9. ISSUES FOR SUSTAINABLE BIOMASS UTILIZATION

The purpose of this task was to examine issues surrounding the sustainability of biomass use in the study area, in part to ensure that biomass use is consistent with environmental quality objectives and potentially to broaden outlet markets for biomass power to include “green” or “environmentally friendly” power and fuel products. Task efforts included the development of sustainability criteria based on input from local stakeholders provided via a regional sustainability focus group.

Estimates of biomass generation and availability incorporated a variety of criteria to ensure that biomass utilization did not hurt land productivity, watershed health or forested areas that have legal, regulatory or planning restrictions on management. Forest biomass generation estimates are from projects implemented on federal, state, tribal, county/municipal and other lands that have undergone all necessary legal, regulatory and planning processes. Forest biomass availability estimates take into account the need to use some biomass to prevent soil disturbance on project sites. Agricultural residue supply estimates incorporate restrictions on the quantity of residue that can be removed without damaging land productivity or water quality. However, these restrictions do not include all of the potential concerns and criteria that are often included under the umbrella term of sustainability.

In November 2002, a focus group on sustainability of agricultural and forest biomass held at the Grande Ronde Model Watershed Program office in La Grande, Ore., helped to gauge the support of local stakeholders from a variety of different viewpoints. Appendix F includes the agenda, the attendee list and a list of concerns and questions arising from this one-day focus group. The results of the focus group are included in discussion of biomass availability as possible barriers or opportunities to long-run, stable biomass supplies. In addition, the focus group results provide guidance for future activities to help build a coalition of support for biomass utilization.

There were 26 attendees at the meeting representing a wide variety of interests including the Oregon Department of Forestry, USFS, USDA, Boise Cascade, Oregon Department of Energy, Oregon State University Extension Service, Hells Canyon Preservation Council, Oregon Rural Action, economic development agencies and others. The broad subjects covered included the environmental and economic consequences of using biomass from forest management and of using agricultural residue for ethanol or power generation.

Table 9-1 outlines issues identified regarding forest biomass utilization. The major areas of concern regarding the use of forestry residues for energy include: potential positive and negative impacts on air emissions, nutrient cycling in forest soils, economics of biomass removal and full accounting of the range of risks, costs and benefits associated with forest management. Other concerns include: ensuring that all management alternatives are considered in project planning, whether power from biomass would be considered “green,” ensuring that a long-run supply would be available and evaluating the impacts of biomass use on forest management intensity.

Table 9-1. Forest biomass sustainability issues

Sustainability issues, by subject matter
Air emissions
• Compare controlled emissions vs. open burning / prescribed burning.
Land management issues
• Who regulates the amount that must be left on land?
• Describe methods used to quantify overstocked land.
• Public vs. private land – where should management occur?
• What is "restoration"? "Restoration" should not be used to mean "thinning" only.
Economics of forest management
• Look at full economic impacts of biomass removal / injection of dollars into community.
• Evaluate costs / Benefits of all options, including doing nothing or other options – removing roads, prescribed burning, etc.
Power generation issues
• How do the area's low rates of electricity influence opportunities for power production
• Would biomass power be considered green?
• Ensuring that biomass power is included in green power definition.
Sustainability of biomass supply
• Not taking trees just to supply an energy site; should be done for other reasons.
• Some participants are concerned that land managers are using catastrophic fire as scare tactics to promote forest management.
• Where does biomass come from?
• How is biomass produced?
• Is management done regardless of biomass plant being there?
• What additional demand for biomass from biomass plant is being generated?
• How much is out there now generated year after year?
• Biomass plant may be able to influence availability if they pay for biomass.
• Oregon Department of Forestry and other landowners are not necessarily driven by profits.
• Need mix of management – some thinning, some prescribed fire, some natural fire.
• What is the sustainability of supply over 20 years?
• How many years of thinning will be done?
• What happens down the line when thinning is done?
• How much is available from non-forest resources?
• What is meant by "sustainability" by various organizations? Stakeholders need to get together to discuss and debate this term.

Table 9-2 outlines agricultural residue sustainability issues identified by the group. Concerns related to agricultural residue utilization include: difficulty of quantifying annual acreage planted and harvested in particular crops due to variability in crop practices, long-run trends in crop practices, farmer preferences related to biomass utilization, competing markets for residues and commercial readiness of new technologies.

Table 9-2. Agricultural residue sustainability issues

Sustainability issue, by subject matter
• Difficult to quantify acres grown of each crop.
• Some crops are grown based on government payments.
• Variability of amount available is important and is influenced by the amount produced in any given year.
• Environmental constraints (soil erosion, wind erosion, soil conditioning index and organic matter) will limit the amount available for energy.
• Farmer attitudes.
• Competing markets – influenced by transportation and commercial readiness of competing technologies (e.g. proposed strawboard plant is too far away).
• Need another study to look at the potential for oil-seed crops to be grown in the area as a new crop in the region. A group is looking at putting in a crusher in Pendleton.
• New climate change study is projecting reduced snowpack and rainfall in the Pacific Northwest. How will that affect agricultural production and irrigation in the region?
• What is the potential for new, small-scale plants to use agricultural residues?
• Emissions issues.

The implications of these results regarding biomass energy utilization are that local support for, and communication about, forest management projects should continue. Developing or using an existing local, ongoing committee to provide input on whether community concerns are being met is one way to do this. Examples of existing committees that could play this role include the Wallowa County Board of Commissioners Natural Resource Advisory Committee[82], the Union County Board of Commissioners Community Forest Restoration Board[83] and the Baker County Board of Commissioners.[84] Each of these groups provides input into the Northeast Oregon Forests Resource Advisory Committee (RAC), which provides input to projects on federal and non-federal land to be funded by the federal government. The Northeast Oregon Forests RAC comprises the Malheur, Umatilla, and Wallowa-Whitman National Forests as well as Baker, Crook, Grant, Harney, Malheur, Morrow, Umatilla, Union, Wallowa and Wheeler Counties.[85]

For forest biomass, the following are vital to the community:

- clear communication by landowners and land management agencies regarding the costs and benefits of forest management and biomass utilization
- evaluation of prescribed burning
- road removal and "no action" alternatives and disseminating the results of this evaluation
- ensuring that projects are driven by watershed concerns rather than a need to supply a biomass facility

The concerns regarding forest biomass are similar to those for forest management as a whole: whether the long-run results will meet management objectives. For agricultural biomass, soil erosion constraints limit availability of some residue for use, and annual variability in crops

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82 Wallowa County Board of Commissioners (http://www.co.wallowa.or.us/boc/commissioners.htm).
83 Union County, *Natural Resources – Community Forestry* (http://www.union-county.org/).
84 Baker County Board of Commissioners (http://www.bakercounty.org/commissioners/commissioners.html).
85 USFS Pacific Northwest Region, *Northeast Oregon Forests Resource Advisory Committee* (http://www.fs.fed.us/r6/malheur/rac/rac.htm).

planted will affect the composition of the feedstock supply. Local producers are concerned with making sure that technology is available and cost-effective for residue collection and conversion. They are also interested in newer, “on-farm” technologies that could provide value-added product opportunities for farmers.

10. ENVIRONMENTAL IMPACTS

10.1 Analysis of Environmental Benefits

In this section, we evaluate the major categories of environmental impacts associated with biomass utilization in the study area. The environmental benefits of using biomass resources is perhaps the most significant driving force encouraging expanded use of biomass for energy production and other associated value-added products. The fundamental environmental reasons for deploying biomass technologies are global greenhouse gas control and local or regional solid waste and water quality control. Biomass energy conversion is a beneficial alternative to landfill disposal of biomass, open burning or allowing forest fuel to accumulate and contribute to unacceptable wildfire risks.

Environmental considerations associated with biomass energy conversion fall into four main categories: (1) watershed impacts, (2) emissions from the conversion process, (3) life-cycle impacts and (4) avoided emissions. The first category addresses the benefits to watersheds from reduction of wildfire risk. The second category addresses air emissions associated with energy conversion of biomass. Under the third category, life-cycle analyses consider the net energy contribution of biomass. The fourth category is based on offsets in emissions from open burning of forestry and agricultural residues.

10.2 Watershed Impacts

The linkage between watershed health and forest health is frequently overlooked in discussions of appropriate forest management and community benefit. In particular, reducing the risk of catastrophic wildfire not only protects lives and property; it prevents long-term impacts on riparian area water quality associated with increased debris and sedimentation into water bodies. Wildfire removes vegetation and exposes mineral soils, decreasing soil's ability to absorb water. This contributes to the potential for massive soil movements and mudslides following wildfires, and it also affects soil productivity for years to come. However, wildfire prevention is only one watershed benefit that can be attributed to appropriate forest management.

Appropriate use of forest management tools including thinning, pruning, prescribed burning and employing no action in currently resilient stands helps prevent catastrophic wildfires and helps create and maintain resilient watersheds, which support communities, wildlife and recreational opportunities and improve forest aesthetics. Overly dense forest stands compete for site resources, including sun, water and soil nutrients. This not only restricts the amount of water yield from forests to riparian areas and reservoirs, but also limits forest productivity and diversity in flora and fauna. Limiting understory vegetation growth increases soil erosion and sedimentation into water bodies, affecting water quality for wildlife and human consumption. These environmental effects create socioeconomic issues for communities, including water availability, sustained timber production and recreational opportunities associated with streams and lakes. Forest density and fuels management in strategic areas can help reverse these negative impacts.

10.3 Air Emissions

10.3.1 Biomass power plant emissions

It is useful to compare biomass with coal because both are solid fuels that employ similar technologies. However, biomass is lower in sulfur than is most U.S. coal. Typical biomass contains 0.05 wt % to 0.20 wt % sulfur on a dry basis. In comparison, coal has 2 wt % to 3 wt % sulfur on a dry basis. The biomass sulfur content translates to about 0.12 to 0.50 lb SO_2/MMBtu. Because of this, burning biomass to generate power typically produces less SO_2 emissions than using coal.

NO_x emissions should usually be lower for biomass than for coal, due to lower fuel nitrogen (N) content and due to the higher volatile fraction of biomass versus coal. However, this difference may not have much influence on the selection of the technology (i.e., coal or biomass) because the compliance costs are relatively insignificant given the small difference in NO_x emissions.

Biomass power production can result in large emissions of carbon dioxide (CO_2). Sometimes biomass combustion results in larger emission values than for fossil fuels because of the lower combustion efficiencies. However, because the CO_2 released by combustion was removed from the atmosphere in the recent past through photosynthesis and new plant growth will continue to remove CO_2 from the atmosphere after biomass is harvested, it is sometimes argued that biomass is "CO_2 neutral." In practice, the picture is more complicated. Other carbon flows are involved in the picture, including CO_2 emissions associated with fossil fuel used in harvesting, processing and transportation operations. Although it is certain the net amount of CO_2 emitted from a biomass power plant is less than a fossil power plant, it must be recognized that under current production practices, biomass power is not a net zero CO_2 process.

Biomass combustion device emissions are estimated on a site-specific basis to determine whether a particular location is appropriate for developing a facility. In many cases, data specific to a particular wood-burning appliance are not readily available. However, the U.S. EPA provides emissions factors that can be used to estimate emissions from wood-fired boilers as part of efforts to estimate effects of specific combustion sources and determine applicability of relevant permitting programs. The document "Air Pollution Emission Factors, 5th Edition, Volume I for Stationary Point and Area Sources," or AP-42 Emissions Factors, lists factors for combustion systems that use mechanical particulate collection devices for emissions controls.[86] Emissions factors are specified in terms of pounds of emittent per million Btu (lb/MMBtu) of fuel burned. Table 10-1 shows the emission factors specified in AP-42. These factors are neither emissions limits nor standards.[87]

[86] U.S. EPA Technology Transfer Network, *Air Pollution Emission Factors*, 5th Edition, Volume I for Stationary Point and Area Sources (http://www.epa.gov/ttn/chief/ap42/index.html).
[87] U.S. EPA, *Introduction to AP-42*, Volume I, Fifth Edition, (http://www.epa.gov/ttn/chief/ap42/c00s00.pdf, January 1995), p. 2.

Table 10-1. U.S. EPA AP-42 emission factors for wood boilers

Pollutants	Emissions factors (lb emittent/ MMBtu fuel input)
Total Particulates*	0.22-0.3
Oxides of Nitrogen	0.49
Carbon Monoxide	0.6
Total Organic Compounds	0.06
Sulfur oxides	0.025

Source: U.S. EPA AP42 (http://www.epa.gov/ttn/chief/ap42/ch13/).
* Emission factors for systems utilizing mechanical particulate collection devices

10.3.2 Ethanol plant emissions

Because no cellulose ethanol facilities exist, data on air emissions is limited to studies that have modeled expected results. It is likely that emittent pollutant levels will be similar to or less than biomass power facilities. Indeed, the capture of CO_2 may be more likely because the confined nature of the fermentation process allows for cost-efficient CO_2 recovery.

10.4 Life Cycle Impacts

10.4.1 Biomass power

The energy used to manufacture fertilizer and the fuel used to operate farm equipment at farms that grow biomass energy crops reduce the net energy produced from biomass power plants that use biomass crop systems for feedstock. Life-cycle analyses of biomass have been conducted by NREL for various configurations of power plants and fuel supplies to determine the net energy available using biomass fuels for power generation.[88] The results indicate that only 2% to 8% of the useful energy output of a biomass power plant fueled by a biomass crop system is required for fertilization, planting, cultivation, harvesting, transportation and fuel preparation. In other words, the amount of useful energy output from a biomass power plant is 12.5 to 50 times as much as the energy required to grow, harvest, transport and process biomass from biomass crop systems. While these studies have not addressed the implications of using forest-derived fuels instead of energy crops, it can be assumed the results would be largely similar for an Oregon scenario using biomass from forest thinning projects. The major difference would be that the energy input associated with a plantation for fertilization, planting and cultivation would be eliminated. Instead, energy would be used for harvesting and processing forest biomass. The energy cost for forest harvesting would be higher than for plantation harvesting, which has more uniform conditions for felling, bunching and skidding and generally occupies level terrain in a row-crop like environment. The transportation energy use for forest biomass may or may not be higher than for biomass crops. Transportation vehicles are very similar, and so transportation distance would be the primary reason for differences in transportation energy use between biomass crops and forest biomass.

[88] M. Mann and P. Spath, *Life Cycle Assessment of a Biomass Gasification Combined Cycle System* (NREL, December 1997).

10.4.2 Ethanol

The net environmental benefits of ethanol depend on how much energy is used to grow and process the biomass feedstock. The ethanol fuel industry has made great efficiency gains. The current energy balance for ethanol is 1.34; that is, for every unit of energy used in growing and producing ethanol, about one-third more energy is produced as fuel. Current trends predict that this ratio will increase to 2.09 for corn ethanol and 2.62 for cellulose ethanol.[89]

According to the DOE, using ethanol made from corn will result in a net air emissions reduction of 20%. Using soybeans will reduce net emissions nearly 80%. Cellulose-based ethanol can lead to even greater decreases, since this type of biomass can be used to generate more electricity than is used in the production of ethanol fuel. The surplus power can then be sold, displacing the burning of fossil fuels for electricity production. This can result in a net reduction greater than 100%. In the case of ethanol from corn stover, the reduction can be as much as 113%.[90]

Another study commissioned by NREL used total fuel cycle analysis to compare reformulated gasoline (RFG) to E10 (a mixture of 10% ethanol with 90% unleaded gasoline by volume) and E95 (a mixture of 95% ethanol with 5% unleaded gasoline).[91] E95 produces only 9% of the net CO_2 produced by the RFG fuel cycle. If one takes into account the carbon sequestration benefits, E95 produces only 4% of the total CO_2 produced by the RFG cycle.[92]

10.5 Avoided Emissions

The issue of avoided emissions associated with biomass encompasses the various biomass fuels and the consequences of not using these fuels in an energy conversion process. As noted by Morris, the biomass energy industry has become an integral part of the solid waste disposal infrastructure.[93]

The major categories of alternative (non-energy) disposal options for biomass residues include:

- Open burning of agricultural and forestry residues including wildfires
- In-forest accumulation of residue as downed and over-growth material
- Landfill disposal of waste wood
- Composting and land application of waste wood; and
- Land spreading of wood chips and bark as mulch and cover.

In-forest accumulation leads to increased risk of forest fires. Recent work conducted by the Canadian Forest Service indicates forest fires emit substantial quantities of CO_2 as well as methane, carbon monoxide, NO_x, particulate matter and other trace gases.[94] As a result, fires not

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[89] U.S. DOE Office of Transportation Technologies, *Biofuels and the Environment* (http://www.ott.doe.gov/biofuels/environment.html).
[90] U.S. DOE Office of Transportation Technologies, *Biofuels and the Environment* (http://www.ott.doe.gov/biofuels/environment.html).
[91] This study does not include ethanol produced from corn.
[92] S. Tyson, *Fuel Cycle Evaluations of Biomass: Ethanol and Reformulated Gasoline* (http://www.afdc.doe.gov/cgi-bin/doc_search/vwbs2.cgi?2380, NREL/TP-463-4950, NREL, November, 1993).
[93] G. Morris, *The Value of the Benefits of U.S. Biomass Power* (NREL/SR-570-27541, November 1999).
[94] B. Amiro et al., "Direct Carbon Emissions from Canadian Forest Fires, 1959-1999," *Canadian Journal of Forest Research*, 31, 512-525.

only affect carbon sequestration but also emit greenhouse gases that potentially affect the climate.[95] Additionally, burned areas change the earth's surface energy balance, which may result in local or regional climate change.

While these emissions are not unexpected, the magnitude of the emissions is noteworthy. The Canadian study found that direct carbon emissions by forest fires ranged from 2% to 75% of CO_2 emissions from all Canadian sources, with an average of 18%. This is a significant portion of the carbon budget for Canada.

Forest Products Equipment reported early in 2002 that National Center for Atmospheric Research (NCAR) scientists have found that as much as "800 tons (more than 19 times the amount the EPA estimates is emitted annually from U.S. power plants) of mercury previously deposited on leaves, grasses, twigs, and other forest vegetation around the world may be re-emitted into the atmosphere each year as the result of forest fires and the burning of other vegetation."[96]

Mercury and other toxic materials are emitted whether a fire is low intensity or high intensity, but considerably more is emitted in a catastrophic, high-intensity fire because more vegetation is burned. Thinning can reduce the extent and intensity of wildfire, therefore reducing forest fuel consumed and the resulting emissions of toxic materials, having beneficial results for air quality.

Biomass power generation may provide air quality benefits in rural settings where forest fuels reduction activities now result in open burning of piled biomass. Burning biomass in a controlled environment can reduce smoke and particulate matter emissions by 95% to 99% over open burning. The overall impacts of biomass combustion on ambient air quality, taking into account potential benefits associated with reduction in open burning, may be a factor in permitting a biomass plant. Another significant benefit of using forest biomass for fuel is that it aids in the reduction of wildfire risks. Wildfire is a significant source of particulate and other air emissions. Burning biomass in a controlled environment represents a significant decrease in emissions relative to wildfire.

[95] General Bioenergy, *Bioenergy Update*, Vol. 5, No. 9 (September 2003).
[96] "Mercury and the Forest," *Forest Products Equipment* (February 2002), p.10.

11. ECONOMIC IMPACTS

Economic benefits of either a biomass power facility or an ethanol production facility result from feedstock handling and processing activities, plant construction and operation, and product marketing. All contribute income to the local economy, due primarily to employment. In the following sections, we address specific aspects of the economic benefits.

While input-output modeling has been performed for biomass facilities, we were not able to find any specific studies for Oregon. Therefore, the information presented is derived from experiences in other parts of the United States. In this section, we discuss the following topics:

- Job creation
- Tax revenue implications
- Insurance estimates of risk reduction from wildfire hazard mitigation; and
- Federal, state and local incentives for biomass utilization.

11.1 Job Creation

11.1.1 Biomass power

Biomass benefits include creation and retention of local jobs in a rural economy. For biomass power systems, it is estimated that six full time jobs are created for each MW of installed capacity.[97] Depending upon power plant capacity, this employment figure includes 15 to 20 or more personnel at the power plant, and the balance of people hold jobs in fuel processing and delivery. Payroll at the power plant is made up of various administrative, maintenance and fuel handling positions at salaries of approximately $20,000 to $35,000 per year and plant management positions in the $60,000 to $100,000 range (see Table 11-1). Fuel procurement and transportation workers are generally paid hourly wages that range from $10/hour to $30/hour, depending on the skill level of the position. Total employment levels (excluding biomass fuel procurement) are presented in Table 11-2.

Table 11-1. Representative jobs and annual salary for a biomass power plant, 2003

Classification	Rate
Plant Manager	$ 60,000/year
Deputy	$ 45,000/year
Operators	$ 25,000/year
Fuel Handling	$ 22,000/year
Maintenance	$ 28,000/year
Administration	$ 20,000/year
Benefits	35%

[97] For California bio-power facilities, in 2003, there are 3,600 direct jobs that support 588 MW of capacity. California Biomass Energy Alliance, *Benefits of California's Biomass Renewable Energy* (http://www.calbiomass.org/technical4.htm).

Table 11-2. Biomass power plant employment and annual compensation, 2003

Category	25-MW Power Plant	5-MW Power Plant
Plant Manager (number)	1	1
Deputy (number)	1	1
Operators (number)	8	8
Fuel Handling (number)	3	2
Maintenance (number)	3	3
Administration (number)	1	0.5
Total number of employees	17	15.5
Total payroll	$ 475,000	$443,000
Benefits	$ 166,250	$155,050
Annual payroll	$ 641,250	$598,050

To calculate fuel consumption for a 5-MW power plant, we used 15.7 GT/hour as the fuel consumption rate and assumed the plant would operate 7,884 operating hours per year. The plant operating hour estimate was based on a 90% plant availability factor. The fuel consumption rate was based on a plant heat rate of 24,420 Btu/kWh and a heat content of 7.8 MMBtu/GT of biomass fuel. Using these assumptions, a 5-MW biomass power plant would need 123,415 GT of biomass fuel per year.

For a 25-MW plant, we estimated a fuel consumption rate of 54.5 GT/hour, with a plant heat rate of 17,000 Btu/kWh, using the same plant availability factor and heat content assumptions as the 5-MW plant. Plant fuel conversion efficiency, and therefore fuel requirements, will differ based on the plant size, feedstock characteristics and conversion technology. Section 12.1.4 provides additional information about the effects of plant size on heat rate.

To estimate fuel procurement employment, we assumed that a six-person crew could produce approximately six full chip vans per day. This includes felling, skidding, chipping and three daily round trips per driver. Assuming a chip van will hold 23 GT of biomass, a 5-MW power plant that consumes 123,415 GT/year of fuel would need three crews operating to provide its fuel. Therefore, a 5-MW plant would employ 18 people in the fuel procurement sector. Using the same assumptions, a 25-MW plant that consumes 430,000 GT/year would require nine crews, for 54 employees in fuel procurement. Thus, the total employment impacts for a biomass power plant ranges from about 34 people for a 5-MW plant up to about 71 people for a 25-MW plant.

11.1.2 Ethanol

For a cellulose ethanol facility, the levels of employment are not as well documented because of the lack of data, as there are no operating commercial scale plants. In this report, we provide an estimate of direct employment by comparing the corn ethanol industry and the biomass power supply industry to a potential cellulose ethanol facility. For the purposes of the employment estimate, we assumed a production capacity of 15 million gallons per year and a feedstock requirement of 600,000 GT/yr, based on a yield of 25 gallons/GT.

The “typical” size of a corn-ethanol dry mill is 40 million gallons/year with an employment level of about 41 persons at the facility.[98] We assume a 15-million-gallon/year cellulose ethanol

[98] J. Urbanchuk and J. Kapell, *Ethanol and the Local Community* (http://www.ethanol.org/, American Coalition for Ethanol, June 20, 2002).

facility would employ about 30 people. Based on the fuel procurement assumptions described in the preceding section and assuming a daily consumption of about 1,640 GT for a 15-million-gallon/year facility, the direct jobs associated with feedstock supply would be about 78, depending upon the level of mechanization and the travel distance (see Table 11-3). Thus, total direct employment at the plant and for fuel supply would be about 108 jobs for a 15 million gallon/year facility. (Note: our approach does not include direct jobs associated with sale and distribution of ethanol.)

For comparative purposes, the California Energy Commission (CEC) estimated 1,600 direct jobs would be created to support a cellulose ethanol industry producing 200 million gallons/year in California.[99] Based on this estimate, on a jobs per gallon basis, a 15-million-gallon/year facility would support approximately 120 jobs. This calculation is reasonably close to our estimate, with an allowance for marketing and distribution employment.

Table 11-3. Estimated feedstock supply jobs for a 15-million-gallon/year cellulose ethanol facility

Category	Units	Value
Supply		
Crew	# people	6
Chip van capacity	GT	23
Daily deliveries	Vans / day	6
Daily quantity	GT	138
Demand		
Plant Capacity	Million gallons/year	15
Feedstock requirements	GT/year	600,000
Feedstock requirements	GT/day	1,644
Transportation requirement	Van / day	72
Number of crews	Crews	12
Direct jobs	People	78

11.2 Tax Revenue Implications

Of interest to many local officials are the impacts of new economic activities on local public finances. Typically, economists employ modeling techniques such as input-output analysis to estimate impacts associated with a particular activity such as a new biomass power or ethanol facility. Such analyses have been conducted for several states and regions.[100] While it was beyond the scope of this project to perform a detailed economic impact analysis, it is useful to identify the key parameters that are important to local officials.

Economic impacts for either a biomass power facility or an ethanol plant can be assessed in terms of the immediate impact associated with construction of the facility and the long-term impact attributable to operations. Both the immediate and long-term impacts are characterized in terms of income, employment and taxes paid. Further, a multiplier effect creates additional jobs and income and further tax payments, and these indirect effects are important and are a key aspect of economic impact analysis. Some of the expenditures of a specific project will "leak"

[99] California Energy Commission, *Costs and Benefits of a Biomass to Ethanol Production Industry in California* (P500-01-002, March 2001).
[100] *For example*, Meridian Corporation, *Economic Impact of Industrial Wood Energy Use in the Southeast Region of the United States* (Southeast Regional Biomass Energy Program, December, 1989).

away from the immediate area. Examples of leakages include purchases of equipment, fuel and specialized services.

Construction-related impacts include income to personnel working on the project, taxes on wages of various personnel associated with engineering, procurement and construction of the plant as well as property taxes on new equipment. Typically, the short-term impacts are considerable and may result in both individual/corporate economic gain and community economic loss and displacement. While the gain is straightforward to measure, the community loss may be more difficult to estimate. Community loss is largely a function of impacts on local services (e.g., schools, health care, public safety, transportation infrastructure) as well as opportunity losses.

Long-term impacts tend to be much higher than immediate impacts if the business is a sustainable operation. Two separate revenue streams dominate economic impacts. The first is the purchase of biomass feedstock and the subsequent re-sale of a product, either electricity or ethanol. In each case, the direct costs and revenues are taxable events that can be modeled with some precision. The other significant impact is the taxable income of the wages for personnel associated with biomass processing and plant operations. Finally, the multiplier effect is marked but varies from site to site due to the specific circumstances of each project.

Results for ethanol economic impact analysis suggest net positive gains associated with a cellulose ethanol facility.[101] In a study in the northeast U.S., a hypothetical 10-million-gallon/year facility constructed in five separate states results in the impacts presented in Table 11-4.

Table 11-4. Average income, jobs and state taxes per million gallons of ethanol produced[102]

Category	Value
Gross	
Income	$919,000
Jobs	14
State taxes	$53,000
Net	
Income	$889,000
Jobs	14
State taxes	$51,000

11.3 Wildfire Hazard Mitigation, Insurance Implications

Wildfires affect public sector budgets as well as property insurance rates. In this section, we identify current issues affecting various parties with regard to insurance implications.

11.3.1 Public Sector

Oregon is the only state that has purchased insurance related to fighting wildfires.[103] While other states pay all wildfire costs out of general funds, Oregon has had forms of wildfire insurance

[101] Resource Systems Group, *Economic Impact of Fuel Ethanol Facilities in the Northeast States* (http://www.nrbp.org/, Northeast Regional Biomass Program, December 2000).
[102] Resource Systems Group, p. 21.
[103] E. Hilbert, *Oregon's Wildfire Insurance Policy Paying Off* (http://info.insure.com/states/or/wildfireins702.html, accessed September 15, 2003).

since the 1960s. After a particularly costly wildfire season in 1987, the state sought a policy that would cover costs in excess of $10 million.

Only in 2000 and 2001 did Oregon use the benefits of its policy. In 2001, over 50,000 acres of forest burned. The damages caused the state's premium to increase about $1 million from one year to the next, according to Roy Woo, Oregon's deputy state forester. The policy helps to pay firefighters as well as cover damages to forests. It does not cover homeowners who are affected by the fires. In 2002, the insurance policy was estimated to save the state approximately $19 million.[104] Renewal of the insurance coverage was completed for 2003 but at a higher annual premium ($5 million over 2002) and with a higher deductible. The increases are attributable to the losses sustained by the insurer during the prior year.

Fires in 2002 affected slightly over one million acres and cost the state approximately $29 million. The net cost to the state after subtraction of the insurance settlement was approximately $10 million.

11.3.2 Homeowner / Business Insurance

It is difficult to say with certainty the effect wildfires have on property insurance rates. The industry factors in the risk associated with a wildfire. However, factors that are more important include a site's proximity to firefighting resources and historical claims for a geographic area versus proximity to overstocked forests. According to a State Farm Insurance representative, "Insurance rates are based on historic trends of 10 to 15 years. So far we haven't had enough history with wildfires to determine a trend" (in reference to the impacts of increasing wildfire activity in the wildland urban interface).[105]

Carole Walker, Executive Director of the Rocky Mountain Insurance Information Association, located in Denver, confirms this opinion. "While fires are certainly much more personal and very devastating to the individual, from an insurance perspective they are not as costly as other disasters." According to Walker, it is not uncommon to see $70 million to $100 million in claims from one large hailstorm as compared to around $80 million in losses due to Colorado's worst summer of wildfires on record (2002). "During the last 12 years the insurance industry has paid out over 100 billion dollars in claims," said Walker. Thus, she expects homeowners insurance to rise by about 20% even without considering wildfires. However, regardless of rising insurance costs, it is still cheaper to insure a home in the mountains of Colorado than on the Eastern plains, which are the hardest hit by hail.[106]

Currently, there is no talk of reduced rates for properties that clear combustible vegetation from near structures to create a "defensible space" that reduces the risk of damage. However, there is talk that insurance companies will raise the rates or drop coverage for homeowners who do not create defensible space, or the companies may place moratoriums on new policies in fire prone areas. During the Missionary Ridge fire in Southwestern Colorado, numerous insurance companies placed a moratorium on new homeowner policies in the area surrounding the fire.

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[104] "State Nears Purchase of Wildfire Insurance," *Briefs Across the Northwest* (http://news.theolympian.com/PalmNews/20030623/wirelessnorthwest/34886.html, September 15, 2003).

[105] J. Dietrich and L. Lewis, "Homeowner Insurance Rates Will Increase Independent of Wildfire Costs," Southwest Colorado Fire Information Clearinghouse (http://southwestcoloradofires.org/articles/article16.htm, accessed September 15, 2003).

[106] Ibid.

In addition, State Farm Insurance, which insures approximately 25% of the nation's homes, has instituted a new program in six western and southwestern states but not including Oregon (see Appendix G). State Farm will work with its customers to institute *FIREWISE* policies and actions.[107] State Farm intends to survey a representative sample of the homeowners and to recommend actions that will make property more defensible. If the homeowner does not comply within 18-24 months, State Farm may elect not to renew the insurance policy.

11.4 Biomass Incentives[108]

Incentives for forest stewardship and for renewable fuel production and use can help increase the attractiveness of biomass utilization from the perspective of project developers, landowners and municipal, county and state governments. Incentives evaluated include, for example, Oregon's business energy tax credit and energy loan programs, the federal production tax credit, renewable portfolio standards, utility green pricing programs, the ethanol production credit and oxygenated fuel mandates. See Appendix H for a comprehensive summary of biomass incentives and programs.

In addition, the Healthy Forests Restoration Act of 2003 contains language that may facilitate future development of biomass projects that utilize forest biomass. Specifically, Title II: Biomass - (Sec. 203) authorizes the Secretary to make grants to: (1) improve the commercial value of forest biomass to produce electric energy, sensible heat, transportation fuels, substitutes for petroleum-based products, wood-based products, pulp, or other commercial products; and (2) offset the cost of projects to add value to biomass.

[107] Additional information on the FIREWISE Program can be found at http://www.firewise.org/
[108] Some of the information in this section and Appendix H was derived from Oregon Department of Energy, *Biomass Energy Incentives* (http://www.energy.state.or.us/biomass/Incentive.htm).

12. BIOMASS FACILITY CHARACTERISTICS

In this section, we summarize information for a hypothetical biomass power facility and a hypothetical biomass-to-ethanol facility matching the available biomass resource including:

- technology overview, operation, size, capital costs, feedstock requirements and outputs
- simple process flow diagrams to illustrate the workings of the plant
- an illustration showing the relationship between facility size and feedstock requirements; and
- an illustration showing the relationship between feedstock cost and economic feasibility.

12.1 Biomass Power

12.1.1 Technology Overview

Direct combustion systems are by far the most common biomass fired technologies employed today. The major types are the circulating fluidized bed (CFB) units, bubbling fluidized bed (BFB) units, inclined fluidized bed (IFB) units and stoker-fired units.

Gasification units are widely believed to hold great promise for future development, and several firms are presently deploying small units. In general, gasification technology allows for fuel flexibility and increased efficiency gains.

12.1.2 Combustion Technologies

<u>Spreader-Stoker Fired Boilers</u>

Stokers currently used today in wood-fired applications fall into two major categories, the air-cooled traveling grate and water-cooled stationary grate. With both of these types of stokers, the wood fuel is distributed across the width of the grate with metering bins on the front wall of the boiler. The fuel is then uniformly distributed over the depth of the grate by air swept spouts. Sawdust and other fines in the fuel are burned in suspension, while larger particles drop to the grate and are dried and burned directly on the grate surface. Heated low-pressure combustion air is evenly distributed through the grate surface to promote fuel drying and provide the primary source of combustion air. To further aid the combustion process, high-pressure over fire air ports are used above the grate to provide turbulence and thorough mixing of the unburned combustion gases with air.

With the traveling stoker, the grate travels from the rear of the boiler to the front with fuel being fed across the depth of the furnace to the rear wall. Ash travels to the front edge of the grate and falls into a pit. This design requires additional maintenance due to the high temperatures that the grate bars are exposed to and the abrasive nature of the wood ash due to the high silica content.

The Detroit Hydro-Grate stoker typifies the stationary water-cooled grate. With this design, the grate bars are attached to a water-cooled tubular grid and the grate is sloped at a slight angle (approximately 6-8 degrees) and is periodically vibrated to assist the movement of the burning fuel and ash down the grate towards the ash pit. The advantage of a water-cooled grate is the reduced maintenance from the minimum of moving parts. Care must be taken in operation not to permit an ash pit fire. This will result in overheating and failure of the water supply tubes feeding the grate's support grid.

Both of these two types of stokers are commercially proven technologies that are highly flexible in the choices of fuels that can be burned, alone or in combination. Turndown and response to rapid load swings with little or no change in steam temperature or pressure are also very good. Steaming capacities of these units range in size from a steam flow of 40,000 to 700,000 lbs/hr.

Circulating Fluidized Bed Boilers (CFB)

The application of wood-fired CFB units has generally been limited to waste wood products that are significantly drier than biomass from the forest. Typically, CFBs use fuels such as demolition wood waste and mill residues but they can be easily designed to fire higher moisture wood fuels, alone or in combination with other solid fuels.

In a CFB unit, fuel is fed into the lower part of the furnace. The fuel mixes with the fluidized bed where the solids are maintained at 1,500 to 1,600 degrees Fahrenheit (F). The fuel introduced to the bed is quickly heated until it reaches ignition temperature. As the fuel burns, the size is reduced to a point where the particles are entrained by the upward flow of combustion gases. Larger particles are removed from the gas stream before it reaches the convection surfaces of the unit by use of a cyclone or particle collector beams, and they are returned to the bed for further burnout and size reduction.

The advantages of a CFB unit include the ability to burn lower grade fuels at reduced temperatures and excess air without loss of combustion efficiency. In addition to the reduced NO_x and SO_x emissions that are inherent with a CFB, these units can burn high-fouling fuels without the normally associated operating problems due to the reduced combustion temperatures. CFB units will suffer from bed sintering from firing fuels that have high alkali metal content.[109] This will result in higher fouling of the bed tube surfaces and excessive above bed burning that will increase furnace exit gas temperatures and superheater fouling. Units equipped with refractory lined cyclones will also have high refractory maintenance requirements due to the abrasive nature of the ash.

Bubbling Fluidized Bed Boilers (BFB)

The application of wood-fired BFB units is much more wide spread than the CFB units. Due to their ability to burn high moisture, low-Btu fuels, they have been uniquely suited to the needs of the pulp and paper industry to burn biomass, wood waste and bark commonly produced in large quantities at a pulp mill. These units have been used extensively in this application with capacities ranging from a steam flow of 25,000 lbs/hr up to 600,000 lbs/hr.

The fuel feeding and combustion process for a BFB unit is very similar to that of a CFB except that the bed is only partially fluidized, and the burning fuel is not entrained in the combustion gas flow and remains in the bed.

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[109] Bed sintering is caused from chemicals or minerals in the fuel that reduce the ash softening temperature and cause large conglomerations of bed material that restrict the bed drains or close them off completely requiring the unit to be shut down and the bed material manually removed from the unit. In addition, sintering causes loss of bed fluidization and reduces combustion efficiency.

The advantage of a BFB unit is its ability to burn difficult low-grade wet fuels. The thermal inertia of the bed and the mechanical action of the sand and ash to break down the fuel particles make a BFB unit insensitive to fuel variations. Unlike a CFB unit, a BFB unit utilizes a non-circulating bed in the furnace bottom that is made up of sand. The wood ash and a small amount of sand are removed through a drain opening in the floor of the furnace to control the bed level. The sand acts as a thermal reservoir, and it mechanically breaks down the size of the fuel to facilitate combustion. BFB units do suffer from the same bed sintering problems as the CFB, but due to the partially fluidized bed, the sintering problems can be much worse and can result in high sand consumption rates due to the high bed drain rates.

Inclined Fluidized Bed Boilers (IFB)

The Inclined Fluidized Bed (IFB) technology combines aspects of the inclined grate and fluidized bed technologies. Unlike most other technologies that mechanically agitate the fuel during combustion, the IFB uses an entirely different concept for performing this function. With the IFB technology, the fuel is fed onto an inclined grate assembly via a feed ram where controlled combustion takes place. Combustion air is provided to each portion of the grate from a combustion air fan through slots in the grate assembly.

The IFB grate utilizes hollow tubes to form the steps on the grate. Each of the tubes is equipped with a number of small nozzles that provide a passage from the tubes to the fuel bed on the grate. The tubes are connected to a common fan that recycles a portion of the exhaust gas. This gas is introduced into the fuel bed as short pressure pulses, controlled by valves on an intermittent basis, providing a burst of energy into the fuel bed. These pulses result in highly efficient agitation of the fuel. The fuel is pneumatically mixed in lieu of a mechanical means, thereby providing efficient oxidation of the fuel.

This technology uses fewer moving parts, which reduces both the equipment capital costs and the maintenance costs. IFB grates are new and have not yet been utilized in an industrial wood-fired application although pilot scale testing has been very successful.

12.1.3 Gasification

The gasification process converts biomass to synthesis gas, which consists primarily of carbon monoxide (CO), carbon dioxide (CO_2) and hydrogen (H_2). Gasification technology has been under intensive development for the last two decades. Large-scale demonstration facilities have been tested and commercial units are in operation worldwide. Producer gas has been used in reciprocating engine-generator sets to generate electricity. Gas impurities have prevented the use of producer gas in gas turbines. Gasification coupled with the production of a higher value liquid fuel is another ongoing area of research, with several pre-commercial technologies that are capable of producing ethanol or other alcohol fuels and bio-crude, a fuel that could be used as heating oil or in low-speed diesel engines. Bio-crude cannot be used in transportation applications without further refining into a biodiesel product.

Biomass gasification systems offer several advantages over direct combustion systems. Gasification reduces corrosion compared to direct combustion because of the lower temperatures in the gases. Gasifiers can convert the energy content of a feedstock to hot combustible gases at 85% to 90% thermal efficiency. In addition, the fuel throughput per unit area is greater for gasification than combustion, which means that smaller gasification units can process the same amount of fuel as larger combustion units. In addition, approximately 80% of the usable energy is in the form of chemical energy in the gas. A final advantage is that, if desired, the materials that cause slagging can be removed at relatively high temperatures through a gas clean-up process. These last two statements imply that the gas can be cleaned up and used at higher temperatures without significant loss of sensible heat, although the costs to do so can be considerable.[110, 111]

Gasification can occur in one of two ways. The first method simply adds the fuel to a fixed bed, a process used in both updraft and downdraft gasification. The second gasification method utilizes the fluidized bed approach. Both systems require the feedstock to be relatively dry prior to gasification. Table 12-1 lists some of the characteristics of gasification systems. Appendix I provides additional information on gasification technologies.

Table 12-1. Gasification system characteristics

Combustion process	**Capital costs**	**Operating costs**	**Combustion temperature** (degrees F)	**Fuel moisture content** (%)	**Comments**
Fixed Bed					
Updraft	Low - Medium	(Not Available)	1,950 - 2,650	< 40	A,D,F
Downdraft	Medium - High	Medium - High	Not Available	< 30	A,B,C,D,F
Fluidized Bed	Medium - High	Medium - High	<1,400	< 50	A,B,E

A = Multiple fuels can be used, B = Clean gas product, C = Feedstock in pellet form, D = Particle size limitations, E = High fuel throughput, F = Alkalis in fuel material must be considered

12.1.4 Feedstock requirements and power output

Feedstock requirements for a biomass power facility are dependent upon the capacity of the facility and, to a lesser extent, the efficiency of a specific technology. Dramatic reductions in demand, on a normalized basis, are achievable with increased size of the facility. As illustrated in Figure 12-1 and Figure 12-2, a 5-MW direct combustion (stoker) power plant has a much higher heat rate than a larger facility. Indeed the larger plant may be approximately 50% more efficient than the smaller installation. The major reason for the higher efficiencies at larger sizes is the increased temperature and pressure that can be economically accommodated in the big facilities to supply larger turbines.

It is interesting to note the difference between a calculated heat rate (shown in Figure 12-1) and reported heat rates from operating facilities (see Figure 12-2). In practice, heat rates appear to be better than what one would calculate from a heat/mass balance perspective. However, the actual results mask differing combustion technologies, varying fuels, plant age, and potential differences in operator practices including data reporting.

[110] R. Rutherford, C. Parnell and W. Lepori, *Cyclone Design for Fluidized Bed Biomass Gasifiers* (ASAE Paper no. 84-3598, 1984).
[111] C. Parnell, W. LePori and S. Capareda, "Converting Cotton Gin Trash into Usable Energy," *Proceedings of the 1991 Beltwide Cotton Conference* (1991), pp. 969-972.

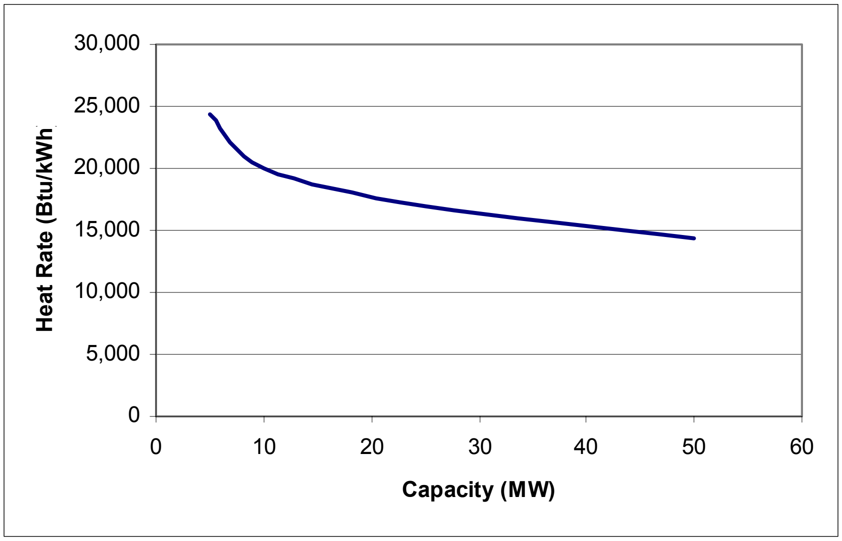

Figure 12-1. Representative efficiencies for biomass power (direct combustion)

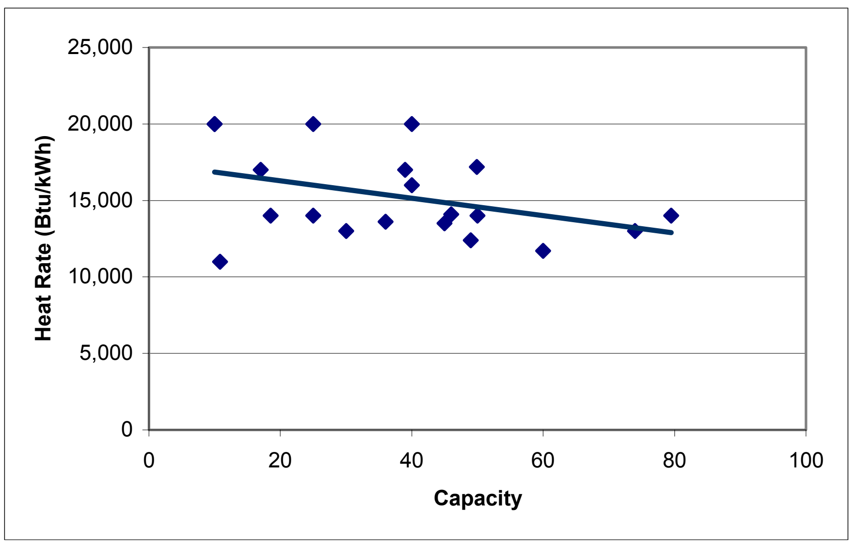

Figure 12-2. Reported heat rate for 20 operating biomass plants[112]

Plant efficiency, fuel characteristics, and operating schedules dictate fuel consumption. As illustrated in both Figure 12-3 and Figure 12-4, fuel consumption is approximately 15 GT/hour for a 5-MW facility and roughly 90 GT/hour for a 50-MW facility.

[112] G. Wiltsee, *Lessons Learned from Existing Biomass Power Plants* (NREL/SR-570-26946, December 2000).

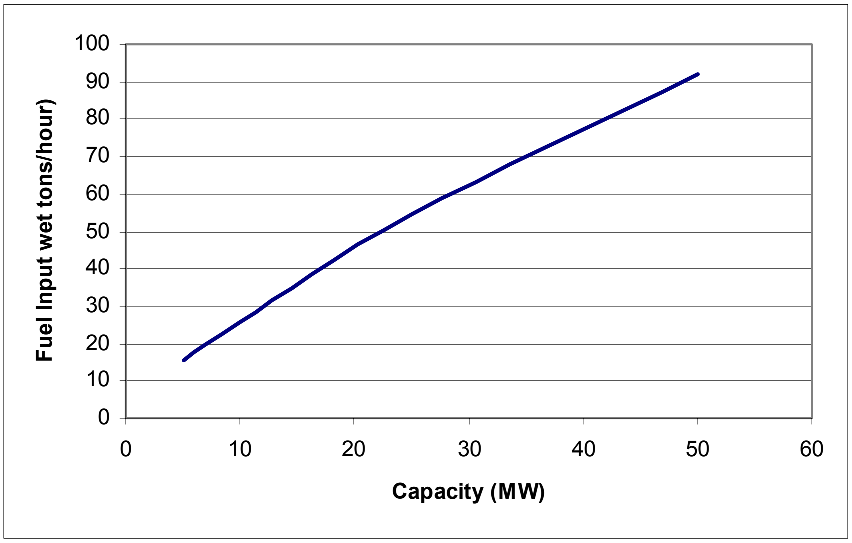

Figure 12-3. Calculated biomass fuel consumption as a function of capacity and heat rate (direct combustion)

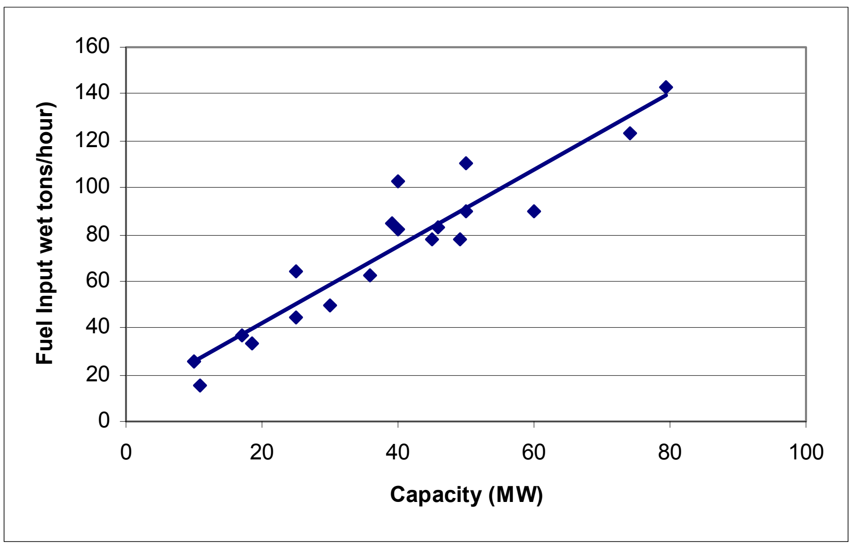

Figure 12-4. Biomass fuel consumption based on 20 operating facilities[113]

12.1.5 Fuel Characteristics

Fuel characteristics greatly affect the combustion process and therefore the decision process for choosing combustion technologies. The most common problems associated with the direct combustion of wood are boiler slagging and fouling, erosion and corrosion, combustion instability and particulate carryover. Fuel characteristics that should be analyzed include heating value, moisture content, ash content, sodium and potassium quantities, particle size distribution, ash fusion temperature and sulfur content.

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[113] Ibid.

Physical fuel characteristics such as density and particle size affect combustion as well as material handling considerations. Changes in fuel density could cause combustion to occur in the wrong place in the boiler, upsetting the heat transfer scheme and therefore the boiler efficiency.

Section 8.1 discusses fuel characteristics and their impacts on biomass power systems in more detail and provides information on the typical physical and chemical properties of a variety of biomass fuels.

12.1.6 Biomass Power Economic Projections

Biomass power is generally an expensive form of electricity. The fuel is often several times more expensive than its major solid fuel competitor, coal, and the biomass fuel also has higher moisture content and lower energy content than coal. Further, capital costs for biomass systems are also more expensive than coal units, primarily because coal plants tend to be quite large and thus capture economies of scale not available to biomass power facilities.

For this report, we have prepared hypothetical pro forma economic calculations for several sizes of biomass facilities to present a general overview of the delivered cost of electricity. The economic model is from the perspective of a private developer.

As presented in Table 12-2 and shown in Figure 12-5, the levelized cost of electricity is expensive and increases slightly as plant capacity increases. This is because fuel costs for the larger plants will increase as additional quantities of (more expensive) biomass is required to supply the facility. Typically, smaller facilities have both higher capital and operating costs. Capital costs are higher on a $/kW basis because manufacturers are afforded economies of scale in the production of the larger components of the plant such as the turbine, boiler and cooling tower. Fixed operating costs, predominantly personnel costs, are higher for smaller facilities because a minimum number of people are required to run a facility while it is possible to operate a much larger facility with only slightly increased staffing levels. However, fuel cost is the primary factor that affects the levelized cost of energy in a biomass power plant. Therefore, the economies of scale associated with larger plants are negated by the higher biomass fuel costs associated with bringing additional quantities of more expensive forest biomass to the larger plants. It should be noted that these costs do not include any costs associated with constructing transmission access to the plant.

Table 12-2. Calculated biomass power direct combustion levelized electricity costs

Capacity (MW)	**Capital cost** ($/kW)	**Fuel consumption** (GT/year)	**Delivered fuel cost** ($/GT)	**Fixed cost** ($/kW-yr.)	**Variable cost** ($/kWh)	**Levelized electricity cost** ($/kWh)
5	2,400	123,415	28.00	94.00	0.003	0.1429
25	2,248	429,577	46.50	84.35	0.003	0.1552
50	2,096	723,205	53.00	74.70	0.003	0.1478

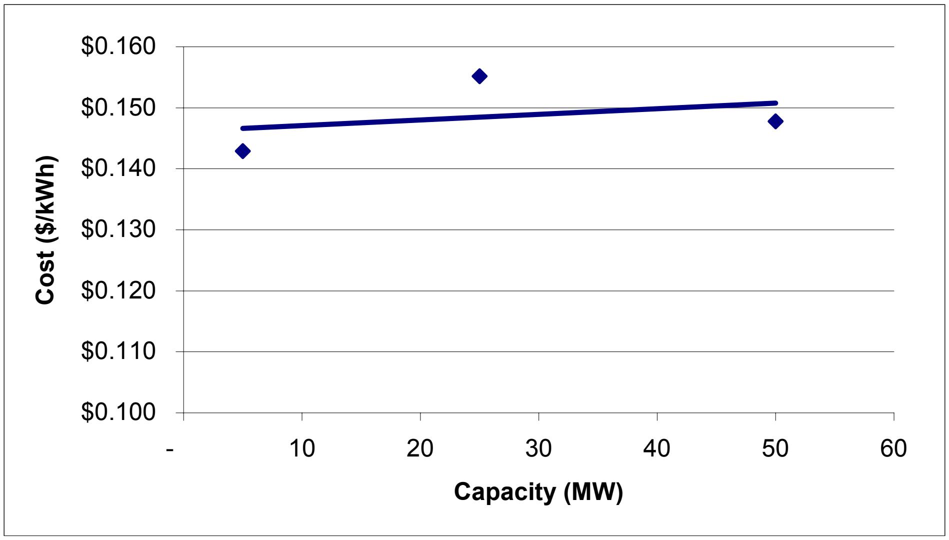

Figure 12-5. Levelized electricity cost as a function of capacity

Figure 12-6 provides a calculated distribution of annual operating costs for a 5-MW direct combustion facility. Fuel costs are the major cost element, representing 66% of annual costs. It is clear that, for biomass to be a competitive source of electricity, fuel costs need to be significantly reduced.

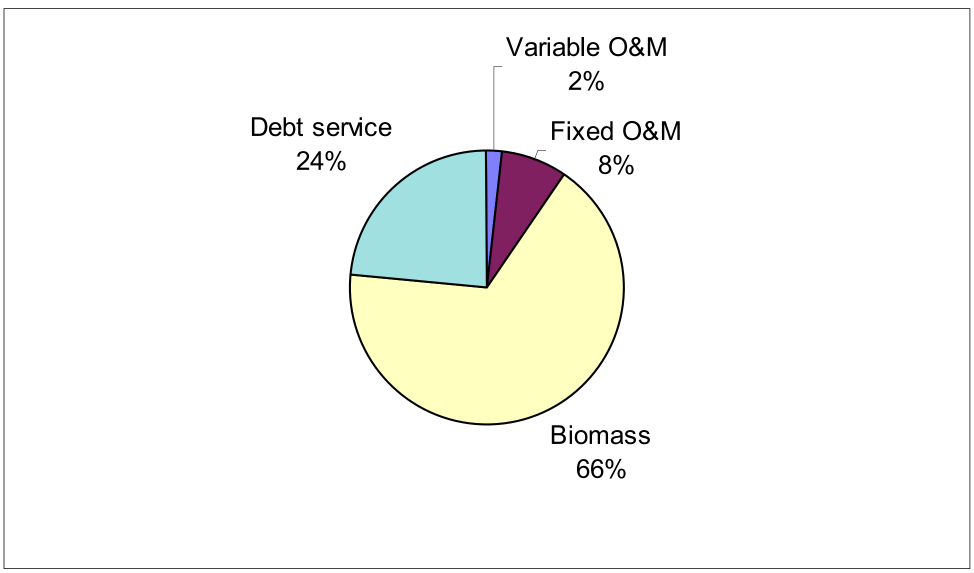

Figure 12-6. Calculated distribution of annual operating costs (5-MW direct combustion)

Figure 12-7 shows the impacts of biomass fuel cost on the levelized cost of energy for three different sized power plants. As fuel costs decrease, the levelized costs of energy also decrease. The figure shows that if fuel costs are equal across the various plant sizes, the cost of energy from the larger plants will be significantly lower than that produced at smaller plants. For example, at $23/GT, the cost of energy from a 5-MW plant will be about $0.13/kWh, whereas the cost from the 50 MW plant will be about $0.085/kWh. It is clearly important to reduce the cost of forest biomass.

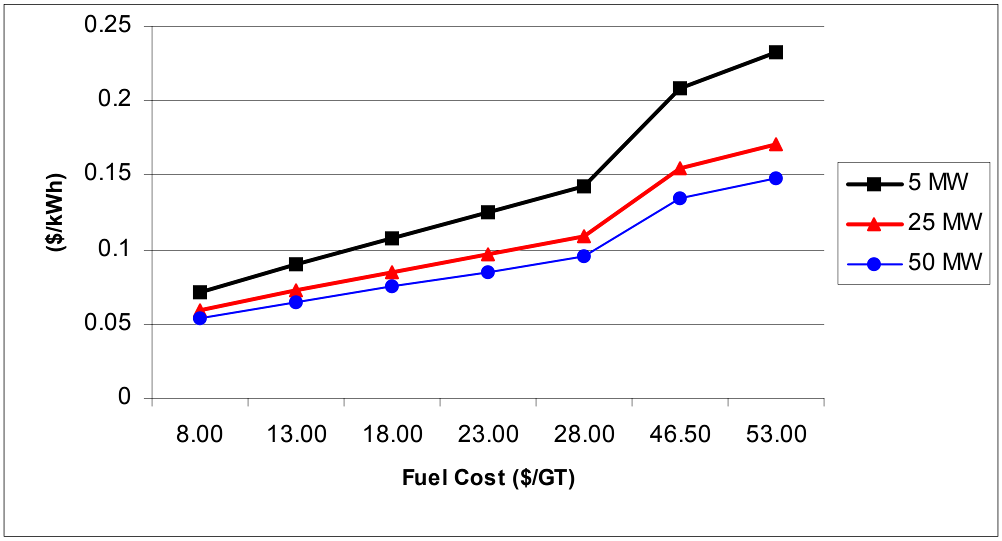

Figure 12-7. Cost of biomass electricity as a function of biomass fuel cost

12.2 Ethanol

12.2.1 Technology Overview[114]

Several technologies can convert cellulose feedstocks into ethanol, including the following:

- Concentrated acid hydrolysis
- Dilute acid hydrolysis
- Enzymatic hydrolysis; and
- Biomass gasification and fermentation.

Concentrated acid hydrolysis

This process is based on concentrated acid decrystallization of cellulose followed by dilute acid hydrolysis to sugars at near theoretical yields. Separation of acid from sugars, acid recovery and acid reconcentration are critical unit operations. Fermentation converts sugars to ethanol.

A flow diagram, shown in Figure 12-8, is one example of how a process based on concentrated acid might be configured. The heart of the process is the decrystallization followed by dilute acid hydrolysis. The original Peoria process, developed by USDA researchers in World War II, and a modified version proposed by Purdue, carry out dilute acid pretreatment to separate the hemicellulose before decrystallization.[115] The biomass would then be dried to concentrate the acid absorbed in the biomass prior to addition of concentrated sulfuric acid. Purdue proposed

[114] U.S. DOE Office of Transportation Technologies, *Concentrated Acid Hydrolysis* (http://www.ott.doe.gov/biofuels/concentrated.html).
[115] Ibid.

recycling sulfuric acid by taking the dilute acid/water stream from the hydrolysis reactor and using it in the hemicellulose pretreatment step.

In Arkenol's process, decrystallization is carried out by adding 70% to 77% sulfuric acid to biomass that has been dried to 10% moisture. Acid is added at a ratio of 1.25:1 (acid: cellulose + hemicellulose), and temperature is controlled at less than 50 degrees Celsius (C). Adding water to dilute the acid to 20% to 30% and heating at 100 degrees C for an hour results in the release of sugars. The gel from this reactor is pressed to remove an acid/sugar product stream. Residual solids are subjected to a second hydrolysis step. The use of a chromatographic column to achieve a high yield and separation of acid and sugar is a crucial improvement in the process that was first introduced by the Tennessee Valley Authority (TVA) and researchers at the University of Southern Mississippi. The fermentation converts both the xylose and the glucose to ethanol at theoretical yields of 85% and 92%, respectively. A triple effect evaporator is required to reconcentrate the acid. Arkenol claims that sugar recovery in the acid/sugar separation column is at least 98%, and acid lost in the sugar stream is not more than 3%.[116]

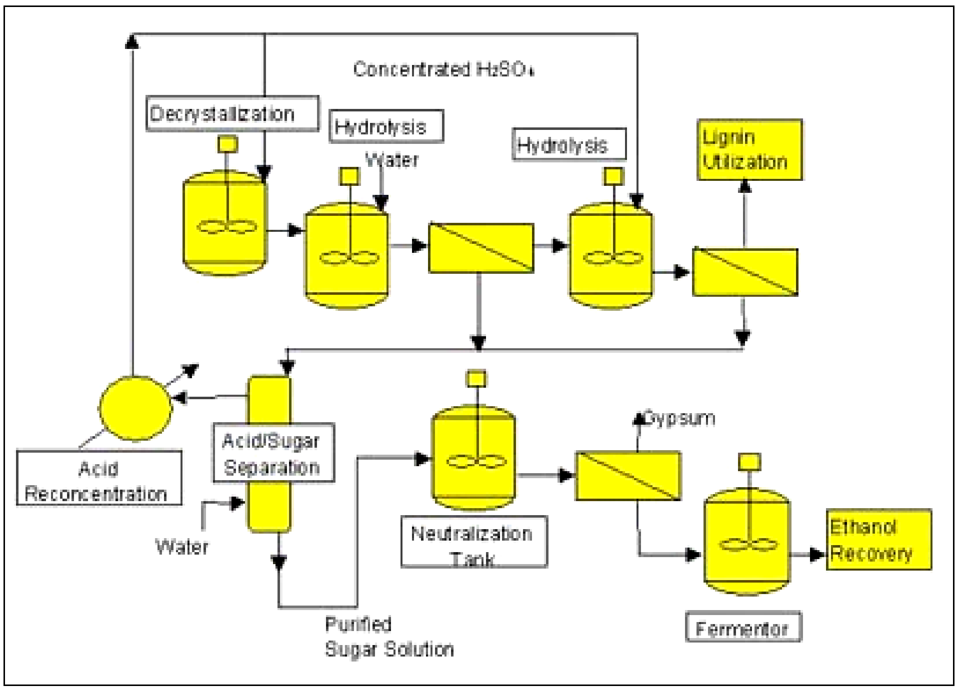

Figure 12-8. Example process flow for concentrated acid hydrolysis

The concentrated sulfuric acid process has been commercialized in the past, particularly in the former Soviet Union and Japan. However, these processes were only successful during times of national crisis, when the economic competitiveness of ethanol production could be ignored. Conventional wisdom in the literature suggests that the Peoria and TVA processes cannot be economical because of the high volumes of acid required. However, improvements in acid sugar separation and recovery have opened the door for commercial application. Two companies in the United States, Arkenol and Masada Resources Group, are currently working with DOE and

[116] Ibid

NREL to commercialize this technology by taking advantage of niche opportunities involving the use of biomass as a means of mitigating waste disposal or other environmental problems.

Dilute acid hydrolysis

Dilute acid hydrolysis of biomass is, by far, the oldest technology for converting biomass to ethanol. Hydrolysis occurs in two stages to maximize sugar yields from the hemicellulose and cellulose fractions of biomass. The first stage is operated under milder conditions to hydrolyze hemicellulose, while the second stage is optimized to hydrolyze the more resistant cellulose fraction. Liquid hydrolyzates are recovered from each stage, neutralized and fermented to ethanol.

While a variety of reactor designs have been evaluated, the percolation reactors originally developed at the turn of the century are still the most reliable (see Figure 12-9). Though more limited in yield than the percolation reactor, continuous co-current pulping reactors have been proven at industrial scale. NREL recently reported results for a dilute acid hydrolysis of softwoods in which the conditions of the reactors were as follows:

- Stage 1: 0.7% sulfuric acid, 190 degrees C and a 3-minute residence time
- Stage 2: 0.4% sulfuric acid, 215 degrees C and a 3-minute residence time

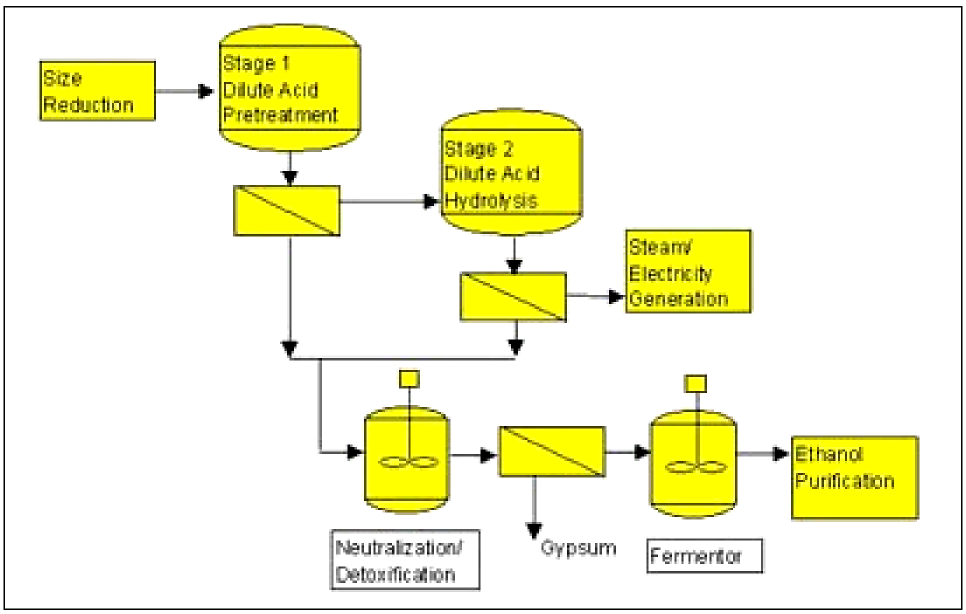

Figure 12-9. Example process flow for dilute acid hydrolysis

These bench scale tests confirmed the potential to achieve yields of 89% for mannose, 82% for galactose and 50% for glucose. Fermentation with *Saccharomyces cerevisiae* achieved ethanol conversion of 90% of the theoretical yield.

There is quite a bit of industrial experience with the dilute acid process. Germany, Japan and Russia have operated dilute acid hydrolysis percolation plants off and on over the past 50 years. However, these percolation designs would not survive in a competitive market situation.

Enzymatic hydrolysis

The first application of enzymes to wood hydrolysis in an ethanol process was simply to replace the cellulose acid hydrolysis step with a cellulase enzyme hydrolysis step. This is called separate hydrolysis and fermentation. The most important process improvement made for the enzymatic hydrolysis of biomass was the introduction of simultaneous saccharification and fermentation (SSF), as patented by Gulf Oil Company and the University of Arkansas. This new process scheme reduced the number of reactors involved by eliminating the separate hydrolysis reactor and, more importantly, avoiding the problem of product inhibition associated with enzymes. In the SSF process scheme, cellulase enzyme and fermenting microbes are combined. As sugars are produced by the enzymes, the fermentative organisms convert them to ethanol. The SSF process has recently been improved to include the cofermentation of multiple sugar substrates. This new variant of SSF, known as Simultaneous Saccharification and CoFermentation (SSCF), is shown schematically in Figure 12-10.

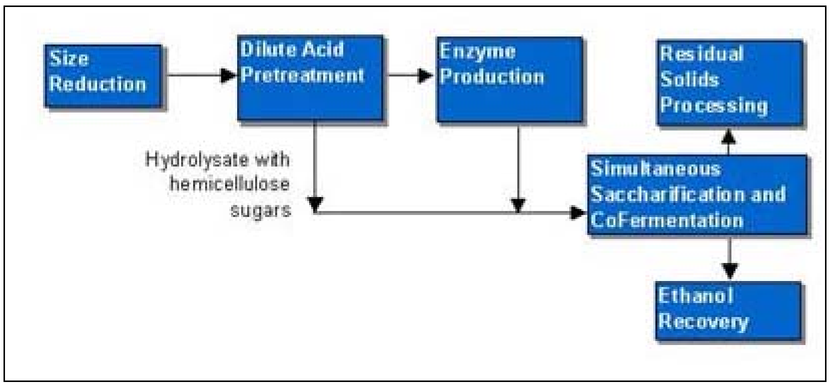

Figure 12-10. Enzyme process for simultaneous saccharification and cofermentation

Cellulase enzymes are already commercially available for a variety of applications. Most of these applications do not involve extensive hydrolysis of cellulose. For example, the textile industry applications for cellulases require less than 1% hydrolysis. Ethanol production, by contrast, requires nearly complete hydrolysis. In addition, most of the commercial applications for cellulase enzymes represent higher value markets than the fuel market. For these reasons, there is quite a large leap from today's cellulase enzyme industry to the fuel ethanol industry. DOE’s partners in commercialization of near-term ethanol technology are choosing to begin with acid hydrolysis technologies because of the high cost of cellulase enzymes. U.S. DOE Biofuels Program researchers see the current high cost of cellulase enzymes as the key barrier to economical production of bioethanol from lignocellulosic material. The Biofuels Program has been working with the two largest global enzyme producers, Genencor International and Novozymes Biotech Incorporated. The objective of this collaboration is to achieve a tenfold reduction in the cost of these enzymes.

In Canada, Iogen Corporation is currently completing construction on the first commercial scale cellulose ethanol plant in the world, using an enzymatic process. The plant is already producing fermentable sugars from 50 tons of wheat straw in 900 lb bale form per week. Iogen is finishing construction on its distillation towers, which should be operational in 2004.[117]

<u>Biomass Gasification and Fermentation</u>

Gasification may be used in conjunction with fermentation technology to produce ethanol. After gasification (see 12.1.3), anaerobic bacteria such as *Clostridium ljungdahlii* are used to convert the CO, CO_2, and H_2 into ethanol. Higher conversion rates are obtained because the process is limited by the transfer of gas into the liquid phase instead of the rate of substrate uptake by the bacteria.

12.2.2 Feedstock requirements and yield

The quantity of feedstock required by an ethanol conversion facility is primarily determined by the size of the facility and the ethanol yield per ton of feedstock. Different conversion technologies have different yields and are at different stages of commercial development. The relationship between yield and feedstock requirement is linear. Figure 12-11 illustrates the relationship for four different ethanol yields from 50 to 80 gallons/ton of feedstock and for facilities with capacities up to 50 million gallons per year. To get some perspective on the quantity of feedstock required, a large pulp mill requires 2,000 tons of feedstock/day or 730,000 tons/year. That quantity of feedstock could produce between 36 and 73 million gallons of ethanol as yield increased from 50 to 100 gallons/ton.

[117] Tania Glithero, Iogen Corporation (personal communication with Tim Rooney, McNeil Technologies, Inc., November 21, 2003). More information on Iogen Corporation can be obtained on-line: http://www.iogen.ca.

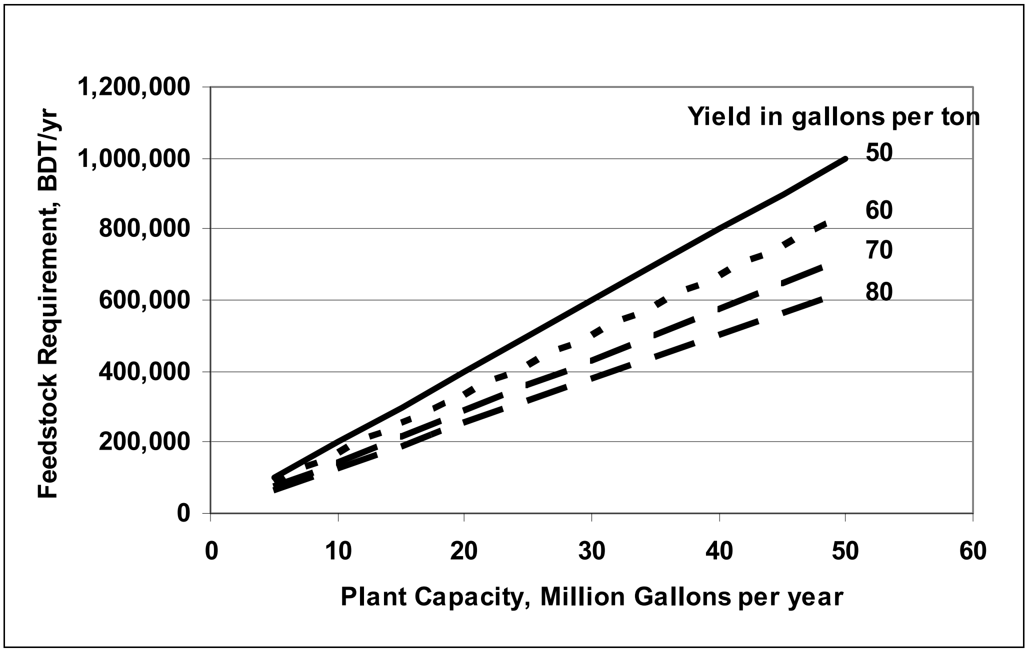

Figure 12-11. Ethanol yield and feedstock relationship

The cost of converting cellulose materials to ethanol is determined by three main cost elements; feedstock, capital and operating costs. Capital costs include costs for equipment, engineering, installation and financing. Operating costs include maintenance and operating labor, marketing, chemicals, utilities and and maintenance supplies. Chemical process industries, like ethanol, are known to have economies of scale. Capital and operating costs per gallon of capacity decline as the capacity increases. Figure 12-12 shows the capital cost/gallon of production, assuming a capital recovery factor of 20%. This illustrates the dramatic increase in capital cost per gallon when facility size drops below 10 million gallons/year. The capital cost data for facilities 20 million gallons and larger came from a CEC report[118], and a Merrick report[119] provided data for facilities less than 20 million gallons.

[118] California Energy Commission, *Evaluation of Biomass-to-Ethanol Fuel Potential in California* (California Energy Commission, December 1999).
[119] Merrick & Company, *Alaska Softwood to Ethanol Feasibility Study* (1999).

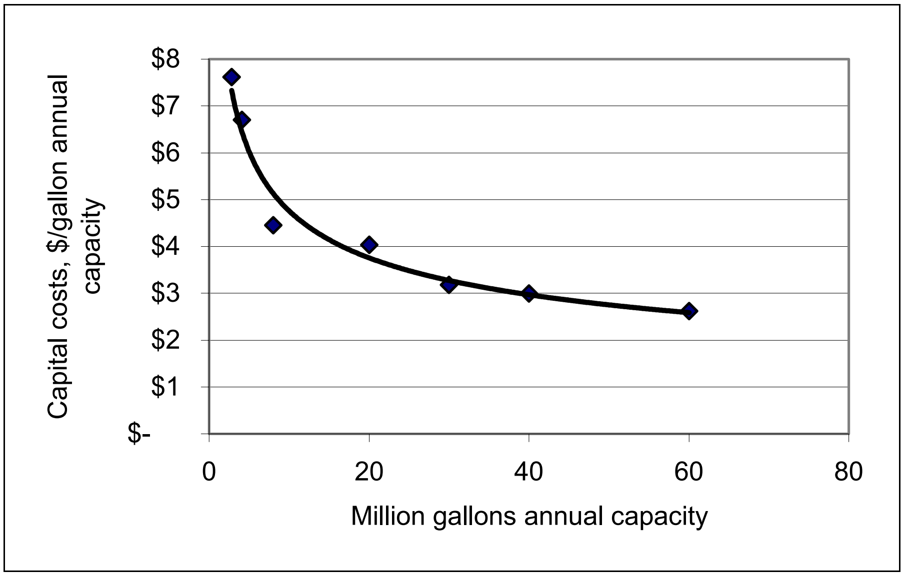

Figure 12-12. Economies of scale for cellulose ethanol facilities

The optimum plant size will depend on the relationships between capital cost, feedstock cost and operating costs. Figure 12-13 shows these relationships using data from the CEC report. The volumes correspond to facilities sized 20, 30 40 and 60 million gallons of annual capacity. The feedstock was assumed to be forest residue with a subsidized cost of $30/ODT. Yields were assumed to be 77 gallons/ton, and maintenance costs were assumed to be $0.15/gallon. The figure shows that capital costs/gallon decrease and feedstock costs/ton increase as the plant size increases and more material is needed. The shape of these curves will change for each facility depending on supply costs, conversion yields and operating and maintenance costs. However, in most cases there will be an economic optimum where the production costs are at a minimum.

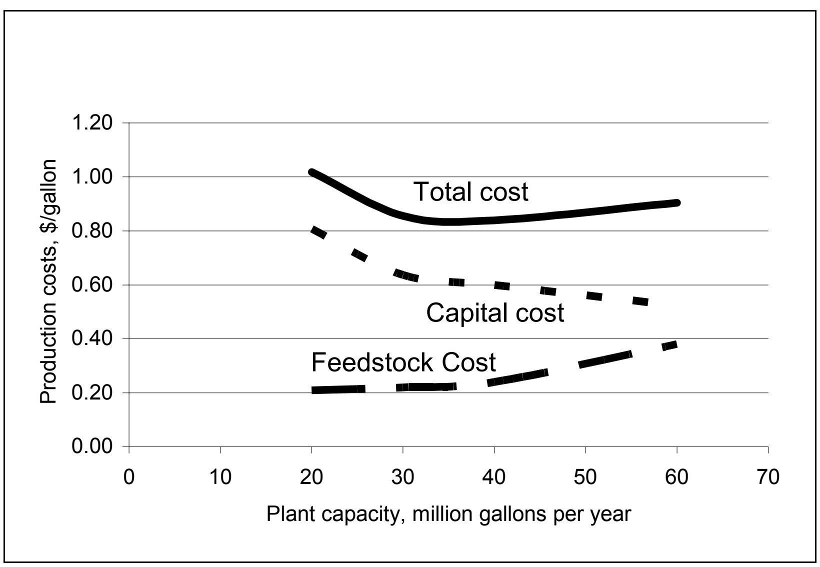

Figure 12-13. Ethanol production costs

12.2.3 Siting requirements

Siting an ethanol production facility requires consideration of water supply needs, wastewater disposal, power needs and transportation access. Make-up water estimates depend on the conversion technology. NREL estimated water requirements for their enzymatic processes. The approximate relationship is that water requirements in gallons per minute equals twelve times the ethanol capacity in million gallons per year. For example, a 50-million-gallon/yr facility would require 600 gallons/minute of make-up water. Wastewater discharge depends on what technologies are employed. The trend in the design of cellulose ethanol facilities is to have zero wastewater discharge. That is, all wastewater is reprocessed and used within the facility. The solids from the wastewater treatment are sent to the biomass boiler. Merrick investigated wastewater disposal options and provided a detailed report.[120] Larger cellulose ethanol facilities are assumed to generate power in excess of their needs and sell the surplus. Power needs are therefore minimal and only required for cold start conditions. Ethanol can be economically transported long distances only by pipeline, rail or ship. For the three counties under consideration, rail is the only alternative. Therefore, rail access is necessary.

In addition, an ethanol conversion site will require on-site storage sufficient to store 15 days of feedstock, assuming that most of the supply would be stored off-site at the supply locations. Using Union County as an example, approximately 60,000 tons of residue is collected per year, and about 2,500 tons would be stored at the conversion facility. If each bale is 16 inches wide, 16 inches high and 48 inches long and weighs 64 lb., then the storage capacity per acre of land is 871 tons. This area includes space for access and handling. Thus, about three acres of land would be required to store 15 days worth of field residues.

[120] Merrick & Company, *Wastewater Treatment Options for the Biomass-to-Ethanol Process* (NREL Subcontract AXE-8-18020-01, Final Report, October 1998).

13. CONCLUSIONS AND RECOMMENDATIONS

This section summarizes conclusions and recommendations drawn from the results of the resource, technology, economic and environmental analysis of biomass utilization in Baker, Union and Wallowa Counties.

13.1 Conclusions

Conclusions drawn from the analysis can be grouped into five categories: biomass supply, conversion technology, potential sites, economic impacts and environmental impacts. The following subsections describe conclusions from each of these areas.

13.1.1 Biomass Supply

The available forest and agricultural biomass resource is sufficient to support a biomass power plant or a biomass ethanol manufacturing facility (with an integrated power generation system to use lignin to generate electricity). In all, 816,195 tons of residue is potentially available for a biomass energy project. The supply is composed of:

- 80,009 field dry tons of agricultural residue
- 310,252 GT of wood products residue (mostly in chip form); and
- 425,934 GT of forest biomass.

Agricultural residue ranges in cost from $26 to $37/field dry ton delivered. Agricultural residue moisture content generally ranges from 10% to 20%, but could be higher depending on the timing of collection, storage method and other site-specific factors. Agricultural residue is best as a feedstock for cellulose ethanol manufacturing, because this resource could cause boiler slagging and fouling in a biomass power plant if used in high proportions. However, the extent to which this is an issue depends on the crop type. The problem can be addressed in system design and manufacturing.

A small quantity of veneer cores (1,500 GT) may be available for a low delivered cost ranging from $3 to $14/GT. Wood products residue in the form of chips is a large source of biomass, but the price paid must at least be cost competitive with the price paid by pulp chip buyers. Delivered chip prices generally range from $16 to $27/GT. In 2003, market prices were low. Historically, chip prices have been as high as $60/GT. Forest biomass costs range from $45 to $58/GT, delivered.

Small diameter forest biomass and agricultural residue are currently not utilized for value-added products. Existing agricultural and forestry expertise and infrastructure are capable of collecting and processing biomass, although expansion of that infrastructure would be required. Agricultural residue is not collected and utilized on a wide scale, but some landowners have experimented with baling systems. There are in-woods chipping operators in the area that produce pulpwood chips. Their capabilities could be expanded to utilize small-diameter forest biomass. Cooperation between private, state and local governments and forestry professionals in land management planning would be needed to assure contractors of a reliable revenue source to justify new equipment investment.

13.1.2 Conversion Technology

Biomass power is a mature technology. Its costs and operating performance are well known, and there are turnkey engineering design/build and operation plants available. Cellulose ethanol is, by contrast, an emerging technology. It has not been done on a commercial scale, though there are several existing pilot- and demonstration-scale plants in existence or under development. However, there is a growing market for ethanol as an oxygenate additive to gasoline. Being a first adopter of the technology could bring in investment and research money to help defray additional costs associated with a first-time deployment of the technology on a large scale.

There are some challenges concerning certifying biomass-based power as “renewable” under certain third-party certification efforts such as the Tradable Renewable Certificate (TRC) program administered by the Center for Resource Solutions, but several renewable energy programs have included biomass as a part of their renewable energy mix, and several utilities have issued requests for proposals for biomass-based power. A variety of credits and incentives might make biomass power more profitable. In particular, extension of the federal biomass power generation credit to “open-loop” biomass such as forest biomass and agricultural residue could greatly help the economics of biomass power generation. Similarly, cellulose ethanol may have challenges competing with corn-based ethanol on a cost basis. However, the significant public benefits associated with cellulose ethanol manufacturing could be the basis for expanding the availability of state and federal production tax credits to biomass ethanol plants.

13.1.3 Potential Sites

There are many industrial sites in the study area that could be host to a biomass ethanol or power plant. This effort identified 37 potential sites and selected three, one in each county, to serve as the basis for an assessment of delivered biomass costs for the study area. These sites are:

- Elkhorn View Industrial Park, Baker City (Baker County)
- Baum Industrial Park, La Grande (Union County); and
- Former Bates Mill site, Wallowa (Wallowa County).

Through a preliminary ranking and scoring procedure, these locations were identified as having characteristics that make them acceptable potential sites based on compatibility with existing land use, proximity to infrastructure (substations, wastewater treatment, rail access), ease of development and other factors. However, several other sites are nearly equivalent in value in each county, so it cannot be said that these are the only or the best sites. A case in point, the former Ellingson mill sites in Baker County are good potential candidates because the current landowner has experience with managing biomass power generation equipment. Multiple Boise Cascade facilities could be the site of a biomass power or ethanol plant. However, the Baum Industrial Park is located adjacent to a Boise Cascade particleboard plant and less than three miles from a Boise Cascade sawmill, and therefore our analysis would apply equally to other Boise Cascade sites. In short, investors should consider other sites in the region that could be good candidates for development beyond the three discussed in this study.

13.1.4 Economic Impacts

Biomass power and ethanol manufacturing would have a positive economic impact from the perspective of the county in which the plant was located and from a regional perspective, as direct and indirect employment impacts from plant construction and operation take hold. Depending on the plant capacity, a biomass power plant would create 15 to 20 or more jobs at the power plant and support employment in the fuel processing and delivery sectors. There would be highly skilled positions for plant engineering and management and entry and mid-level positions in administration, maintenance and fuels handling.

There are not widespread data on cellulose ethanol employment impacts, but a comparison can be made with the corn-based ethanol industry. A 15-million-gallon/year cellulose-based ethanol plant, based on our estimates, would need about 30 full-time employees. The number of jobs associated with feedstock supply and delivery would be about 70, depending on the degree of mechanization and travel distance. Tax revenue implications would include income taxes for state and federal government and property taxes. A significant long-run gain for communities can come from reduced risks of wildfire. Wildfire suppression and cleanup costs affect communities, state and federal government, utilities, homeowners and businesses. Over time, these costs can be large and they can be unpredictable. Reducing the risks of catastrophic losses of property and risks of injury and death can be of substantial economic benefit and can help to preserve the watershed and recreational benefits of forests.

13.1.5 Environmental Benefits and Risks

The environmental benefits associated with watershed and forest protection that can be achieved through development of small-diameter forest biomass markets have already been mentioned. However, using forest and agricultural biomass for ethanol or biomass power generation can also reduce air emissions. Currently, crop residue and slash or forest biomass from thinning projects is often burned in the open. Producing liquid fuels with that material or burning it in a controlled environment to produce renewable energy can result in significant net emission reductions. Reducing the risk of catastrophic forest fires can help reduce the risk of large smoke plumes from forest fires that frequently contain harmful materials such as mercury and that can exacerbate respiratory problems for residents. Using ethanol as a fuel additive also has a further positive impact because its use displaces gasoline use, thereby reducing sulfur and other emissions associated with using petroleum-based fuels in an internal combustion engine.

13.2 Recommendations

Following up on several recommendations can help land managers and communities develop a biomass resource supply for a bioenergy facility that meets both economic and environmental objectives. First, cooperation by federal agencies, state agencies, private landowners and existing forestry professionals will be needed to develop a multi-year planning process for fuels management and small diameter material utilization. A multi-year planning horizon is needed to justify investment by forestry professionals and plant investors. The willingness of all parties to develop this resource has not been fully gauged and should be the topic of future efforts.

One key need to ensure continuity of this effort is to secure funding for a local contact to continue these efforts, whether it is done through a land management agency, county economic development agency or other local coalition. Disseminating the results of this project through a public meeting can serve as a springboard to identify key coalition partners and leaders. This meeting can also help follow up on the sustainability focus group. A local biomass sustainability council or review board could be set up to help establish expectations for communications between forest land managers, farmers and local community groups. A community-based monitoring program could be developed to ensure that the biomass resource is utilized in a sustainable manner.

This study focused on biomass resource availability and technology but concentrated very little on markets for biomass power and fuel-grade ethanol. Markets should be a key focus for potential plant developers. A market for power or fuel grade ethanol that will make biomass power and fuels manufacturing profitable must be identified. If a utility power purchase price is not sufficient to cover the costs and overhead for biomass power generation, biomass power sellers may be able to take advantage of green power marketing.

One key technology sector that was not evaluated for this study, but could be another potentially beneficial market, is biomass facility heating, cooling and small-scale power generation. Biomass heating is a proven technology with low capital cost requirements relative to power generation or ethanol manufacturing. It can be used at a wide variety of community, government, commercial and other institutional properties that have a significant heating load, and generally requires a smaller resource base than power or alternative fuels manufacturing. As a result, biomass-heating systems could be installed in multiple locations, reducing feedstock transportation costs and helping to develop local forest biomass outlets for communities that seek to reduce wildfire risk from nearby overstocked forests.