be consulted early in the formation of plans for new green pricing biomass products. Without their support, it will not be feasible to seek greater acceptance.

Support from these opinion leaders will also help in the marketing of biomass power as a green pricing option. Their views and concerns need to be addressed early and to inform other biomass energy development activities. Regular meetings with these groups that identify and address concerns will help motivate them to adopt biomass cofiring as a core strategy. Several of these groups have made supportive statements toward biomass energy. However, the ultimate goal of the activity should be to garner their support for including biomass cofiring as an endorsed green power activity.

6.2.5.2 Market research and message development

To better understand the concerns and perceptions of the green pricing market, a market study is proposed. This study will evaluate perceptions of green pricing program participants regarding biomass energy. It will also test terms to best communicate the concept of energy crops, "closed loop biomass" and the other terms used in the field that are too often too technical or too arcane. The initial messages tested should come from the best work of parties involved in the roundtable.

Once the market research has been done, the perceptions and claims from respondents should be evaluated and tested. Are perceptions well-founded? If not, what information might address a given perception? It would also be useful to know what information the respondents might be missing. This activity will inform future educational efforts.

6.2.6 Collaboratives

Resources for biomass energy development activities are scarce and most individuals working on these efforts are disconnected from others. Furthermore, many of the challenges faced by project developers are common. One method that has been useful in other areas of the country are collaboratives or consortia to work toward developing this energy resource.

An example of such a collaboratives is the Salix Consortium in New York State. The Salix Consortium "is a partnership of over 30 industrial, government agency, outreach/technology transfer, farming, research and academic institutions committed to making wood biomass crops for energy a viable enterprise in New York, throughout the Northeast and beyond (SUNY College of Environmental Science & Forestry)." This program has made considerable advances in willows as an energy crop.

This development includes close-spacing and short rotations as well as cofiring willows in a utility boiler.

There are many organizations that might be involved in a Wisconsin energy crop consortium. This includes the university and forest service researchers who have already made significant advances in new strains of crops. Private parties and the tree farming industries can also provide practical, production-level input. Farmer interests can also be represented by agricultural groups with full-time staffers. Environmental groups, utilities, policy makers and state staff are also obvious choices for participants.

6.2.7 Policy recommendations

The playing field for the energy marketplace is influenced by government regulatory, environmental and tax policies. This playing field is already dominated by favorable treatment for the fossil fuel industry. It is not reasonable to expect the renewable energy industry to compete on such an unlevel playing field without changes to the existing structure.

6.2.7.1 Crack down on mercury emissions

Coal-fired power plants are the single largest source of mercury emissions. Due to these, and other, mercury emissions, Wisconsin lakes and rivers, as well as wildlife and some humans have become contaminated with mercury. Fish advisories have been issued for several hundred Wisconsin lakes where mercury has been found. These emissions create health risks. The considerable sports fishing industry is threatened.

This contamination of our waterways must be discouraged. Legislation needs to be passed at the state or federal level to crack down on emissions of mercury. Coal plants can address these emissions by introducing biomass cofiring at their existing plants. Reducing mercury emissions won't directly save money for the utility industry, but it will save money for people who will otherwise face health bills, loss of quality of life, or for the sportsfishing industry.

Basically, the costs for mercury emissions must be borne by the power industry. Rules pending at the Wisconsin Department of Natural Resources and the US Environmental Protection Agency should be supported.

6.2.8 Industrial operator buy-in

Utility boilers have the lowest costs for coal fuel. This provides a tougher competitive analysis for biomass fuels. However, other large boiler owners face higher coal costs. In addition, these boiler owners tend to use stoker boilers, which are better suited to cofiring because they do not require the small particle size fuels. Therefore, the retrofit costs wold be lower due to lower size reduction requirements. The economics of wood-coal cofiring at these plants would be much better.

It may be fruitful to approach these plant owners to seek interest in biomass cofiring. However, they have fewer reasons to implement cofiring than do the utilities. They have no mandates, no renewable portfolio standard to meet. A partnership and power purchase contract between these firms and the utilities may provide a vehicle to implement cofiring and additional electrical production where it is most economically advantageous. The utility could include this renewable capacity in their renewable portfolio or green pricing programs. The first step in this process is to identify those facilities that require high quality steam produced by combined heat and power installations.

6.2.9 State Government Leadership

The State of Wisconsin owns numerous coal burning facilities to provide district heat and cooling and, in some cases, power. As a smaller institutional user, the state faces higher coal costs. The state could take lead on an effort to demonstrate biomass energy potential by taking the lead on developing the resource. The state could commit to convert one or more of these units to cofiring capacity. As these are stoker boilers, both the retrofit and fuel costs would be lower.

The Governor could demonstrate leadership in this area by issuing an executive order to use wood fuels in state boilers. Prior to this, it would be helpful to have a feasibility study conducted for every boiler in the state system, to provide a total of benefits and costs. By basing the new capacity on energy crops, the state would also aid local farmers and further demonstrate the potential for new uses for agriculture.

Table 9: State-owned coal boilers

Capital Heating & Power
Green Bay Correctional Institute
Hill Farms Central Plant
Mendota Mental Health Institute
Northern Wisconsin Center
Sanger Powers Correctional Institute
Taycheedah Correctional Institute
UW - Eau Claire
UW - La Crosse
UW - Madison
UW - Oshkosh
UW - Platteville
UW - River Falls
UW - Stevens Point
UW - Stout
UW - Superior
UW - Whitewater
Waupun Correctional Institute
Winnebago Mental Health Institute

6.3 Development of energy crop resource

The key to moving forward on energy crops is to get them planted and to begin to develop some practical experience. Field trials and demonstration plantings will help test claims of energy crop advocates and identify obstacles and opportunities for further improvements. Involving more practitioners will help find ways to increase yields, lower production, transport, and size reduction costs.

After all the studies and meetings of typical study efforts are done, we still do not have much to show in terms of actual, physical progress. Planting energy crops should be a part of all development efforts so that tangible progress is made.

A Wisconsin consortium could focus on means to get crops planted. This might involve futures contracts for energy crops, such as used by Minnesota Power. These trees may also be used for fiber for paper and other products. This way, the utility (or other entity) invests in a possible fuel source, with established, alternative markets available. This might be more difficult for prairie grasses, where other markets have not developed.

The Renewable Energy Public Benefits funds could be invested this way to establish energy crops while developing real-world experience. Contracts would need to be structured so as to assure that growers maintain crops, not simply plant them.

6.3.1 Evaluate the potential for futures contracts

One method to increase planting of energy crop was used by Minnesota Power. They purchased futures contracts for trees grown by farmers. This provided cash to farmers for setup and crop maintenance. At the end of the contract, the trees can be used for energy or for other uses, such as fiber. A similar program in Wisconsin could jump start plantings.

6.3.2 Evaluate Using Conservation Reserve lands

The Sierra Club is exploring using Conservation Reserve Program lands as Energy Reserve Lands. This approach would reduce, though not eliminate, the subsidy costs for the conservation program. The costs for crops could then be reduced to some degree, as well. The result would be an integrated into the conservation program that provides environmental benefits while also reducing costs for a renewable fuel.

The Energy Reserve program shows promise and should be pursued. The details and implications of the program need to be explored. There is some latitude for these programs on the local level, which may provide opportunities to test pilot programs.

6.4 Increase the Renewable Portfolio Standard

The Renewable Portfolio Standard is set at a low level. This RPS should be increased to more aggressively foster development of renewable energy forms of all types.

7 Utility coal boilers in Wisconsin

FACILITY NAME	CITY	Particulate matter (tons)	PM-10 (tons)	SO2 (tons)	NOX (tons)	CO (tons)
DAIRYLAND POWER COOP ALMA STATION	ALMA	674.1	118.2	9,150.6	7,453.2	474.6
DAIRYLAND POWER COOP GENOA STATION-EOP	GENOA	1,426.2	205.0	12,513.0	4,180.4	236.9
MADISON GAS & ELEC FITCHBURG GENERATING STAT	FITCHBURG	5.8	5.8	0.4	60.8	14.3
MADISON GAS & ELECTRIC CO BLOUNT ST STN	MADISON	220.6	215.5	3,711.2	1,810.7	128.2
MADISON GAS & ELECTRIC CO SYCAMORE STATION	MADISON	3.5	3.5	0.3	37.3	8.5
MANITOWOC PUBLIC UTILITIES	MANITOWOC	148.5	127.9	2,770.1	762.8	328.4
NORTHERN STATES POWER CO - FLAMBEAU GEN STN	PARK FALLS	4.0	4.0	0.1	41.8	10.4
NORTHERN STATES POWER CO WHEATON GEN PLANT	EAU CLAIRE	16.0	7.4	48.2	185.9	8.5
NORTHERN STATES POWER CO-BAY FRONT GEN STN	ASHLAND	106.6	32.0	973.2	1,151.9	365.4
NORTHERN STATES PWR CO FRENCH ISLAND GEN PLT	LA CROSSE	43.1	6.0	102.1	233.8	33.7
WI PUBLIC SERVICE CORP - JP PULLIAM PLANT	GREEN BAY	703.7	192.9	6,398.1	7,696.0	372.1
WIS ELECTRIC POWER CO - PARIS	PARIS	54.6	54.6	1.2	573.6	141.6
WIS ELECTRIC POWER COMPANY	WATERTOWN	47.8	47.8	3.2	504.4	119.1

FACILITY NAME	CITY	Particulate matter (tons)	PM-10 (tons)	SO2 (tons)	NOX (tons)	CO (tons)
WIS ELECTRIC POWER GERMANTOWN STATION	GERMANTOWN	21.7	13.5	56.5	248.0	39.1
WIS ELECTRIC POWER OAK CREEK STATION	OAK CREEK	450.7	104.2	28,241.5	16,973.1	860.1
WIS ELECTRIC POWER PLEASANT PRAIRIE STATION	PLEASANT PRAIRIE	510.7	72.5	28,072.9	18,951.7	1,644.7
WIS ELECTRIC POWER POINT BEACH STATION	TWO RIVERS	1.2	1.2	0.9	13.5	0.7
WIS ELECTRIC POWER PT WASHINGTON STATION	PORT WASHINGTON	90.1	6.1	11,163.0	3,040.5	120.6
WIS ELECTRIC POWER VALLEY STATION	MILWAUKEE	135.9	31.3	16,864.5	6,649.3	160.5
WIS PUBLIC SERVICE CORP	PESHTIGO	37.6	37.6	3.0	181.0	93.7
WIS PUBLIC SERVICE CORP - WESTON PLANT	ROTHSCHILD	945.3	164.2	11,418.7	6,157.7	633.8
WIS PUBLIC SERVICE CORP-EAGLE RIVER PEAKING	EAGLE RIVER	0.6	0.6	0.4	8.9	1.9
WIS PWR & LIGHT BLACKHAWK GEN STATION	BELOIT	0.8	0.8	0.1	34.1	10.2
WIS PWR & LIGHT COLUMBIA GEN STATION	PORTAGE	1,247.9	213.4	29,882.0	15,236.4	1,114.4
WIS PWR & LIGHT EDGEWATER GEN STATION	SHEBOYGAN	791.1	58.0	19,467.0	15,235.0	497.3
WIS PWR & LIGHT SHEEPSKIN	EDGERTON	1.4	1.4	0.1	14.6	3.6
WIS PWR & LIGHT-NELSON DEWEY GEN STATION	CASSVILLE	177.8	15.4	14,150.0	5,000.4	170.6
WIS PWR & LIGHT-ROCK RIVER GEN	BELOIT	36.9	8.9	1,399.2	1,694.2	82.8

FACILITY NAME	CITY	Particulate matter (tons)	PM-10 (tons)	SO2 (tons)	NOX (tons)	CO (tons)
STATION						

Source: Wisconsin Department Natural Resources, Bureau of Air Management

8 Non- Utility Coal Boilers In Wisconsin

Plant	County	Boiler Type	Primary Fuel	Capacity mmBTU/hr	Heat Input mmBTU
APPLETON PAPERS INC LOCKS MILL	OUTAGAMIE	Spreader Stoker	COAL	341	1,026,309
CONSOL PAPERS INC BIRON DIV	WOOD	Cyclone	COAL	340	829,777
CONSOL PAPERS INC BIRON DIV	WOOD	Spreader Stoker	COAL	445	937,235
CONSOL PAPERS INC WISCONSIN RIVER DIV	PORTAGE	Stoker	Coal	173	
CONSOLIDATED PAPERS INC-KRAFT DIV	WOOD	Spreader Stoker	COAL	412	933,999
CONSOLIDATED PAPERS INC-KRAFT DIV	WOOD	Spreader Stoker	COAL	412	774,125
FORT HOWARD CORPORATION	BROWN	Stoker	Coal	140	
FORT HOWARD CORPORATION	BROWN	Stoker	Coal	200	
FORT HOWARD CORPORATION	BROWN	Stoker	Coal	200	
FORT HOWARD CORPORATION	BROWN	Stoker	Coal	249	
FORT HOWARD CORPORATION	BROWN	Stoker	Coal	350	
FORT HOWARD CORPORATION	BROWN	Spreader Stoker	COAL	350	1,113,716
FORT HOWARD CORPORATION	BROWN	Fluidized Bed	COAL	486	1,278,202
FORT HOWARD CORPORATION	BROWN	Cyclone	COAL	615	2,008,769
FORT MCCOY U.S. ARMY BASE	MONROE	Stoker - Gas Retrofit	Coal	117	
FORT MCCOY U.S. ARMY BASE	MONROE	Stoker - Gas Retrofit	Coal	217	
GM- NAO JANESVILLE- TRUCK PLATFORM	ROCK	Stoker	Coal	118	
GM- NAO JANESVILLE- TRUCK PLATFORM	ROCK	Stoker	Coal	118	
GM- NAO JANESVILLE- TRUCK PLATFORM	ROCK	Stoker	Coal	118	
GM- NAO JANESVILLE- TRUCK PLATFORM	ROCK	Stoker	Coal	118	

Plant	County	Boiler Type	Primary Fuel	Capacity mmBTU/hr	Heat Input mmBTU
GREEN BAY PACKAGING INC MILL DIVISION	BROWN	Stoker	Coal	229	
MILWAUKEE CO. DEPT. PW&D-POWER PLANT	MILWAUKEE	Stoker	Coal	140	
MILWAUKEE CO. DEPT. PW&D-POWER PLANT	MILWAUKEE	Stoker	Coal	140	
MILWAUKEE CO. DEPT. PW&D-POWER PLANT	MILWAUKEE	Stoker	Coal	140	
MOSINEE PAPER CORP	MARATHON	Stoker	Coal	212	
NEKOOSA PAPERS INC NEKOOSA MILL	WOOD	Dry Bottom	Coal	153	
NEKOOSA PAPERS INC NEKOOSA MILL	WOOD	Dry Bottom	Coal	153	
NEKOOSA PAPERS INC NEKOOSA MILL	WOOD	Stoker	Coal	303	
NEKOOSA PAPERS INC NEKOOSA MILL	WOOD	Spreader Stoker	COAL	303	957,519
NIAGARA OF WISCONSIN PAPER CORP	MARINETTE	Dry Bottom	Coal	103	
NIAGARA OF WISCONSIN PAPER CORP	MARINETTE	Dry Bottom	Coal	103	
NIAGARA OF WISCONSIN PAPER CORP	MARINETTE	Stoker	Coal	103	
NIAGARA OF WISCONSIN PAPER CORP	MARINETTE	Dry Bottom	Coal	123	
NICOLET PAPER COMPANY	BROWN	Stoker	Coal	105	
NICOLET PAPER COMPANY	BROWN	Stoker	Coal	105	
REPAP WISCONSIN INC	OUTAGAMIE	Stoker	Coal	138	
REPAP WISCONSIN INC	OUTAGAMIE	Stoker	Coal	165	
REPAP WISCONSIN INC	OUTAGAMIE	Tangential	Coal	249	
RHINELANDER PAPER CO	ONEIDA	Cyclone	Coal	300	941,435
TENNECO PACKAGING INC.	LINCOLN	Stoker	Coal	122	
TENNECO PACKAGING INC.	LINCOLN	Cyclone	Coal	191	

Plant	County	Boiler Type	Primary Fuel	Capacity mmBTU/hr	Heat Input mmBTU
THILMANY PULP & PAPER COMPANY	OUTAGAMIE	Cyclone	Coal	192	
THILMANY PULP & PAPER COMPANY	OUTAGAMIE	Cyclone	Coal	379	1,078,694
WIS DOA / UW MADISON--CHARTER ST	DANE	Stoker	Coal	125	
WIS DOA / UW MADISON--CHARTER ST	DANE	Stoker	Coal	250	

Source: Wisconsin Department Natural Resources, Bureau of Air Management

Following are other boilers not regulated by the Wisconsin Department Natural Resources, Bureau of Air Management. Information on state-owned boilers is provided in Table 9 on page 37.

- Gilbert Paper Company
- Kerwin Paper company, Riverside
- Menasha Electric & Water Utilities
- Milwaukee House of Corrections
- Scott Paper Company
- Uniroyal Goodrich Tire Company

9 Bibliography

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Alliant Energy-Wisconsin Power & Light. *Coal-Wood Co-firing Plant Opportunities and Conceptual Assessments.* Madison, WI. December 14, 1998.

Alliant Energy's study of cofiring at their Edgewater plant. Reviewed in the main report.

Appel Consultants, Inc. "Bay Front Station, Ashland, Wisconsin" in Lessons Learned from Existing Biomass Power Plants, http://www.westbioenergy.org/lessons/les02.htm, ,

This paper provides a case study of the Bay Front Station. It is a part of a larger study looking at operational experience for numerous biomass power plants. It, interestingly, mentions in the study that wood fuel costs are cheaper than coal by a "factor of two."

Center For Resource Solutions. *Green-e Renewable Electricity Certification Program, Code of Conduct, Appendix B*. San Francisco, CA. Downloaded February, 2001.

This is one of the the appendices to the contract for Green-E certification. It covers qualifying technologies, business practices, marketing, labeling, logo use, and more. See the website for more details http://www.green-e.org/power/contract.html.

Bartelt, G. A., Kleme, R., Paine, L., Peterson, T., Rineer, K.C., Sample, D.W., Temple, S., and Undersander, D.J. *Biomass Energy Development in Wisconsin: an Environmental Perspective* in Olsen, A., Stevenson, R., eds. *Biomass Energy Infrastructure Development*. Madison: Wisconsin Public Utility Institute, 1996.

A scientific environmental assessment of energy crops, considering biodiversity, available lands, erosion impacts, wetlands and water quality, plantation siting. The authors clearly favor grasses over woody (tree) crops. They also provide useful guidelines for growing energy crops. For example, energy crops can improve habitat by connecting other fragments of forest or field.

Clemmer, S. and Wichert, D. *The Economic Impacts of Renewable Energy Use in Wisconsin*. Wisconsin Department of Energy. Madison, WI. 1994.

This is a pioneering study done to capture the overall economic benefits to society of using different forms of renewable energy. The study uses an economic model to evaluate a wide array of renewable energy systems.

Cooper, J., Braster, M.., Woolsey, E. "Overview of the Chariton Valley Switchgrass Project: A Part of the Biomass Power for Rural Development Initiative." Proceedings of BioEnergy `98 Expanding BioEnergy Partnerships. October 4-8, 1998. Madison: Great Lakes Regional Biomass Energy Program, 1998.

This paper focuses on efforts in southwestern Iowa to establish cofiring using switchgrass for the biomass component. The plan would modify a 750 MW Alliant Energy powerplant to burn 5% biomass .

Demeter, Christian and Lindsey, Christopher. *A Model To Evaluate Green Electricity Tariffs For Biomass Power*. Proc. Of Bioenergy `98 Expanding Bioenergy Partnerships, October 1998, Great Lakes Regional Biomass Energy Program.

An evaluation of green pricing programs in general, and green pricing for biomass energy. The authors cite several studies and provide a methodology for estimating green pricing premiums for biomass cofiring.

Ellis, R. Biomass Utilization at Northern States Power Company. From Proceedings of Bioenergy 94. October 2-4, 1994. Reno: Western Regional Biomass Energy Program.

Environmental Law & Policy Center. *Repowering the Midwest: The Clean Energy Development Plan for the Heartland*, Chicago, IL. 2001.

This is a successor to the previous Powering the Midwest study by the Union of Concerned Scientists. Whereas the previous study focused on estimating the availability of renewable energy, this study goes the next step and describes policies to bring that capacity online. The study also updates some of the estimates derived previously. Cofiring is one of the technologies considered. The study estimated approximately

Graham, Robin L., Allison, Linda J. and Becker, Denny A. *The Oak Ridge Energy Crop County Level Database*. 1996. Environmental Sciences Division, Bioenergy Feedstock Development Program, Oak Ridge National Laboratory. December 20th, 1996. <http://bioenergy.ornl.gov/oreccl/database.html>

A useful database of modeled energy crop production costs for counties across the country. They include factors such as land lease costs and productivity.

Izaak Walton League of America, *Mercury in the Upper Midwest A must-read report for anglers in Minnesota, Wisconsin and Michigan*. St. Paul: MN. 1998.

Morris, David. Green Consumerism vs. Green Citizenship in *Sustainable Minnesota*, Volume 7, Number 2. Spring 1997.

A very intriguing dissent on the value of green pricing programs. Reflected in the text.

Nienow, S., McNamara, K.T., Gillespie, A. Assessing plantation biomass for co-firing with coal in northern Indiana: A linear programming approach.

National Resources Defense Council. *Benchmarking Air Emissions of Electric Utility Generators in the U.S*. February 15, 2001. <http://www.nrdc.org/air/energy/util/chap2.asp>

A straightforward review of air emissions from the electric power industry. This source is much more helpful than the WDNR or EPA sources, which tend to disclose less useful information, which may offend the industry y its very publication.

Olsen, A., Stevenson, R., eds. *Biomass Energy Infrastructure Development*. Madison: Wisconsin Public Utility Institute, 1996.

This report summarizes the Biomass Energy Infrastructure Workshop held in Madison. The workshop focused on energy crop development and use and brought together a wide variety of stakeholders not previously involved in the program. The document provides an overview of energy crops, biomass energy technologies, as well as the results of facilitated workgroups that brainstormed on barriers and solutions to advance development of biomass energy.

Plasynski, Sean; Hughes, Evan; Costello, Raymond; Tillman, David;. *Cofiring Biofuels in Coal-Fired Boilers: Summary of Test Experience*, Proceedings from Sixteenth Annual International Pittsburgh Coal Conference. Pittsburgh, October 11-15, 1999.

> A summary of results of cofiring tests funded by the Electric Power Research Institute at several coal-fired plants. Addresses fuel characteristics, impacts on boiler operations, and air emission impacts. Biomass cofiring is described as the least cost green power alternative available today.

SUNY College of Environmental Science & Forestry. Willow Biomass News, Volume 1, Number 1. < http://www.esf.edu/willow/news1/n1salix.htm>

Swezey, Blair G., Porter, Kevin L., Feher, J. Sherman. *The Potential Impact of Externalities Considerations on the Market for Biomass Power Technologies*, National Renewable Energy Laboratory: Golden, CO, 1994.

> Although dated, this study provides an interesting view of ways in which to monetize the environmental costs of dirty fuels. This entire trend was swept aside by deregulation.

Tillmans, D.A., Hughes, E., Plasynski, S. Cofiring Biofuels in Coal-Fired Boilers: Summary of Test Experience.

> This is a summary description of cofiring tests funded by the Electric Power Research Institute (EPRI).

Union of Concerned Scientists. *Powering the Midwest Renewable Electricity for the Economy and the Environment*. Cambridge, MA. 1993.

> This study provides an estimate of the amount of renewable energy that could be harvested throughout the Midwest. The authors provide resource assessments, electricity supply estimates and charts, and geographic analysis of the potential from renewables. In addition, a useful description of existing energy technologies provides a useful overview to those new to renewable energy. Biomass energy figures prominently in many states, including Wisconsin. The estimates for wood residue availability seem low.

Volk, T.A. et al. "Developing A Willow Biomass Crop Enterprise For Bioenergy And Bioproducts In The United States". Proceedings of Bioenergy 2000. October 15-19, 2000. Buffalo, NY: Northeast Regional Biomass Energy Program, 2000.

> This paper provides information on status of the Salix Consortium, based in New York State. This consortium seeks to develop willows as an energy source. The consortium has already successfully tested willows as a cofired in the pulverized coal Greenridge and Dunkirk plants. In addition, the consortium has planted 600 acres of willows and worked on new clones and the logistics of increasing fuel supply.

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A good, thorough overview of biomass cofiring, including technical, financial and environmental aspects. They provide useful information and a list of cofiring projects.

U.S. Department of Energy Green Power Network. *U.S. Green Pricing Activities*. February 24, 2001. <http://www.eren.doe.gov/greenpower/pricing.shtml>

A useful site for information on green power marketing programs, if somewhat outdated.

Wisconsin Department of Natural Resources, Bureau of Watershed Management. " The Wisconsin Mercury SourceBook" Madison, WI. May, 1997.

This document was apparently meant to be continuously updated, but they apparently have stopped. It is a useful if spotty resource on mercury pollution issues