Biomass Resource Assessment and Utilization Options for Three Counties in Eastern Oregon

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ABSTRACT

This report documents a biomass resource and technology assessment focusing on Baker, Union and Wallowa counties in Northeastern Oregon funded through the U.S. Forest Service National Fire Plan and the Oregon Department of Energy. A significant amount of biomass that is not merchantable in wood products or other manufacturing industries is available from forest resource management, agriculture and wood products manufacturing in the region. Biomass energy facilities could provide a potential economic use for this material. The feasibility of using this material is enhanced by locating an energy facility close to the source of the material and sizing the facility appropriate to the volume of material available on a long-term, sustained basis. Using current and near-term technology, biomass energy facilities could convert surplus biomass into electricity, industrial steam energy and fuel ethanol. A barrier to private sector investment in biomass energy facilities is the lack of specific information about the amount of biomass feedstock available, the cost of feedstock delivered to the plant site and the best locations for proposed facilities relative to both feedstock supply and markets for energy products. There is a critical need for this information in view of both high fire-risk in the forest and the need for economic stimulus in rural communities. This report addresses that need for information

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Dr. Jim Kerstetter provided technical support to McNeil on this project. In addition, the authors want to thank all the stakeholders who participated in the focus group (held in November 2002) that explored issues surrounding biomass sustainability. The authors regret if there are any omissions to the above list.

Finally, despite our best efforts at editing and revisions, mistakes may remain within this document. Any mistakes or omissions are the sole responsibility of the authors. Any questions or comments should be addressed to McNeil Technologies Inc., 143 Union Blvd., Suite 900, Lakewood, CO 80228. McNeil staff members who worked on this project are Scott Haase, Tim Rooney and Jack Whittier.

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ABBREVIATIONS AND ACRONYMS

$	U.S. dollars
ASV	all surface vehicle
ATV	all terrain vehicle
BDT	bone-dry tons (0% moisture content); also referred to as oven-dry tons (ODT)
BEF	Bonneville Environmental Foundation
BFB	bubbling fluidized bed
BLM	U.S. Bureau of Land Management
Btu	British thermal units
C	Celsius
CCF	hundred cubic feet (ft^3)
CF	cubic feet (ft^3)
CFB	circulating fluidized bed
CFR	Code of Federal Regulations

Ch	chains; a chain is a U.S. survey unit that is the equivalent of 66 feet (20.1 meters)
CHP	combined heat and power
CLAMS	Coastal Landscape Analysis and Modeling Study
CO	carbon monoxide
CO_2	carbon dioxide
COIC	Central Oregon Intergovernmental Council
CORE4	Conservation for Agriculture's Future
CRP	Conservation Reserve Program
CSREES	Cooperative State Research, Education and Extension Service
CTIC	Conservation Technology Information Center
CVS	continuous vegetation survey
DBH	diameter breast height
DEQ	Department of Environmental Quality
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
DSL	Oregon Division of State Lands
E10	gasoline containing 10% ethanol by volume
E95	gasoline containing 95% ethanol by volume
EIA	U.S. DOE Energy Information Administration
EPA	U.S. Environmental Protection Agency
EPACT	Energy Policy Act
ETBE	ethyl tertiary butyl ether
EVG	existing vegetation
F	Fahrenheit
FEEMA	Financial Analysis of Ecosystem Management Activities
ft	feet
GAP	Gap Analysis Program
GRMWP	Grande Ronde Model Watershed Program
GT	green tons
H_2	hydrogen
HHV	higher heating value
ICBEMP	Interior Columbia Basin Ecosystem Management Project
in	inches
kW	kilowatt
kWh	kilowatt-hour
lb	pounds
LHV	lower heating value
MBF	thousand board feet
MC	moisture content
MCF	thousand cubic feet
MMCF	million cubic feet
mi^2	square miles
MMBF	million board feet
MMBtu	million British thermal units
MSW	municipal solid waste
MTBE	methyl tertiary butyl ether

MW	megawatt
MWh	megawatt-hour
NASS	National Agricultural Statistics Service
N	nitrogen
NO_x	oxides of nitrogen
NRCS	Natural Resources Conservation Service
NREL	National Renewable Energy Laboratory
ODF	Oregon Department of Forestry
ODT	oven-dry tons (0% moisture content); also referred to as bone-dry tons (BDT)
ORS	Oregon Revised Statutes
OSU	Oregon State University
psi	pounds per square inch
PURPA	Public Utility Regulatory Policy Act
RBEP	Regional Biomass Energy Program
REPA	Renewable Energy Production Incentive
RFG	reformulated gasoline
ROI	return on investment
SCI	Soil Conditioning Index
SDI	Stand Density Index
SO_x	oxides of sulfur
SSCF	simultaneous saccharification and cofermentation
S	sulfur
TPA	trees per acre
TSI	timber stand improvement
TVA	Tennessee Valley Authority
U.S.; USA	United States of America
USDA	United States Department of Agriculture
USFS	United State Forest Service
VOC	volatile organic compound
WRBEP	Western Regional Biomass Energy Program
wt %	weight percent
yr	year

EXECUTIVE SUMMARY

INTRODUCTION

The forests of Northeast Oregon are susceptible to increased risks of wildfire, caused in part by past forest management activities, decades of aggressive fire suppression and climatic conditions. These conditions have led to significant levels of biomass fuel in the forests. Wildfire threatens local communities with loss of life and property. Wildfire may also damage water quality, wildlife and the recreational and resource values associated with forestland.

Federal and state agencies, local government and private forest landowners are using thinning and prescribed burning in strategic locations to reduce forest fuels and wildfire risks. Most of the material generated from fuels reduction activities is not suitable for wood products manufacturing. In many cases, biomass from these activities is left on-site or piled and burned at an additional cost. An alternative outlet for this wood could help reduce the costs of thinning and mitigate environmental impacts associated with prescribed burning and wildfires. In addition, local agricultural producers are seeking to develop new income opportunities and looking for alternatives to burning crop residues, which contributes to air pollution. This study focuses on using these resources to develop biomass energy opportunities in Baker, Union and Wallowa Counties in Northeast Oregon. The Oregon Department of Energy and the U.S. Forest Service provided financial assistance to this project because it supports their mutual interests in renewable energy development, natural resource protection and safeguarding communities.

The study area is of particular interest because it is the focus of the Grande Ronde Model Watershed Program (GRMWP), a unique group of public and private stakeholders that are collaborating to help improve watershed conditions in the region. GRMWP projects, include but are not limited to, riparian habitat protection, upland and mixed habitat protection (including thinning), road improvement and closure, fish habitat passage improvement and irrigation diversion improvement.[1] In addition, the Oregon Governor's Office, with the assistance of the U.S. Forest Service Pacific Northwest Research Station, has completed a vegetation assessment targeting small diameter timber potential in the Blue Mountains that complements the potential for biomass energy development in the area.[2]

<u>Project goals and objectives</u>

The goal of this study is to promote the cost-effective, sustainable use of biomass for power and/or ethanol manufacturing in Baker, Union and Wallowa Counties in Northeast Oregon (see Figure ES-1). The objectives of the study are to:

- identify how much biomass is generated in the region
- determine how much biomass is available, where it is located, its physical and chemical characteristics and the cost
- provide information on best locations for a potential biomass site in each county
- evaluate the economic and environmental impacts of biomass use; and

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[1] Grande Ronde Model Watershed Program, *GRMWP Restoration Projects* (http://www.fs.fed.us/pnw/modelwatershed/grmwp-project-page.html).

[2] Oregon Office of the Governor and Oregon Department of Agriculture, *Assessment Of Timber Availability From Forest Restoration Within The Blue Mountains Of Oregon* (http://www.fs.fed.us/bluemountains/pubs.htm, Blue Mountains Demonstration Area, November 14, 2002).

- provide an overview of biomass energy technologies, feedstock requirements, and the economic potential to convert biomass to electricity or ethanol.

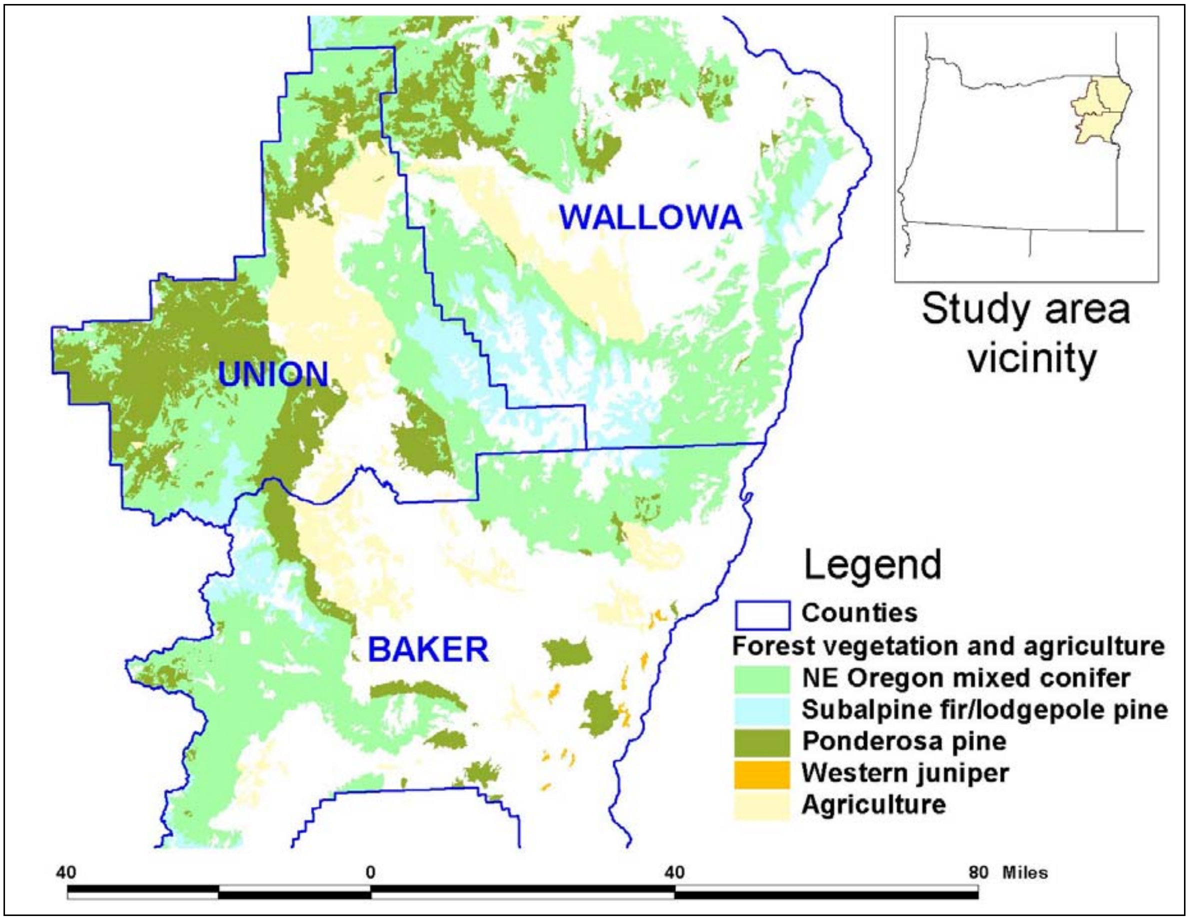


Figure ES-1. Study area

The study area includes 8,280 square miles of territory.[3] Forests cover 48%, agricultural land comprises 9%, and shrub and grassland make up 39% of the total area. The remaining 4% of the study area cover consists of urban, alpine, wetland and open water.[4] Public land makes up 52%, with the U.S. Forest Service owning and managing 45% of the total land area.[5] The counties are largely rural, with a historic economic base dependent on agriculture, forestry and tourism. The estimated combined population of the three counties in 2002 was 48,350; the 2001 average unemployment rate was 8.5 percent.[6]

[3] U.S. Census Bureau, *State & County Quickfacts* (http://quickfacts.census.gov/qfd/states/41000.html).
[4] R. Eber, Rural Lands Database, *Gap Analysis Program (GAP) Vegetation Cover Database* (Oregon Department of Land Conservation and Development).
[5] U.S. Forest Service area land from U.S. Department of Agriculture Forest Service, Wallowa-Whitman National Forest, *Forest Facts,* accessed September 22, 2003 (http://www.fs.fed.us/r6/w-w/forest_facts.htm) and Umatilla National Forest, *Total Forest Acres,* accessed September 22, 2003 (http://www.fs.fed.us/r6/uma/acres.htm). Total land area from U.S. Census Bureau, *State & County Quickfacts* (http://quickfacts.census.gov/qfd/states/41000.html).
[6] U.S. Census Bureau, *State & County Quickfacts* (http://quickfacts.census.gov/qfd/states/41000.html).

BIOMASS RESOURCE GENERATION AND AVAILABILITY

The plant-based biomass resource in Northeast Oregon consists of forest biomass, wood products manufacturing residues and agricultural crop harvesting residues. Forest biomass is generated because of forest fuels reduction, commercial timber harvest, non-commercial thinning and timber stand improvement (TSI) activities. Non-commercial thinning includes pruning and tree removal designed to help shape and guide development of forest stands to meet a variety of goals, but it generally does not result in removal of trees that can be used to manufacture products. Timber stand improvement can accomplish similar goals, but it often results in removal of some commercially valuable trees. Wood manufacturing residues consist of bark, sawdust, chips, and veneer cores. Agricultural residues consist of straw, grass and leaves left over after harvesting the major crop types in the region, including grass seed, spring wheat, winter wheat, oats and barley. Currently, the material is left on-site, burned or in some cases used for animal feed.

Data sources and analytical approach

The overall approach to assessing the biomass resource was to first estimate the quantity of material generated from forestry and agricultural practices in the area. We then evaluated the quantity of material that could be recovered from these practices taking into account technical and environmental constraints associated with slope, soils, wildlife habitat and other site factors. Data sources for forest management on federal land included monitoring and reporting information from Wallowa-Whitman and Umatilla National Forests for fuels reduction, noncommercial thinning and TSI activities. Oregon Department of Forestry long-term timber harvest data from all landowners were used to estimate residue from timber harvesting.

We calculated agricultural residue generation based on annual average acres harvested, yield values per acre, and estimated residue generation factors. Data sources for harvest and yield values were from the U.S. Department of Agriculture National Agriculture Statistics Service. Residue generation factors were calculated for barley, spring wheat and winter wheat based on methods developed by the Natural Resources Conservation Service.[7]

Biomass availability was determined based on a variety of factors. Forest biomass availability was determined based on slope constraints on forestland. Forest biomass removal is technically more difficult and costly on land with steep slopes. We estimated the forestland area that is less than 30% slope for each county, based on U.S. Forest Service Forest Inventory & Analysis plot data. We then multiplied estimated biomass generation by the percentage of forestland in each county that is less than 30% slope. Other factors limit forest biomass availability, including the need to leave materials on-site for soil conservation and wildlife habitat. These constraints provided a conservative estimate of the quantity of biomass that could be removed on forestland, given current levels of forest management intensity.

Agricultural biomass availability is limited by the estimated quantity of material that must be left on site to maintain soil productivity. We used a computer model developed by the U.S. Department of Agriculture called the Soil Conditioning Index (SCI) to estimate the quantity of residues that could be removed while preserving soil productivity. The results of the SCI calculations showed that the quantity of residue that could be removed without resulting in a

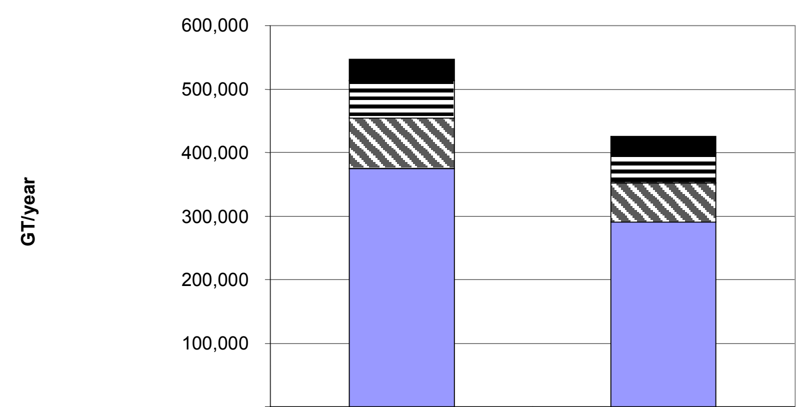
[7] NRCS, *National Agronomy Manual* (ftp://ftp.nssc.nrcs.usda.gov/pub/agronomy/SCIfiles/Latest_revisions/Training%20Materials/NAM508.pdf).

decrease in soil organic matter varied from 1 to 1.5 tons per acre. We then calculated agricultural residue availability by multiplying the total harvested acres in each county by the residue availability factor for each county. The SCI does not apply to grass straw. We relied on regional expertise to provide us with the assumption that 85% of grass straw could be recovered. However, unless a biomass facility could afford to pay at least $10/ton to landowners, Kentucky Bluegrass straw is considered not available because it is sold for feed.

Manufacturing residue availability was based primarily on the existence of competing uses for the residues. In the study area, most sawmill residue is used internally by Boise Cascade facilities. Bark is used for energy; shavings, sawdust and planer trim are all used for making particleboard. Because these materials are fully utilized internally by Boise Cascade, they are not considered available for purposes of this study. Chips, however, are sold for pulp, and could be available if the price paid for the material is competitive.

<u>Forest biomass generation and availability</u>

The estimated quantity of forest biomass generated is 547,620 green tons (GT) per year. The estimated quantity available is 425,934 GT/year (see Figure ES-2). The majority of the biomass available, 69%, is from timber harvesting residues. Fuels treatment, TSI and non-commercial thinning comprise the remaining 31% of the available resource.

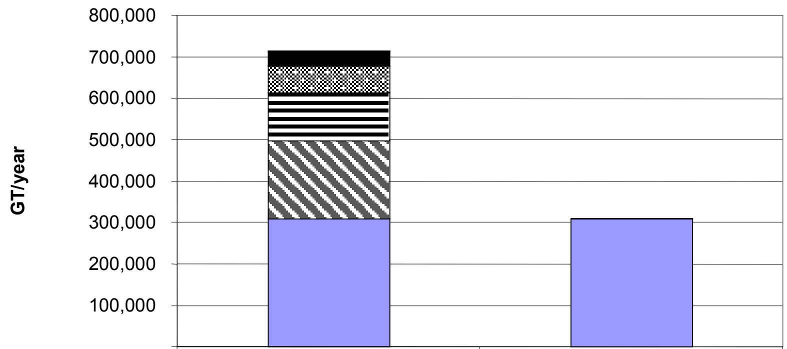


	Generation	Available
Non-commercial thinning	33,710	26,355
Fuels treatment	58,807	45,976
TSI	79,120	61,857
Timber harvesting residue	375,983	291,745

Figure ES-2. Forest biomass generation and availability

<u>Wood products residue generation and availability</u>

A total of 714,852 GT of wood product residue are generated each year. Of this, 310,252 GT could be available if the price paid were competitive with existing markets (see Figure ES-3).

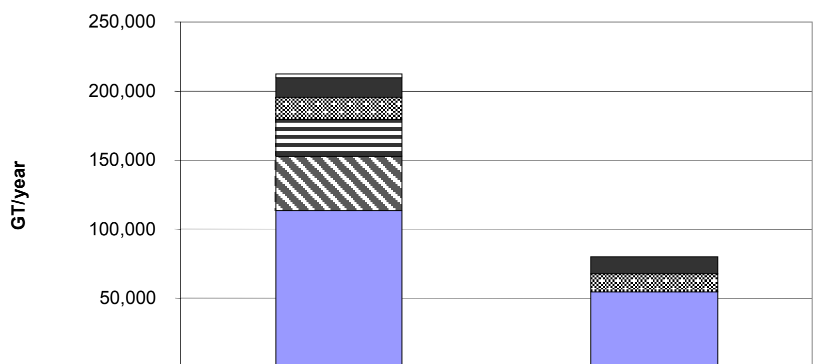


	Generation	Available
Veneer cores	1,458	1,458
Plywood trim	33,875	-
Planer shavings	64,603	-
Sawdust	115,961	-
Hog fuel	190,160	-
Chips	308,794	308,794

Figure ES-3. Wood products manufacturing residue generation and availability

Agricultural residue generation and availability

The estimated quantity of agricultural residues generated in the study area each year is 212,661 GT. The estimated quantity available, that which can be removed without diminishing soil productivity, is 80,009 GT/year (see Figure ES-4).



	Generation	Available
Oats	2,649	-
Kentucky bluegrass	14,287	12,144
Other grass	15,917	13,529
Spring wheat	26,608	-
Barley	39,907	-
Winter wheat	113,294	54,335

Figure ES-4. Agricultural residue generation and availability

Winter wheat straw makes up 68% of the total quantity available, while grass straw from Kentucky Bluegrass and other grass seed production makes up the remaining 32%.

Summary of biomass generation and availability – all sources

Total estimated annual biomass generation is 1,475,133 GT; 55% of that total quantity or 816,195 GT could be available for use at a biomass facility annually (see Figure ES-5).

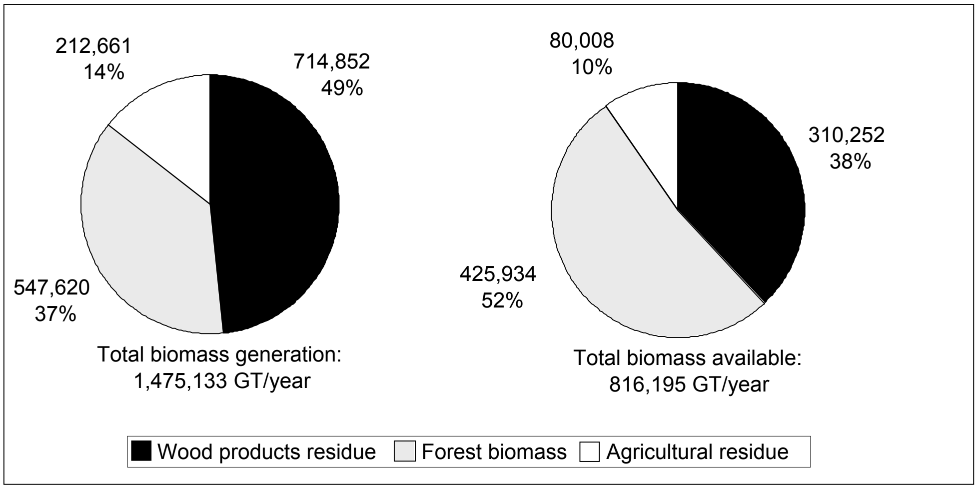


Figure ES-5. Biomass generation and availability – all sources

FACILITY SITING

Prior to developing an estimate of the cost and quantity of the biomass supply delivered to a biomass power or bioethanol plant, we identified potential sites that have adequate infrastructure and other characteristics to support such a plant. This task was not meant to recommend one site over another; rather the intent was to identify one potential site in each study area county where, upon preliminary investigation, a biomass conversion facility could be located. These three sites were used as the basis for a more detailed investigation of the delivered biomass costs to the plants in the area. There are other sites in the study area that are geographically very close to the sites chosen in each county that also could support a biomass energy facility, and the results for the supply analysis in many cases are applicable to these sites as well.

Three sites were selected with favorable characteristics:

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

Figure ES-6 shows the locations of each of these sites.

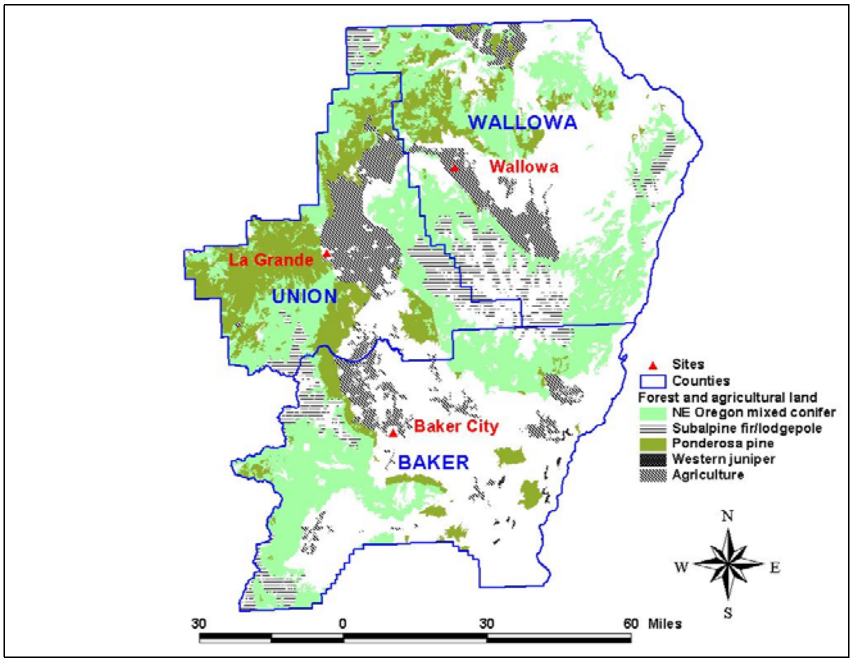


Figure ES- 6. Location of potential facility sites

Baum Industrial Park is located four miles northeast of La Grande. Total acreage at the site is 80 acres. The Baum site is adjacent to a Borden Chemical plant and a Boise Cascade particleboard processing facility. A Boise Cascade sawmill is less than two miles away from the site. Sustainable Energy Development Inc. has purchased property at the Baum Industrial Site as a possible cellulosic ethanol plant location.

Elkhorn View Industrial Park is located near U.S. Highway 30 in Baker City. It has a total area of 71 acres. Ellingson Lumber sites in Baker City and South Baker City are both very similar in siting potential to the Elkhorn View Industrial Park. The results of the supply analysis could be modified slightly to be applicable to these other sites, which also merit attention.

The Bates Mill site is a former sawmill, adjacent to wastewater treatment facilities and a rail line. There are ongoing efforts to redevelop portions of adjacent parcels for small-scale forest products enterprises. Wallowa Resources is working with a number of parties to evaluate possible siting of firewood and post-and-pole manufacturing businesses on the property, which could complement a bioenergy facility at the site.

BIOMASS SUPPLY

Collection and processing cost estimates are based on published values for forest and agricultural biomass. Forest biomass costs include the costs to cut, process and forward biomass materials to the roadside for transportation to the point of use. These costs can range from $30 to $46/GT, based on regional time and motion studies of forestry operations; a value of $38/GT is assumed for this analysis. Agricultural biomass collection costs include swathing, baling and stacking costs and can range from $24 - $26/field dry ton, based on custom contractor rates in the study area. A value of $24/field dry ton is assumed for wheat straw for this analysis. Costs for Kentucky bluegrass straw are $34/field dry ton because they include a $10/field dry ton payment to farmers to compensate them for the fee they are currently paid for their straw.

Table ES-1 shows estimated supply quantity and average biomass costs delivered to potential plant locations within the study area. The total quantity is the same for all three potential locations since each potential site would be drawing from the available quantity in all three of the counties. We developed two supply curves: one for biomass ethanol and one for biomass power. Agricultural residue is not included in the biomass power supply, due to technical issues associated with burning large quantities of agricultural residue in biomass boilers.

A biomass power plant may use only a limited quantity of agricultural residue due to the potential for boiler slagging and fouling associated with agricultural residue alkali content. The exclusion of agricultural residue brings the average resource cost for a biomass power plant slightly above that for a biomass ethanol plant, but not enough to significantly impact plant feasibility. The average delivered costs differ slightly between the three potential facility sites. Specifically, the biomass resource cost is lowest in Union County, primarily due to the fact that transportation costs for sawmill chips are much lower than for Baker and Wallowa.

Table ES-1. Biomass supply quantity and weighted average biomass cost delivered to potential plant sites in Baker, Union and Wallowa Counties

Supply type	Quantity (GT/year)	Average cost ($/GT delivered)		
		Baker County	Union County	Wallowa County
Biomass ethanol				
Agricultural residue	80,009	35.24	31.39	34.31
Forest biomass	425,934	48.66	48.20	49.49
Mill chips	308,794	25.39	15.93	27.15
Veneer cores	1,458	12.46	3.00	14.22
Total	816,195	38.47	34.26	39.51
Biomass power				
Forest biomass	425,934	48.66	48.20	49.49
Mill chips	308,794	25.39	15.93	27.15
Veneer cores	1,458	12.46	3.00	14.22
Total	736,186	38.22	34.57	40.19

The average costs shown in Table ES-1 are the most important from a facility planning perspective, but the price will vary based on the type of material the facility receives, how much material is required and the source of the material.

A biomass facility will first utilize the lowest cost material, which is frequently generated closest to the facility. Lower cost feedstocks include clean wood waste from veneer manufacturing, sawmill chips and agricultural residue. These resources range in cost from $3 - $14/GT delivered for veneer cores up to $26 - $37/GT for agricultural residues, depending on the facility location. In total, these feedstocks represent an estimated 390,261 GT of biomass per year that could be available for a biomass facility. Sawmill chips make up 79% of this quantity. As the quantity demanded increases, a facility will purchase forest biomass at higher cost than other residue sources. The lowest delivered cost for forest biomass is $45/GT; the estimated upper bound on forest biomass costs is $58/GT. A biomass power plant that needs more than 300,000 GT of material per year would need to purchase forest biomass. Alternatively, if a facility uses forest biomass exclusively, its average feedstock costs would be significantly higher than if it used a blend of manufacturing residues and forest biomass.

SUSTAINABILITY OF BIOMASS UTILIZATION

To ensure local support, several community concerns related to sustainability of biomass use should be addressed if a biomass power or ethanol manufacturing facility is developed in the area. Based on the results of a November 2002 focus group held in La Grande, Ore., we developed a list of issues associated with forest management, agriculture and economic viability that concern local stakeholders. The focus group included a wide variety of participants, including representatives from state and federal resource management agencies, environmental organizations, farmers, economic development agencies and local residents.

The major issues associated with the use of forest biomass include potential effects on soil productivity, long-term availability of forest biomass, economics of forest biomass (i.e., who pays for thinning), overall costs and benefits of forest biomass utilization and whether energy from biomass would be considered environmentally friendly. Issues raised relating to agricultural residue utilization include difficulties of quantifying acreage devoted to particular crops, annual variability in resource availability, soil productivity impacts, competing markets for crop residues and an overall need to ensure that residue use will help farmers economically.

ECONOMIC AND ENVIRONMENTAL IMPACTS OF BIOMASS UTILIZATION

The net economic benefits include increased employment in a rural, natural resource-based economy. An estimated six jobs are created for each megawatt (MW) of biomass power capacity that is installed. These jobs include positions at the plant and also in the fuel processing and delivery sectors.[8] A 5-MW stoker-fired biomass power plant would use an estimated 123,000 green tons of fuel per year and would create an estimated 16 new jobs at the plant with payroll and benefits equal to $600,000. A 25-MW stoker-fired biomass power plant would use an estimated 430,000 green tons of biomass per year, but would only require one additional employee at the plant, for a total of 17 employees. Total payroll and benefits for the 25-MW biomass power plant would equal $641,250. This does not include employment in the fuel supply and delivery sectors. A 5-MW stoker-fired plant will employ approximately 18 people in fuel procurement. A 25-MW plant will employ 54 people in fuel procurement. Therefore, total new jobs from a 5-MW plant are 34, while a 25-MW plant would support 71 new jobs.

A 15-million-gallon per year biomass ethanol facility would employ approximately 30 people at the plant; approximately 70 people would be employed in feedstock supply and delivery systems, bringing the total economic impact to approximately 100 jobs. The biomass ethanol plant would require approximately 600,000 green tons of biomass per year. The higher feedstock requirements and sophistication of plant equipment result in a higher employment impact for a biomass ethanol plant than for a biomass power plant.

The positive environmental impacts in the region include improved forest resilience to disease and insect infestation, reduced threats to communities and watersheds associated with lower risks of wildfire, improved water quality and clarity for consumption and for wildlife, reduced air emissions from wildfire and open crop residue burning and increased reliance on renewable energy resources. In particular, using biomass in a controlled combustion system such as a boiler or converting it to fuel ethanol both result in a significant net reduction in air emissions relative

[8] 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).

to wildfire or crop residue burning. Potential environmental risks include loss of soil productivity in forests and on agricultural crop land if excessive biomass is removed. Wildlife habitat impacts include possible habitat reduction or deterioration if appropriate levels of dead and dying trees are not left for habitat or if forest density is reduced too aggressively.

BIOMASS TECHNOLOGY

Biomass power generation is a proven, mature technology with over 7,000 MW of installed capacity in the U.S. It is one of the largest sources of renewable energy, second only to hydroelectric power.[9] Biomass installations range in size from very small units (e.g., 5-10 kW) to large facilities up to 50 MW. The two primary biomass energy conversion technologies are direct combustion and gasification. Because direct combustion is commercially available today, it is the primary focus of this study.

Estimated total biomass feedstock requirements for a 5-MW stoker-fired biomass facility are 123,415 GT/year. Efficiency improvements in larger units make estimated feedstock requirements for a 25-MW unit equal 429,577 GT/year, and a 50-MW facility will consume 723,205 GT/year (see Table ES-2). Thus, a facility that is ten times the installed capacity of a 5-MW facility only uses 5.8 times as much fuel.

Estimated biomass power generation costs are $0.1429/kWh for the 5-MW unit, $0.1552/kWh for a 25-MW plant and $0.1478/kWh for a 50-MW plant.

Table ES-2. Comparison of estimated biomass power fuel use, capital and operating costs

Variable	5 MW plant	25 MW plant	50 MW Plant
Installed plant capacity (MW)	5	25	50
Fuel consumption rate (GT/hour)	15.7	54.5	91.7
Operating hours (hours/year)	7,884	7,884	7,884
Feedstock requirements (GT/year)	123,415	429,577	723,205
Capital costs ($/kW)	2,400	2,248	2,096
Total capital costs ($)	12,000,000	56,200,000	104,800,000
Fuel Costs ($/GT)	28.00	46.50	53.00
Total power generation (MWh/year)	39,420	197,100	394,200
Levelized cost of electricity ($/kWh)	0.1429	0.1552	0.1478

Figure ES-7 shows the impact 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 costs 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. These costs do not include transmission costs that the generator would have to pay to interconnect to the grid or to wheel power outside of the study region. It is clearly important to reduce the cost of forest biomass if biomass power plants are to be economically viable.

[9] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Biopower Program, *Biopower Basics* (http://www.eere.energy.gov/biopower/basics/).

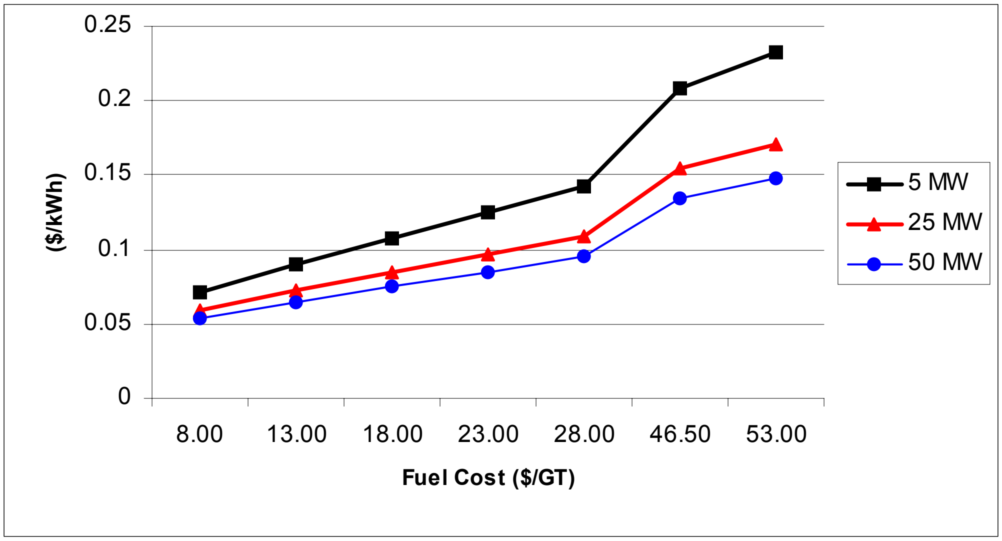


Figure ES-7. Impact of biomass fuel cost on cost of energy

There are potential incentives for developers that could help the economics of a biomass power plant. The U.S. Congress could expand the 1.5 ¢/kWh renewable energy production tax credit under Section 45 of the Internal Revenue Code for biomass power to include biomass resources such as forest biomass and mill residues. Currently, this tax credit extends only to biomass from crops grown specifically for energy production. The Healthy Forests Restoration Act of 2003 also contains language that will facilitate biomass power development. In addition, the U.S. Department of Agriculture Rural Business Cooperative Service provides a wide array of programs for rural communities to develop renewable energy resources both for biomass power and alternative fuels such as ethanol.[10]

Nearly all ethanol consumed in the U.S. is produced from the starch component of grain crops. Manufacturing ethanol from the lignocellulosic components of biomass (commonly referred to as "biomass ethanol") is an emerging technology. There are no commercial biomass ethanol facilities in the U.S., only demonstration scale or scale-up plants designed to prove the technical viability of cellulose-to-ethanol technology. The facility closest to a full-scale operation is the Iogen Corporation facility in Ottawa, Canada. This facility is currently converting 50 tons of wheat straw to fermentable sugars per week, and Iogen is in the process of completing construction on distillation columns for the plant in 2004. When completed, the plant is expected to be able to manufacture 700,000 liters (184,940 gallons) of ethanol per year using an enzymatic hydrolysis process.[11]

In contrast with the Iogen facility, a commercial-scale plant would produce 15 million gallons or more of ethanol per year. However, for any proposed facility, an economic optimum plant size would be determined based on feedstock (and other operating) costs, ethanol yield and capital costs. Figure ES-8 shows how estimated cellulose ethanol production costs change with plant size.

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[10] U.S. Department of Agriculture, Rural Business – Cooperative Service, *Rural Business – Cooperative Service Home Page*, http://www.rurdev.usda.gov/rbs/.

[11] 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.

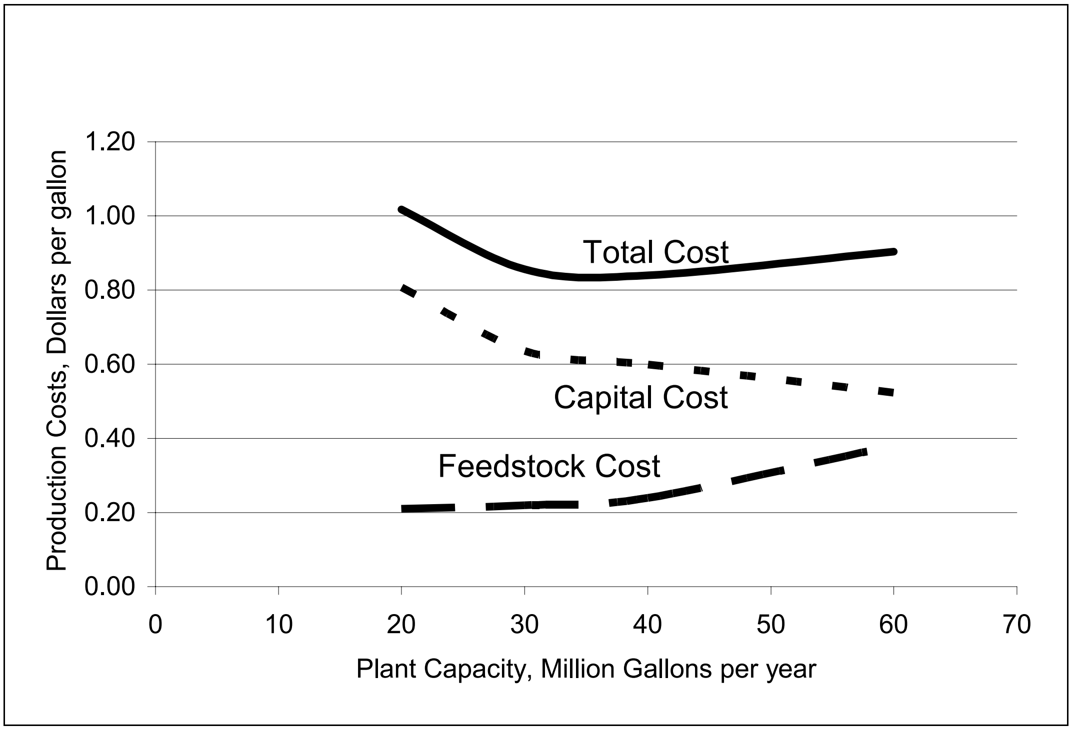

Figure ES-8. Cellulose ethanol production costs

The biomass ethanol technologies that are closest to commercialization include concentrated acid hydrolysis, dilute acid hydrolysis and enzymatic hydrolysis. A technology that has promise for possible smaller-scale applications is biomass gasification, followed by catalytic conversion to ethanol. Most cellulose ethanol facilities are assumed to generate power in excess of their needs by burning the lignin left over from processing biomass into sugars.

The feedstock requirements for a biomass ethanol plant can be significantly higher than for biomass power generation. Figure ES-8 shows that a 15 million gallon per year biomass ethanol plant would need an estimated 600,000 green tons of biomass per year to operate, the majority of the available supply in the study area. However, the positive regional economic impacts of biomass ethanol are also greater than for biomass power.

There is an existing market for ethanol as a fuel additive. In addition, as California phases out the use of methyl tertiary butyl ether (MTBE) as a fuel additive, regional ethanol markets will expand. Cellulose ethanol can help meet that demand in California and elsewhere. The California Energy Commission provides detailed information about the MTBE phase-out on its website.[12]

CONCLUSIONS AND RECOMMENDATIONS

The project conclusions and recommendations fall within three overall categories:

- resource availability, supply planning and communication,
- opportunities and barriers for biomass utilization and
- recommendations for next steps.

[12] California Energy Commission, *Ethanol in California* (http://www.energy.ca.gov/ethanol/).

Resource availability, supply planning and communication

Biomass resource availability in the region is adequate to support the development of one large or several smaller biomass energy facilities. Modification of existing forest and agricultural practices will be required in order to make the biomass available, and sufficient assurances for both forestry professionals and farmers will be required to attract investment in new equipment and expansion of existing operations.

Significant community input and communication will be required in order to develop support for large-scale biomass resource development. The larger the annual resource requirement, the more significant will be concerns from stakeholder groups and individuals in local communities, industry and government.

Opportunities and barriers for biomass utilization

The two potential applications evaluated for this project are:

- biomass power or cogeneration; and
- ethanol manufacturing from cellulosic biomass sources.

The available resource, as discussed previously, is capable of supporting either of these two options. Clearly, the high cost of forest biomass is a major barrier to the development of cost-effective biomass energy outlets in the region. The biomass power option presents less risk since it is a proven technology and it requires a lower proportion of the available resource. Because it uses less of the available resource, it is more sheltered from unanticipated supply variability, and fuel costs will, in general, be lower. However, ethanol may have a growing market outlet as gasoline refineries phase out MTBE in favor of ethanol as an automotive fuel additive in California. Also, the market value of ethanol is higher than the value of electricity.

A technology focus that was not considered in detail for this study, but should be mentioned, is the potential for small- to mid-scale biomass heating for institutions such as schools, hospitals, commercial buildings, government and other community facilities. Such systems require a smaller biomass resource, have lower capital cost requirements and can serve as a valuable hedge against volatile natural gas prices. Since these systems are smaller and there is a broader spectrum of applications, many systems can be installed throughout an area, reducing transportation distances and fuel costs. The Fuels for Schools Program, in which a biomass heating system is being installed at a school in Darby, Montana, is one example of how biomass heating technology can contribute to community-level fuels reduction.[13] In this project, the local school district teamed up with the USFS to install a biomass heating system that will save the district money on its heating bills and promote community engagement in renewable energy development and forest stewardship. Similar projects are planned in Nevada, Colorado and California. Vermont has been heating schools and public buildings with wood for many years.

Estimated biomass power generation costs exceed local retail power rates as well as the expected buyback rate from regional electric utilities by a significant margin, and it is unclear whether local and regional markets for green power or green tags will cover the gap between generation costs and the retail power costs or buyback rates. Development of green power and green tag markets in the future could improve the economics of biomass power generation. This report was

[13] Bitter Root Resource Conservation & Development Area, Inc., *Fuels for Schools* (http://www.fuelsforschools.org/).

not meant to provide a detailed economic analysis of biomass energy opportunities. Potential projects in the region must conduct their own site-specific, technical and economic feasibility studies. The information developed in this report can be used to feed into site-specific studies.

In the case of cellulose ethanol, corn-based ethanol is currently less expensive than cost projections for cellulose ethanol, though no real cost information exists for cellulose ethanol since it has not been commercially demonstrated. Future market growth for ethanol as it expands to meet the gap left by MTBE exceeds current corn-based ethanol capacity, which could create a niche for cellulose ethanol as demand grows.

<u>Recommendations for next steps</u>

Several recommendations regarding resource planning can help facilitate development of the biomass resource in the region:

- Federal forest management officials and private landowners should investigate the costs and benefits of removing biomass from forest management sites as an alternative to piling and burning wherever possible
- There should be greater cooperation across forest landowners (federal, state, private and local) on planned thinning projects and biomass product offerings through a regional database managed by a multi-agency governmental group, local non-profit organization or resource advocacy group
- Multi-year forest resource planning should be conducted to enable long-term biomass supply planning; and
- Outreach to farmers should be realistic and emphasize where and how residue utilization can help reduce burning costs and generate new revenue sources, while being compatible with best practices for maintaining soil productivity.

In order to overcome local concerns regarding sustainability and the impacts of biomass utilization, the following steps should be taken to garner community support from a wide array of interests:

- A multi-agency governmental group, local non-profit organization or resource advocacy group should develop an annual monitoring process in cooperation with (and with the support of) project developers. The monitoring process should document the resources affected and the results of biomass removal, using measures such as the total extent and the proportion of land actually affected by management in each vegetation type and potential land use; and
- Project developers should consider installing multiple smaller systems over a period of time rather than a single large system that would immediately draw from a large land area and continue to do so each year.

Now that the preliminary technical, economic and environmental impacts of biomass resource development have been evaluated, we recommend the following steps to further evaluate the cost-effectiveness of biomass power and cellulose ethanol in the area:

- Build on the forest resource data and information developed for this study by working with resource advisory groups to develop more detailed, multi-year project level data showing biomass availability and locations for forest management projects for federal, state and private landowners

- Identify agricultural producers and conduct a more detailed assessment of their willingness to collect and bale crop residues
- Begin a formal discussion with Boise Cascade regional management to evaluate their heating and power purchase requirements, and determine if they are willing to investigate a cogeneration facility
- Further evaluate the production costs and markets for a cellulose ethanol facility in light of future market growth for ethanol as a fuel additive in the wake of the California MTBE phase-out
- Further evaluate biomass facility and district heating and cooling technology potential
- Network with regional non-profit organizations to take advantage of the analytical expertise, resource analysis and marketing support these groups can offer a developing industry. Two such regional organizations are Renewable Northwest Project (http://www.rnp.org/) and NW Energy Coalition (http://www.nwenergy.org/).
- Develop an annual monitoring report for biomass collection and utilization showing the impacts and benefits of biomass utilization; and
- Identify and pursue potential grant opportunities to help reduce the costs of biomass fuel.

It should be noted that developing the biomass resource and large-scale markets is a multi-year process. This should be taken into account when making business decisions.

1. INTRODUCTION

1.1 Purpose

The purpose of this project was to conduct a biomass resource and bioenergy technology assessment for Baker, Union and Wallowa Counties in Northeast Oregon. This assessment covers both forest biomass and agricultural residues. The federal, state and private forests in the area are at high risk for wildfire, and the development of a bioenergy facility would provide a market outlet for un-merchantable biomass and provide much needed jobs and tax revenues in the local economy. This assessment provides information that can help support the future development of biomass energy facilities in the three-county area. The assessment includes information regarding optimal locations for development of energy facilities in those counties, taking into account proximity to feedstocks and existence of supporting infrastructure.

1.2 Study Area

The project area includes Baker, Union and Wallowa Counties in Northeast Oregon (Figure 1-1).

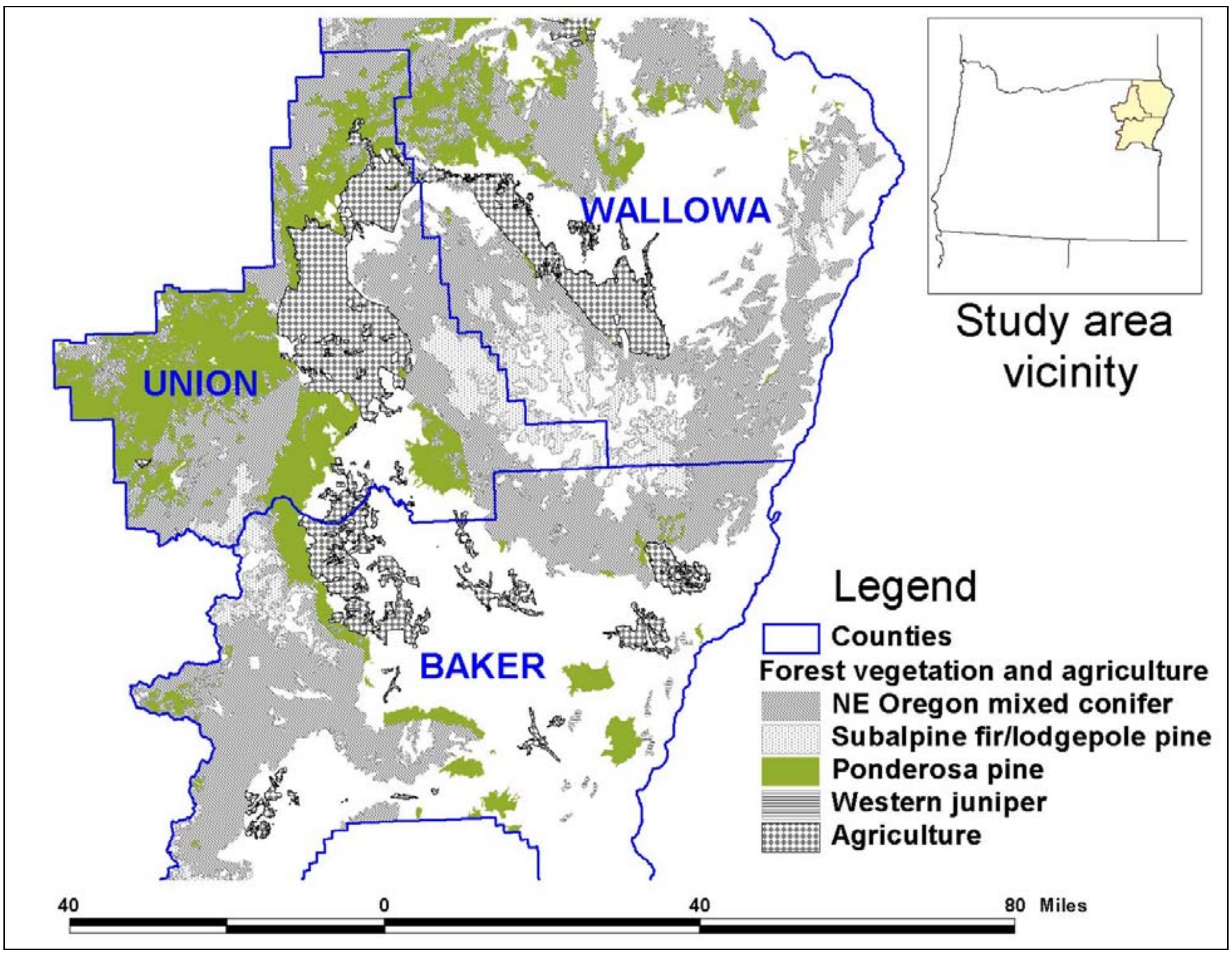

Figure 1-1. Project study area

Public land makes up 52% of total land ownership in the study area, with U.S. Forest Service (USFS) lands representing 45% of the total land area (Table 1-1).

Table 1-1. Land ownership in the study area

Landowner	Baker	Union	Wallowa	Total
Bureau of Land Mgmt [acres][14]	369,120	6,452	16,213	391,785
USFS Wallowa-Whitman[15]	598,553	514,789	1,020,293	2,133,635
USFS Umatilla[16]	3	102,268	123,550	225,821
State land [acres][17]	5,497	1,300	2,212	9,009
Total federal & state [acres]	973,173	624,809	1,162,268	2,760,250
Total area [acres][18]	1,976,960	1,304,320	2,017,920	5,299,200
Federal & state land [% of total area]	49	48	58	52

Table 1-2 shows summary statistics for population, housing, income, unemployment and precipitation for the three counties.

Table 1-2. Summary statistics for the study area[19]

Metric	Baker	Union	Wallowa
Population	16,700	24,550	7,100
Population density (Persons/mi^2, 2000)	5.5	12.0	2.3
Area [mi^2]	3,089	2,038	3,153
Housing units, 2000	8,402	10,603	3,900
Median household value (owner-occupied), 2000[$]	84,700	93,600	111,300
Median household income, 1999 [$]	30,367	33,738	32,129
Labor force, 2001	7,306	12,352	3,359
Unemployment rate, 2001 [%]	8.8	5.8	10.8
Local government employment (full-time equivalent), 1997	599	896	414
Annual precipitation [in]	10.63	18.79	13.08

1.3 Project Need

A significant amount of biomass that is not merchantable in traditional small-wood industries or for the manufacture of new wood products is available from forests in the three-county study area in Northeast Oregon. Biomass energy facilities (either stand-alone or integrated with an existing industrial facility) could provide a potential economic use for this material. Feasibility depends on locating an energy facility close to the source of the material and sizing the facility appropriate to the volume of material available on a long-term, sustained basis.

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[14] Bureau of Land Management Oregon Office, *BLM Facts – Oregon and Washington 2001,* accessed September 22, 2003 (http://www.or.blm.gov/BLMFacts/2002BLMFacts.pdf).

[15] U.S. Department of Agriculture Forest Service, Wallowa-Whitman National Forest, *Forest Facts,* accessed September 22, 2003 (http://www.fs.fed.us/r6/w-w/forest_facts.htm).

[16] Umatilla National Forest, *Total Forest Acres,* accessed September 22, 2003 (http://www.fs.fed.us/r6/uma/acres.htm).

[17] Oregon Division of State Lands, *DSL Land Ownership Acreage*, accessed November 11, 2003 (http://statelands.dsl.state.or.us/acreage_map.htm).

[18] U.S. Census Bureau, *State & County Quickfacts* (http://quickfacts.census.gov/qfd/states/41000.html).

[19] U.S. Census Bureau, *State & County Quickfacts* (http://quickfacts.census.gov/qfd/states/41000.html).

Using current and near-term technology, biomass energy facilities could convert surplus forest biomass into electricity, industrial steam energy and fuel ethanol. A barrier to private sector investment in biomass energy facilities is the lack of specific information about the amount of biomass feedstock available, the cost of feedstock delivered to the plant site and the best locations for proposed facilities relative to both feedstock supply and markets for energy products. There is a critical need for this information in view of both high-fire risk in the forest and the need for economic stimulus in rural communities.

The National Fire Plan is a collaborative effort between the U.S. Department of Agriculture's U.S. Forest Service (USFS) and the U.S. Department of Interior (DOI) to reduce wildfire risks to communities, natural resources, firefighters and the public through hazardous fuels reduction, forest rehabilitation and restoration, community support and research. This project addresses the goals of the National Fire Plan by supporting the development of a locally-based biomass energy industry that would provide a long-term market for utilization of biomass material resulting from fuels treatment projects on public lands. Information developed through this project is needed to assess the economic feasibility of biomass energy development. Locally based facilities would benefit rural communities through on-site and in-forest job creation, local tax revenue potential and local economic activity associated with construction and operation.

The Oregon Department of Energy supports the development of clean, reliable and affordable energy resources. This mission extends to the use of renewable energy resources, including biomass. The Oregon Department of Energy pursued this project because it promotes utilization of sustainable, clean biomass resources and protection of Oregon's natural resources.

1.4 Project Team

The Oregon Department of Energy assembled the project team that conducted this work. McNeil Technologies, Inc. (McNeil) conducted the primary work on the project. At McNeil, Scott Haase was the project manager, Tim Rooney was the principal investigator and Jack Whittier provided technical support and analysis. Dr. James Kerstetter provided technical assistance and conducted the assessment of agricultural residues. It is also important to acknowledge the many federal, state and local project participants, without whom this project could not have been completed. These include, but are not limited to: the Oregon Department of Forestry, the Grande Ronde Model Watershed Program, USFS staff at Wallowa-Whitman National Forest, the Pacific Northwest Research Station (USFS), Wallowa Resources, Oregon State University's Department of Forest Science and Oregon State University Extension Service staff in Baker, Union and Wallowa Counties.

1.5 Project Goals and Objectives

The overall project goal was to promote cost-effective, sustainable biomass use for power and liquid fuel manufacturing in Baker, Union and Wallowa Counties. An additional goal of the project was to identify potential sites in the area where a long-term, sustainable supply of biomass feedstock is available economically within a reasonable transportation distance from a potential plant.

The objectives of the project were to:

- conduct a review of previous related studies and assessments,
- evaluate the quantity of biomass produced in the region,

- conduct a preliminary siting analysis and identify potential facility sites
- determine biomass availability and costs for delivery to potential sites in the counties,
- develop biomass supply curves for each county,
- identify issues associated with the sustainable use of biomass,
- describe social, economic and environmental impacts of biomass energy use, and
- discuss biomass facility characteristics and quantify feedstock requirements for hypothetical biomass power and cellulose ethanol plants to be developed in the region.

1.6 Summary of Activities Performed

The primary analysis provided biomass supply curves for the study area and identified candidate facility sites in each county. The secondary phase of the project identified issues associated with the sustainable use for biomass, identified applicable biomass technologies for the study area and described the environmental, economic and social costs and benefits of biomass utilization.

This report contains supply curves for forest biomass and agricultural residues from all sources in the study area, including public and private lands. Forest biomass is further segmented to include logging residues and urban wood residues in addition to surplus biomass resulting from fuels reduction treatments on forests in high-fire threat zones. The assessment in this report also includes locally available agricultural residues as a supplemental or alternate feedstock source.

2. REVIEW OF PREVIOUS STUDIES

This section identifies and reviews seven studies that evaluate biomass resources in or near the study area. These studies provided background information for the present work. In this section we provide a brief overview of each study. Additional information on three of the studies is provided in Appendix A. Additional studies that have some relevance to the project area are identified and categorized in Appendix B.

2.1 Blue Mountains Vegetation Assessment

In November 2002, the USFS, Pacific Northwest Research Station released the results of the Blue Mountains Vegetation Assessment, a joint project by the USFS, the Oregon Department of Forestry (ODF), Oregon State University, and the Malheur, Wallowa-Whitman and Umatilla National Forests. The primary purpose of the study was to evaluate the availability of timber based on land suitability, vegetation conditions and harvest economics. The assessment includes Baker, Grant, Harney, Morrow, Umatilla, Union and Wallowa Counties of Oregon. Lands in Crook and Wheeler Counties managed by the Malheur National Forest were also analyzed. Appendix A provides additional information on the resource assessment and other findings of this study.

The study determined that a majority of the National Forest land in the study area (71%) is unavailable for substantial or sustained timber harvest due to Congressional designations, forest planning allocations or non-forested conditions. The remaining 29% (1,616,000 acres) of National Forest land is designated as “active forestry” land and could be available for substantial and sustainable timber harvest. The definition of “active forestry” includes land where timber harvest may occur, where significant and sustainable timber supplies are anticipated and where the resource direction is compatible with mechanical treatment. Up to 32% of these acres have experienced timber harvest or non-commercial thinning since 1988. Non-commercial thinning includes forest management that removes material that cannot be used in conventional wood products, and it is done for the purpose of guiding forest development to meet forest management objectives.

The results indicated that an estimated 943,000 acres of forested National Forest land classified as “active forestry lands” are overstocked, or 58% of the total area in that planning allocation. The criteria for overstocking was determined for specific groups of plant associations based on methods developed by Cochran, et al.[20], using analysis of aerial photographs and existing vegetation data. For this assessment, a stand was considered overstocked if its stand density index (SDI) exceeded 45% or if the number of trees per acre between 0.1 and seven inches in diameter at breast height (DBH) exceeded 300. The SDI is a measure of competition between trees for available site resources (water, sun and soil nutrients) and individual tree growth. Generally, stands with an SDI greater than 50% can be said to have greater competition between trees and lower tree resilience to environmental change, disease and pest infestation.[21]

[20] Cochran, Geist, Clemens, Clausnitzer and Powell, *Suggested Stocking Levels for Forest Stands in Northeastern Oregon and Southeastern Washington* (Research Note RN-513, Pacific Northwest Research Station, 1994).
[21] D. Wilson and D. Maguire, *Draft: Potential Small-Diameter Timber Resource from Restoration Treatments in Overstocked Stands on National Forests in Eastern Oregon* (Oregon State University Department of Forest Sciences, 2002).

Thinning on 39,900 acres had a positive net value based upon the economic assumptions used. These treatments harvested 167 million board feet (MMBF) of timber with an error margin of plus or minus 36 MMBF.

The study also determined that an estimated 581,000 acres of private land were overstocked in the Blue Mountains region, although analysis of potential timber volume and economics was not complete at the time of the current study.

The results provide an indication of the potential for economically viable timber harvesting to contribute to fuels reduction goals and a sustainable biomass supply. The results of the assessment can also be used to validate estimates of long-term biomass availability from timber harvesting residuals on National Forest land.

The estimates of overstocked acres and potential timber harvest volumes do not take into account many significant site-specific variables. Analysis of these variables is best done on a project-by-project basis. Some of the information on overstocked stands was as much as 20-years-old. However, validation of the mapping with USFS ranger district personnel indicated that the identification of overstocked stands was correct about 80% of the time. County-level estimates are limited in accuracy because of the small number of plots. However, 95% confidence interval data make it possible to estimate an upper and lower boundary for overstocked acres and potential timber volumes in some counties. For these reasons, the analysis is only a starting point for project level planning.

2.2 Dry Forest Mechanized Fuels Treatment Trials Project

The Central Oregon Intergovernmental Council administered a study that evaluated the effects of forest biomass harvest projects at four locations in three states. The study investigated costs, productivity and impacts of biomass harvesting at each project location. The project was funded through a National Fire Plan grant from the USFS, Pacific Northwest and Intermountain Regions. In all, 15 different fuels treatment systems were demonstrated.[22] Field trials were conducted at locations near Idaho City, Idaho; Leavenworth, Washington; and Sisters, Ore. during the winter of 2001 and spring of 2002. Each location was representative of wildland urban interface sites that are likely to be treated in the next decade. Appendix A provides additional information on the resource assessment and other findings of this study. The study results can also be obtained on-line at: http://www.theyankeegroup.com/mechfuels/.

The results indicate that no single equipment configuration or treatment is appropriate for all forest stands. Rather, the results present information about the performance of many equipment configurations under a variety of conditions.

The cost and productivity data collected during the study are by no means comprehensive. Rather, the data are intended to show the broad range of performance that can be obtained using various equipment configurations at different sites. For all the project trial sites, production costs ranged from a low of $330/acre to a high of $2,187/acre. However, for most extraction systems, which remove trees from the forest, costs ranged from $500 to $1,000/acre. For mastication

[22] E. Coulter, K. Coulter, T. Mason, J. Szymoniak and L. Swan, *Dry Forest Mechanized Fuels Treatment Trials Project* (http://www.theyankeegroup.com/mechfuels/, Central Oregon Intergovernmental Council, October 24, 2002).

systems, which grind material and leave it on-site, costs range from $400 to $850/acre. Administrative and follow-up treatment costs were not included.

2.3 Oregon Cellulose-Ethanol Study

In a study issued in June 2000, the Oregon Department of Energy evaluated the potential to manufacture biomass ethanol in Oregon. Major findings included:

- There are no ethanol plants in Oregon;
- Approximately 30 million gallons of ethanol are used each year in Oregon;
- In 1998, more than 8.5 million bone-dry tons (BDT) of biomass were generated;
- The biomass supply consists of 49% agricultural residue, 35% forest residue and 16% municipal solid waste (MSW);
- Based on estimated biomass availability from wheat straw and forest thinnings, 280 million gallons of ethanol per year (million gallon/year) could be manufactured in Oregon; and
- National Renewable Energy Laboratory economic modeling of hypothetical production plant scenarios showed potential internal rates of return of 19% for a 29-million-gallon/year plant using forest biomass and 18.3% for a 54-million gallon/year plant using and wheat straw, assuming delivered feedstock cost of $28/BDT for forest biomass and $30/BDT for wheat straw and assuming a natural gas boiler for process heat.[23]

Appendix A provides more information on the resource assessment and other findings of this study. Agricultural residues comprise the largest biomass resource in Oregon. Agricultural residue generation in Oregon was greater than four million BDT in 1998. Not all residues generated would be available due to restraints on residue removal for soil agronomic concerns and competing markets for grass straw, much of which is shipped to Japan for animal feed.

Biomass from forest thinning is the second largest biomass supply source in Oregon. However, a lack of a consensus of forest policymakers on the type of treatment needed and the extent to which forests should be managed actively contributes to a forest biomass supply that is difficult to quantify. This study estimated that more than 2.9 million BDT of biomass could potentially be available from forest management annually in Oregon. Estimates of forest residue availability are based on an estimate of acres requiring treatment for forest health reasons, assuming conservatively that 2% of the land area is treated annually with a biomass yield of 21 BDT/acre.

Municipalities generate an estimated 6,184 BDT/year in clean biomass residues in Baker, Union and Wallowa Counties. This estimate does not include wood waste from industrial sources.

The total potential ethanol yield in Oregon if all biomass generated were used for ethanol manufacturing exceeds 500 million gallons/year. As not all residues could be converted, analysis of biomass availability from wheat straw and forest biomass suggest that a more realistic estimate of annual biomass ethanol potential in Oregon is closer to 280 million gallons.

[23] A. Graf and T. Koehler, *Oregon Cellulose-Ethanol Study* (Oregon Department of Energy, June 2000).

2.4 Markets and Processing Options for Small Diameter Trees

The Central Oregon Intergovernmental Council (COIC) commissioned a study in May 2002 that evaluated available biomass supply infrastructure, processing technologies and markets.[24] The COIC study focused on the Deschutes, Ochoco and Winema-Fremont National Forests and the Prineville Bureau of Land Management (BLM) region. While the focus of this study was not energy, it did offer insights on supply challenges that are similar for Northeastern Oregon. Key observations include that supply reliability and predictability needs to be improved to encourage new investment. Timber contracting and National Fire Plan planning procedures do not necessarily make this easy in all cases. Multi-year planning, coordination between fuels reduction and timber programs, collection of biomass removal volume data and coordination between National Forests at the regional level to coordinate annual biomass material offerings could help create a sustainable biomass supply.

2.5 Oregon Department of Forestry Private Land Resource Assessment

The Oregon Department of Forestry (ODF) conducted an assessment of overstocked stands on private land in the study region. ODF's criterion for overstocking was different than that used in the Blue Mountains Vegetation Assessment. The ODF study considered forested areas to be overstocked if the canopy closure rate was greater than 80% based on satellite imagery analysis. The treatable acreage would most certainly be lower than the overstocked acreage shown in Table 2-1 because of site-specific conditions that preclude thinning or suggest other management options, landowner preference and other factors.

Table 2-1. ODF estimates of overstocked acres on private land

County	Overstocked acres
Union	7,637
Wallowa	7,134
Baker	1,597
Subtotal – study area	***16,368***
Umatilla	16,436
Total with Umatilla County	***32,804***

Table 2-1 shows acreage in Umatilla County because the estimates resulted in significant areas of overstocked forestland in this adjacent county to the study area. Notably, the overall acreage of private land considered overstocked in this study was significantly smaller than the estimates conducted for the Blue Mountains Vegetation Assessment (Section 2.1).

2.6 Western Forest Health and Biomass Energy Potential

In April 2001, the Oregon Department of Energy issued a broad-level evaluation of biomass resources and policy initiatives in the Western U.S., with a special focus on Northeastern Oregon.[25] The study assessed potential forest biomass availability in Grant and Wallowa

[24] Mater Engineering, Ltd., *Markets and Processing Options for Small Diameter Trees* (Central Oregon Intergovernmental Council, June 2002).
[25]N. Sampson, M. Smith and S. Gann, *Western Forest Health and Biomass Energy Potential* (Oregon Department of Energy, April 2001).

Counties. There are an estimated 1.36 million acres of National Forest lands in Wallowa County. Of this, 56% is protected in wilderness areas, 7% is unsuitable for management or is reserved land and 29% is in the Hell's Canyon National Recreation Area. This leaves 8%, or 115,000 acres, available for forest management. There are 150,000 acres of private industrial forestland and 130,000 acres of non-industrial private forestland. The results of the assessment indicated that between 395,000 and 593,000 BDT of forest biomass could be available annually from Wallowa County forests if half of the available forestland were thinned over a 10-year period (5% of the available land each year). This assumes yields of 10 to 15 BDT/acre.

2.7 Agricultural Residue Supply Curves

In January 2001, the Washington State University Energy Program, under contract to the U. S. Department of Energy (DOE), developed supply curves for logging residue and agricultural field residue for Idaho, Montana, Oregon and Washington. Only logging residue in Western Oregon counties were included in the assessment, so those results are not reported here. Agricultural residue was limited to the straw residue from wheat and barley production. Agricultural quantities from Baker, Union and Wallowa Counties were included in this study.

Table 2-2 shows the average residue generation and delivered costs from each of these three counties to Pendleton, Ore. The residue generation estimates assume that 1.5 field dry tons/acre would be left on the field after straw removal. Field dry residue typically contains between 10% and 20% moisture content (MC). Estimated residue collection costs were $32/acre and transportation costs were calculated assuming a fixed cost of $5.50/ton, plus variable costs of $0.088/mile.

Table 2-2. Quantity and costs for agricultural field residue

County	**Quantity** (tons[a]/year)	**Yield** (tons/acre)	**Travel distance** (miles)	**Harvest cost** ($/ton)	**Fertilizer & storage cost** ($/ton)	**Hauling cost** ($/ton)	**Total cost** ($/ton)
Union	75,241	1.61	47	20	10	10	39.61
Baker	14,703	1.83	90	17	10	13	40.93
Wallowa	29,977	1.14	89	28	10	13	51.38
Total/ *weighted average*	119,921	1.52	63	22	10	11	42.71

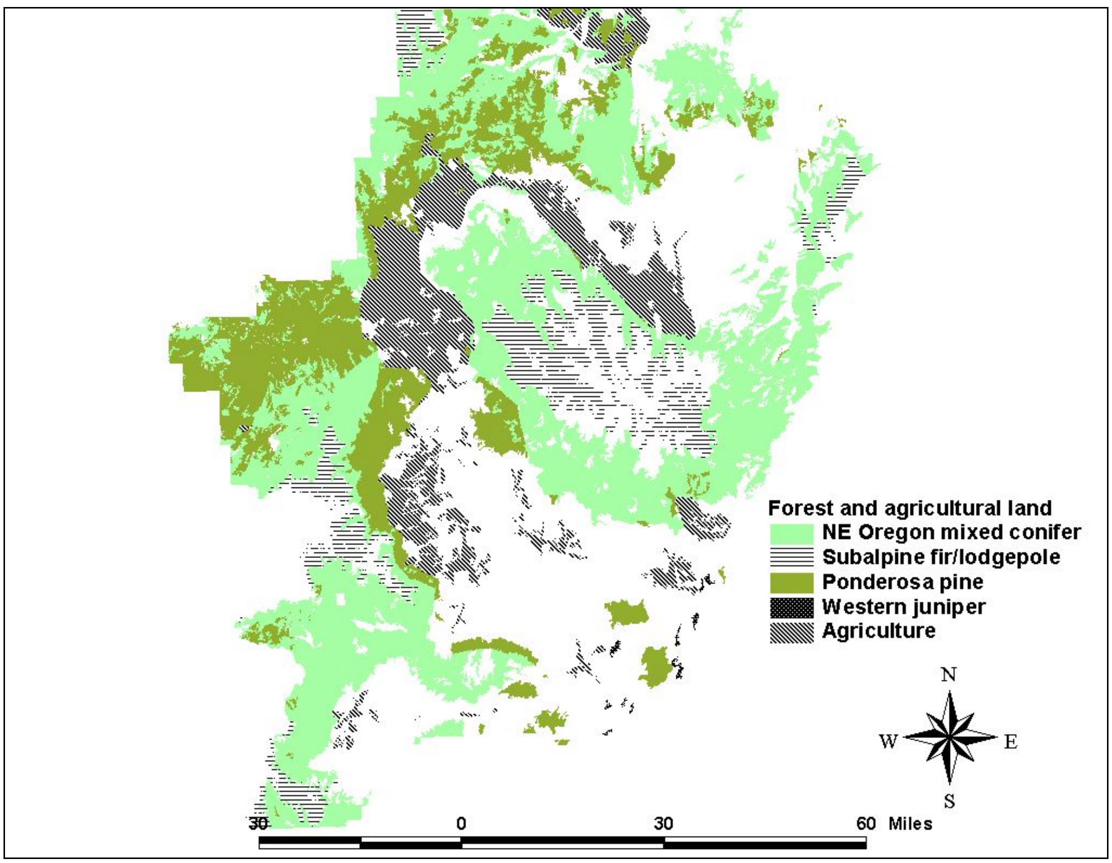
[a] Field dry tons.

3. FOREST BIOMASS GENERATION AND AVAILABILITY

This section provides estimates of annual generation and availability of forest biomass from commercial timber harvesting, timber stand improvement (TSI), fuels treatment and non-commercial thinning on federal, state, county, private and municipal land. Timber stand improvement can result in removal of some commercially valuable trees, but it is conducted primarily as a means of manipulating stand composition and maximizing stand productivity and timber stand value. Non-commercial thinning activities have the objective of maximizing timber value or meeting other resource management goals but generally do not result in removal of commercially valuable trees.

3.1 Forest Biomass Generation

Figure 3-1 shows the distribution of forest types that are the focus of most active management within the study area. Agricultural land is also shown.



Source: Eber, Ron, Rural Lands Database, *Gap Analysis Program (GAP) Vegetation Cover Database*, Oregon Department of Land Conservation and Development.

Figure 3-1. Distribution of forest vegetation and agricultural land

Forests covers 48.3% of the land area in the study area, based on Gap Analysis Program data for vegetation cover.[26] This supply analysis focuses, however, on biomass availability from active forest management on only the portion of this area that is managed annually, a small percentage of the total forested area.

A wide range of forest management activities generate biomass in the form of tops, branches, dead and dying trees and trees being removed to help meet the goals of a forest management prescription. This section describes the methods and results used to estimate forest biomass generation in Baker, Union and Wallowa Counties. Later, Section 3.2 discusses how much of this forest biomass is potentially available to generate power and or ethanol.

3.1.1 Methods

Forest biomass generation estimates relied on historical timber harvest data and estimated overstocked acreage on public and private timberland. Forest biomass quantities are reported in green tons (GT) in this report. Table 3-1 summarizes the data sources used to estimate forest biomass generation.

Table 3-1. Data sources used to estimate forest biomass generation

Biomass source	Data source			
	USFS	**ODF Timber harvest database**	**National Fire Plan**	**ODF Private land assessment**
Timber harvest	yes[a]	yes[b]		
TSI	yes[a]			
Fuels treatment			yes[c]	yes[d]
Non-commercial thinning	yes[a]			

[a] USFS Umatilla National Forest Planning, *Tri-forest Planning for Malheur, Umatilla and Wallowa-Whitman National Forest* (http://www.fs.fed.us/r6/uma/nepa/planning.htm).
[b] ODF Forest Resources Planning Program, *Complete Harvest Database: 1962 – 2001* (http://www.odf.state.or.us/DIVISIONS/resource_policy/resource_planning/,ODF, 2002).
[c] USFS, *GEOMAC National Fire Plan Maps: 2000-2001 National Fire Plan Fuels Reduction Project data for Congressional District*, accessed March 19, 2003 (http://wildfire.geomac.gov/NFPmaps/viewer.htm?extent=Oregon).
[d] A. Johnson, *Unpublished report: Overstocked Private Land Assessment for Baker, Union, Wallowa and Umatilla Counties* (ODF, 2002).

USFS planning and monitoring data were used to estimate biomass generation from timber harvest, TSI and non-commercial thinning on USFS land. A 30-year ODF timber harvest database was used to estimate timber harvesting residue generation from private, tribal, state, county and municipal land. National Fire Plan data for USFS projects were used to estimate biomass generated from fuels reduction on federal land. National Fire Plan project data for other federal land management agencies (U.S. Fish & Wildlife Service and BLM) were collected, but these projects are frequently prescribed fire or fuels reduction activities on Pinyon/juniper stands that yield little biomass. These projects could serve as a supplemental source of biomass for a power or ethanol manufacturing facility, but they should not be considered as available for

[26] R. Eber, *Rural Lands Database: GAP Vegetation Cover Database for Union, Baker and Wallowa Counties* (http://geography.uoregon.edu/infographics/rldatabase/, Oregon Department of Land Conservation and Development).

planning purposes. The results of an ODF analysis of overstocked acreage were used to estimate biomass generation from private land.

Different biomass yields were used to estimate biomass generation from timber harvesting and three other silvicultural treatments: (1) TSI, (2) non-commercial thinning and (3) fuels treatment projects. Different values were used because timber harvesting residues consist mainly of tops and branches that are a byproduct of commercial timber removal. TSI results in removal of a limited volume of commercially valuable trees, and non-commercial thinning and fuels treatment involve both pruning and removal of whole trees that are mostly too small or not of sufficient quality to use for wood product manufacturing.

The generation of timber harvest residue was estimated from harvest volumes as shown in Table 3-2. This method was adapted from one used by USFS at the Black Hills National Forest.[27]

Table 3-2. Description of method used to estimate timber harvesting residues

Variable	Description	Value
A	Total residue weight/square foot basal area of 12-inch DBH tree to a 6-inch top diameter (GT)[a]	0.20
B	Basal area per 12-inch DBH tree (square feet)	0.785
A*B	Estimated residue weight per tree harvested (GT)	0.157
C	Trees/MMBF of timber (assuming 80 board feet/tree [b])	13,333
A*B*C	Estimated residue weight/MMBF of timber harvested (GT/MMBF)	2,099

[a] Brown, Snell and Bunnell, *Handbook for Predicting Slash Weight of Western Conifers* (USFS Intermountain Forest and Range Experiment Station GTR INT-37, 1977).
[b] Colorado State Forest Service, *Forest Products Utilization Handbook, 1980*. Based on top diameter inside bark of eight inches, two sawlogs/tree and 40 board feet/log (International rule).

Biomass yields from non-commercial thinning, TSI and fuels reduction depend on the degree to which current forest stand density exceeds optimal levels for forest productivity, wildlife habitat, fuel loading and fire risks. Yields range from as little as two GT/acre for pruning and trimming projects to 40 GT/acre or more for sites with heavy accumulation of ground fuels. For this study, yields of 5, 10 and 15 GT/acre were used to estimate biomass generation from fuels reduction projects.

The assumption of 15 GT/acre is consistent with yields from the Starkey Fuels Reduction project. This project was conducted on 1,782 acres of the Wallowa-Whitman National Forest during 2001 and 2002. The Starkey project contract specified the removal of 12,025 hundred cubic feet (CCF) of White fir and Douglas-fir biomass.[28] Assuming 2.13 GT/CCF of biomass (average of 2.35 GT for White fir and 1.9 GT/CCF for Douglas-fir[29]), the resulting yield for that project was 14.3 GT/acre.

The estimates of forest biomass generation are based on planning and monitoring data for USFS land, on a conservative estimate of forest management on overstocked private land and on actual

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[27] B. Cook, *Internal Report – Black Hills Annual Timber Management Program: Annual Estimated Biomass Availability - FY 1998* (U.S. Forest Service Black Hills National Forest, 2002).
[28] USFS, *Starkey Fuels Reduction Costing White Paper* (http://www.fs.fed.us/bluemountains/docs/starkey-final-tsc-portion.pdf, May 1, 2001).
[29] J. Morrison Corona and W. Wilcox, *Forest Products Utilization Handbook* (Colorado State Forest Service, January 1979).

past timber harvest practices from other landowners. Other studies have focused on what the potential biomass supply would be if all overstocked stands were managed. It is valuable to compare estimates of biomass generation based on current management practices with what potential biomass generation could be under a more aggressive management scenario. To do this, the authors calculated potential biomass yields from estimated overstocked acreage from the Blue Mountains Vegetation assessment. Appendix A discusses this study in more detail.

Quantities are reported in green tons (GT) for forest biomass because that is the typical fuel characteristic of biomass received at a biomass conversion facility. Similarly, agricultural residue quantities are reported in field dry tons, which includes approximately 10% to 20% moisture content (MC). Biomass power and biomass fuel production facilities use GT quantities as the basis for fuel supply planning. Differences in moisture content between biomass types (i.e., agricultural residue, mill residue and forest biomass) will affect the efficiency of combustion processes and fuel yields. Section 8 provides more information on typical moisture content values for various biomass types.

3.1.2 Results

Figure 3-2 shows estimated annual forest biomass generation in the study region assuming yields of 5, 10 and 15 GT/acre. Total estimated forest biomass generation varies from 463,000 to 636,000 GT/year (37% difference) using different yield assumptions. The quantity of timber harvesting residues shown in Figure 3-2 remains the same for the 5, 10 and 15 GT/acre yield scenarios because timber harvesting residues were estimated assuming 2,099 GT/MMBF of timber harvested, as described in Table 3-2.

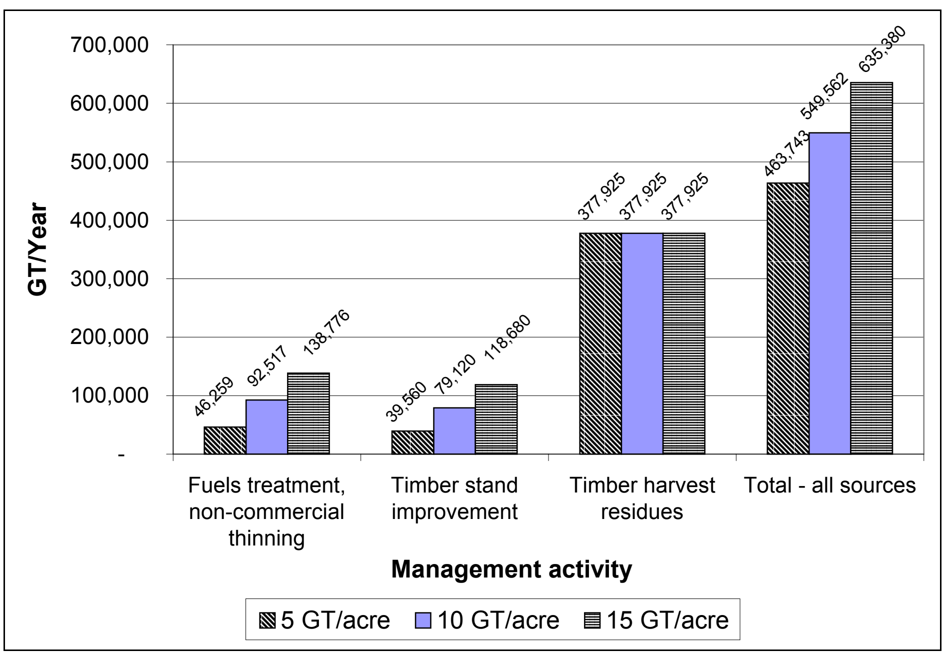
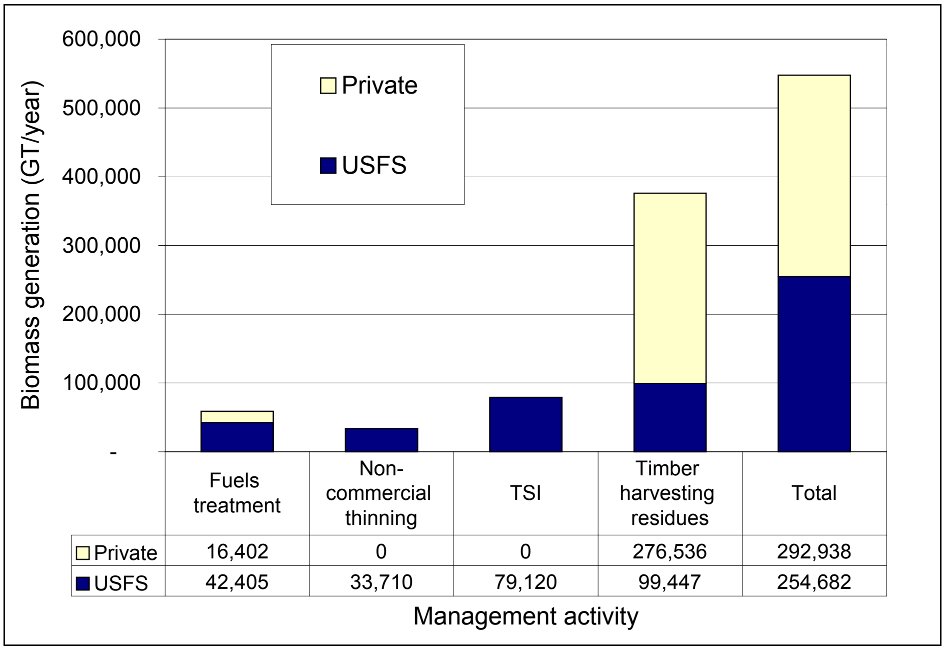


Figure 3-2. Estimated forest biomass generation, with different yield scenarios

Based on the quantities shown in Figure 3-3, 53.3% of the total forest biomass generated comes from private land, and 46.3% comes from federal land. This assumes a yield of 10 GT/acre for fuels treatment, non-commercial thinning and TSI. The remaining 0.4% comes from state, county and municipal land.



Note: Biomass generated from state and county/municipal land is not shown, but these sources make up less than 1% of the total. Quantities from fuels treatment, non-commercial thinning and TSI assume that 10 GT of biomass is generated per acre of land treated.

Figure 3-3. Forest biomass generation by landowner and management activity

The vast majority (94%) of the supply from private land is from timber harvesting residue. On federal land, 155,035 GT, or 61%, of the biomass supply is generated from fuels treatment, non-commercial thinning or TSI. The remainder of the supply from USFS is from timber harvesting residue. Appendix C provides the data that underlie Figure 3-3.

In order to provide a basis for comparison of the results in Figure 3-2 and Figure 3-3, the authors developed estimates of biomass generation based on the analysis of overstocked lands provided in the Blue Mountains Vegetation Assessment (see Section 2.1 for more information). Section 3.1.3 describes the results of this effort and its implications for the reliability of the estimates in this section.

3.1.3 Comparison of Blue Mountains Results with Current Analysis

This section provides a comparison of the volume of small-diameter material generation estimated in Section 3.1.2 with estimates derived from the Blue Mountains Vegetation Assessment evaluation of overstocked forest acreage and potential timber harvest yields.

Table 3-3 shows estimated annual biomass generation based on the Blue Mountains assessment. The Blue Mountains assessment identified a total of 251,000 overstocked acres on USFS active forestland. The Blue Mountains economic analysis showed that timber harvesting on 16,100 acres of this area could result in a positive net value, yielding an estimated 84 MMBF of sawlogs with an error margin of plus or minus 24 MMBF. The estimates in Table 3-3 assume that the remaining 234,900 acres of overstocked land would be treated using a combination of fuels reduction, TSI or non-commercial thinning treatments.

Timber harvesting residue generation was estimated using the method in Table 3-2. The volume of small-diameter biomass that could be removed on overstocked land was also estimated.

These estimates employed several assumptions:

- Commercial timber harvest would occur on overstocked land identified as yielding economically viable timber,
- Remaining overstocked land would be treated via combination of fuels treatment, TSI and non-commercial thinning, and
- Timber harvest and fuels treatment would occur over a 20-year timeframe.

This method provides an approximation of biomass generation, because it is really not known how much of the overstocked acreage will be treated, or over what time frame. The total biomass generated annually would double if treatment were done over 10 years; likewise if overstocked land is treated over a 40-year timeframe, the annual total generated would be cut in half.

Table 3-3. Estimates of annual biomass generation from overstocked land[30]

Biomass source	Total overstocked area (acres)	Annual treated area (acres)	Total biomass generated (GT)	Annual biomass generation over a 20-year time frame (GT/year)
Timber harvest on economically viable forest land	16,100	850	176,316	8,816
Thinning overstocked forest land (assumes 10 GT/year yield)	234,900	11,745	2,349,000	117,450
Total	251,000	12,595	2,525,316	126,266

The Blue Mountains study focused on the potential for removals from overstocked land, rather than focusing on residue available from all timberland in the study area. Because of that, total biomass generation from this study is perhaps best compared to the estimates of biomass generation from fuels treatment, non-commercial thinning and TSI on USFS land shown in Figure 3-3, based on USFS planning and monitoring data for the Umatilla and Wallowa-Whitman National Forests. Those estimates totalled 155,235 GT/year, which is similar to the estimate of 126,266 GT derived from the results of the Blue Mountains study.

In Baker, Union, and Wallowa Counties, the Blue Mountains Vegetation assessment determined that there are an estimated 213,000 acres of overstocked stands in active forestry areas on privately owned land. However, timber volumes from private stands had not been assessed by the time the current study was completed.

It is worth comparing the Blue Mountains assessment estimate of overstocked private forestland to a recent ODF analysis, which showed only 16,368 acres of overstocked private forestland in Baker, Union and Wallowa Counties. The Blue Mountains study used a criterion to determine

[30]Oregon Office of the Governor and Oregon Department of Agriculture, *Assessment Of Timber Availability From Forest Restoration Within The Blue Mountains Of Oregon* (http://www.fs.fed.us/bluemountains/pubs.htm, Blue Mountains Demonstration Area, November 14, 2002) [Hereafter, Blue Mountains Demonstration Area Assessment.]

overstocking based on stocking guides developed by Cochran et al., described further in Appendix A. The ODF study defined overstocked acres using a criterion of 80% crown closure and estimated overstocked acres through analysis of satellite imagery. Nearby Umatilla County had 16,436 acres of overstocked land, bringing a regional total to 32,804 acres. The ODF method is a more conservative means of determining the extent of overstocking and probably underestimates the forested area that could benefit from forest management, whereas the USFS estimate probably overestimates this area because it does not incorporate sufficient site-specific data on tree distribution, canopy cover and other factors.

3.2 Forest Biomass Availability

Forest biomass availability is affected by a variety of factors. Some biomass must be left on-site to reduce soil erosion and compaction, conserve soil nutrients and retain dead standing and fallen trees for wildlife habitat. Slope constraints also limit forest biomass recoverability.

Yield assumptions used to estimate forest biomass generation in Section 3.1 are consistent with actual biomass removals from fuels reduction and thinning projects after the projects have satisfied all planning requirements, management practice guidelines and laws related to soil conservation, wildlife habitat and forest productivity. It should also be recognized that biomass availability is ultimately site-specific. High, mid-range and low biomass yield assumptions were used to reflect this variability. Therefore, the analysis of forest biomass generation in Section 3.1 already accounts for the quantities required to maintain soil productivity and wildlife habitat.

Some percentage of slash will technically not be removable, due to slope considerations and because some biomass will be heavily contaminated with soil and other debris. These constraints were applied to forest biomass generation estimates to provide a more realistic portrayal of forest biomass availability in the study area.

This section discusses biomass requirements for prevention of soil erosion and compaction, conservation of wildlife habitat and maintenance of soil productivity. It also provides estimates of forest biomass availability in the study area, adjusting for slope and technical barriers.

3.2.1 Prevention of Soil Erosion and Compaction

Some degree of soil compaction can take place on as much as 10% to 40% of land harvested using tractors, but compaction can be reduced to as little as 5% with careful planning.[31] Designating skid trails is one major way to reduce the potential for soil compaction. Skid trails are paths used to move harvested trees to a central location in the forest or by the road for further processing or hauling to a conversion site. Leaving slash in mats or distributed on the forest floor, especially in areas such as skid trails where equipment will make multiple passes, is another way to help reduce the potential for soil compaction. Leaving slash in place on landing sites after use can also guard against future soil movement.

On USFS land, the Wallowa-Whitman National Forest Land & Resource Management Plan specifies the following standards and guidelines to maintain and enhance soil productivity: "...Minimize detrimental soil conditions with total acreage detrimentally impacted not to exceed 20% of the total acreage within the activity area including landings and system roads. Where

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[31] K. Birch, *First Approximation Report: Criterion 4, Indicator 22*, (http://www.odf.state.or.us/DIVISIONS/resource_policy/resource_planning/far/FAR/crt4ind22.asp, ODF, April 2000).

detrimental conditions affect 20% or more of the activity area, restoration treatments will be considered."[32] On private land, the Oregon Forest Practice Rules require projects to cause soil deterioration on less than 20% of the soils in a management unit. They also require that operators place slash in a landing site to prevent soil movement.[33]

Forestry professionals working on projects in the Wallowa-Whitman National Forest use several methods to reduce compaction and displacement during mechanized harvesting. Ground-based harvest systems are normally limited to slopes of 30% or less. Cable-yarding systems are typically used for slopes greater than 30%. When feller-buncher/harvester/forwarder systems are operating in areas where compaction is a concern, the equipment will lay slash down in front of itself on the skid trails as it operates and then "walks over" that slash to reduce impacts to soils. In addition, equipment is often operated on frozen ground or over snow to avoid compaction. Many landings and skid trails are used over and over and are dedicated for that purpose. Others are mitigated by tilling soil followed by planting or seeding to reduce erosion risks, to prevent noxious weed invasion and to put these areas back into forage or tree production.[34]

The quantity of slash required to reduce soil compaction on skid trails varies from site to site. In most cases, slash will only be used on a small percentage of skid trails, if at all. Figure 3-4 provides a graphic showing how skid trail spacing and percentage of skid trail coverage affect the quantity of slash on skid trails.

Timing of operations and careful skid trail design and layout can minimize the need to use biomass on skid trails to prevent soil erosion and compaction. If equipment is operated on frozen ground, over snow or on dry soils, no material may be required. In most cases, operators would have to use slash on less than 20% of the skid trail area. However, with close skid trail coverage or wet soils, operators may need to use a significant quantity of material on skid trails to reduce the potential for soil compaction. In such operating conditions, the amount of biomass required to prevent soil compaction could be substantial.

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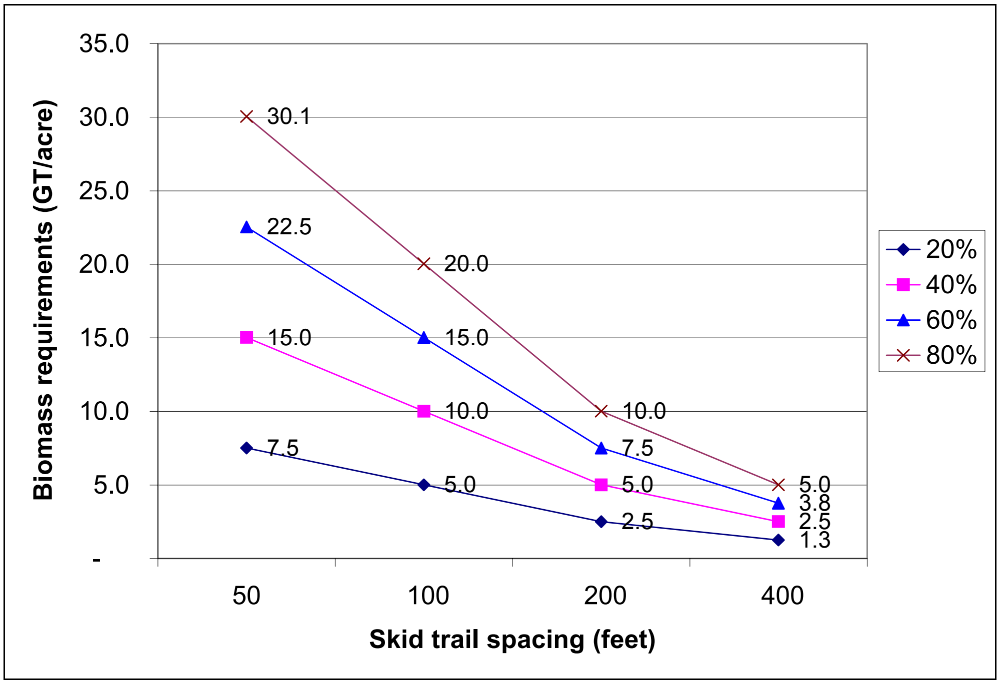
32 USFS, *Wallowa-Whitman National Forest Land & Resource Management Plan* (Wallowa-Whitman National Forest).

33 ODF, *Oregon Forest Practice Rules – Guidance – Skidding and Yarding Practices OAR-629-630-300* (http://159.121.125.11/FP/RefLibrary/RuleLawGuidance/Administrative%20Rules%20and%20Guidance/RuleGuidanceTableContents1200.htm).

34 Victoria Rockwell, Forest Silviculturalist, USFS Wallowa-Whitman National Forest (personal communication with Tim Rooney, McNeil Technologies, Inc., July 23, 2003).



Note: Assumes slash depth of one foot and 12 foot skid trail width.

Figure 3-4. Biomass requirements for prevention of soil compaction based on skid trail spacing and percentage of skid trail coverage

3.2.2 Retention of Coarse Woody Material

Forestry professionals are required to retain standing and downed trees in management areas to provide for wildlife habitat considerations. Some of this wildlife requirement can contribute to the long-term soil productivity needs as well.

The Oregon Forest Practice Rules specify that forest operators leave standing and downed woody materials in forestry operations that are larger than 25 acres and that require wildlife leave trees (Harvest Type 2 and 3). The rules require two snags or green trees at least 30 feet in height and 11 inches DBH or larger, at least 50% of which are conifers, and two downed logs or downed trees, at least 50% of which are conifers that each comprise at least 10 cubic feet gross volume to be left on-site.[35] The estimated weight of biomass an operator must leave on-site to meet these requirements is 1.2 GT/acre (Table 3-4).

[35] Oregon Revised Statutes 527.676.

Table 3-4. Weight of biomass required to be left on-site for wildlife habitat

Biomass Category	Number of trees/ acre	Tree length (feet)	Tree diameter (feet)	Total tree volume (cubic feet)	Estimated total weight (GT /acre)[a]
Standing snags or green trees	2	30	0.9	40	0.8
Downed trees	2	6	Not provided	20	0.4
Total	4	N/A	N/A	60	1.2

Source: Oregon Forest Practices Act, ORS 527.626; Oregon Department of Forestry (http://www.odf.state.or.us/divisions/protection/forest_practices/default.asp?id=403010601 Interpretive Guidance link).
Note: N/A means not applicable.
[a] Assumes 0.005 GT/cubic foot of solid wood

Other sources recommend that greater amounts of biomass be left on-site than the Oregon Forest Practice Rules require. Recommendations for amounts and sizes of large diameter standing live and dead wood need to be developed for local geoclimatic and vegetation types in the Blue Mountains. In the absence of local data, the interim amounts of coarse woody debris by forest type in Table 3-5 from the Interior Columbia Basin Ecosystem Management Project (ICBEMP) have been recommended for on-site retention for wildlife habitat.

Table 3-5. Recommendations for leaving biomass for the Interior Columbia Basin

Forest type	Green tons per acre (GT/acre)
Dry Forest**:**	
ponderosa pine	4-8
Douglas-fir	5-9
lodgepole pine	4-8
Moist Forest:	
mixed conifer	10-20
Cold Forest:	
spruce/fir	8-12
whitebark pine	5-15

Source: Victoria Rockwell, Forest Silviculturalist, USFS Wallowa-Whitman National Forest (personal communication with Tim Rooney, McNeil Technologies, Inc., July 23, 2003).

Fuels planners at Wallowa-Whitman National Forest are comfortable with burn plans or piling contracts that specify no more than five to seven tons/acre remaining after treatment, whether treatments involve mechanical or underburning activities. This is the case mostly in warm/dry ponderosa pine or mixed conifer forest types, where most of the thinning and fuels reduction work has been occurring. Moist and cold forest types typically require that more biomass be left on-site in order to protect forest soils from disturbance.[36]

3.2.3 Slope as a Technical Barrier to Biomass Removal

Collecting and using biomass from projects on slopes greater than 30% presents challenges, because typically some form of cable-yarding is recommended to transport material from the

[36] Victoria Rockwell, Forest Silviculturalist, USFS Wallowa-Whitman National Forest (personal communication with Tim Rooney, McNeil Technologies, Inc., July 23, 2003).

point where it is felled to a landing site. Cable-yarding is practical for removal of trees that are of commercial size (approximately 10 inches DBH for sawlogs and five to 10 inches DBH for pulp wood). However, removal of tops, branches and small diameter trees (less than five inches DBH) can be difficult for both technical and economic reasons. Recent modeling of biomass availability in Oregon's Klamath region assumed that all materials less than five inches DBH would be left on-site in areas where the slope exceeds 30%.[37]

For this study, it is assumed that forest biomass would not be removed from project areas with a slope greater than or equal to 30%. However, slope data for current and future thinning and other forest management projects are not available. To provide a conservative estimate of biomass availability that takes into account slope constraints, USFS Forest Inventory & Analysis (FIA) estimates of forested acreage with slopes greater than or equal to 30% was divided by the total forested acreage by county. These values were then multiplied by total biomass generation from Section 3.1 to provide a revised estimate of biomass availability.

Table 3-6 shows total forested acreage and forested acreage with slopes less than 30% (excluding USFS land, which was not included in most recent FIA data) in the study area.

Table 3-6. Estimated forest land slope restrictions, excluding USFS land

County	Landowner				
	BLM	**Private**	**State**	**Local**	**Total/*weighted average***
Baker					
Total forested acres	23,325	242,914	-	-	266,239
Acres with slope less than or equal to 30%	11,213	154,939	-	-	166,152
Percent with slope less than or equal to 30%	48	64	NA	NA	*63*
Union					
Total forested acres	-	747,802	-	-	747,802
Acres with slope less than or equal to 30%	-	609,147	-	-	609,147
Percent with slope less than or equal to 30%	NA	81	NA	NA	*81*
Wallowa					
Total forested acres	23,368	667,388	23,441	7,351	721,549
Acres with slope less than or equal to 30%	-	540,555	23,441	7,351	571,348
Percent with slope less than or equal to 30%	-	81	100	100	*79*
All counties					
Total forested acres	46,693	1,658,104	23,441	7,351	1,735,590
Acres with slope less than or equal to 30%	11,213	1,304,642	23,441	7,351	1,346,646
Percent with slope less than or equal to 30%	48	79	100	100	*78*

Source: USFS, *FIA Database 1999 Cycle 4* (www.fia.fs.fed.us).

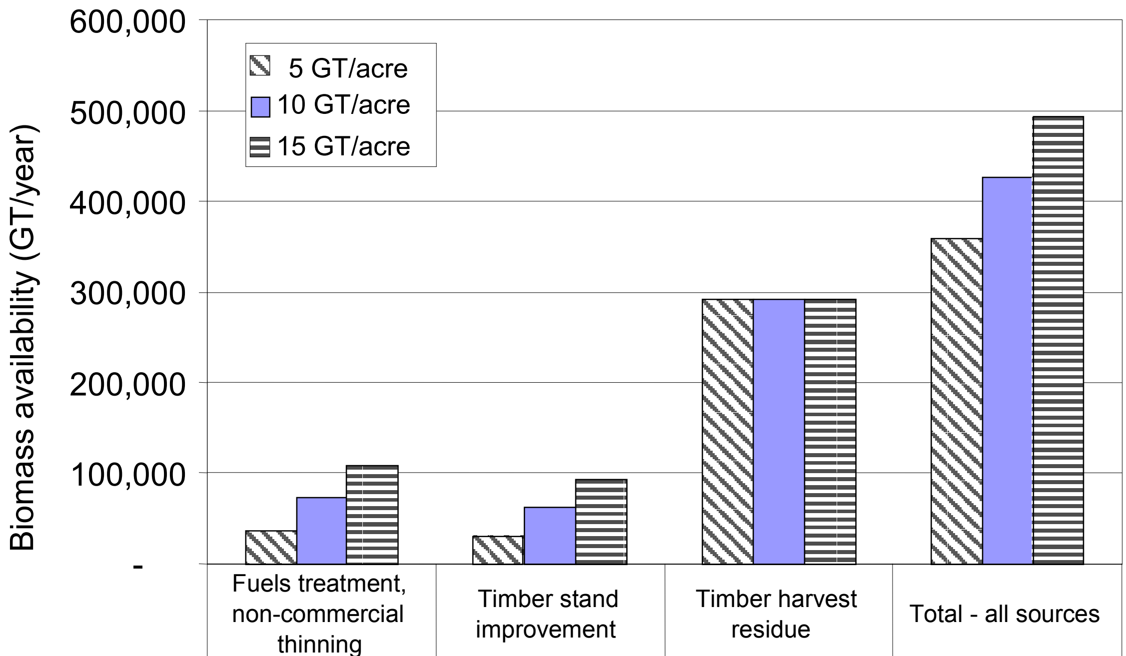
This approach provides a conservative estimate of biomass generation, because it assumes that the forestland being managed has topography similar to the region as a whole, when most likely project areas will have an average slope that is lower than the entire region. Estimates of total

[37] J. Fried, J. Barbour, R. Fight, G. Christensen and G. Pinjuv, *Small Diameter Timber Alchemy: Can Utilization Pay the Way Towards Fire Resistant Forests* (http://www.fs.fed.us/pnw/fia/ear/jfried/pubs/, USFS Pacific Northwest Research Station, 2000).

forested area in the region from the Oregon GAP analysis identified 2,539,669 acres.[38] The slope information in Table 3-6 therefore represents approximately 68% of the total forested area. This is one source of error in estimates of forest availability, since average slopes may be different on federal land than for other landowners.

3.2.4 Estimated Forest Biomass Availability

Figure 3-5 provides estimated forest biomass availability. The different columns in Figure 3-5 show biomass availability by treatment type and overall availability. In addition, the estimates show the effects of using 5, 10 and 15 GT/acre yield assumptions on biomass availability.



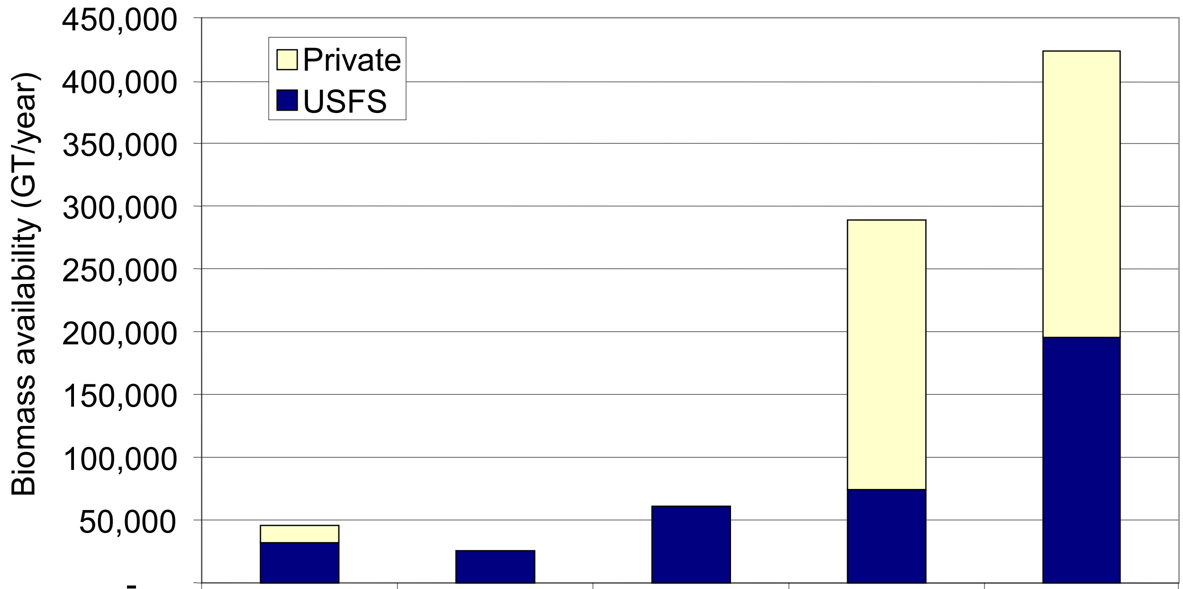
	Fuels treatment, non-commercial thinning	Timber stand improvement	Timber harvest residue	Total - all sources
5 GT/acre	36,166	30,929	291,745	358,840
10 GT/acre	72,331	61,857	291,745	425,934
15 GT/acre	108,497	92,786	291,745	493,028

Figure 3-5. Forest biomass availability with different yield scenarios for fuels treatment, non-commercial thinning and timber stand improvement

Figure 3-6 shows the distribution of forest biomass availability between private and USFS land, assuming a yield of 10 GT/acre for fuels reduction, TSI and noncommercial thinning. Timber harvesting residue from private land accounts for approximately 50% of the available supply.

[38] R. Eber, *Rural Lands Database: GAP Vegetation Cover Database for Union, Baker and Wallowa Counties* (http://geography.uoregon.edu/infographics/rldatabase/, Oregon Department of Land Conservation and Development).

Supply planning should take a conservative approach to how much biomass will be available from forest management due to the site-specific variability, annual variability from the different landowners and unknowns such as landowner interest in providing biomass from their forests.



	Fuels treatment	Non-commercial thinning	TSI	Timber harvesting residue	Total
Private	12,823	0	0	215,187	228,010
USFS	33,153	26,355	61,857	74,641	196,006

Management activity

Note: Based on yields of 10 GT/acre for fuels treatment, non-commercial thinning and TSI. Timber harvesting residue availability does not change because estimate is based on a 10-year average of timber harvest volumes.

Figure 3-6. Forest biomass availability by landowner and management activity

4. WOOD PRODUCTS RESIDUE GENERATION AND AVAILABILITY

4.1 Wood Products Residue Generation

Residue generation, use and cost data were collected from manufacturers through personal interviews with the generators and with a fiber broker in the region. Boise Cascade is the primary residue generator. Boise Cascade operates sawmill and particleboard mills in La Grande and a stud and plywood mill in Elgin. The particleboard mill produces little residue, and uses a large quantity of residue from other Boise Cascade facilities. Nearby Pilot Rock, Ore., in Umatilla County is the site of a sawmill that generates residue from poplar logs produced on a Potlatch Corporation hybrid poplar plantation in Boardman, Ore. Some logs from this plantation are also sold to a Boise Cascade paper mill in Wallula Junction, Wash.[39]

This section summarizes residue generation for the region from the study area and the Wallula Junction and Pilot Rock mills. Quantities are shown in aggregate and prices are given as averages in Table 4-1 to protect confidentiality of individual residue generator information.

Chips and planer shavings are the most expensive residue sources; other residues are significantly less expensive.

Table 4-1. Mill residue generation and price, excluding transport costs

Residue type	Annual quantity (GT/year)	Average price ($/GT)
Planer shavings	64,603	$19.10
Chips	308,794	$15.93
Plywood trim	33,875	$7.14
Hog fuel (mixed bark, sawdust and chips)	190,160	$5.56
Sawdust	115,961	$4.31
Veneer cores	1,458	$3.00
Total/*weighted average*	714,852	$11.13

Sources: John Dick, Fiber Manager, Wallula Resources and Jared Rogers, Region Engineer, Boise Cascade (personal communication with Tim Rooney, McNeil Technologies, Inc., May 13 - 14, 2003).

4.2 Wood Products Residue Availability

In the study region, all of the residue generated is currently utilized. Chips are sold for pulp. Shavings, sawdust and planer trim produced by Boise Cascade facilities are used internally for particleboard. Boise also purchases residue from other mills for use in its facilities. Bark is converted to hog fuel and burned on-site for heating or sold to a nearby cogeneration facility. A small quantity of bark is processed, bagged and sold for mulch.

Because of the high degree of integration of the Boise Cascade facilities and existing markets and uses for other residue, it is likely that much of the residue supply would not be available for use in a new cogeneration facility. However, chips that are currently sold for pulp may be

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[39]M. Sullivan, *Potlatch Poplar Farm Earns Forest Stewardship Council Certificate and Launches Cooperative Certified Lumber Marketing Effort* (http://www.potlatchcorp.com/company/newnews/news_story.asp?id=59, August 24, 2001).

available if the price offered is competitive. This should not affect the availability of residue used internally by regional facilities.

An increase in regional demand for wood fiber, caused by a diversion of chips normally sold for pulp being used for energy, is likely to drive up prices because the supply of residue is relatively inflexible. This is because residue is a co-product of lumber and veneer manufacturing in the region. The quantity of material harvested and processed is determined in part by factors other than pulp markets, including availability of material from public and private lands and markets for lumber and plywood.

The extent to which fiber prices would increase in response to a large regional demand shift is not known. However, current chip generation is approximately 309,000 GT/year. Using 10% to 20% of chips for energy that would otherwise be sold for pulp would not likely be a large driver for pulp supplies. A short-term price fluctuation is possible, but paper mills can respond to supply shifts by relying on other resources if the change is not too drastic. The 2003 chip prices were at a historically low level, however, and future escalating chip prices could make chips an uneconomical feedstock supply.

Because mill residue is currently fully utilized and the impacts of large regional demand shifts for residues could negatively impact other manufacturers in the region, it is recommended that only residue not currently used internally by local mills be considered as potentially available. In the region, this supply consists of 310,252 GT of sawmill chips and veneer cores. To avoid large shifts in regional resource utilization that could dramatically increase residue prices, it is recommended that only 20% of this quantity, or 62,050 GT/year, be considered available for energy purposes. This quantity could increase or decrease, depending on lumber, plywood and pulp markets, energy prices and other factors. It is likely that chip purchase prices will increase somewhat from its current levels due to the change in regional demand, at least in the short-term.

5. AGRICULTURAL RESIDUE GENERATION AND AVAILABILITY

5.1 Agricultural Residue Generation

Figure 5-1 shows the location of agricultural crop areas in the study area.

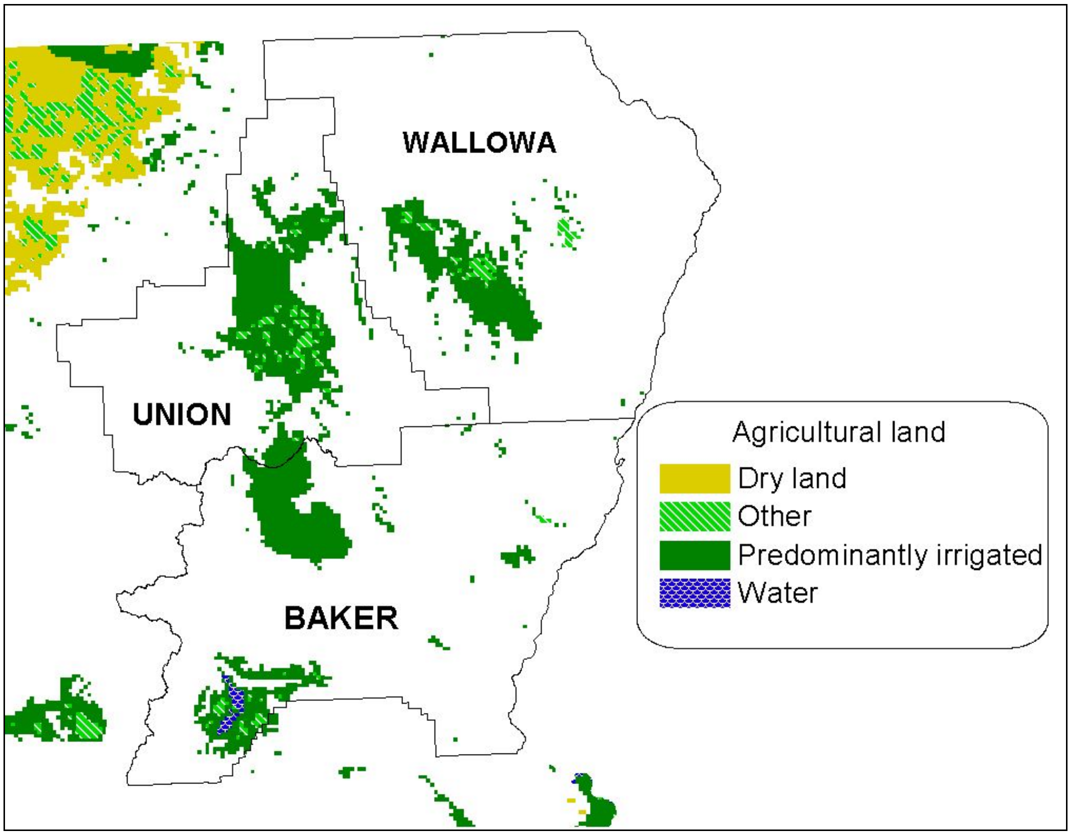
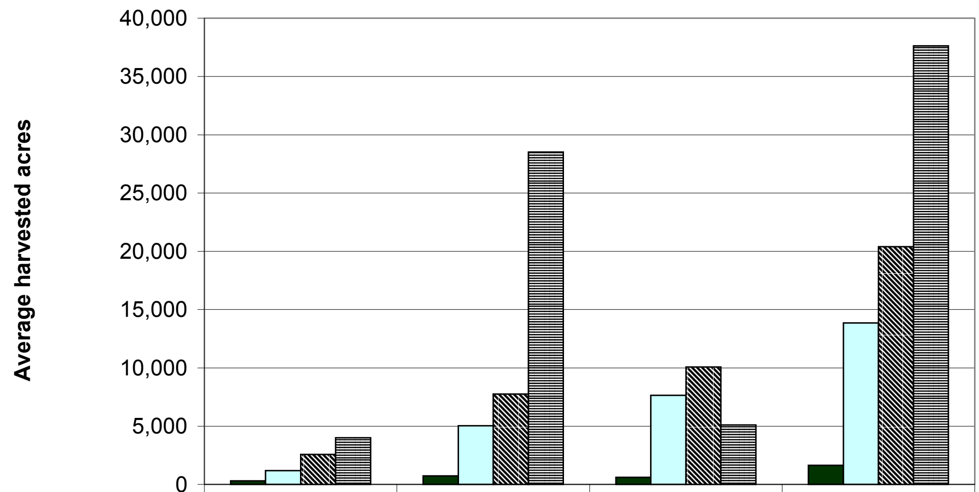


Figure 5-1. Location of agricultural land

The quantity of agricultural residues is directly related to crop production, which in turn depends on crop yield and acreage harvested. These quantities vary annually and are determined by weather conditions and the farmer's decisions on how many acres to plant. The relationships between crop yield and the quantity of residue produced are known. To account for annual variations, we use ten years of annual data (1992 - 2001) to determine the average and the range of values.

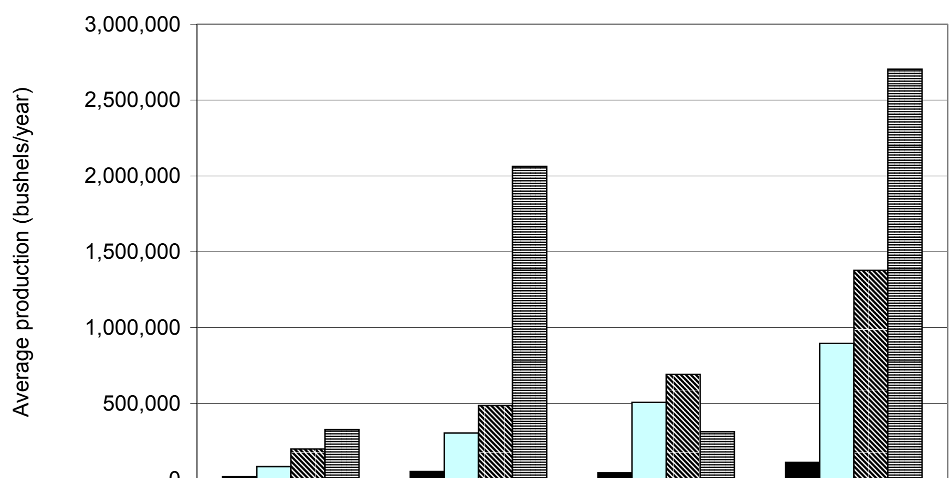
Figure 5-2 and Figure 5-3 show 1992 - 2001 average crop acres harvested and production, respectively, for major field crops in the study area. Grass seed, not shown, is also a major cash crop, though acreage and yield data are less readily available. Oat yields are significantly higher than for other crop types. Also, there is significant annual variability in both annual harvested acres and production, which is incorporated into estimates of biomass generation. The data in Figure 5-2 and Figure 5-3 reflect production from both irrigated and non-irrigated farmland; yields from irrigated farmland are often significantly higher than for non-irrigated land. This difference is also accounted for in biomass generation estimates.



	Baker	Union	Wallowa	Total
Oats	299	720	611	1,630
Spring wheat	1,180	5,020	7,650	13,850
Barley	2,580	7,750	10,070	20,400
Winter wheat	3,990	28,530	5,100	37,620

Source: USDA, National Agricultural Statistics Service, Annual Agriculture Survey. On-line at: http://www.nass.usda.gov:81/ipedb.

Figure 5-2. Acres harvested for major crop types (1992 - 2001)



	Baker	Union	Wallowa	Total
Oats	17,292	51,296	42,983	111,571
Spring wheat	83,698	305,631	507,119	896,447
Barley	200,384	485,577	690,985	1,376,945
Winter wheat	326,904	2,063,318	313,051	2,703,273

Source: USDA, National Agricultural Statistics Service, Annual Agriculture Survey. On-line at: http://www.nass.usda.gov:81/ipedb.

Figure 5-3. Average crop production for major crop types (1992 - 2001)

The major data source for field crop production is the annual survey conducted by the USDA, National Agricultural Statistics Service (NASS).[40] This survey is by county and focuses on grains and other commodity crops. The data of interest are: agricultural practice (irrigated or non-irrigated), acres planted, acres harvested, yield and total production. The grain crops of interest are wheat, barley and oats. The Oregon Agricultural Statistics Service[41] also collects data on grass seed production for each county, by year and seed type.

The USDA Census of Agriculture is conducted every five years, and all farms provide data.[42] It is not a statistical sample like the NASS survey and covers all agricultural production, not just grain crops. The data from census years 1992 and 1997 allows comparison between the survey data and census data to estimate the accuracy of the survey data. The Census also has information on the size and number of farms, which is of interest in determining how many different landowners may be involved.

Residue factors show the relationship between the quantity of residue generated and the quantity of grain produced. Residue factors were obtained from the database within the soil conditioning index (SCI) computer program documented in Part 508 of the Natural Resources Conservation Service (NRCS) National Agronomy Manual.[43] This database gives residue factors as a function of grain yield. For example, for winter wheat in the Pacific Northwest the residue factor is 1.75 pounds (lb) of residue per pound of grain harvested for a 30 bushel/acre crop yield and 1.32 lb of residue per pound of grain harvested for 100 bushel/acre yield. This gives a more realistic value than using a single value of 1.7 lb of residue per pound grain harvested that is typically used as a residue factor. The residue factors are given in Table 5-1.

Table 5-1. Residue factors

Crop	Relationship (lb of residue/lb grain) for yield in bushels/acre	R-squared fit
Barley	= 11.133*(yield(bu/acre)^-0.5248	0.999
Spring Wheat	= 9.3045*(yield(bu/acre)^-0.4775	0.998
Winter Wheat	= 3.9121*(yield(bu/acre)^-0.2371	0.997

The quantity of crop residues generated was computed for Baker, Union and Wallowa Counties for barley, spring wheat, winter wheat, oats and grass straw. Data over a 10-year period were used to develop average, minimum and maximum values for biomass generation. Total estimated agricultural residue generation in the study area is 202,772 dry tons (Table 5-2). Generation is reported in field dry tons. Field dry residues may contain 10% to 20% MC (wet basis).

[40] NASS, *Annual Agriculture Survey* (http://www.nass.usda.gov:81/ipedb).
[41] Oregon State University Extension Service, *Oregon Agricultural Information Network* (http://ludwig.arec.orst.edu/oain/SignIn.asp).
[42] NASS, *Census of Agriculture* (http://www.nass.usda.gov/census/).
[43] NRCS, *National Agronomy Manual* (ftp://ftp.nssc.nrcs.usda.gov/pub/agronomy/SCIfiles/Latest_revisions/Training%20Materials/NAM508.pdf).

Table 5-2. Estimated agricultural residue generation by crop (field-dry tons/year)

County	Barley straw	Spring wheat straw	Winter wheat straw	Oat straw	Grass straw	Total straw
Baker	5,539	2,353	13,244	419	0	21,555
Union	14,728	9,979	86,365	1,248	20,314	132,634
Wallowa	19,640	14,275	13,685	983	0	48,583
Total	39,907	26,608	113,294	2,649	20,314	202,772

Winter wheat straw makes up the largest component of agricultural residue generation (Figure 5-4). Union County is the largest source of winter wheat straw and agricultural residues overall.

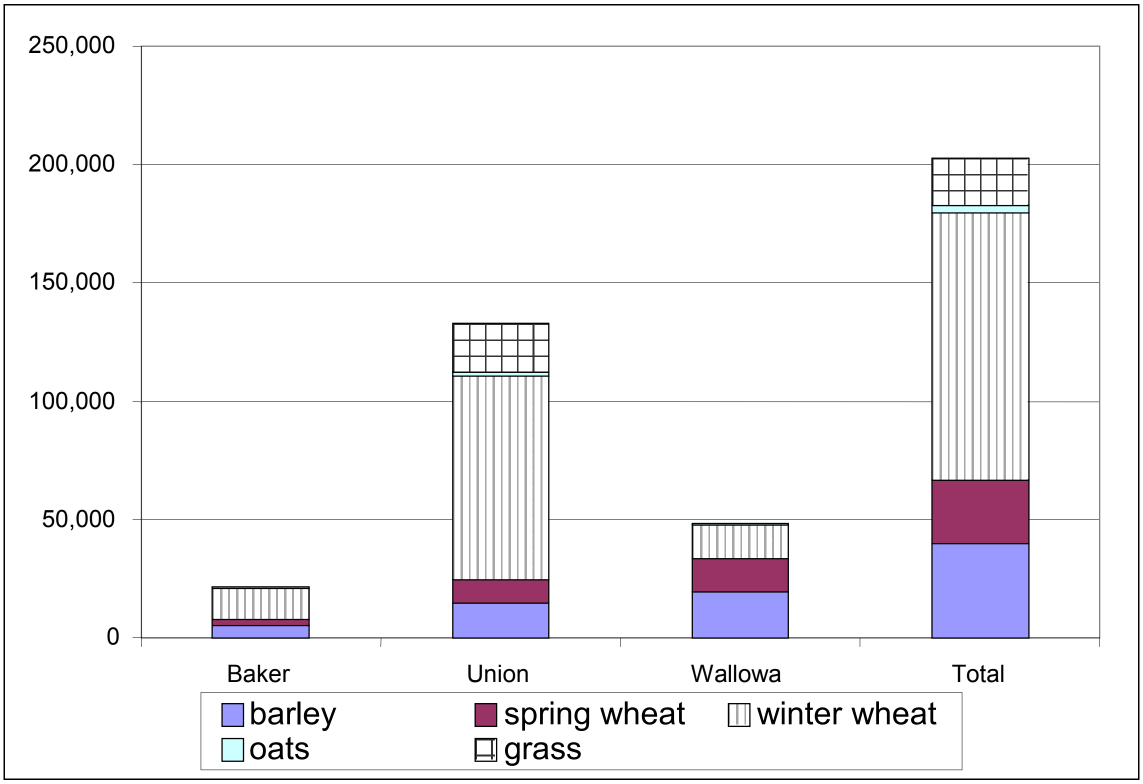


Figure 5-4. Average agricultural residue generation (field-dry tons/year)

Average agricultural residue generation does not reflect annual variation in residue generation (see Section 5.2). Figures 5-5 through 5-7 show the average, high and low values for annual residue generation for the counties in the study area.[44] Figure 5-6 includes grass straw generation for Union County. In Union County, grass straw is generated as a byproduct of the production of Kentucky bluegrass seed and other grass seed crops. Figure 5-6 shows total grass straw generation.

[44] Note, for Figure 5-5, Figure 5-6 and Figure 5-7, the column shows average residue generation, the superimposed line illustrates the range of annual values.

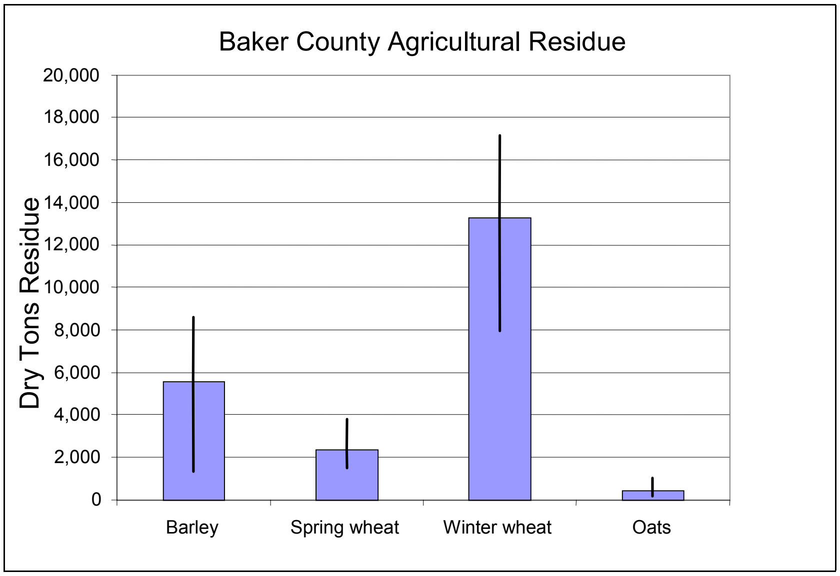


Figure 5-5. Agricultural residue generation in Baker County by crop (field dry tons/year)

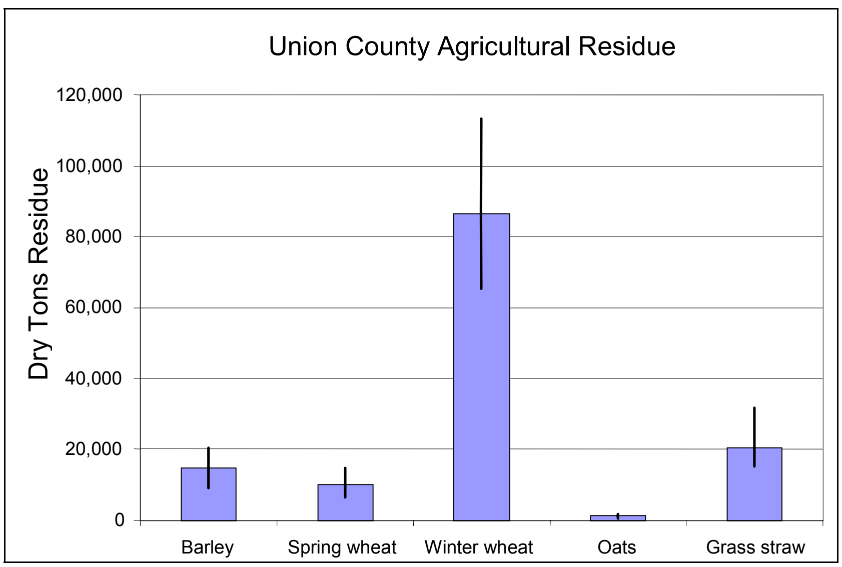


Figure 5-6. Agricultural residue generation in Union County by crop (field dry tons/year)

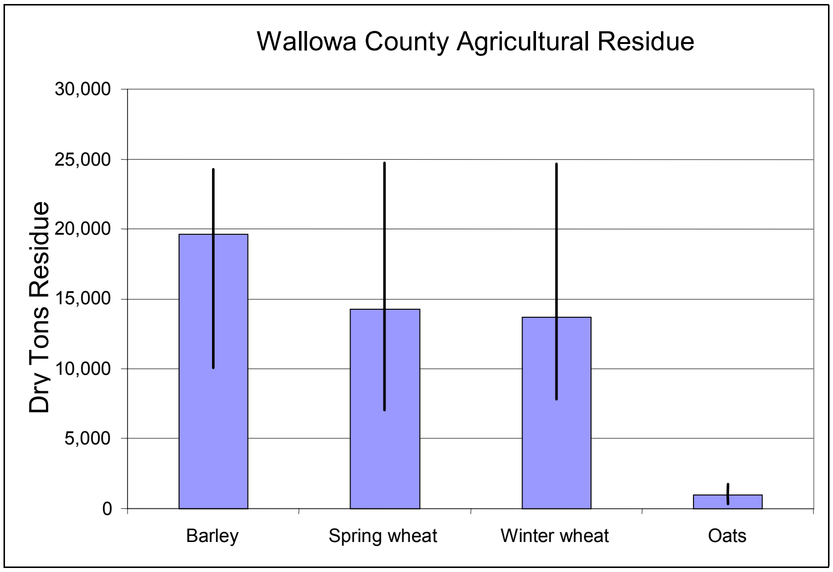


Figure 5-7. Agricultural residue generation in Wallowa County by crop (field dry tons/year)

5.2 Agricultural Residue Availability

The quantity of straw generated is a straightforward computation compared to determining the quantity of material available for recovery. We use the term "available" in a broad sense to mean the materials available after accounting for how much must be left to insure the long-term productivity of the land. This is not an easy number to quantify. The quantity that must be left depends on weather, crop rotation, existing soil fertility, slope of the land, wind patterns, rainfall patterns, historic farming culture and tillage practices. We talked to several agricultural and soil scientists about this issue.[45] They all acknowledged the difficulty of coming up with generalities that could be applied at the county level and still give a meaningful number. Some used rules of thumb such as, "don't take any straw off of lands with yield of less than 60-70 bushels/acre," "leave 8-10 inches of straw" and "leave 5,000 pounds of residue/acre."

The USDA has regulatory authority in addressing this question. Landowners who want to participate in federal commodity programs must prepare a soil conservation plan for their farms if the land is classified as highly erodible.[46] The 1997 Oregon National Resources Inventory estimated that only 10,100 acres (3%) out of the 291,100 acres in the Lower Snake hydrologic unit (Union and Wallowa Counties) had a water erosion rate of greater than the soil loss tolerance factor, T.[47] Baker County had less than 1% of its cropland, Conservation Reserve Program (CRP) land and pastureland with erosion rates greater than the tolerance factor. The USDA Soils Reports contain the soil tolerance factors (T-values) for each soil type in each

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[45] Don McCool, Washington State University; Dennis Roe, Natural Resources Conservation Service, Pullman, Washington, and Valerie Oksendahl, Natural Resources Conservation Service, Spokane, Washington (personal communications with Jim Kerstetter).
[46] Highly erodible lands are those with a soil loss eight times greater than the soil loss tolerance factor, T. The soil loss tolerance factor is defined as the maximum rate of annual soil loss that will permit crop productivity to be sustained economically and indefinitely on a given soil.
[47] NRCS, *Oregon Natural Resources Inventory* (http://www.or.nrcs.usda.gov/nri/geoarea/huc6/orb6/usle/orb6uslett.PDF).

county.[48] The weighted average T-values for prime croplands in Baker and Union Counties are 3.75 and 4.48 tons/acre-year, respectively. The soil data for Wallowa County were not available. The use of water or wind erosion methods to determine residue availability suffers from the reliance on the soil loss tolerance used as the benchmark. T-values are not currently accepted by the scientific community as an adequate level of protection.[49]

Tillage practices also affect residue availability. The Conservation Technology Information Center (CTIC) surveys tillage practices in each county for spring and fall planted crops. CTIC is a branch of the National Association of Conservation Districts and promotes the adoption of conservation tillage and residue management.[50] The survey reports the number of acres with residue covers of 0% to 15%, 15% to 30%, and 30% or greater. Table 5-3 shows the tillage practices reported in 1997 for Baker, Union and Wallowa Counties. Greater than 80% of the land in Baker and Union Counties and 60% in Wallowa County do not meet the conservation tillage criteria.

Table 5-3. Conservation tillage practice by percent of cropland

Crop type by county	Conservation Tillage (> 30% residue cover)			Conventional Tillage (< or = 30% residue cover)	
	No-till	Ridge-till	Mulch-till	15-30%	0-15%
Baker					
Spring seed	0	0	0	33.3	66.7
Fall seed	0	0	20	50	30
Union					
Spring seed	4	0	16	54	26
Fall seed	2.8	0	1.4	86.1	9.7
Wallowa					
Spring seed	9.6	0	33.7	33.7	23
Fall seed	3.4	0	34.1	37.5	25

The quantity remaining after replanting depends on the quantity generated and on the tillage method used. For example, disk plowing removes 80% to 90% of the straw from the surface. Other methods, such as use of a rodweeder (a cultivating implement equipped with rods that turn underground to flip weeds and distribute soil evenly across planting beds), are much less disruptive and only remove 10% to 20% of the straw from the surface.

CTIC developed a program called Conservation for Agriculture's Future (CORE4) that aims to protect and improve the land while addressing on-farm profits. They set the criteria for qualifying as conservation tillage at 30% residue cover for water erosion protection and 1,000 pounds/acre of small grain residue for wind erosion protection.[51] The NRCS supports the CTIC/CORE4 marketing plan.

Rather than use wind or water erosion methods or the CTIC residue standard to estimate agricultural residue availability, we used the USDA Soil Conservation Index (SCI) computer model to develop benchmarks to determine what levels of agricultural residues could be removed without negatively affecting soil productivity. The SCI model estimates the impacts of tillage

[48] NRCS, *Soils Report* (http://www.or.nrcs.gov/soil/oregon/or_databases.htm).
[49] L. Mann, V. Tolbert, and J. Cushman, *Agriculture, Ecosystems and Environment* 89 (2002) pp.149-166
[50] Conservation Technology Information Center (http://www.ctic.purdue.edu/Core4/CT/CT.html).
[51] NRCS, *Core4 Conservation Practices Training Guide* (August 1999).

and residue management practices on soil organic matter, another indicator of soil productivity. The SCI appears to be a more conservative tool to estimate the quantity of residues that can be removed and maintain soil productivity.

The SCI computes the effects of residue management and tillage practices on soil organic matter.[52] The result is an index and not an absolute value. The index predicts a qualitative change in organic matter. The organic matter declines if the SCI is less than zero, increases if the SCI is greater than zero, or is in equilibrium if it equals zero. The model calculates the SCI number by applying weighting factors of 40% to organic material subfactor, 40% to the field operations subfactor and 20% to the erosion subfactor.

The SCI program has default values for residue quantities related to crop yields, root mass adjustments and rate of crop residue decomposition. The model uses these values and model inputs to calculate the results for a particular combination of subfactors that are benchmarked to actual soil organic measurements made at a test plot in Texas. The model input variables are:

1. Location that contains default values for the initial maintenance amount of organic matter each year to maintain soil organic matter levels
2. Soil type that contains default values for a soil organic modifier factor used to compute the average maintenance amount
3. Number of years in crop rotation
4. Crop grown in the rotation
5. Quantity of residue removed, which is used to compute the organic material subfactor
6. Field operations, which account for the effects of the type and number of tillage operations on organic matter. Each operation is assigned a soil disturbance rating that accounts for the effects on soil aeration, lifting, shattering and compaction; and
7. Erosion factors, which are entered and then indexed to erosion at the Texas benchmark location. The benchmark erosion level in Renner, Texas, is four tons/acre-year.

We obtained typical tillage practices from the Oregon state conservation agronomist, Tom Gohlke, soil types from the soils data base, crop yields from NASS and soil erosion values from the 1997 National Resources Inventory (NRI). The tillage practices were used as input to the field operations module to compute subfactors. We chose a range of subfactors for irrigated and non-irrigated land to see their effect on the SCI. We chose rotations of winter wheat with either barley or spring wheat and used the average yields for each crop. We assumed the removal of residues ranging from zero to three tons per acre. This allows computation of the organic matter subfactor. Finally, we used NRI erosion values to compute the erosion subfactors.[53]

We looked at rotation combinations of winter wheat with both barley or spring wheat for irrigated and non-irrigated lands. The tillage practices for non-irrigated land included a rotation period of three years and a sequence of operation including one year of summer fallow. The more severe tillage operation included straight point chisel, sweep and coil spring harrow while the less severe operation included field cultivation, rodweeding and weed spray. The average soil disturbance ratings were 59.0 and 39.7 for barley and wheat, respectively. For irrigated lands, the

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[52] USDA, *Soil Conditioning Index* (http://soils.usda.gov/sqi/sci.htm).
[53] Mark Tilton, Resource Inventory Specialist, NRCS Oregon Office.

two tillage practices considered were the more severe operation that included chisel disk, multiple field cultivations and harrow. The less severe practice included conservation moldboard plow and field cultivation. The average soil disturbance ratings were 107.0 and 93.5 for barley and wheat, respectively.

Those combinations of crop type, yield, soil, location, tillage practice, amount of residue removed and erosion that give a positive value of the index were chosen as the values for the allowable quantity of crop residues that could be removed. Removing both winter wheat straw and either spring wheat or barley straw resulted in index values less than zero. Therefore, we assumed that only winter wheat straw would be recovered with the rotation crop of barley or spring wheat providing the necessary organic matter. In general, only 1 to 1.5 tons of residues could be removed and still maintain a positive soil conditioning index (i.e., no decrease in soil organic matter). The total quantity of residues available for removal is then computed by multiplying the tons/acre available for removal by the acres harvested.

Figure 5-8 shows a range of estimated quantities of field crop residue available for removal from the field. The columns show the average quantities over a ten-year period, and the error bars are the range of values for the highest and lowest availability over the same period. The figure shows the two tillage practices used in the model. They represent a high and a low degree of tillage severity based on current tillage practices. The tillage practice used on a particular field will depend on the crops grown, the landowner's experience with different tillage practices and the amount of residue or weeds that have to be dealt with before planting the next crop.

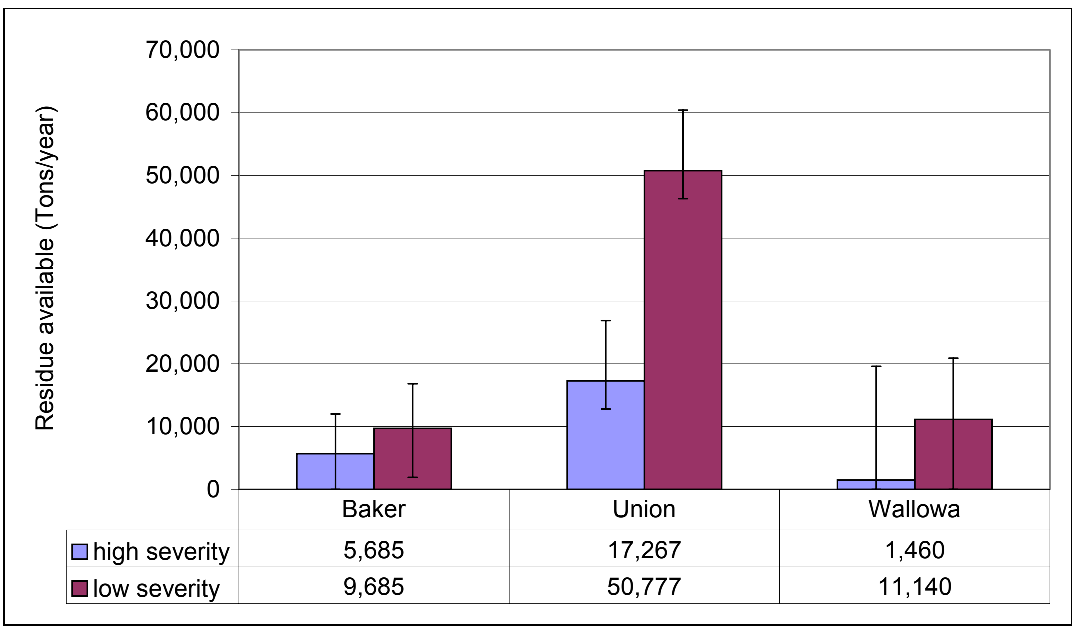
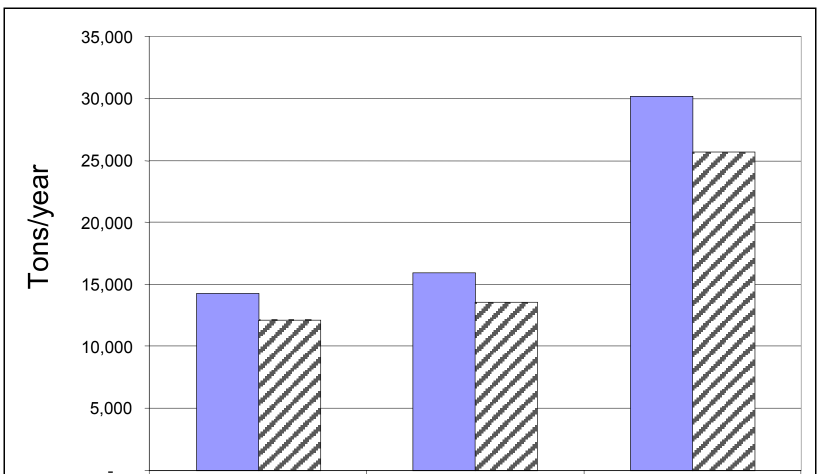


Figure 5-8. Availability of agricultural residue

Figure 5-8 shows the significant effect of tillage practice. For example, in Wallowa County, the annual availability varies between 1,460 and 11,140 tons depending on the tillage practice. In reality there would be a host of intermediate tillage practice, each indicating a different quantity of residue available. Low-till practices would tend to allow more residue to be removed but there are still the soil erosion constraints that must be met.

The computer models developed to determine water and wind erosion and soil organic matter are based on inputs for specific agricultural fields using a specific crop rotation and tillage practice. Their application at a county level represents a gross approximation of what may be expected using average input parameters. The quantities indicated by the SCI model are similar to those estimated from another report using different methodologies. Kerstetter and Lyons reported 65,000 tons of winter wheat residue available in Union County based on leaving 1.5 tons/acre on the field after harvest.[54] Graef and Koehler assumed that 1.7 tons/acre of wheat residue could be removed from wheat lands in Northeastern Oregon and still maintain soil fertility.[55] The SCI model gave an average value for the three counties of 1.3 tons/acre of residue available.

The SCI model allowed us to estimate agricultural residue availability from field crop residues. In addition, grass straw from the production of Kentucky bluegrass seed and other grass seed commodities may be available for biomass energy. Figure 5-9 summarizes grass straw generation and availability in the study area. Grass straws are traditionally burned or removed from the fields for agronomic purposes. We assumed that 85% of the grass straws generated could be recovered. This quantity represents the amount that is technically recoverable from land used for grass seed production. However, Kentucky bluegrass has an economic value as feed and would not be available for energy uses unless the project could afford the additional cost of $10/ton that is currently paid to the landowners. We considered straw from Kentucky bluegrass to be available, under the assumption that biomass energy could cover this additional cost.



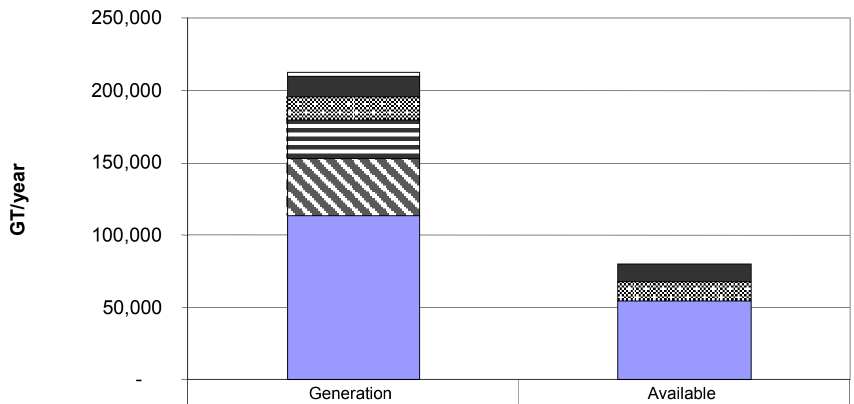
	Kentucky bluegrass straw	Other grass straw	Total
Generated	14,287	15,917	30,204
Available	12,144	13,529	25,673

Figure 5-9. Grass straw generation and availability (all located in Union County)

Figure 5-10 summarizes overall agricultural residue availability in the study area. Field crop residue availability is based on 10-year annual average availability as shown in Figure 5-8. We assumed that low-severity tillage practices would be used on field crops, thus increasing agricultural residue availability from field crops. The rationale for this assumption is that

[54] J. Kerstetter and K. Lyons, *Logging and Agricultural Residue Supply Curves for the Pacific Northwest* (Washington State University, January 2001).
[55] A. Graf and T. Koehler, *Oregon Cellulose-Ethanol Study* (Oregon Department of Energy, June 2000).

development of an outlet market for agricultural residue would increase adoption of low-severity tillage options. A total of 85% of straw from grass seed production is assumed to be available.



	Generation	Available
Oats	2,649	-
Kentucky bluegrass	14,287	12,144
Other grass	15,917	13,529
Spring wheat	26,608	-
Barley	39,907	-
Winter wheat	113,294	54,335

Figure 5-10. Overall agricultural residue generation and availability in the study area

6. FACILITY SITING ANALYSIS

This section describes the process used to identify, screen and rank potential conversion sites in the study area. The sites identified within each county were screened for appropriateness as potential conversion sites, and then sites were ranked to identify one potential candidate site within each county. In each county, there were multiple sites that could be suitable, and the differences between some sites are minimal. Consideration should be given to alternative sites should a detailed engineering evaluation be conducted in the future.

6.1 Site Identification and Preliminary Screening

The site identification effort identified 37 potential locations (see Appendix D). While there certainly are other suitable sites in the three counties, these were the most readily identified without a detailed examination of parcel databases or aerial photography. Identifying sites involved collecting information on existing industrial sites and candidate new sites that could accommodate biomass power or liquid fuel manufacturing. Data sources for industrial sites included the Oregon Department of Environmental Quality (DEQ) and the U.S. Environmental Protection Agency (EPA) AirGraphics database. Specifically, the Oregon DEQ Facility Profiler is an online mapping application that allows users to identify facilities with existing state permits.[56] Oregon DEQ staff provided information on industrial boilers in the study area. The EPA Enviromapper Internet pages show sites with permits required under federal environmental laws. County planning and economic development agencies provided information on new industrial parks. Appendix E provides a list of all permitted boilers in the study area, provided by the Oregon Department of Environmental Quality. Boise Cascade currently has large wood boilers, and Johnson Lumber has smaller wood boilers, but neither currently generates power.

We conducted a preliminary screening to narrow the number of candidate sites. Criteria for this initial screening included sites with total land acreage less than five acres (a 5-MW facility can be sited on approximately five acres), sites located in cities or towns that would interfere with existing land uses (e.g., residential or commercial) and sites located next to airports. The first criterion was meant to eliminate sites that are not large enough to accommodate a biomass power or ethanol manufacturing facility. The second and third criteria eliminated sites that are likely to be subject to stringent zoning conditions and resident opposition.

Table 6-1 provides the results of this initial screening.

[56] Oregon Department of Environmental Quality, *Facility Profiler 2.0* (http://deq12.deq.state.or.us/fp20/startpage.aspx).

Table 6-1. Top candidate sites for power or fuels manufacturing

Site name	County	Location	Existing land use
Elkhorn View Industrial Park	Baker	Baker City	Mostly industrial - little residential nearby
Ellingson Lumber main	Baker	Baker City	Industrial - closed sawmill (1997)
Ellingson Lumber S. Baker	Baker	Baker City	Closed particle board mill
Ellingson Halfway	Baker	Halfway	Former mill site
Far Site Concrete	Baker	Baker City	Sand/gravel pit - Primarily agricultural land use
Triple C Redi Mix	Baker	Baker City	Sand/gravel pit - Primarily agricultural land use
Boise - La Grande	Union	La Grande	Large sawmill
Boise - Elgin	Union	Elgin	Stud mill, Veneer/Plywood mill
Boise - Island City	Union	La Grande	Particle board mill, neighbors Baum Industrial Park, Borden Chemical
Baum Industrial Park	Union	La Grande	Industrial Park, neighbors Boise - Island City (particle Board plant), Borden Chemical
Union Industrial Park	Union	Union	Closed sawmill site. Next to agricultural experiment station
Elgin Industrial Park	Union	Elgin	Adjacent parcel to Boise - Elgin (stud mill, plywood mill)
Gelmekern Industrial Park	Union	La Grande	Industrial park - Primarily agricultural land use
Joseph mill site	Wallowa	Joseph	Former mill site
Bates mill site	Wallowa	Wallowa	Former mill site

6.2 Site Ranking

The sites listed in Table 6-1 were assessed for viability using the criteria in Table 6-2.

Table 6-2. Criteria used to rank potential conversion sites

Criterion	Score	
	Ethanol	Power
1) Miles to substation		
> five miles	1	1
One to five miles	2	2
< one mile	3	3
2) Zoning and existing land use		
Residential nearby	0	0
Undeveloped	1	1
Industrial	3	3
3) Combined heat and power (CHP)		
No	0	0
Possible	2	2
4) Likelihood of siting at location		
Never	Showstopper	Showstopper
Difficult	1	1
Moderate	2	2
Straightforward	3	3
5) Rail access		
Now	3	0
Could be developed	2	0
Not likely	Showstopper	0

The sites with the highest overall score were chosen for further evaluation. Information on each of these criteria was collected from site visits conducted in May 2003. Distance to a substation was determined either visually or, if a substation was not evident, by determining where substations were located on maps relative to the location. Zoning was determined by talking to landowners and county planners during the site visit. This criterion is somewhat subjective, because it takes into account proximity to residential and commercial areas and a sense of whether the site is likely to encounter problems because of inconsistency with surrounding land uses. Sites that were already industrial received higher scores for this criterion.

The potential for combined heat and power (CHP) was determined by evaluating whether there were obvious high heating loads such as major industrial uses near the land parcel. The likelihood of siting a facility at a particular location was in part subjective, but took into account values such as proximity to scenic byways or other natural features and total lack of industrial or other infrastructure. Rail access is vital to an ethanol plant, but it is not required for a power plant. Therefore, this criterion was used only for scoring sites for potential ethanol plants.

Table 6-3 provides the results of this scoring effort. The top sites within each county are very close in score. In Baker County, the Ellingson Lumber site in Baker City and the one in S. Baker City are both very similar in siting potential to the Elkhorn View Industrial Park. The differences are that the Elkhorn View site is largely undeveloped and is farther from residential areas, and thus may have fewer development issues. However, the Ellingson sites are owned and maintained by a motivated manager with experience in the industry. This could make these sites viable as well.

In Union County, all of the Boise Cascade facilities are potential sites due to existing land use, interested management and on-site heating loads. The Baum Industrial Park is adjacent to the Boise Cascade particleboard plant and a Borden chemical facility that produces adhesives. Because a cellulose ethanol plant developer has purchased the Baum site, it was the highest scoring site. However, a cogeneration facility or ethanol plant could also be sited at Boise Cascade facilities adjacent to or near the Baum site. The close proximity of the top sites within Baker and Union Counties makes the resource and technology assessment results applicable to any of the sites.

In Wallowa County, the Joseph mill site does not have access to municipal wastewater treatment, which makes it less desirable than the Bates mill site.

Table 6-3. Results of site scoring

Site	Location	Rail access (ethanol only)	Zoning / Existing Land Use	CHP	Siting Potential	Miles to Substation	Ethanol total	Power total
Baker County								
Elkhorn View Industrial Park	Baker City	2	3	0	3	2	**10**	**8**
Ellingson Lumber main	Baker City	3	2	0	2	3	**10**	**7**
Ellingson Lumber S. Baker	Baker City	3	3	0	2	2	**10**	**7**
Ellingson Halfway	Baker City	Showstopper	2	0	1	3	**0**	**6**
Far Site Concrete	Baker City	Showstopper	3	0	1	2	**0**	**6**
Triple C Redi Mix	Baker City	Showstopper	3	0	1	2	**0**	**6**
Union County								
Baum Industrial Park	Elgin	2	3	3	3	3	**14**	**12**
Boise - La Grande	La Grande	3	3	2	3	3	**14**	**11**
Boise - Elgin	Elgin	3	3	2	3	3	**14**	**11**
Boise - Island City	La Grande	3	3	2	3	3	**14**	**11**
Union Industrial Park	Union	2	1	0	1	3	**7**	**5**
Elgin Industrial Park	Elgin	3	3	0	2	3	**11**	**8**
Gelmekern Industrial Park	La Grande	0	1	0	2	3	**6**	**6**
Wallowa County								
Joseph mill site	Joseph	3	3	0	2	2	**10**	**7**
Bates mill site	Wallowa	3	3	0	3	2	**11**	**8**

Several sites that were not closely examined but have been the focus of interest by other parties include Eastern Oregon University, for which another cogeneration feasibility study was recently performed by Tritchka Engineering under contract to the Union County Economic Development Corporation.[57] This siting analysis was not intended to eliminate potential sites from consideration. Other suitable sites exist in the study area.

[57] Vernon Tritchka, Tritchka Engineering (personal communication with Tim Rooney, McNeil Technologies, Inc., May 14, 2003).

6.3 Detailed Descriptions of Candidate Sites

This section provides additional information about the sites selected to be the focus of the more detailed resource, technology and economic analysis for this study. Figure 6-1 shows the three candidate sites.

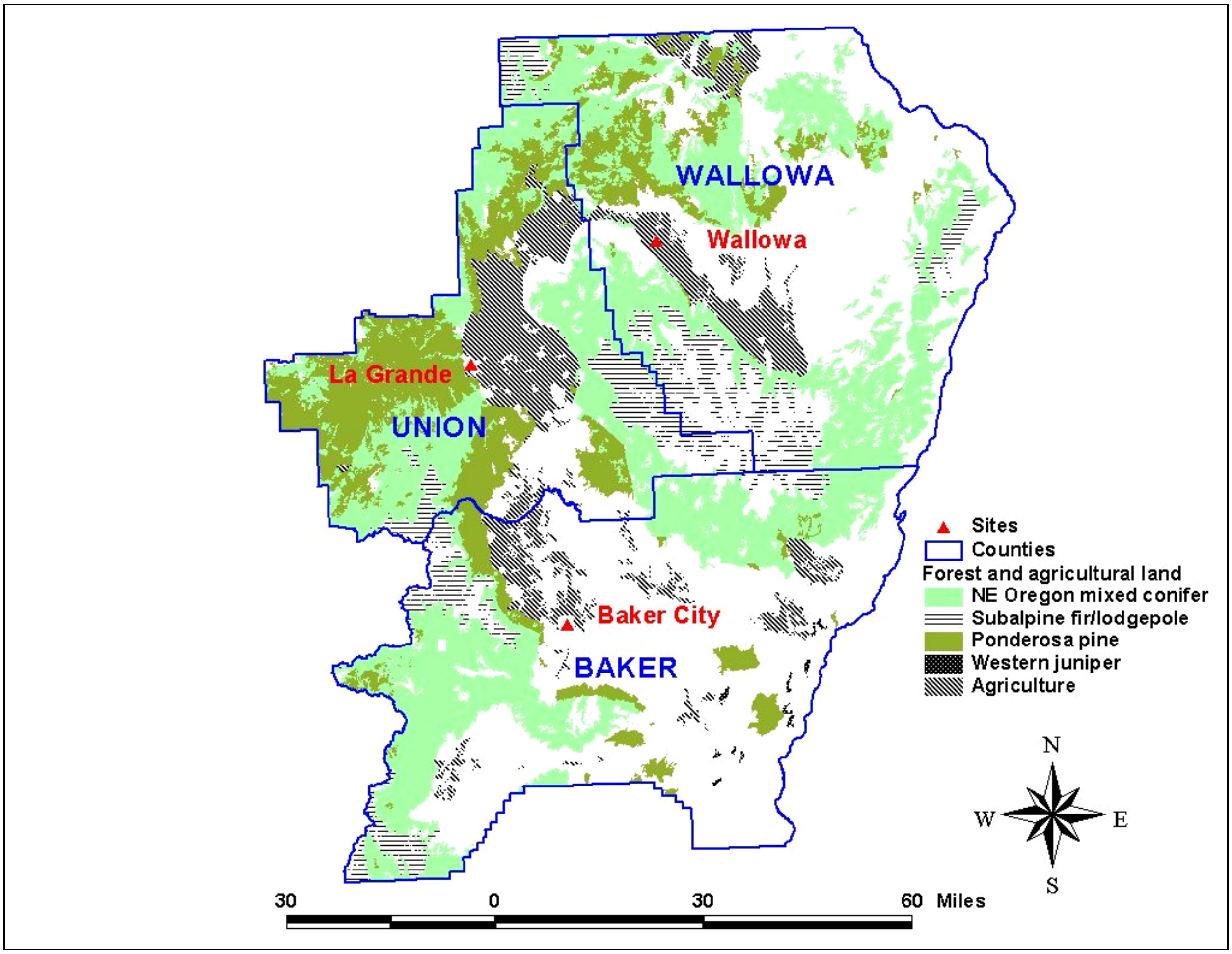


Figure 6-1. Candidate biomass facility conversion sites

6.3.1 Elkhorn View Industrial Park - Baker County

Elkhorn View Industrial Park (Figure 6-2) has a total area of 71 acres. Sewer, water, roads as well as electric, gas and telecommunications technology serve the site, which lies within Baker City's urban growth boundary or city limits. A Union Pacific rail line runs behind the property. The property is largely undeveloped. There is very little residential property nearby. The neighbors to the property include a metal fabrication company and, farther away, a hospital.

Figure 6-2. Elkhorn View Industrial Park, Baker City, Ore.

6.3.2 Baum Industrial Park - Union County:

Baum Industrial Park (Figure 6-3) is located four miles northeast of La Grande, Ore. Total acreage at the site is 80 acres. The site is zoned heavy industrial. Land is available for $14,000/acre. The site is located 2.5 miles from I-84.[58] The Baum site is adjacent to a Borden Chemical plant and a Boise Cascade particleboard processing facility. Sustainable Energy Development Inc. has purchased property at the Baum Industrial Site as a possible cellulose ethanol plant location.

Electricity is provided by Oregon Trail Electric Cooperative. Avista provides natural gas to the site. At the appropriate time, the site will be supplied by an 18-inch water line, with water provided by the City of La Grande. Water pressure fluctuates between 130 and 145 lb per square inch (psi).[59]

Photo courtesy of Union County Economic Development

Figure 6-3. Baum Industrial Park, La Grande, Ore.

[58] Union County Economic Development Corporation, *Industrial Sites,* La Grande, Oregon (http://www.ucedc.org/industrial.htm).
[59] Union County Economic Development Corporation, *Industrial Sites,* La Grande, Oregon (http://www.ucedc.org/industrial.htm).

6.3.3 Bates Mill Site - Wallowa County

The Bates Mill site (Figure 6-4) is a former sawmill location adjacent to wastewater treatment facilities and a rail line. There are ongoing efforts to redevelop portions of adjacent parcels into small scale forest products enterprises. The owner of the parcel is interested in investors who can redevelop the property into a viable business. Wallowa Resources is working with a number of parties to evaluate possible siting of firewood and post and pole manufacturing businesses on the property, which could complement a bioenergy facility at the site.

Figure 6-4. Former Bates mill site, Wallowa, Ore.

7. BIOMASS COST AND SUPPLY

This section presents the estimated supply of agricultural residue, wood products residue and forest residue in the study region. Biomass supply curves integrate estimates of the quantity of available resources and the costs of collection, processing and transportation to provide a picture of the delivered cost for biomass in each of the three counties for various supply quantities.

7.1 Agricultural Residue Cost and Supply

Developing the agricultural residue supply curves involved estimating the quantity and cost of available residue from barley, spring wheat, winter wheat, oats and grass crops delivered to the potential conversion sites in La Grande, Wallowa and Baker City shown in Figure 6-1. The purpose of the supply curve is to indicate the quantity and cost of agricultural residues for a biomass power or ethanol conversion facility in the study area. Quantities for agricultural residues are given in field-dry tons. Field dry residues may contain 10% to 20% moisture content.

7.1.1 Collection Costs

Residue collection costs were based on current custom harvest rates provided by two companies operating in Baker, Union and Wallowa Counties (Express Hay and North Slope Hay). Both operators break out their costs into swathing costs ($6/ton), baling costs ($14 to $15/ton), and stacking costs ($5 to $7/ton). Bales are the traditional three foot by four foot size. These costs were for fields having a minimum recovery of one ton per acre. The stacking cost assumed four to five miles as the maximum transport distance to where the stacks were stored.

7.1.2 Other Costs

Storage costs depend on the method chosen for storage. Methods include field/road side stacked, field/road side stacked and tarped, pad stacked, pad stacked and tarped and covered storage/pole barn. Storage costs vary with the method chosen. Selection of a storage method depends on the bale size, length of storage, location of storage, cost of storage and degradation. Storage costs for rice straw have been estimated by the Rice Straw Venture[60] to range from zero for uncovered field side stacks to $7 to $25/ton. We assumed storage costs would not be incurred for this study because uncovered field storage would be used. Residue has a fertilizer value depending on the amounts of nitrogen, phosphorus and potassium in the material. We assumed a fertilizer value of $3 per ton of residue removed that would be paid to the landowner. While this price represents the fertilizer value of the residue, it may not be sufficient compensation for growers.

These costs do not include any additional payment to the landowner. The current collection of wheat straw that goes to the animal bedding market operates on this basis. The farmer benefits by having reduced tillage expenses. Kentucky bluegrass residues are different because they have a feed value, and the farmer is paid $10 per ton.

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[60] Rice Straw Feedstock Joint Venture, *Rice Straw Feedstock Supply Study for Colusa County California* (Western Regional Biomass Energy Program, 1999).

7.1.3 Transportation Costs

The cost of moving material from the farm to a conversion facility is mainly a function of the transportation distance. We chose the physical center of the wheat growing area within a county to compute the distance from the farm field to conversion facility. The road distances from the center to facility were measured using Microsoft MapPoint and tracing the roads to be used. Transportation costs were taken from the Rice Straw Feedstock Study.[61] The costs are computed as a fixed cost of $5.50/ton plus a cost of $0.088/mile. Thus, for a 50-mile haul, the cost would be about $10/ton. These costs are similar to those quoted by a local trucking firm.

7.1.4 Supply Curve Development

The supply curve is developed by determining the quantity of residue available and then estimating the cost of recovery and transportation to the facility. We developed supply curves showing the available quantity and cost of biomass delivered to the three potential sites identified in Section 6: Baum Industrial Park in Union County, Elkhorn View Industrial Park in Baker County and the former Bates mill site in Wallowa County.

The cost to transport biomass to potential conversion sites is estimated by first creating supply locations surrounding the conversion facility locations. Each supply location consists of a circle with a 4-mile radius. Since collection costs include delivery up to four miles, the center of the supply locations is chosen to encompass all agricultural land within a 4-mile radius of the center of the supply location. The lowest cost supply locations are the first areas that residue would come from. The first supply location is positioned at the conversion facility so there would be no transportation costs involved. As the demand increases, additional locations are added. The other supply locations are chosen and positioned so the total crop area is covered with a minimum number of supply locations. As the transportation distance increases, the marginal cost of residue will increase, but it is the average cost that is most important to the facility. The average cost is the cost of supplying all residue needed, divided by the total cost from each supply location.

Union County required a sublevel of computation to account for grass straw. Grass straw collection requires only raking, so the collection cost is only $24/ton compared to $26/ton for wheat straw. However, for Kentucky bluegrass, $10/ton is paid to the landowner to compensate for the feed value of the grass straw.

Table 7-1 gives the supply location, the quantity of residues within the four-mile radius of the supply location center, the transportation distance to the facility and the delivered residue cost for supplies within each county. For example, Union County required three supply locations to cover all agricultural land. The average cost is the total costs from all three locations divided by the total residues from all three locations. Thus, for Union County, the average cost is $32.25/ton to deliver 59,183 tons of residues. Supply costs for Baker and Wallowa were calculated in a similar manner.

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[61] Rice Straw Feedstock Joint Venture, *Rice Straw Feedstock Supply Study for Colusa County California* (Western Regional Biomass Energy Program, 1999).

Table 7-1. Agricultural residue availability and cost data for each county

Location			Residues	Transport	Costs ($)			
#	Latitude	Longitude	Tons	Miles	Total collection costs ($)	Total transport cost ($)	Marginal cost ($/ton)	Average ($/ton)
Union County								
1	N45 21.0	W118 2.0	11,245	0	305,684	0	27.18	27.18
2	N45 20.0	W117 53.7	22,490	8	611,367	139,526	33.39	31.32
3	N45 27.8	W117 57.5	25,449	9	691,810	160,124	33.48	32.25
Total/*average*			59,183	NA	1,608,861	299,650	NA	*32.25*
Baker County								
1	N44 47.7	W117 51.0	1,351	0	35,114	0	26.00	26.00
2	N44 52.1	W117 17.8	2,089	8	54,320	12,961	32.20	29.77
3	N44 53.1	W117 56.1	3,388	10	88,075	21,612	32.38	31.06
4	N44 59.3	W117 57.5	2,858	18	74,301	20,244	33.08	31.66
Total/*average*			9,685	NA	251,810	54,818	NA	*31.06*
Wallowa County								
1	N45 34.5	W117 31.9	811	0	21,095	0	26.00	26.00
2	N45 36.5	W117 23.9	1,210	8	31,468	7,509	32.20	29.71
3	N45 30.4	W117 23.4	1,487	12	38,659	9,748	32.56	30.92
4	N45 22.3	W117 8.4	1,538	26	39,983	11,976	33.79	31.79
5	N45 28.8	W117 4.2	1,281	31	33,313	10,542	34.23	32.29
6	N45 29.3	W117 12.1	1,458	25	37,914	11,228	33.70	32.55
7	N45 40.0	W117 1.8	1,240	44	32,228	11,617	35.37	32.94
9	N45 30.7	W117 17.8	723	18	18,809	5,125	33.08	33.21
8	N45 34.9	W117 3.9	1,391	40	36,171	12,548	35.02	33.22
Total/*average*			11,139		289,640	80,293		*33.22*

Note: NA means not applicable.

Supply curves were also developed for each county site assuming that one county received all the agricultural residues available in the three county area (Table 7-2).

Table 7-2. Agricultural residue availability and cost data for all counties combined

Centroid	Tons	Haul distance in miles from centroid to site in:			Delivered cost ($/ton) from centroid to site in:		
		Baker County	Union County	Wallowa County	Baker County	Union County	Wallowa County
U1	11,245	44	0	41	36.56	27.18	36.29
U2	22,490	52	8	33	37.26	33.39	35.59
U2	25,449	53	9	32	37.35	33.48	35.50
B1	1,351	0	44	85	25.99	35.36	38.97
B2	2,089	8	36	77	32.21	34.67	38.28
B3	3,388	10	34	75	32.38	34.49	38.10
B4	2,858	18	26	67	33.08	33.79	37.39
W1	811	85	41	0	38.99	35.12	26.01
W2	1,210	93	49	8	39.69	35.82	32.21
W3	1,487	97	53	12	40.03	36.16	32.55
W4	1,538	111	67	26	41.26	37.39	33.78
W5	1,281	116	72	31	41.71	37.84	34.23
W6	1,458	110	66	25	41.18	37.31	33.70
W7	1,240	129	85	44	42.84	38.97	35.36
W8	1,391	125	81	40	42.50	38.63	35.02
W9	723	103	59	18	40.58	36.71	33.10
Total	80,009						

The information from Table 7-2 was used to develop charts showing the agricultural residue supply in each county.

Figure 7-1 shows the supply curves for Baker, Union and Wallowa Counties, assuming residues from all three counties can be delivered to the hypothetical conversion facility site in each county. For Union County, the rate of cost increase slows when the quantity demanded increases to approximately 35,000 tons. For Baker and Wallowa Counties, the rate of cost increase is much steeper for smaller quantities than for Union County.

In all three counties, a commercially viable cellulose-to-ethanol plant would need all of the available agricultural residues and a significant quantity from outside the study area. Therefore, the facilities would not be likely to be able to take advantage of lower prices available at smaller supply quantities. At the high end of the supply curve, Union County has the least costly agricultural residues at $33/GT delivered, followed by Wallowa County at $36/GT and Baker County at $37/GT. However, site-specific variability in agricultural residue collection, processing and transportation costs could make this cost distinction between the counties unimportant.

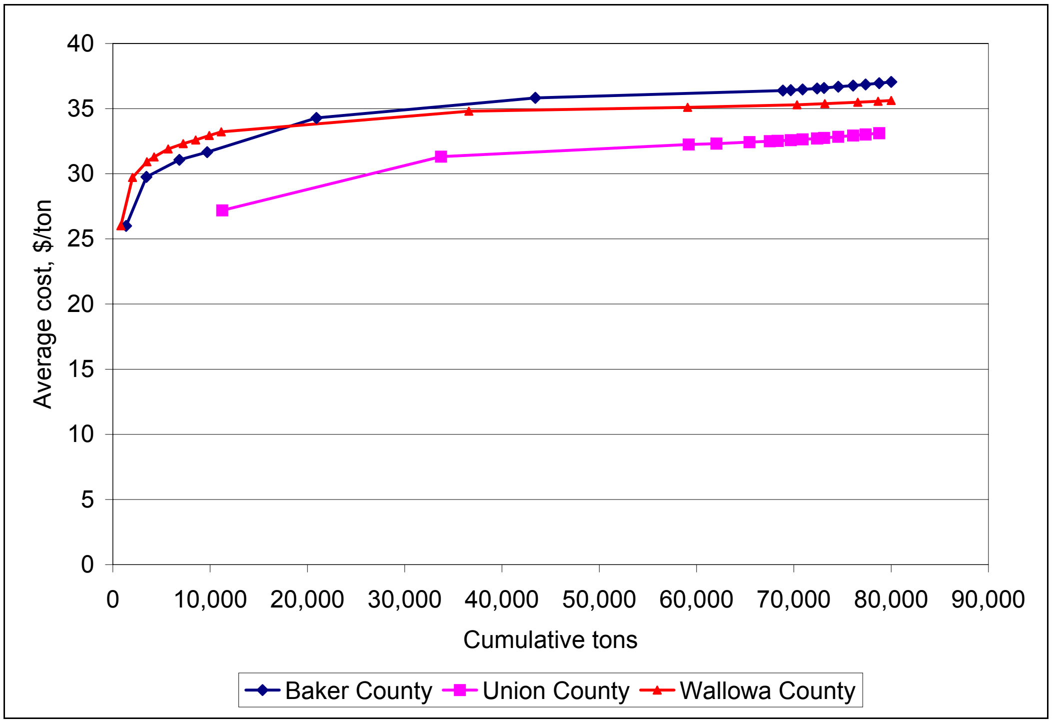

Figure 7-1. Agricultural residue supply curve for Baker, Union and Wallowa Counties, using residues from all three counties in study area

7.1.5 Logistics of Recovery

The infrastructure for collection, storage and transportation of large quantities of wheat straw does not currently exist in Oregon. The Isobord facility in Canada is an example of meeting infrastructure needs. Isobord is not necessarily a model for Oregon, but it is an example of what others have done. Isobord produces strawboard from wheat straw. They purchase straw from a farmer co-op with 450 members for $5/ton. In 1998, they harvested and transported 176,000 tons of straw to the plant. The straw was transported directly to the plant and not stored on the farm. Isobord purchased 36 tractors and balers and provided the labor for collection and transport.

The number of landowners a conversion facility must contract with is a question that should be addressed. The Canadians formed a co-op so Isobord only had to deal with one entity rather than 450 individual landowners. An estimate of the number of landowners can be made for the study area based on the average farm size per county. There are 277 wheat farms and 57,190 planted acres in the study area. The majority of the land is on farms greater than 500 acres. Fifty farms account for over 50% of the wheat acreage in the three counties. Figure 7-2 shows the size distribution for wheat farms in the three Oregon counties. There appears to be a reasonable number of farms that could supply straw to a conversion facility without requiring a large number of contracts. Nevertheless, a farm supply co-op may prove to be the best contracting arrangement, but that remains to be evaluated.

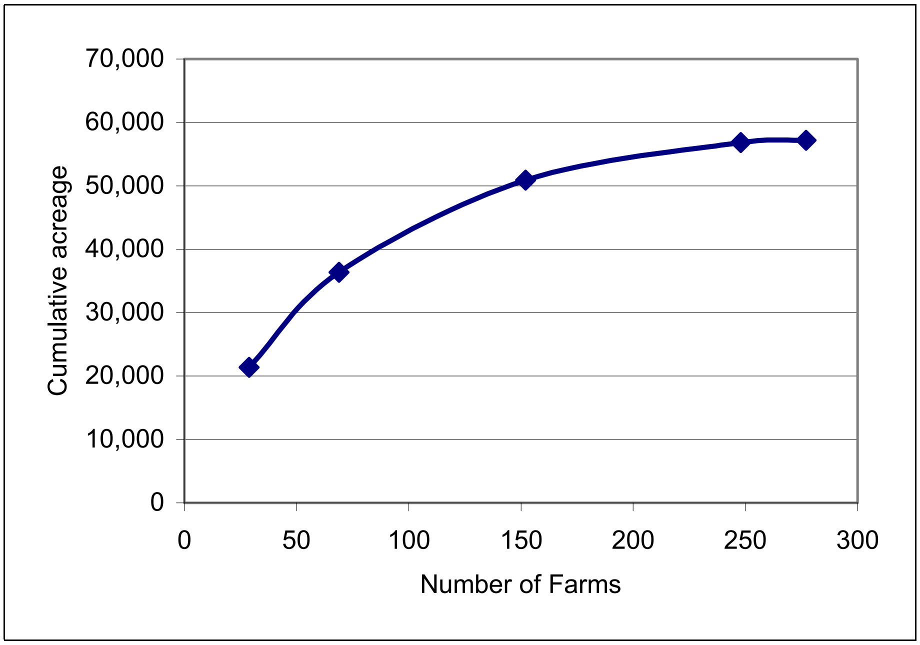

Figure 7-2. Wheat farm size distribution

7.2 Forest Biomass

The supply curves for forest biomass were developed using a similar approach to that for agricultural residue: by developing the quantity of residue available and the costs for collecting, processing and transporting that residue from the forest to potential conversion sites.

7.2.1 Collection and Processing Costs

Methods used to collect and process forest biomass vary from site to site, based on slope, climate, soils, forest stand density and a variety of other site-specific factors. This section discusses methods and costs for collecting and processing forest biomass from thinning projects and timber harvesting residues.

In forest thinning projects, whole, small diameter trees and understory brush are removed to reduce forest density and obtain the desired forest structure. Removing trees is accomplished in three primary steps: felling (cutting the trees to be removed), bucking (cutting trees to length) and delimbing, and forwarding downed trees to a landing site for further processing and transportation to a conversion facility.

Felling is typically accomplished manually with chainsaws or mechanically using a feller-buncher, which can grasp and cut trees. When cut trees are bucked in the woods, the resulting logs can be loaded onto a forwarder for transportation to the roadside. A forwarder typically consists of a rubber-tired modified tractor with a grapple loader and a log trailer. Alternatively, logs can be transported to a landing site in the woods for processing using a skidder, which is a rubber-tired machine with grapple or cabled drum that drags partially-suspended whole trees. A crawler is similar in function to a skidder but it has tracks, rather than tires.

Table 7-3 summarizes the types of felling, processing and primary transportation systems used in forest management operations that can also be used to supply biomass for energy applications.

Table 7-3. Overview of common types of forest biomass harvest systems

Common harvesting systems	Felling	Processing	Primary transportation
Conventional Ground Based	Manual	Manual bucking	Skidder or crawler
Mechanized Ground Based	Feller-Buncher	At landing	Skidder or crawler
Mechanized Ground Based	Feller-Buncher	In woods	Forwarder
Mechanized Ground Based	Cut-to-Length	Cut-to-Length	Forwarder

Source: T. Keatley, *Harvesting Options in Small Diameter Stands Operating on Gentle Slopes* (University of Idaho, October 2000).

In conventional timber harvest operations, tops and branches are often lopped and scattered, left in skid trails to reduce soil disturbance or piled on-site to be burned later. However, a portion of these residues can be collected and transported to a landing for chipping or grinding.

Systems for collecting and transporting timber harvest residue are similar to those for harvesting whole, small diameter trees. It is typically less costly to utilize timber harvesting residue with a mechanized, ground-based system that processes trees at a landing site. In such a system, the whole tree is transported to a landing site, where it is delimbed and cut to length. Then a grapple loader can be used to load timber residue directly into a chipper or grinder and skidder/crawler equipment, and labor is not used to transport low value materials. A cut-to-length felling and processing system fells, bucks and delimbs trees in the forest in one process. Cut trees can then be forwarded to a roadside area for transportation to a mill. Cut-to-length systems are best for operations in medium-size (7 to 18 inches DBH) forest stands.[62] Cut-to-length systems can cost more than other mechanical ground-based systems.

Processing typically occurs at forest landing sites in order to increase the density of the biomass for transportation, thereby reducing trucking costs. In this way, more biomass weight can be shipped per truckload. The most common methods of processing residue into denser biomass material at a landing site include chipping and grinding. Chipping often produces a uniform size and shape product for feedstock handling systems for either biomass power generation or ethanol manufacturing.

Table 7-4 provides estimates of roadside forest biomass costs based on time and motion studies for the western United States. Roadside is an encompassing term that captures costs associated with felling, skidding, chipping and loading material into a chip van for transport.

[62] T. Keatley, *Harvesting Options in Small Diameter Stands Operating on Gentle Slopes* (University of Idaho, October 2000), p. 5.

Table 7-4. Range of roadside-chipped forest biomass costs and yields

Project	Roadside chip cost ($/GT)[a]
Ponderosa Pine Partnership[63]	
Unit 1	41.76
Unit 4	46.41
Unit 5b	39.06
Unit 5e	29.80
Wyoming time and motion studies[64]	
Wyoming – Neuson	41.68
Wyoming – Manual	30.88
Average	38.26

[a] Chipping costs for both the Ponderosa Pine Partnership and Wyoming time and motion studies were assumed to be $ 6.39/GT. Source: S. Haase and T. Rooney, NEOS Corporation, *Evaluation of Biomass Utilization Options in the Lake Tahoe Basin* (U.S. DOE Western Regional Biomass Energy Program, September 1997). Chipping cost estimates were escalated from 1997 values to 2003 using an assumed 2% inflation rate.

Bundling systems that produce bales for transportation to a conversion site are beginning to see use in the U.S. as an alternative to chipping and grinding in the forest. These systems could reduce the costs of biomass, but to be conservative, we assumed that biomass would be chipped and blown into a chip van for transport. A John Deere bundling system (Figure 7-3) was demonstrated west of La Grande in July 2003, in a project sponsored by the Oregon Department of Forestry, USFS, Union County Extension Service, John Deere and Jim Voelz (landowner).

[63] D. Lynch and K. Mackes, *Evaluating Costs Associated with Fuel Hazard Reduction and Forest Restoration Projects in Colorado* (Department of Forest Sciences, Colorado State University, 2002).
[64] J. Klepac and R. Rummer, *Smallwood Logging Production and Costs: Mechanized vs. Manual* (ASAE International Meeting, July 28-31, 2002, Paper Number 025007).

Figure 7-3. John Deere 1490D slash bundler system demonstrated in La Grande, Ore.

7.2.2 Transportation Costs

Most frequently, forest biomass is transported by a tractor trailer-drawn chip van to a conversion facility or to a rail-loading site for transportation by rail. For this study, we assumed that transportation would be by truck.

Truck transportation costs will vary, but the value used for agricultural residue transportation, \$5.50/ton fixed cost and \$0.088/mile transported, is also a reasonable value for forest biomass transportation. This value was used for the supply curve analysis and for economic analysis of biomass power plant scenarios in Section 0. Costs may be lower if arrangements such as back hauls can be made to use empty chip vans on a return trip from another location. However, because it is likely that the location of forest management projects will change, relying on lower costs for planning purposes is not prudent.

7.2.3 Supply Curve Development

An analogous methodology to that used for agricultural residue was used to develop the supply curves for forest biomass. Forest biomass collection and processing costs were added to transportation costs to determine an average delivered forest biomass cost at each of the potential conversion sites. Transportation costs were calculated based on haul distance from the supply location to the conversion facility. A similar method to that used for agricultural residues was used to estimate the transport distance from the center of supply locations within the study area

(Figure 7-4) to potential biomass conversion sites. The supply radii in Figure 7-4 exclude federal wilderness study areas and national recreation areas. Each supply radius is assumed to represent an equal proportion of the total quantity of available forest biomass.

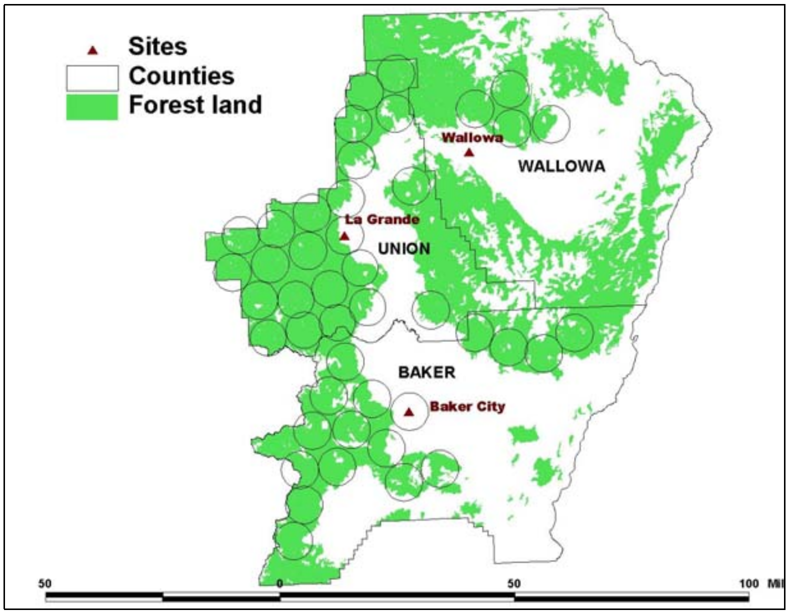

Figure 7-4. Forest biomass supply locations

Rather than trace the road-hauling route for the many supply locations in the area, transport distances were estimated by multiplying the number of supply locations by eight miles, the distance between the centers of supply locations. We multiplied this value by 1.5 to account for road curvature and to provide a conservative estimate of haul distance.

Unlike agricultural crops that are frequently planted in the same area, there is uncertainty about which forest areas will be subject to management activities from year to year. Therefore, the quantity of forest biomass coming from each supply location was estimated by multiplying the percentage of total forest area in each supply location by the total forest biomass availability.

Estimated biomass costs and available quantities were used to develop supply curves for potential processing sites in each of the three counties (Figure 7-5). The curves provide a basis for showing the difference in fuel supply economics for power plants of different sizes. The supply curves appear similar in shape because there is relatively little information about the geographic distribution of potential forest management sites in the study area. The primary difference in supply cost between the counties is due to differences in transportation costs.

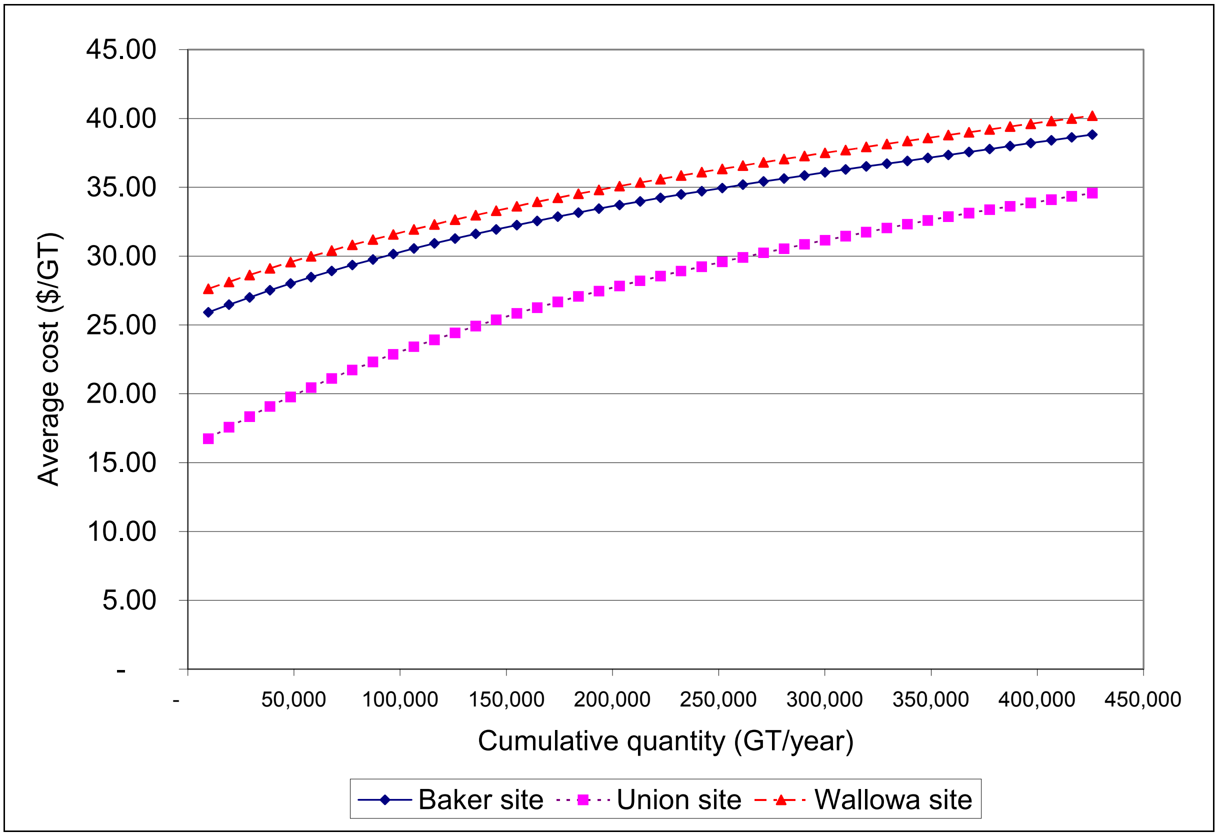

Figure 7-5. Forest biomass supply curves for potential conversion sites in Baker, Union and Wallowa Counties

Better data on the location of overstocked stands would permit a more accurate analysis of the geographic distribution of the biomass resource. This would require public and private landowners to plan forest management efforts for several years into the future. Geographic information systems (GIS) software could then be used to map out the locations of projects, estimated biomass availability and costs specific to each project.

7.2.4 Logistics of Recovery

Developing the forest biomass supply in the region will require participation by federal agencies, state agencies, private landowners and existing forest management practitioners in the area. Due to the current and historic background of the region with conventional forest products, the transition to utilizing forest biomass will be easier than in many other areas in the Western U.S.

Forestland managers in the region are committed to conducting active management to meet fuels reduction and watershed quality objectives, which will be vital for the development of a biomass energy infrastructure. The USFS is the single largest forest landowner in the region; the largest single private landowner is Boise Cascade. Both of these major landowners actively conduct fuels reduction and other non-commercial thinning on their forestland. Coordination between the two major landowners in mid- to long-range management planning would help ensure a stable supply. Current federal land management information on planned project acreage and treatment type is insufficient to do detailed, operational planning for a biomass conversion facility. Biomass supplies from private land may be sufficient to support a bioenergy plant, but multiple-year project planning on federal land would reduce the risks of short-term supply shortages that would drive up costs if land management patterns change on a single landownership. In addition, consistent management patterns and cooperation across landowners will increase the overall effectiveness of forest and watershed management strategies. It would also be necessary to support increased investment in forest management equipment and employees in the area.

The current supply infrastructure is capable of collecting and processing small diameter forest biomass for energy applications. There are existing chipping operations that operate in and near the study area that supply pulp to regional paper operations. These operators have the expertise to expand and adapt their chipping operations to include the utilization of small-diameter materials for energy, should a market for such materials develop. Trucking companies in the region that have in-woods chipping operations will be able to transport chips for energy applications as well, but some ramp-up of capacity may be required.

7.3 Wood Products Residues

Residue from the existing wood products industry (mill residue) is currently fully utilized. It is likely that only a portion of the residue generated would be available because much of the supply is utilized internally to support existing particleboard manufacturing capacity. Therefore, the wood products residue supply in the region is limited to chips currently sold for pulp and a small quantity of veneer cores that are sold sporadically for post and pole operations.

The total quantity of chips and veneer cores generated annually in the region is 310,252 GT. The entire quantity may not be available immediately because of multiple supply contracts, and the price would have to be competitive with the existing use. Table 7-5 shows the cost of wood products residues delivered to the potential conversion sites. La Grande, Ore. generates the bulk of the residues. Therefore, the primary cost difference between the regions is the difference in transportation. A price premium may be needed to entice residue generators to switch outlet markets, so the costs in Table 7-5, based on current prices, could be an underestimate. There is, however, little means of determining the price-sensitivity of suppliers until an offer is made to purchase the residues.

Table 7-5. Wood products residue supply costs delivered to conversion sites

Type	Price at mill ($/GT)	Transport distance (miles)			Transport costs ($/GT)			Total costs ($/GT)		
		Union site	Baker site	Wallowa site	Union site	Baker site	Wallowa site	Union site	Baker site	Wallowa site
Chips	$15.93	0	45	65	0	9.46	11.22	$15.93	$25.39	$27.15
Veneer cores	$3.00	0	45	65	0	9.46	11.22	$3.00	$12.46	$14.22

The residue supply price is subject to fluctuations associated with markets for lumber, paper pulp, plywood and particleboard that could affect the cost-effectiveness of this supply. The cyclical nature of pulp chip prices, in particular, could affect availability of this supply. In the past, prices for clean chips from sawmills have been as high as $60/GT, which would make this residue supply source as costly as forest biomass. This is why reliance on low pulp chip prices as a basis for economic analysis of a potential biomass power or ethanol manufacturing facility is a risky assumption.

7.4 Regional Biomass Supply Curve – All Sources

Biomass supply curves show how the average price that a biomass energy facility would pay per delivered ton changes as the total quantity of feedstock needed increases. The biomass supply consists of forest biomass, wood product manufacturing residue and agricultural residue. Biomass supply curves were developed based on estimated biomass availability and feedstock costs delivered from the entire three-county study area to one potential plant location within each county.

The first step in developing the supply curves was to estimate biomass availability for forest biomass, manufacturing residue and agricultural residue. Forest biomass included residue from timber harvesting, fuels reduction, timber stand improvement and non-commercial thinning on both public and private land. The estimated quantity of biomass from timber harvesting was based on a 10-year average of timber harvest volume. It was assumed that fuels reduction, timber stand improvement and noncommercial thinning projects would yield 10 GT of biomass per acre of forestland treated. This yield assumption was chosen to represent a conservative yield value; in practice, biomass yields can range from as little as two GT per acre to as much as 30 GT per acre. Forest biomass was considered available from forest management projects on land with slopes less than or equal to 30%. Section 3 provides more details about how forest biomass generation and availability were estimated. Wood product manufacturing residue generation and availability were determined by a survey of local manufacturers. Section 4 discusses manufacturing residue availability in more detail. The quantity of agricultural residues available was estimated based on historical crop production data, residue generation factors based on crop yield and soil conservation requirements. Section 5 provides more details on how agricultural residue generation and availability were estimated.

The next step to develop the biomass supply curves was to estimate delivered biomass costs to the potential plant sites in each county. Costs to collect and transport forest and agricultural biomass to a roadside location for transportation to a biomass energy facility were based on published values. Transportation distances were estimated for forest and agricultural biomass from four mile radius supply areas, each representing a portion of the agricultural or forest biomass supply, to potential plant sites within each county. Transportation costs were estimated assuming $5.50 fixed cost per GT of biomass plus $0.088 per GT-mile. Delivered costs were the sum of roadside and transportation costs. Supply curves specific to potential plant locations were then developed by sorting biomass supply sources in order of ascending cost. Then weighted average biomass costs were calculated to show the average cost a biomass facility operator would expect to pay per GT delivered as the quantity demanded changes.

There are really two biomass supply curves for each potential plant site - one for biomass power and one for ethanol. The difference is that there can be technical issues associated with burning agricultural residue in many boiler systems. Therefore, agricultural residue is not included in the supply for biomass power systems. Should it be necessary and if it is technically feasible, agricultural residue may be utilized in a biomass power system, but this will not greatly affect the cost of the overall supply. For ethanol, there is not enough agricultural residue available in the study area to support a cost-effective ethanol plant, based on current near-commercial cellulose ethanol technologies. This makes it necessary to evaluate forest biomass and mill residue as part of the supply. Using all biomass sources at a single plant may require separate feedstock handling and processing systems and possibly more care in blending the feedstocks or switching between them as they are available. However, this is not likely to be an insurmountable technical issue.

The biomass power supply curve in Figure 7-6 includes only forest biomass and mill residues. For the biomass power supply curve, the lowest cost supply is from mill residue chips, with the exception of a small quantity (1,458 GT) of veneer cores, which can be purchased for $3/GT, but require further processing. The primary difference in cost between the sites is associated with transportation. Union County has the lowest-cost biomass supply, primarily because the difference in transportation costs for mill residues. However, chip markets can be volatile. An increase in chip prices of $10/GT could eliminate the cost advantage that the Union County site currently has over other sites. A price swing of this magnitude is consistent with past price volatility for pulp chips. In contrast, forest biomass is at the high end of the cost curve.

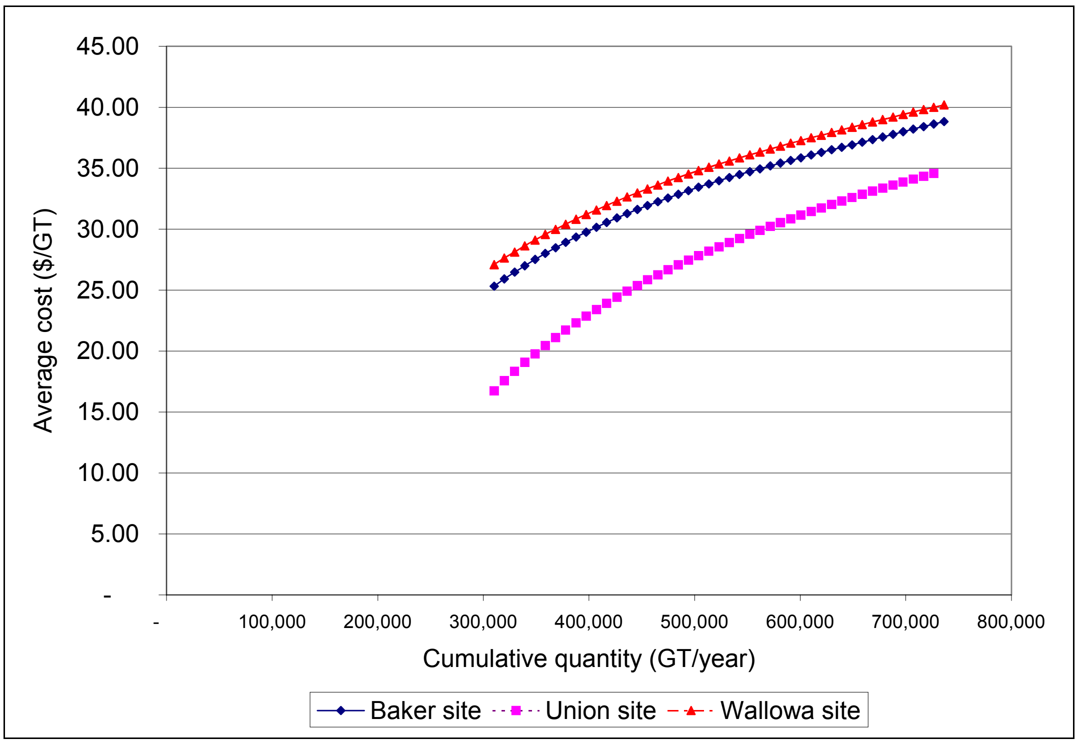

Figure 7-6. Biomass supply curve for biomass power plant

The ethanol supply curve shown in Figure 7-7 includes all residue sources. The least expensive supply source is mill residue. Agricultural residue is the next least costly at quantities less than approximately 300,000 GT. For a biomass ethanol facility, the higher-cost forest biomass would be utilized as the feedstock requirement for the facility exceeds about 400,000 GT/year, athough even at lower feedstock requirements, some forest biomass may be used to fill in periods of short supply of other resources. Forest biomass might also be used when mill residue chips cannot be purchased at a competitive price.

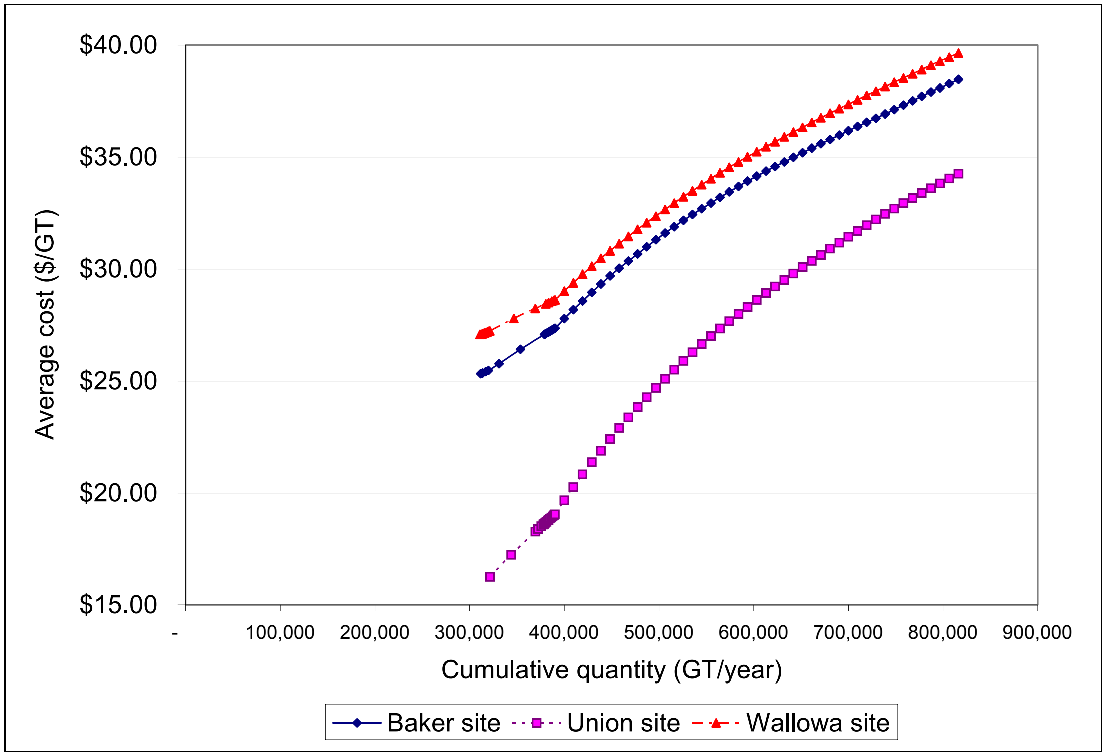

Figure 7-7. Biomass supply curve for cellulose ethanol facility

Table 7-6 shows the supply quantity and weighted average cost for the biomass supply for a biomass power or cellulose ethanol plant in each of the three counties. The weighted average cost in Table 7-6 is the uppermost bound on the average cost. It shows the annual average cost a biomass energy facility would expect to pay if it used all of the available residues in the study area. The overall quantity available is the same for each county for biomass power or ethanol. The overall quantity is larger for an ethanol plant due to the inclusion of agricultural residue in the supply. The average cost for an ethanol plant would be slightly lower than the average cost for a biomass power plant, because the use of agricultural residue reduces the average feedstock cost for an ethanol plant.

Table 7-6. Supply availability and cost in Baker, Union and Wallowa Counties

Supply source	Quantity (GT/year)	Baker County – Biomass cost ($/GT)			Union County – Biomass cost ($/GT)			Wallowa County – Biomass cost ($/GT)		
		Min	Max	Weighted average	Min	Max	Weighted average	Min	Max	Weighted average
Cellulose ethanol										
Agricultural residues[a]	80,009	25.99	37.04	35.24	27.18	33.21	31.39	26.01	35.63	34.31
Forest biomass[b]	425,934	44.82	54.32	48.66	44.82	52.21	48.20	44.82	54.32	49.49
Mill chips[c]	308,794	25.39	25.39	25.39	15.93	15.93	15.93	27.15	27.15	27.15
Veneer cores[c]	1,458	12.46	12.46	12.46	3.00	3.00	3.00	14.22	14.22	14.22
Total	816,195			38.47			34.26			39.51
Biomass power										
Forest biomass[b]	425,934	44.82	54.32	48.66	44.82	52.21	48.20	44.82	54.32	49.49
Mill chips[c]	308,794	25.39	25.39	25.39	15.93	15.93	15.93	27.15	27.15	27.15
Veneer cores[c]	1,458	12.46	12.46	12.46	3.00	3.00	3.00	14.22	14.22	14.22
Total	736,186			38.82			34.57			40.19

[a] Available agricultural biomass includes straw from winter wheat, Kentucky bluegrass seed production and other grass seed production. Availability was calculated based on the quantity of residue needed to be left on-site to maintain soil productivity. Section 5 provides more information on agricultural residue generation and availability.

[b] Forest biomass consists of timber harvesting residue and forest biomass from fuels reduction, timber stand improvement and noncommercial thinning activities. Timber harvesting residue generation was estimated based on historical timber harvest volumes. Biomass from fuels, timber stand improvement and noncommercial thinning projects assumed a yield of 10 GT per acre treated. Forest biomass was considered available only from forestland with slopes less than 30%. See Section 3 for more information on forest biomass generation and availability.

[c] Mill residue chips are currently sold for pulp, but are not under long-term contracts. Mill chip prices are subject to variability that is not reflected in this study. Figures shown here represent annual average mill prices for 2002. There is little or no current market for veneer cores, which need to be chipped prior to utilization for biomass energy. Section 4 provides more information on mill residue generation and availability.

8. BIOMASS CHARACTERIZATION

This section describes the physical and chemical characteristics of various forms of biomass that are likely to affect power and ethanol manufacturing feasibility in the study region.

8.1 Biomass Fuel Characteristics

Biomass can be converted to thermal energy, liquid, solid or gaseous fuels and other chemical products through a variety of conversion processes. These processes include physical conversion to “densified” fuels (e.g. pellets or cubes), thermal conversion through combustion or pyrolysis, chemical conversion, and microbial conversion or fermentation. The abundance of plant organic constituents and other physical and chemical characteristics vary significantly by plant type and the proportions of plant components such as leaves, stems, bark and twigs in the feedstock. Design of a biomass power or ethanol facility requires careful consideration of the effects that feedstock characteristics and composition have on the conversion process. Table 8-1 describes the key factors that affect the product yield in biomass conversion processes.

Table 8-1. Feedstock characteristics that affect biomass conversion processes

Characteristic	Conversion process				
	Physical	Combustion	Pyrolysis	Gasification	Fermentation
Physical characteristics					
• Density	✓	✓			
• Particle size & distribution	✓	✓	✓	✓	
Moisture content	✓	✓	✓	✓	✓
Energy content		✓	✓	✓	
Non-combustibles					
• Ash content		✓	✓		✓
• Ash composition		✓	✓	✓	✓
• Sulfur content		✓	✓	✓	
Bulk / biochemical composition					
• Plant type	✓	✓	✓	✓	✓
• Plant components	✓	✓	✓	✓	✓
• Carbohydrate / non-carbohydrate proportions			✓	✓	✓
• Cellulose / hemicellulose proportions					✓
• Volatiles		✓	✓	✓	✓

Generating electricity and useful heat energy is most frequently done by direct combustion of biomass in a boiler. Energy content, moisture content and chemical makeup are among the most important biomass characteristics affecting combustion processes. Biomass gasification yields a combustible gas that can be used to generate electricity. Particle size, energy content, moisture content and volatiles are among the biomass characteristics affecting gasification.

The technology that is closest to commercialization for converting biomass to ethanol involves extracting complex carbohydrates, primarily cellulose and hemicellulose, from the biomass feedstock and reducing these components to simple sugars (a process called hydrolysis). Cellulose is a long polymer of glucose, and it serves as a structural component of plant cell walls. It is often found in a composite mixture with hemicellulose and lignin. Hemicellulose is a polymer containing a variety of simple sugars and is more soluble than cellulose. Lignin is a ring-type carbohydrate that acts as cement in plant walls.[65] The lignin portion of biomass is not converted to simple sugars through hydrolysis, but lignin can be burned to generate process heat and electricity.

Extracting the carbohydrates may involve "steam explosion" of the cell walls or dissolving the organic constituents with acids, enzymes or organic solvents. Sugars resulting from hydrolysis are then converted into ethanol through microbial fermentation. The bulk and biochemical composition of the feedstock largely determine ethanol yield because these traits affect the hydrolysis and fermentation processes.

8.1.1 Physical Characteristics

The physical characteristics of the various feedstocks will affect any technology option considered for development in the region. Physical characteristics, including particle size, density and moisture content, add important considerations for transportation and material handling as well as for conversion process efficiencies. Nearly all biomass energy conversion processes require some form of physical manipulation of the fuel. This may include sorting, storing, sizing, screening and moving the material from one location to another. Because low-density materials occupy more space in truck trailers, they cost more per unit of weight to deliver and thus increase feedstock costs. For most biomass energy applications, forest biomass will be transported in chip form in order to increase the quantity of material that can be transported per truckload. Forest biomass often, but not always, includes significant quantities of tops, branches and foliage that preclude the use of conventional log trucks for transportation. However, as discussed in Section 7.2.1, slash bundling equipment that permits transport of compressed bundles can increase truck capacity over chip vans. Agricultural residue moisture content is often low but volume is a limiting factor on the quantity of material that can be transported, which is why baling is a necessity.

In general, the smaller the feedstock particle, the more rapid and complete the conversion process, whether it is a drying process, biomass combustion or the enzymatic hydrolysis of cellulose. The process design often determines the optimum range of particle sizes and particle size distribution. Density and particle size are frequently controlled in the pre-treatment process through chipping, shredding, grinding and screening, depending on the process and biomass type.

8.1.2 Moisture Content

Moisture content (MC) is the most important characteristic affecting the quality of biomass fuel for thermal processes like combustion, gasification and pyrolysis. Materials with lower moisture content cost less to transport and can reduce the size of handling, processing and energy conversion equipment needed for biomass power because a smaller volume of feedstock would be required to meet the fuel requirements for a plant. On the other hand, high moisture content is desirable for a microbial fermentation process, where a liquid water medium is essential. This

[65] H. Bungay, *Introduction to Sugar Structures: Starch/Cellulose* (http://www.rpi.edu/dept/chem-eng/Biotech-Environ/FUNDAMNT/cellulos.htm, Rensselaear Polytechnical Institute, Department of Chemical Engineering, March 6, 1998).

section discusses moisture content and its effects on both biomass power and cellulose ethanol processes.

Moisture content can be measured on a wet or a dry basis. The wet basis method, in which the moisture content is expressed as a percentage of the total weight, is usually used in engineering calculations. In forest product calculations, the dry basis method is used, in which the moisture content is expressed as a percentage of the dry weight of the wood. For example, a two-pound piece of wood may consist of one pound of wood biomass and one pound of water. Using the wet basis method, the moisture content would be expressed as 50%. Using the dry basis method, the moisture content would be 100%. This report uses the wet basis method.

The moisture content of freshly harvested forest and crop residue typically varies from 40% to 60% by weight, and can be higher, especially if the residue exposed to precipitation.[66] The moisture content of crop residue, such as cereal straws, can be reduced to 15% or less by open-air solar drying. By contrast, wood residue typically ranges from 18% to 25% MC or more after air-drying for approximately one year, depending on climate, storage conditions and bulk characteristics. Bark often has lower moisture content than wood. Moisture content can be influenced by weather. Under drought conditions, the moisture content of standing live trees can drop below 20%, adding to the threat of wildfires.

In combustion processes, high moisture content can lead to incomplete combustion, low thermal efficiency, low flame temperatures, excessive emissions and the formation of tars that could cause slagging problems. Maximum thermal efficiency is achieved at zero moisture content, referred to as oven-dry (OD) or bone-dry (BD); but complete drying is often too costly or impractical. Woody and herbaceous biomass with moisture content in the range of 10% to 20% is considered optimal for conventional combustion systems.[67] Low moisture content is especially important for most pyrolytic gasification processes, where variations in the moisture content of the feedstock cause large variations in the quality of the gas product.[68] Drying costs must be weighed against the advantages of handling drier feedstock and incremental improvements in the conversion process. Some fluid-bed combustors, however, are designed to operate with variable moisture content of the feedstock up to 50%. Many large-scale combustion plants operate well with little apparent concern for the effects of moisture content in the biomass feedstock on the combustion process.[69] Pre-treatment involving size reduction and air drying, and/or blending with dry fuel may be adequate and cost-effective for such operations.

Biomass feedstocks with high moisture content have higher transportation costs because a large proportion of the weight being shipped is water. Because of the negative impact of moisture content on combustion processes and increases in delivered feedstock costs, a good rule is to attempt to minimize moisture content of the feedstock. This can be done by using a blend of feedstocks, including lower moisture content mill residue such as sawdust to offset higher moisture content forest biomass. Alternatively, it is possible to reduce moisture content through passive or active drying. For ethanol feedstock, the increased delivered costs of biomass with higher moisture content probably outweigh the costs of increased process water requirements, but this needs to be examined on a site-specific basis.

[66] Klass, *Biomass for Renewable Energy, Fuels, and Chemicals* (Academic Press, 1998), p. 161.
[67] Ibid, p. 197.
[68] Ibid, p. 165-67.
[69] Ibid, p. 163.

8.1.3 Energy Content

Thermal energy is released from organic materials as the carbohydrates and other hydrocarbons (lignin and volatile chemicals) are ultimately reduced to carbon dioxide and water. The amount of usable thermal energy that can be obtained from fuel is known as the higher heating value (HHV). By contrast, the lower heating value (LHV) is equivalent to the HHV of the fuel minus heat required to vaporize the liquid water of the fuel. Interestingly, on a dry, ash-free basis, most biomass has about the same energy content (HHV) of 8,000 to 8,500 British thermal units per pound (Btu/lb).[70] However, the practical heating value of biomass, as received, varies considerably due to differences in the content of ash-forming minerals and moisture.

Table 8-2 shows the HHV, ash content and moisture content of various plants that are common in Northeastern Oregon. The importance of the ash content will be discussed below.

Table 8-2. Heat, moisture and ash content of tree and crop residue

Plant variety	HHV (Btu/lb)	Field MC (wt %)	Ash (wt %)
Softwoods			
Ponderosa pine	8,613	40-60	0.29
White fir	8,582	40-60	0.25
Western hemlock	8,626	40-60	0.2
Douglas-fir	8,733	40-60	0.8
Douglas-fir bark	9,507	40-60	1.2
W. white pine	8,905	40-60	0.1
Loblolly pine	8,733	40-60	0.5
Loblolly pine bark	9,370	40-60	0.4
Slash pine bark	9,365	40-60	0.7
Pine wood	9,137	40-60	0.5
Pine shavings	8,337	40-60	1.43
Pine bark	8,776	40-60	2.9

Plant variety	HHV (Btu/lb)	Field MC (wt %)	Ash (wt %)
Hardwoods			
Red Alder	8,303	40-60	0.4
Black Alder	8,647	40-60	1
Aspen	8,776	40-60	4.1
White Oak	8,354	40-60	1.52
Poplar	8,927	40-60	0.57
Crop residues			
Barley straw	7,929	10-20	8.96
Wheat straw	7,627	10-20	8.9
Oat straw	7,782	10-20	7.82
Rice straw	6,771	10-20	16.2
Rice hull	6,943	10-20	18.34
Switchgrass	7,744	10-20	10.05

Chemical composition, and therefore heat content, varies by plant component and biomass type. For example, the relative proportions of carbohydrates and other hydrocarbons vary between the two types of woody biomass: softwoods and hardwoods. Carbohydrates carry lower heat content (6,000 to 7,000 Btu/lb) than the other hydrocarbons in organic matter (such as lignin at 10,000 to 12,000 Btu/lb)[71] but are easier to hydrolyze into higher-value fuels and chemicals in fermentation processes than other hydrocarbons. Softwoods generally contain a higher percentage of volatile hydrocarbons, in the form of gums and resins, than do hardwoods. As a result, softwoods often, but not always, have higher heat content than hardwoods. In addition, bark often has higher lignin content than wood, which is one reason why its HHV is higher than wood of the same species.

Fuels with low heat content increase feedstock transportation costs per unit of usable thermal energy, thereby affecting the economics of biomass power generation. While it may be possible

[70] M. Reed, L. Wright, R. Overend and C. Wiles, *CRC Handbook of Mechanical Engineering* (Frank Kreith, Ed., CRC Press, Inc., 1998), Section 7 – Energy Resources, p. 26.
[71] Richard Elander, Pretreatment R&D Team Leader, NREL Division of Biotechnology for Fuels and Chemicals (telephone interview, Sept.11, 2002).

to pay less per ton for a feedstock with a lower HHV, it is likely to cost the same amount to transport a ton of low-energy fuel as it would to transport a ton of high energy-density material. In addition, the energy content of biomass fuels per unit volume can increase feedstock quantity requirements for combustion and gasification. This affects storage, handling and processing needs and the sizing of boiler and gasification systems. For example, using biomass fuels with low energy densities per unit volume may require a larger boiler vessel to achieve the same heat output as a boiler system run with a biomass fuel that has a higher energy density.

8.1.4 Chemical Composition

The chemical characteristics of biomass affect a variety of different processes. The chemical composition of the organic component of plant biomass is particularly important for microbial fermentation, pyrolysis and gasification. The non-combustible constituents of biomass supplies greatly affect biomass combustion processes. The overall chemical constituents are similar for most plant materials. Plant cell walls consist of water and complex carbohydrates, particularly cellulose and hemicellulose. Lignin is a non-carbohydrate plant component, the highly cross-linked polymer "mortar" that binds the plant-cell bricks together to add to the plant's structure as it matures. The cellulose, hemicellulose and lignin portions of the vegetable matter in terrestrial plants are also referred to as the *lignocellulosic complex*. These components along with proteins, gums and resins, and ash-forming minerals make up the plant's chemical structure.

The relative proportions of cellulose, hemicellulose and lignin vary widely in proportion between softwoods, hardwoods and herbaceous plants. Woody plants typically consist of about 50% cellulose, 25% hemicellulose, 25% lignin and trace amounts of ash-forming minerals. Herbaceous plants may contain about 40% cellulose, 25% hemicellulose, 15% lignin, 5% minerals and 15% proteins and resins.[72] The chemical composition of biomass feedstocks varies according to plant type but also by plant part (i.e., leaves, twigs, bark, stems and roots). Variation in the proportion of different plant types and plant part components affects a variety of biomass conversion processes.

Hardwood tree species tend to contain more hemicellulose and less lignin than softwoods. Grasses contain more volatile compounds in the form of proteins, fats and resins than other herbaceous and woody plants. Table 8-3 represents typical proportions of the primary organic components and ash content of several tree and crop varieties.

[72] Klass, *Biomass for Renewable Energy, Fuels, and Chemicals* (Academic Press, 1998), pp. 80-85.

Table 8-3. Abundance of chemical components in biomass

Category	Chemical Composition (wt%)				
	Volatiles	Ash	Lignin	Cellulose	Hemicellulose
Softwoods	0-5	0.5	25-35	40-45	25-28
Pine	0.7	0.5	34.5	40.4	24.9
Hardwoods	0-5	1	15-25	40-50	25-40
Poplar	1	2.1	25.6	41.3	32.9
Cereals	10-20	3-12	14-18	30-45	22-30
Barley straw	-	4.1	16.4	42.4	22.7
Wheat straw	-	8.3	16.2	33.5	25.4
Oat straw	-	5.3	14.7	35.1	24
Flax	-	8	2.2	71.2	18.6
Cotton	-	0.1	-	99.9	-

Non-combustible Components

The chemical characteristics of cellulose biomass are particularly important in combustion processes. Therefore, these characteristics are important to the decision process for choosing combustion technologies. While energy content is affected by the carbohydrate content in the plant material, the non-combustible fraction is particularly important for combustion because of operational issues associated with boiler efficiency, boiler slagging and fouling, erosion and corrosion, combustion instability and particulate carryover.

The amount of boiler slagging and fouling largely depends on the fusion temperature of the ash and the abundance and composition of ash-forming minerals. Slagging occurs when alkaline deposits accumulate or ash clumps together on the surfaces inside boilers. Alkalis such as sodium (Na) and potassium (K) are the primary causes of boiler slagging and typically have low melting points, reducing the ash fusion temperature. High alkalinity also causes fouling and slagging in stoker type boilers and agglomeration in fluidized bed combustors (consumption of fluidized bed material along with biomass fuels). Typically, agricultural residue has higher alkalinity than does wood residue.

The value of pounds of alkali per million Btu (lb/MMBtu) can be used as an indicator to estimate the risk of boiler slagging and fouling problems. Research indicates that biomass fuels with alkali contents below 0.4 lb/MMBtu are not likely to cause slagging problems.[73] Consequently, biomass feedstocks with high alkalinity are often blended with other fuels to reduce alkali concentrations to control fouling and slagging problems.

The minerals that combine to form ash have no energy value, so the HHV of a feedstock generally decreases as the ash content increases, reducing boiler efficiency. The ash content of a biomass feedstock should be analyzed to assess these impacts and estimate the amount of ash requiring disposal. Usually, clean softwood and hardwood fuels contain only trace amounts of ash-forming minerals, but cereal straws such as rice straw may have ash contents above 15% to 20%. Silica (SiO_2) is an abundant ash-forming mineral in crop residues that is abrasive, buffers acid reactions in pretreatment processes, adds to slagging problems in boilers.[74] Because the abundance of ash-forming minerals varies widely between woody and herbaceous plants and

[73] T. Miles et al., *Alkali Deposits Found in Biomass Boilers, Vol. II* (http://www.trmiles.com/alkali/alkali.htm Sandia National Laboratory and NREL, NREL/TP-433-8142 and SAND96-8225, February 1996), pp. 198-200.
[74] Ibid.

among plant components such as bark, leaves and stems, full characterization of the feedstock will ensure appropriate conversion process design.

Table 8-2 indicates typical ash contents for the residue of various trees and crops. Table 8-4 shows the mineral composition of the ash for several representative feedstocks. The presence of chlorine in the cereal straws should be noted. Research indicates that chlorine plays an important role in alkali release during combustion by exacerbating slagging.[75] High chlorine levels in oat straw, coupled with high sodium and potassium content, reduces the value of oat straw as an important fuel source for direct combustion unless it is blended with other, low-chlorine and low-alkali fuels.

Table 8-4. Mineral composition of the ash content of biomass materials

Material	Mineral Composition (wt%)														
	CO_2	Na_2O	K_2O	Cl	MgO	CaO	SrO	BaO	Al_2O_3	Fe_2O_3	SiO_2	TiO_2	Mn_2O_4	P_2O_5	SO_3
Pine	-	0.44	2.55	-	0.44	49.2	-	-	4.5	3.53	32.5	0.4	-	0.31	2.47
Poplar	14	0.18	20	-	4.4	47.2	0.13	0.7	0.94	0.5	2.59	0.26	0.14	5	2.74
Barley straw	6.2	1.15	30.2	4.5	2.15	11.3	-	-	0.4	0.45	42	-	-	3.7	2.85
Wheat straw	2.52	0.78	21.2	3.49	2.12	6.02	-	-	0.78	0.45	49	0.07	-	2.59	3.74
Oat straw	6.7	7.52	31.8	13.1	1.72	6.9	-	-	0.61	0.42	16.9	-	-	1.77	2.97
Switchgrass	-	0.1	15	-	2.6	4.8	0.04	0.22	0.45	0.45	69.9	0.12	0.15	2.6	1.9

It is important to analyze the sulfur content of the feedstock to estimate the amount of sulfur oxides (SO_x) likely to occur in fuel emissions. In addition to polluting the atmosphere, sulfates form deposits on boiler convection tubes, contributing to slagging problems. Overall, biomass has lower sulfur content and particulate emissions than coal, so biomass utilization benefits the environment by reducing the emissions of SO_x and ash associated with coal-fired boilers.

8.2 Ethanol Yields

The variations in organic composition of biomass require thorough consideration to obtain high product yields from a microbial conversion process. In fermentation processes, the lignocellulosic complex is naturally resistant to hydrolysis, so woody and herbaceous biomass often requires significant preparation and pre-treatment. During pre-treatment, weak acids may be used to dissolve and hydrolyze the hemicellulose, leaving a solid residue of cellulose and lignin. Next, the cellulose may be separated and reduced through enzymatic hydrolysis, leaving behind the insoluble lignin. The lignin may then be removed, dried and burned to provide heat for the process. After the cellulose and hemicellulose are hydrolyzed to simple sugars, microbial conversion uses yeast or bacteria to ferment the sugars, converting them to ethanol, methane or other chemicals.

Cellulose and hemicellulose are composed of different types of sugars that possess different chemical properties. For example, the primary sugar component of cellulose is glucose, a type of hexosan (or 6-carbon sugar). Hemicellulose is primarily xylose, which is a type of pentosan (or

[75] D. Dayton and T. Milne, "Laboratory Measurements of Alkali Metal Containing Vapors Released During Biomass Combustion," *Applications of Advanced Technology to Ash-Related Problems in Boilers: Proceedings of the Engineering Foundation Conference* (Engineering Foundation, July 1995), pp. 161-185.

5-carbon sugar). As a result, the cellulose and hemicellulose must be extracted and hydrolyzed through separate processes. Furthermore, different microbes specialize in fermenting specific sugars; so different fermentative organisms are often needed to convert the hexosans and pentosans into fuel to achieve a high product yield. Hydrolysis of the holocellulose (the collective term for cellulose and hemicellulose) also produces varying amounts of mannose, galactose and arabinose sugars, depending on the types of plants in the feedstock.

Typical sugar proportions are shown as they occur in several representative tree and crop residues in Table 8-5. Sugars require specific enzymes to convert each of them into ethanol and other products. To maximize product yield from a microbial conversion process, it is important to analyze the sugar composition of the feedstock and tailor the enzymes used in the conversion process to optimize fermentation of the specific sugar constituents according to their relative proportions.

Table 8-5. Proportions of sugars, lignin and ash in several biomass types

Material	Biomass Composition (wt%)							
	Volatiles	Ash	Lignin	Glucan	Mannan	Galactan	Xylan	Arabinan
Softwoods	0-5	0.5	25-35	40-50	8-12	0-1	5-15	1-3
Pine	-	0.4	29.5	46.5	11.7	-	8.9	2.4
Hardwoods	0-5	1	15-25	40-50	4-6	1	15-20	2
Poplar	-	0.5	18.1	49.9	4.7	1.2	17.4	1.8
Cereals	10-20	3-12	14-18	32-40	0-1	0-2	15-22	2-4
Barley straw	-	10.8	13.8	37.5	1.3	1.7	15	4
Wheat straw	13	9.3	18.2	36.2	0.3	1.5	19.1	2.6

Research has focused on microbes that can rapidly generate high product yields from xylose and glucose, the primary sugar constituents in commonly available biomass feedstocks. Most fermentative organisms specialize in digesting particular sugars, and few produce the enzymes needed to directly ferment xylose or arabinose. Recently, several strains of yeast and bacteria have been genetically engineered to digest the sugar components of both cellulose and hemicellulose.[76] Yeast tends to be a very robust organism in ethanol conversion processes, but bacteria, which have the potential to be more efficient, are more susceptible to weak acids and other feed stream toxins such as chemical extractives. Softwoods evolved higher levels of gums and resins that inhibit fungal or bacterial growth. As a result, softwoods and hardwoods usually require distinct enzymatic or microbial conversion processes for optimal yields.

In the conversion of cellulose to ethanol, the approximate ethanol yield per ton of feedstock is a function of three variables: the weight fraction of holocellulose in the feedstock, the fraction of cellulose in the total carbohydrates and the fraction of total carbohydrates converted to ethanol.[77] Figure 8-1 illustrates the relationship between these factors and the estimated theoretical ethanol yield where the ratio of cellulose to hemicellulose is assumed 2:1.

[76] J. McMillan, "Hemicellulose Conversion to Ethanol," *Handbook on Bioethanol: Production and Utilization* (C. Wyman, Ed., Taylor & Francis, 1996), p. 288-89.
[77] C. Wyman, "Economic Fundamentals of Ethanol Production from Lignocellulosic Biomass" (American Chemical Society, 1995), pp. 278-79.

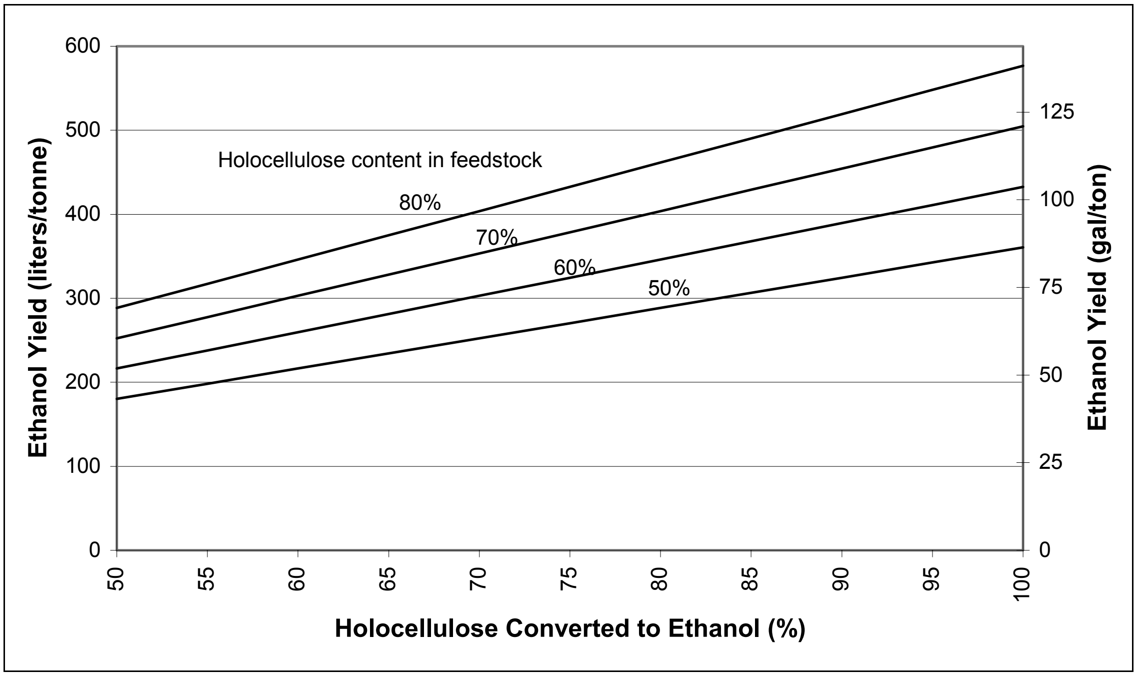

Figure 8-1. Volumetric ethanol yield per weight of feedstock

For example, if the feedstock contains 70% holocellulose, of which 80% is converted to ethanol, then the estimated yield is about 95 gallons per ton. The fraction of cellulose in the total carbohydrates tends to have a minor effect on ethanol yield in this process. Lignin is insoluble and is left behind as a solid residue after chemical and microbial conversion. The lignin is not easily reduced or fermented and is sometimes wasted, but it has similar heat content to low-grade coal (about 10,000-12,000 Btu/lb) and may be dried and burned as fuel in cogeneration systems. Assuming that most of the remaining 30% of the feedstock in the above example is lignin, enough material can be burned to provide the heat and electricity to power the entire conversion process, as well as excess electricity that can be sold for additional revenue.[78]

Several methods have been developed to estimate the ethanol yield from a biomass feedstock. Charles Wyman describes the method used to produce the plot in Figure 8-1 that estimates the net ethanol yield based on the ratio of cellulose to holocellulose, the weight fraction of holocellulose in the feedstock and the percentage of holocellulose converted to ethanol.[79] NREL developed another method that estimates the total theoretical ethanol yield according to the dry weight percentages of the sugar components in the feedstock.[80]

Table 8-6 summarizes the ethanol yields in gallons per ODT (gallons/ODT) calculated by these methods using the data from Table 8-3 and Table 8-5. The theoretical yield assumes 100% conversion of the feedstock carbohydrate content. Actual yield may be anywhere from 60% to 90% of the theoretical yield depending on the feedstock and the design of the conversion

[78] Wyman, 277.
[79] Wyman, 278-79.
[80] U.S. DOE Office of Transportation Technologies, *Theoretical Ethanol Yield Calculator* (http://www.ott.doe.gov/biofuels/ethanol _calculator.html, September 24, 2002).

process. Lab results indicate that ethanol yields can be expected in the 75% to 80% range for a well-designed process.[81]

Table 8-6. Theoretical biomass ethanol yields calculated from carbohydrate content

Wyman method	Cellulose (wt %)	Hemicellulose (wt %)	Theoretical ethanol yield (gallons/ODT)	75% of theoretical yield (gallons/ODT)
Pine	40.4	24.9	113	84.7
Poplar	41.3	32.9	128.6	96.4
Barley straw	42.4	22.7	112.5	84.4
Wheat straw	33.5	25.4	102	76.5

NREL method	Glucan (wt %)	Mannan (wt %)	Galactan (wt %)	Xylan (wt %)	Arabinan (wt %)	Theoretical ethanol yield (gallons/ODT)	75% of theoretical yield (gallons/ODT)
Pine	46.5	11.7	-	8.9	2.4	120.6	90.5
Poplar	49.9	4.7	1.2	17.4	1.8	130.4	97.8
Barley straw	37.5	1.3	1.7	15	4	103.6	77.7
Wheat straw	36.2	0.3	1.5	19.1	2.6	104.1	78.1

The yields calculated by the two methods cannot be directly compared here because the data come from different sources. In practice, yields will likely be lower than shown here. Research conducted by NREL, indicates that ethanol yields up to 70 gallons/ODT of clean pine wood can be obtained using a two-stage dilute acid hydrolysis process to extract and reduce the carbohydrates. That number drops to 60 gallons/ODT for pre-treated forest thinnings, and only 40 to 50 gallons/ODT for hogged thinnings. On the web page for NREL's ethanol yield calculator, a theoretical yield of 81.5 gallons/ODT is listed for softwood forest thinnings, or a practical yield (75% of theoretical yield) of about 61 gallons/ODT.

[81] Richard Elander, Pretreatment R&D Team Leader, NREL Division of Biotechnology for Fuels and Chemicals, telephone interview, Sept. 11, 2002.

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

[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.

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[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

Spreader-Stoker Fired Boilers

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.

[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.

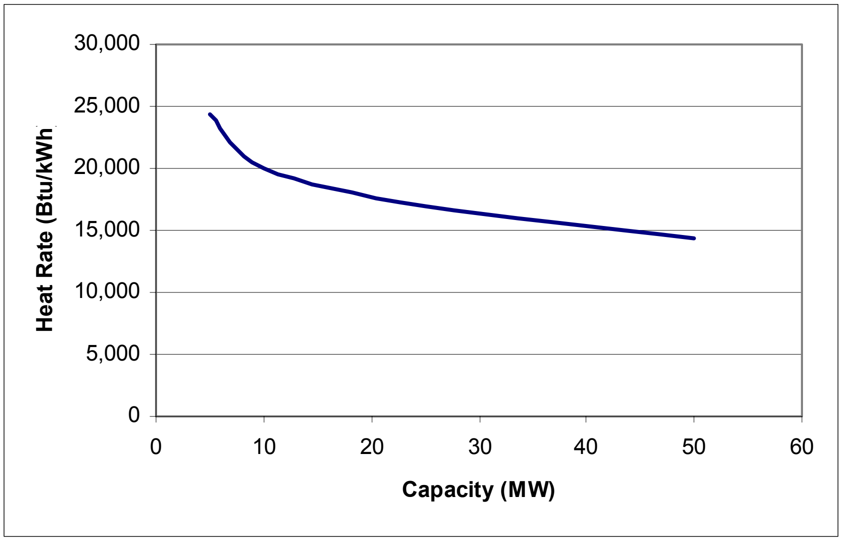

Figure 12-1. Representative efficiencies for biomass power (direct combustion)

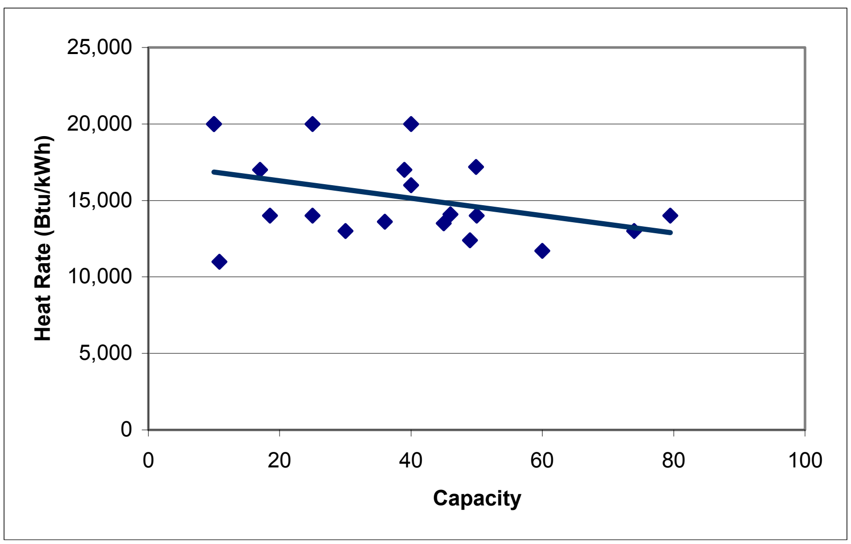

Figure 12-2. Reported heat rate for 20 operating biomass plants[112]

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).

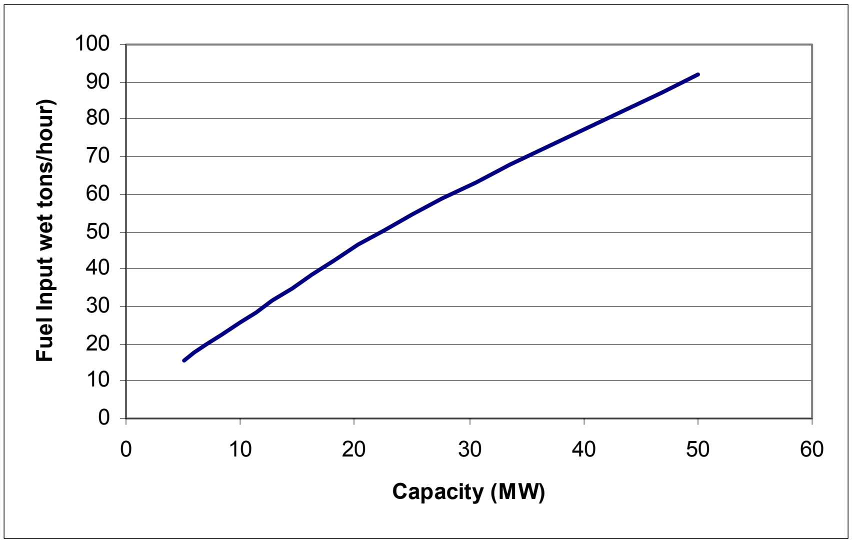

Figure 12-3. Calculated biomass fuel consumption as a function of capacity and heat rate (direct combustion)

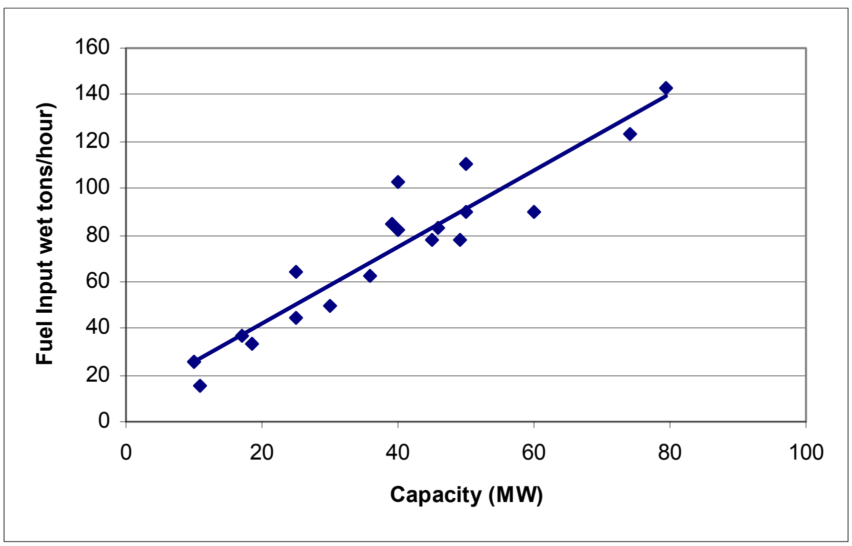

Figure 12-4. Biomass fuel consumption based on 20 operating facilities[113]

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.

[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

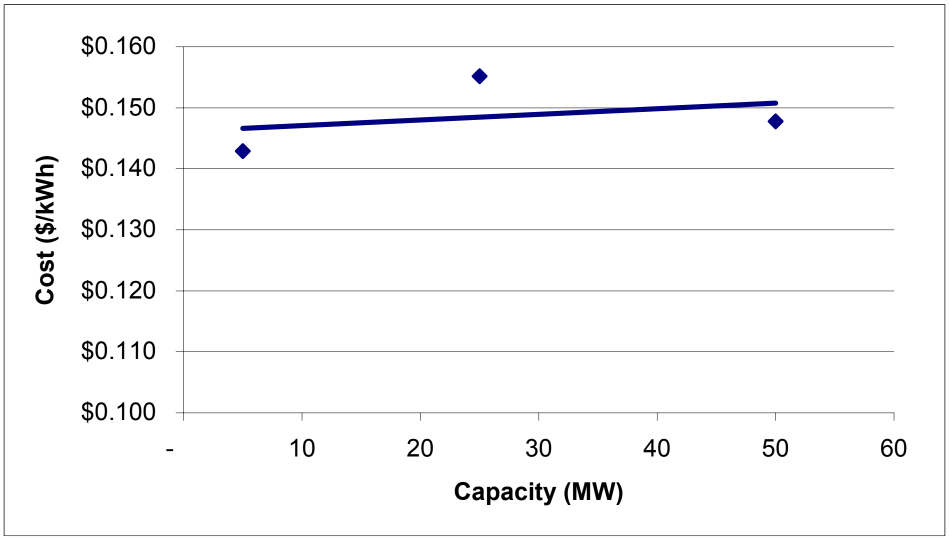

Figure 12-5. Levelized electricity cost as a function of capacity

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.

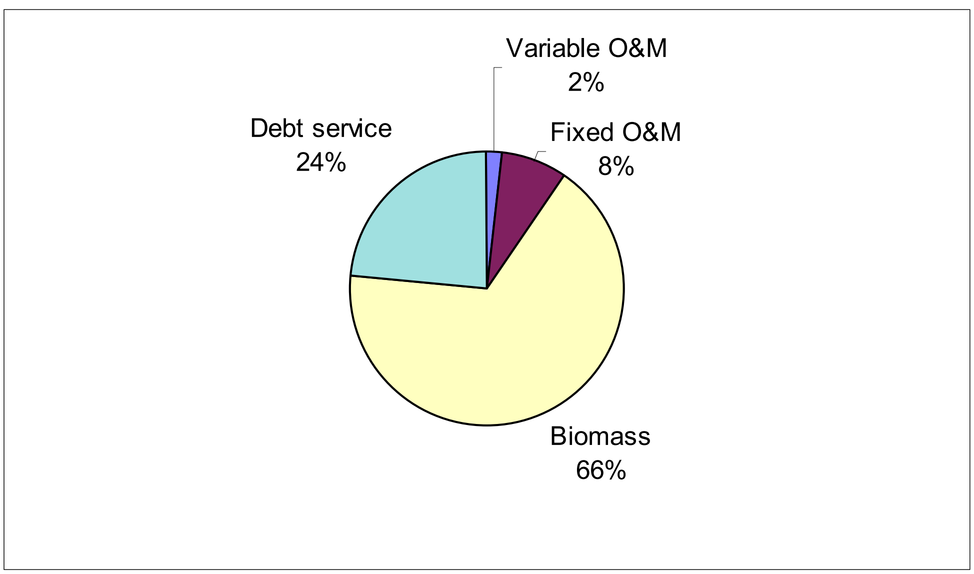

Figure 12-6. Calculated distribution of annual operating costs (5-MW direct combustion)

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.

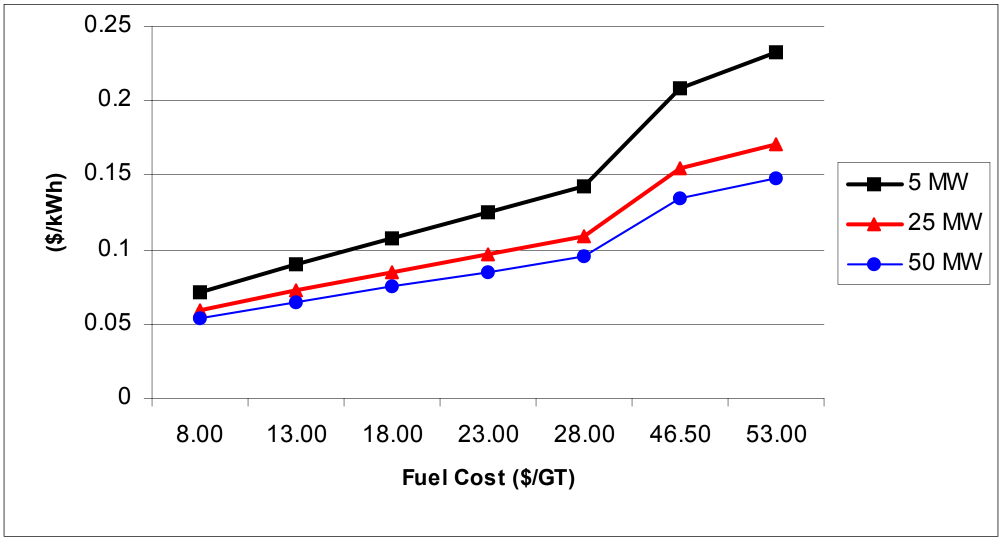

Figure 12-7. Cost of biomass electricity as a function of biomass fuel cost

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]

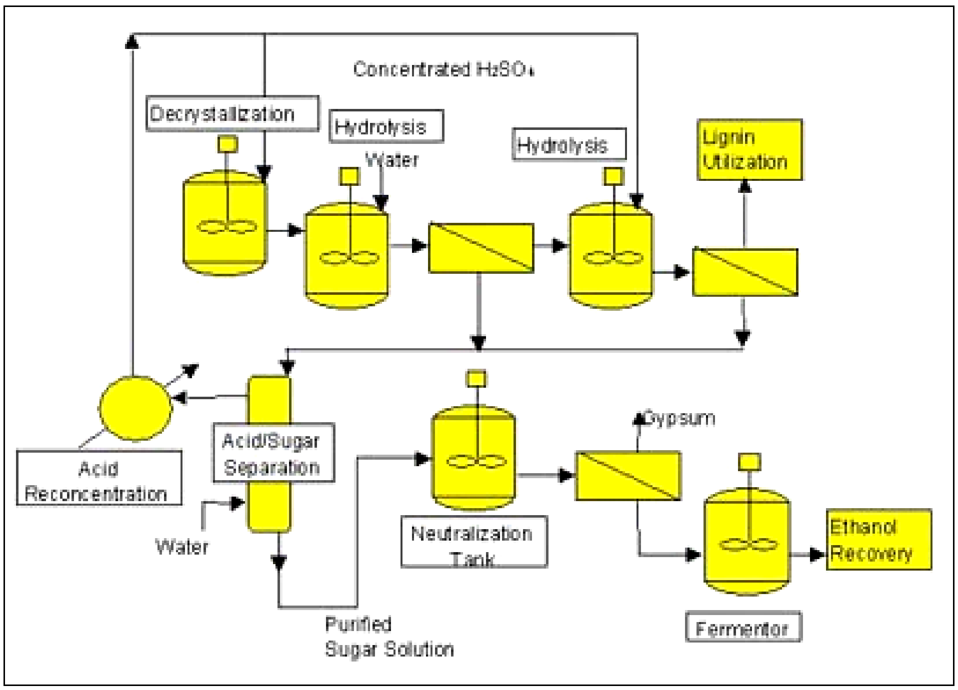

Figure 12-8. Example process flow for concentrated acid hydrolysis

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

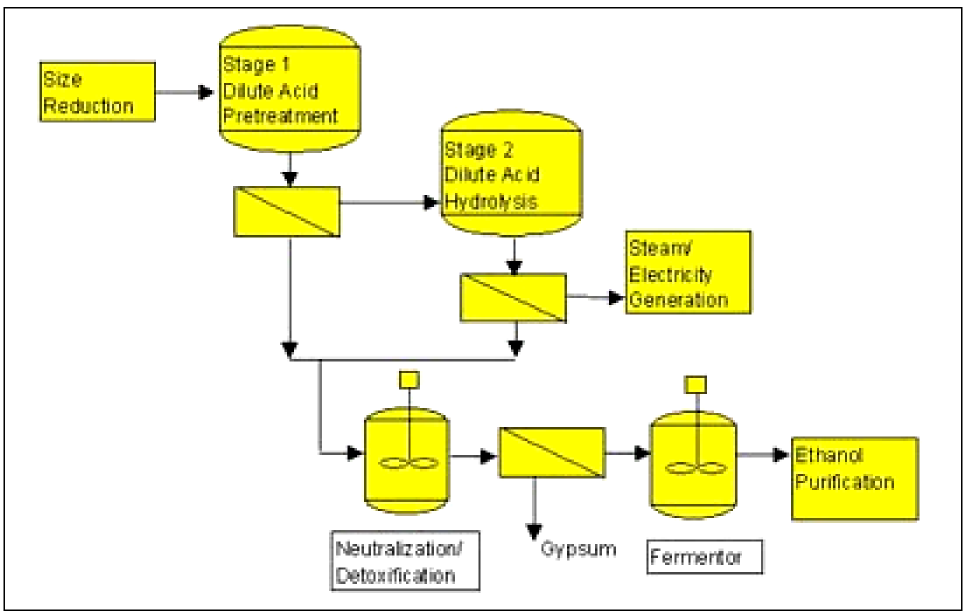

Figure 12-9. Example process flow for dilute acid hydrolysis

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.

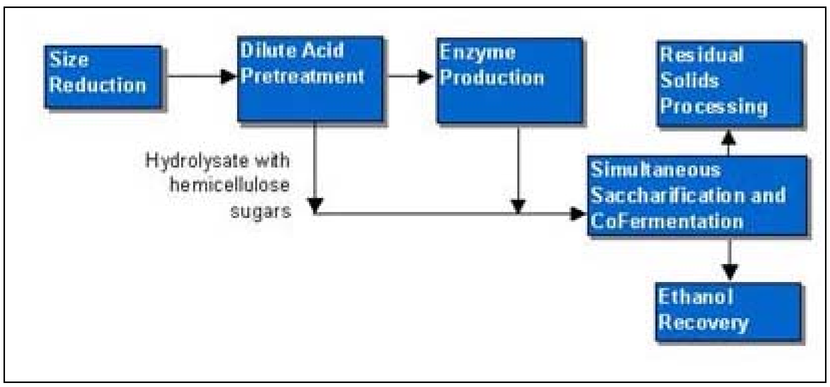

Figure 12-10. Enzyme process for simultaneous saccharification and cofermentation

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]

Biomass Gasification and Fermentation

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.

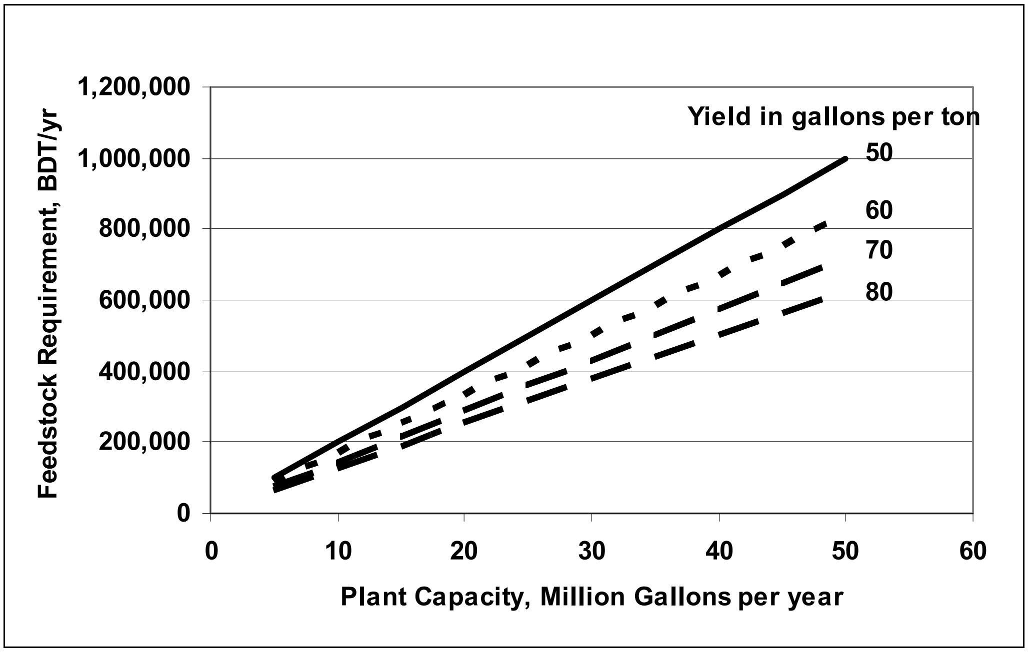

Figure 12-11. Ethanol yield and feedstock relationship

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).

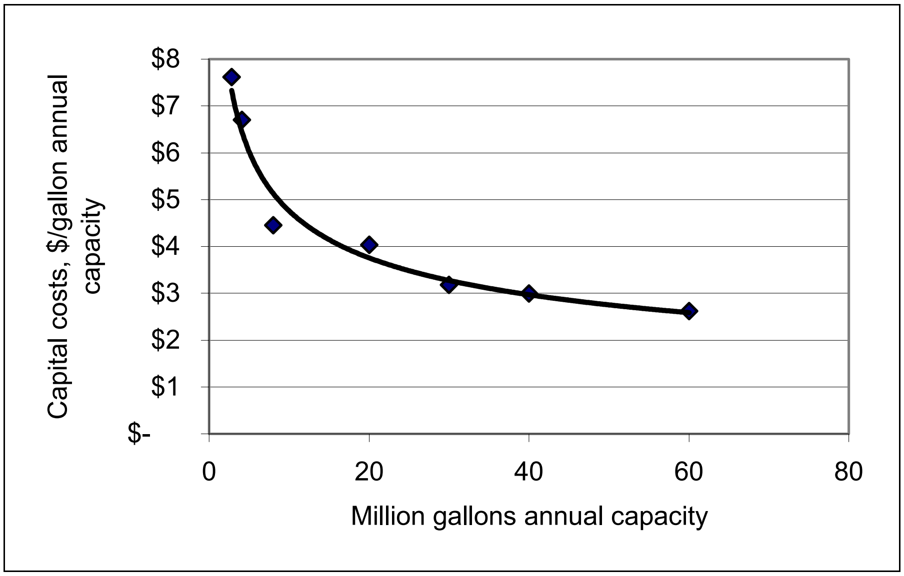

Figure 12-12. Economies of scale for cellulose ethanol facilities

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.

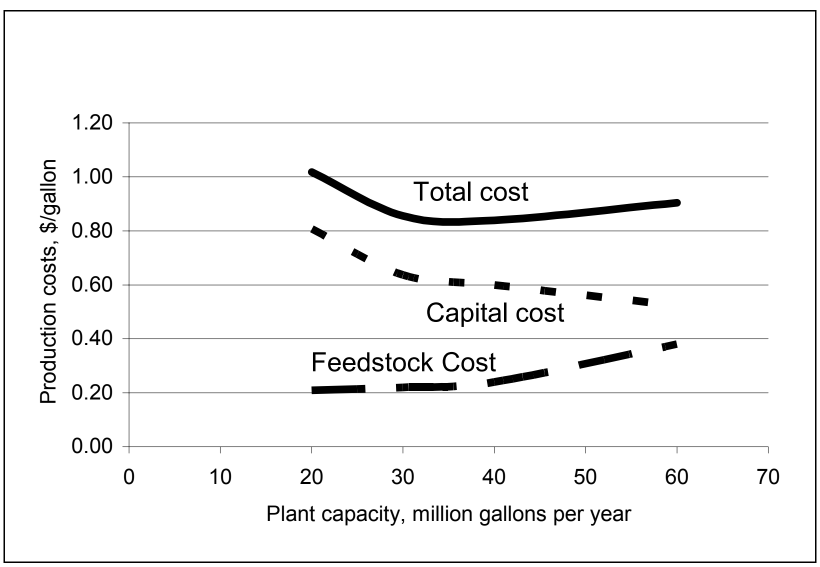

Figure 12-13. Ethanol production costs

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.

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[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.

APPENDIX A. SUMMARY OF KEY REGIONAL STUDIES

1. BLUE MOUNTAINS VEGETATION ASSESSMENT

This study consisted of three major task areas:

- Analysis of historical management activities and forest conditions
- Identification of overstocked stands; and
- Estimation of potential timber availability from overstocked stands.

The analysis of overstocked stands and potential timber volumes from these stands focused on National Forest land. The Oregon Department of Forestry provided estimates of overstocked stands on private lands.

The methods to perform each of these task areas are described below.

<u>Historical timber harvest and management</u>

The USDA TRACS-SILVA database provided acres of timber harvest, forest density management and reforestation attainments by fiscal year. Timber harvest volumes on private and National Forest lands in Baker, Grant, Harney, Malheur, Umatilla, Union, Wallowa and Wheeler Counties were determined using Oregon Department of Forestry timber harvest reports.

<u>Identification of overstocked stands</u>

Estimation of overstocked stand acreage focused on National Forest planning allocation areas called active forestry (where sustained timber harvest is permitted and likely to occur), restricted (riparian, roadless and old growth areas where timber harvest is permitted) and Lynx habitat (where timber harvest is permitted but timber harvest may be limited). The analysis excluded areas with non-forested conditions and forest reserves, which have legal, regulatory or Forest Plan restrictions on timber harvesting.

Aerial photo interpretation and analysis of existing vegetation data were used to identify overstocked stands in Umatilla and Wallowa-Whitman National Forests. Potential vegetation types, or plant associations, were aggregated into biophysical groups. Overstocking thresholds for each biophysical group were identified using methods described in Cochran et al. (Cochran)[121] and Powell.[122] Where stand information on numbers of trees or basal area per acre was not available, canopy closure was used as a surrogate for stand density and stand density thresholds.

Figure A-1 shows the location of forest planning allocations on National Forest land in the Blue Mountains.

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[121] Cochran, Geist, Clemens, Clausnitzer and Powell. *Suggested Stocking Levels for Forest Stands in Northeastern Oregon and Southeastern Washington, Research Note. RN-513* (Pacific Northwest Research Station, 1994).

[122] Powell, *Suggested Stocking Levels for Forest Stands in Northeastern Oregon and Southeastern Washington: An Implementation Guide for the Umatilla National Forest*, F14-SO-TP-03-1999 (USDA Forest Service, Umatilla National Forest, 1999).

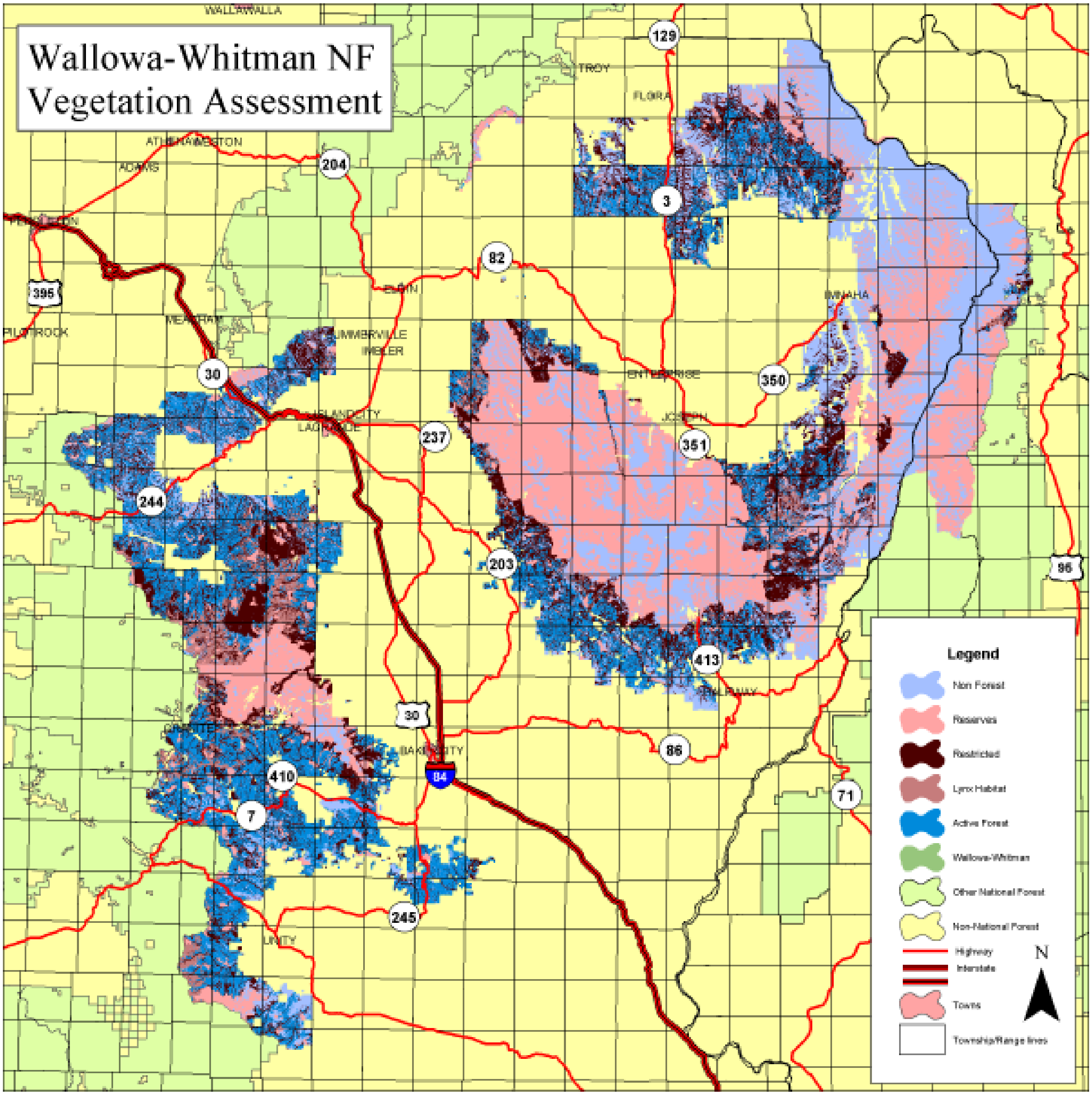

Figure A-1. Map of National Forest land showing location of active forestry and other forest management allocations in the Blue Mountains region

<u>Timber availability</u>

Continuous vegetation survey (CVS) inventory plot data from 1994 to 2001 and forest planning allocation data was used in the Forest Vegetation Simulator (FVS), a mathematical growth and yield model, to project potential timber volumes in active forestry areas in 2002. Non-forest and late and old forest structure CVS plots were removed. If multiple species were present, a preference was established that favored leaving western white pine, western larch and ponderosa pine over all other species.

Maximum Stand Density Indices (SDI) and desired residual stand densities for plots were determined based upon the plant association and stand densities identified in Cochran and Powell. Plot stand densities were compared with the maximum indices described in these papers. Plots that met the following conditions were considered overstocked and were thinned as described:

- If the stand density was more than 45% of the maximum SDI for the plot's plant association, then the stand was thinned to 35% of the maximum SDI.
- If the stand density was less than 45% of the maximum SDI for the plot's plant association, but the number of trees/acre (TPA) with diameters ranging from 0.1 to seven inches diameter breast height (DBH) was greater than 300, the stand was thinned to 135 TPA.

The stand prescription within the FVS model was "thinning from below" which emphasizes removal of smaller trees and leaving larger trees. An exception was that trees with severe mistletoe infection or other serious damage were marked for removal.

Economic analysis

Financial outcomes for management were estimated using the Financial Analysis of Ecosystem Management Activities model (FEEMA) (http://www.fs.fed.us/pnw/data/feema/feema.htm). Economics were analyzed only for removal of merchantable material. Analysis of costs for removal of non-merchantable materials was not performed.

Sawlog harvest costs in dollars per hundred cubic feet ($/CCF) for each stand were assigned based upon log size and the number of trees harvested per acre (Table A-1). Cable-based yarding systems were assumed on slopes greater than 35%.

Table A-1. Harvesting cost assumptions (in dollars per hundred cubic feet)

Tree size (CF/tree)	**Number of cut trees/acre**					
	5	**20**	**50**	**100**	**200**	**400**
Ground based harvest system						
3	104	97				
5	85	78	73			
10	67	61	57	54		
50	41	38	38	36	36	
100	38	38	38	38	36	35
150	37	37	37	37	36	35
Cable harvest system						
3	368	257				
5	385	232	178			
10	296	207	141	119		
50	86	82	75	73	72	
100	71	59	57	57	56	56
150	57	55	54	54	54	54

Table A-2 presents a range of estimated delivered sawlog costs based on the harvest cost inputs from Table A-1. These costs assume average conditions for hauling, road maintenance, contractual, and temporary road costs. The costs in Table A-2 do not represent costs of removing non-merchantable materials.

Table A-2. Estimated range of delivered sawlog costs

Cost component		Ground-based systems			Cable-based systems		
		$/CCF	$/GT[a]	$/MBF[b]	$/CCF	$/GT[a]	$/MBF[b]
Harvest costs	Low	$35.00	$68.83	$420.00	$54.00	$-	$648.00
	High	$104.00	$204.53	$1,248.00	$368.00	$-	$4,416.00
Other costs	Hauling	$27.00	$53.10	$324.00	$27.00	$53.10	$324.00
	Road Maintenance	$7.00	$13.77	$84.00	$7.00	$13.77	$84.00
	Contractual	$9.00	$17.70	$108.00	$9.00	$17.70	$108.00
	Temp. Roads	$1.00	$1.97	$12.00	$1.00	$1.97	$12.00
Delivered sawlog costs[c]	Low	$79.00	$155.37	$948.00	$98.00	$86.53	$1,176.00
	High	$121.00	$237.97	$1,452.00	$385.00	$33.43	$4,620.00

[a]Conversion from $/CCF to $/GT assumes 0.020 GT/cubic foot, based on an average of values for western white pine, Douglas-fir and ponderosa pine. Source: Colorado State Forest Service, *Forest Products Utilization Handbook* (Colorado State University, 1980), p. D-10.
[b]MBF= thousand board feet
[c] Delivered sawlog costs are the sum of harvesting and other costs.

Costs were assigned to individual forest stands based on the size and number of stems harvested per acre using cost values from Table A-1.

Positive net values resulted when log values exceeded total operation costs. Product prices for the 4th quarter of 1999 and the 4th quarter of 2001 were averaged to estimate the wood value for each log species group (Table A-3).

Table A-3. Assumed dollar value of logs delivered to a mill ($/CCF) by species grouping and small end diameter

Small End Diameter (inches)	**Douglas-fir and Larch**	**Hemlock, Grand fir and Engelmann spruce**	**Ponderosa pine**	**Lodgepole pine**
4	1	1	1	1
6	90	58	11	43
7	143	106	84	100
10	186	144	155	142
13	210	166	206	163
16	225	180	248	173
19	236	190	284	178

Source: Oregon Department of Forestry, Timber Sales, Log Price & Scaling Information. On-line: http://www.odf.state.or.us/DIVISIONS/management/asset_management/

Table A-4 summarizes the availability of National Forest land for timber harvest in the Blue Mountain region.

Table A-4. Acreage of Blue Mountains National Forest land in each land availability category

Category	Malheur		Umatilla		Wallowa-Whitman		Total	
Non-Forest	484,000	29%	188,000	13%	727,000	30%	1,400,000	26%
Reserved	248,000	15%	483,000	34%	648,000	27%	1,378,000	25%
Restricted	312,000	18%	180,000	13%	426,000	18%	918,000	17%
Lynx	7,000	<1%	105,000	8%	76,000	3%	189,000	3%
Active Forestry	647,000	38%	452,000	32%	517,000	22%	1,616,000	29%
Total	1,698,000	100%	1,408,000	100%	2,394,000	100%	5,500,000	100%

Table A-5 shows county-level estimates of acreage of overstocked forest stands on National Forest land.

Table A-5. Estimates of overstocked acres on National Forests within each county, number of inventory plots used to develop estimates and error margins

County	**Overstocked area** (000 acres)	**Number of plots**	**Overstocked area** (000 acres) yield < 4 CCF per acre of merchantable timber	**Number of Plots**	**Overstocked area** (000 acres) yield > 4 CCF per acre of merchantable timber	**Error margin** +/-	**Number of plots**
Baker	113	88	42	32	71	4	56
Grant	391	260	188	123	203	9	137
Harney	167	117	90	61	77	5	56
Morrow	51	26	33	17	18	3	9
Umatilla	58	35	38	24	20	5	11
Union	89	77	45	38	44	6	39
Wallowa	49	41	22	19	27	6	22
Crook/ Wheeler	25	14	12	7	13	2	7
Total	943	572	472	235	471	16	337

Table A-6 shows the species group composition of the sawlog volumes.

Table A-6. Percentage of sawlog volume by species group

County	Douglas fir (%)	Grand fir (%)	Ponderosa pine (%)	Lodgepole pine (%)	Juniper (%)	Larch (%)	Alpine fir/ E. spruce (%)
Baker	41	19	26	6	4	2	2
Grant	34	26	20	14	4	2	0
Harney	25	17	49	0	9	0	0
Morrow	44	17	7	15	1	11	5
Umatilla	29	28	0	34	0	1	8
Union	40	23	4	22	0	8	2
Wallowa	38	24	4	16	0	10	9
Crook/ Wheeler	41	21	26	0	2	3	6
Total	35	23	22	12	4	3	2

Table A-7 shows the estimated number of acres that can be harvested for various net present values based on the economic analysis.

Table A-7. Acreage of overstocked active forestry land (thousand acres) by net present value of harvesting operations in Blue Mountains (National Forests only)

County	Net Present Value of Treatment				
	< -$750	-$500 to -$750	-$500 to $0	$0 to $500	>$500
Baker	16.5	7.1	36.4	8.1	1.5
Grant	44.9	23.0	123.1	11.2	0.0
Harney	7	11.7	47.0	8.9	0.0
Morrow	4.3	2.4	9.9	0.9	0.0
Umatilla	1.4	4.3	14.0	0.0	0.0
Union	7.1	8.4	24.3	4.1	0.0
Wallowa	4.2	2.2	18.2	2.4	0.0
Other	6.2	4.1	0	2.7	0.0
Total	91.6	63.2	272.9	38.3	1.5

Figure A-2 shows the county-level distribution of overstocked stands by net present value of treatment.

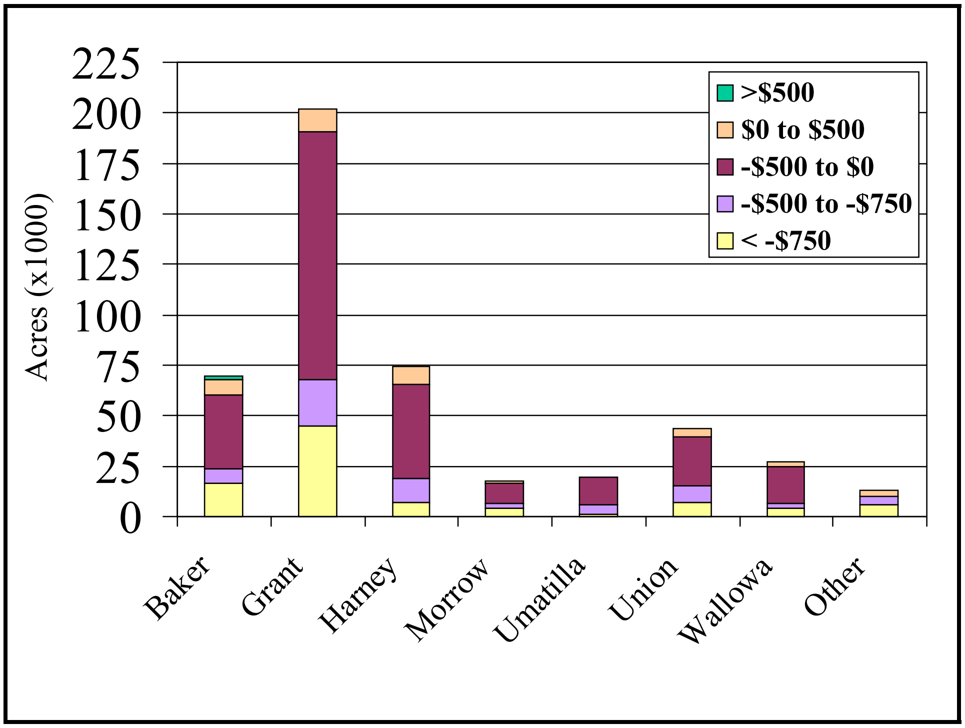

Figure A-2. Acres of overstocked stands on National Forest land by county and distribution of net values associated with thinning

Table A-8 shows the estimated number of overstocked acres on private land in the region.

Table A-8. Estimated overstocked acres on private forest land in the Blue Mountains

County	Overstocked acreage on non-industrial private lands (thousand acres)	Overstocked acreage on industrial lands (thousand acres)	Total (thousand acres)
Baker	36	4	40
Umatilla	50	22	72
Union	54	34	88
Wallowa	45	40	85
Other[a]	234	62	296
Total	419	162	581

[a] Other includes Grant, Wheeler, Harney, Morrow and Gilliam Counties

Table A-9 shows the estimated potential sawlog and gross volume of merchantable materials that can be harvested from overstocked stands with a minimum yield of 400 cubic feet per acre.

Table A-9. Potential sawlog and gross volumes from overstocked National Forest stands yielding more than 400 CF/acre

County	Potential sawlog volume (MMBF)	Error margin (+/-)	Potential gross cubic foot volume (thousand CF)	Error margin (+/-)
Baker	236	31	61	6
Grant	590	45	174	12
Harney	200	21	60	6
Morrow	68	23	18	6
Umatilla	73	24	20	6
Union	143	48	39	6
Wallowa	128	36	32	11
Crook and Wheeler	78	36	22	9
Total	1,517	95	425	24

Douglas fir, grand fir and ponderosa pine make up 80% of the volume of sawlog volume that could be removed from overstocked stands in active forestry planning areas of National Forest land in the Blue Mountains region (Table A-6).

The sawlog volume that could be removed from overstocked stands on active forestry land in the region that would result in a positive net value is 167 MMBF (+/- 36) (Table A-10).

Table A-10. Number of overstocked acres and timber volume where thinning would result in a positive net value on National Forest land

County	Overstocked area with a positive net value (000 acres)	Error margin (+/-)[a]	Sawlog volume with a positive net value (MMBF)	Error margin (+/-)[a]	Gross volume with a positive net value (MMCF)	Error margin (+/-)[a]
Baker	9.6	1.8	49	16	11	4
Grant	11.2	2.6	42	13	10	3
Harney	8.9	2.5	27	12	8	3
Morrow	1.0	-	3	-	1	-
Umatilla	0	-	0	-	0	-
Union	4.1	2.6	14	8	3	2
Wallowa	2.4	-	21	-	5	-
Crook/ Wheeler	2.7	4.8	10	4	3	2
Total	39.9	4.6	167	36	41	8

[a] The symbol "-" indicates that no confidence limits could be estimated because less than two plots were available.

2. DRY FUELS MECHANICAL TREATMENT STUDY

This study evaluated equipment productivity and cost, fuels and fire risk impacts and soil impacts of biomass removal at four sites in three states.

Of particular interest is the John Day, Ore., site, which is located in the Blue Mountains, 20 miles southeast of John Day in the Malheur National Forest and is nearest to the current study area. The stand was composed of large ponderosa pine (20-60 trees > 21 inches DBH/acre) and 800-8,000 stems of suppressed ponderosa and lodgepole pine less than six inches DBH. The prescription called for thinning trees ranging in size from saplings 1.5 feet in height to trees 9 inches DBH or less within 30 feet of large (> 21 inches DBH) ponderosa pine trees.

The main treatment impacts on fire risks and stand resilience include:

- Increased canopy base height, improving stand resistance to crown fire initiation
- Increased average stand height without a significant increase in fuel bed depth.

Figure A-3 shows pre-treatment stand conditions at the Blue Mountain trial site near John Day. Note the large number of stems and buildup of live biomass in the understory.

Figure A-3. Blue Mountain pre-treatment stand conditions

Figure A-4 shows post-treatment conditions at the Blue Mountains trial location. The Spyder 4-wheeled excavator was demonstrated at this site. This system has a mastication head with guarded blades. Note that this system distributes debris evenly along the surface floor without significantly increasing the surface fuel profile.

Figure A-4. Blue Mountain post-treatment Spyder stand conditions

<u>Equipment productivity and cost</u>

Equipment productivity and costs were estimated for each trial. Time and motion study data were collected on one day for each trial using accepted methodology. The production cycle of each system was broken down into activities such as travel, cut or process. The set of activities for a system was unique to the functions of that system. The authors used the standard methods to calculate hourly machine costs. The study's final report documents all assumptions, but overall assumptions included:

- Initial costs used were the mean of the ranges given in the system descriptions
- Machine life of five years
- Operating season of 1600 hours/year
- After five years the owner would expect to receive 20% of the purchase price for the equipment (salvage value)
- Interest cost is 10% of the average annual investment
- Insurance cost is 2% of the average annual investment
- Property tax cost is 3.4% of the average annual investment
- Fuel cost is $1.25/gallon
- Operator wages plus benefits is $20/hour
- Profit and risk is 15% of owning and operating costs, excluding labor
- All production costs ($/acre) are calculated based on 800 stems to treat per acre

Table A-11 lists the equipment costs and productivity for each system employed in the field trials. The final report describes in more detail the relative advantages and disadvantages of each system for various stand conditions. Overall, the authors noted that mastication systems with knives (e.g., Promac, Spyder) may be faster in dealing with trees less than three-inches DBH, while the mastication system with fixed teeth on a rotating wheel (Nordstrom, Unnamed Mastication System) may be faster and more efficient when treating larger trees greater than six inches DBH. The location of the biomass to be treated affects the choice of which system is most appropriate. For treating fuel loads on the ground, a mastication system with a horizontal drum (Fecon, Merri Crusher) is more appropriate than a head mounted on the end of an excavator boom (Nordstrom, Unnamed Mastication System, Spyder, Promac).

Table A-11. System hourly costs, production rates, and production costs

System	Cost/ hour	Hours/acre		Acres/8-hour day		Cost/acre	
		Low	High	Low	High	Low	High
ATV with Forwarding Arch	$23.89	32	50	0.2	0.3	$756	$1,194
CTL (Timberjack)	$228.13	3	5	1.7	2.5	$675	$944
CTL (Kobelco, Timberjack)	$184.78	6	8	1.0	1.3	$799	$999
ASV (cut and skid, two machines)	$92.37	8	9	0.9	1.0	$493	$677
ASV (cut, skid, and masticate, one machine)	$46.18	14	19	0.4	0.6	$640	$899
Yarder – Government	$42.98	23	35	0.2	0.4	$967	$1,504
Yarder - Contractor	$194.39	5	11	0.7	1.8	$875	$2,187
Fecon (ASV- mounted)	$54.07						
Fecon (excavator- mounted)	$68.69	6	10	0.8	1.3	$440	$659
Fecon (RT400- mounted)	$90.46	6	10	0.8	1.3	$579	$868
Unnamed Mastication System	$67.33	6	13	0.6	1.3	$431	$862
Promac	$68.69	5	8	1.0	1.7	$330	$550
Nordstrom	$125.84	3	6	1.3	2.5	$403	$805
Bandit (with harvester and rubber-tired skidder)	$248.34	2	3	2.5	3.3	$428	$672
Spyder	$85.40	6	8	1.0	1.3	$547	$683
Hakmet	$136.08	14	26	0.3	0.6	$1,265	$2,094

Table A-12 shows the equipment configurations used at the Blue Mountains site.

Table A-12. Equipment Configurations used at John Day Trial Location

System	System cost	Contact
Hakmet	$20,000-$30,000 Felling head $50,000-$70,000 Excavator $20,000-$30,000 Merri Crusher $70,000-$90,000 crawler tractor	Hakmet USA, Inc., Reijo "Ray" Ulmonen Phone: 800-566-0690, 530-224-1397 Cell: 530-515-8423 Fax: 530-224-1398 E-mail: kakmetus@jett.net Web: www.hakmetusa.com
Unnamed Mastication System	$35,000-$50,000 Mastication head $110,000-$130,000 excavator	None
ATV w/ Forwarding arch	$1,500 Forwarding arch $3,000 - $7,000 ATV	Future Forestry Products Mark Havel, Willamina, Ore. Phone: 1-888-258-1445 Web: www.futureforestry.com E-mail: contact@futureforestry.com
All surface vehicle (ASV) w/multiple attachments	$60,000-$80,000 ASV $8,000-$10,000 shear $5,000-$10,000 hot saw $5,000-$7,000 mastication system $3,000-$5,000 delimber $5,000-$7,000 grapple	Grouse Mountain Tractor, Byron Haberly, John Day, Ore. Phone: 541.575.2908 Web: www.ASVI.com
ASV with shear, Bobcat skid steer with grapple	$60,000-$80,000 ASV with shear $60,000-$80,000 Bobcat with grapple	Deschutes National Forest, Sisters Ranger District, Dave Moyer Phone: 541-549-7718 Cell: 541-549-7700 Email: dmoyer@fs.fed.us
Spyder 4-wheeled excavator	$290,000	Kemp West, Inc. (Kaiser Spyder) Phone: 425-334-8253 Cell: 425-508-4609 Fax: 425-334-5366 email: kari.hasko@get.net

Fire risk and fuels impacts

Fire risk and fuels impacts of treatment were examined in the study. To determine fire risk and fuels impacts, pre- and post-treatment stand conditions were modeled using the FMAPlus Program (http://www.fireps.com/fmanalyst/). The fuel model results showed that pre-treatment stand conditions at most trial locations did not pose a serious risk of either passive or active crown fire. In Washington, the Okanogan/Wenatchee pre-treatment stand exhibited conditions that showed passive crown fire when 20-foot wind speeds increased by three miles/hour to 13 miles/hour.[123] The majority of the systems showed negligible soil impacts, with the exception of systems designed to incorporate biomass into the soil.

Table A-13 shows the results of the fuels modeling for the John Day field trials.

[123] Coulter, et al., 32

Table A-13. Blue Mountain fuel model results

System	Crown Base Height (ft)	Change in Crown Base Height (ft)	Basal Area (ft^2/ac)[a]	Fire Type	Rate of Spread (ch/hr)[b]	Flame Length (ft)	Average Stand Height (ft)
Pretreatment	3		143.71	Surface	1.1	0.8	23
Hakmet	32	29	203.91	Surface	2.1	1.4	65
Unnamed Mastication System	51	48	203.91	Surface	2.1	1.4	79
ATV	81	78	330.27	Surface	4.4	2.1	63
ASV	50	47	64.51	Surface	1.1	0.8	103
Spyder	22	19	10.05	Surface	2.1	1.4	65

[a] Square feet/acre
[b] Chains/hour. A chain is a U.S. survey unit that is the equivalent of 66 feet (20.1 meters)

In all but two cases, the post-treatment stand conditions did not support active or passive crown fires. In the two exceptions (Idaho City Bandit and Okanogan/Wenatchee Fecon treatments), the model showed that post-treatment conditions were conducive to passive crown fire.

The results show a significant increase in both crown base height and stand height for each harvesting system demonstrated. The model results in Table A-13 show slight increases in rate of fire spread and flame length in the post-treatment stands for trials that used mastication systems, which the authors attribute to that fact that in the post-treatment stands, what had once been vertical biomass was now distributed on the forest surface.[124] In the majority of the treatment areas, there was not a significant increase in the forest surface vertical fuel profile.

The increase in fire spread and flame length in the post-treatment stand, combined with an increase in canopy base height, suggest that while a fire in the post-treatment stand may move slightly faster than in the pre-treatment condition, there is less likelihood of a passive or active crown fire since the fire itself will remain near the forest surface. The changes in flame length and fire spread should be considered in light of the fact that the pre-treatment stand did not pose a large risk of active or passive crown fire. A more significant comparison could be made between a pre-treatment stand at greater risk of crown fire and a post-treatment stand thinned to a similar characteristic as the trial location.

Figure A-5 shows the changes in canopy base height between pre- and post-treatment stands.

[124] E. Coulter, K.Coulter, T. Mason, J. Szymoniak and L. Swan, *Dry Forest Mechanized Fuels Treatment Trials Project* (Central Oregon Intergovernmental Council, October 24, 2002, http://www.theyankeegroup.com/mechfuels/), p. 32.

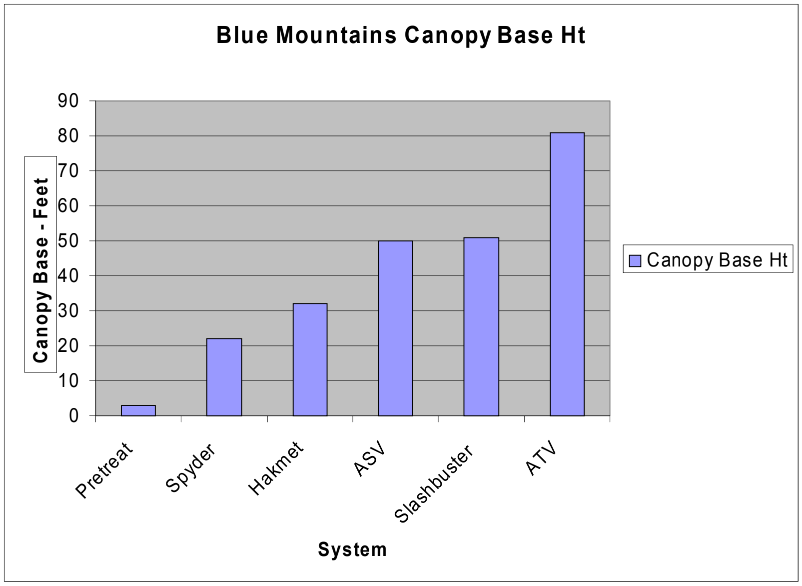

Figure A-5. Blue Mountain canopy base height difference

The ATV system produced the largest change in canopy base height, followed by the ASV systems, Hakmet system and Spyder system.

Extractive systems (e.g., ATV, ASV/Skid Steer systems) reduced the potential crown percentage scorched and risks of tree mortality. Extractive systems left debris in piles or in skid trails, while mastication systems distributed debris evenly across project sites.[125]

Soil impacts

Treatment impacts on soil resources were estimated using a visual soil assessment protocol created by Weyerhaeuser and later adapted by Steve Howes, USFS Soils Program Manager for Washington and Oregon. The soil disturbance class values range from “0” to “6.” Increasing values represent greater levels of soil disturbance. The values shown in Table A-14 show the percentage of observations within each disturbance class at the John Day site.

Table A-14. Soil impact summary for the John Day site

Disturbance Class	Pre-Treatment	Unnamed Mastication System	ASV	ATV	Hakmet	Spyder
0- Undisturbed	0%	0%	0%	5%	0%	0%
1 – Slight disturbance	33%	43%	50%	86%	14%	21%
2 – Some disturbance	0%	52%	43%	9%	36%	79%
3 – Moderate disturbance	67%	4%	7%	0%	50%	0%
4 – High disturbance	0%	0%	0%	0%	0%	0%
5 – Severe disturbance	0%	0%	0%	0%	0%	0%
6 – Altered drainage	0%	0%	0%	0%	0%	0%

[125] Ibid., p. 33.

Discussion

The fire model results did not present definitive support for the effectiveness of the mechanical thinning treatments in reducing initiation of active and passive crown fire. In part, this is because of an issue with the choice of trial locations. The fuel model results for the pre-treatment stands showed that there was no serious risk of either active or passive crown fire at any of the trial locations. Only the fire model results for the Okanogan/Wenatchee pre-treatment stand conditions showed a likelihood of active or passive crown fires, and then only in the case of stronger wind speeds. The fuel model results show that the post-treatment stand conditions are not, in most cases, likely to support active or passive crown fires. However, this only supports the assertion that mechanical thinning is not likely, under most circumstances, to exacerbate crown fire risks. Without pre-stand conditions that show evidence of the likelihood of supporting active or passive crown fires, the effectiveness of mechanical treatments in reducing fire risks at these locations cannot be determined.

The result showing that the treatments increased canopy base height suggest that the treatments were likely to reduce the risk of initiation of crown fires. In addition, other studies conducted throughout the western U.S. support the effectiveness of mechanical thinning in the reduction of crown fire risks.

Using the fire model to compare the results of fire behavior in pre- and post-treatment stands under elevated wind speeds would supplement the study results by showing the effectiveness of the treatments in preventing crown fires in conditions of elevated wind speed. It has been shown that wind speed is an influential factor in the spread of crown fires in the western U.S. In addition, selection of pre-treatment stands that exhibit conditions that are supportive of active or passive crown fires could provide more information about the effectiveness of stand treatment in preventing crown fires.

3. OREGON CELLULOSE-ETHANOL STUDY

This section summarizes some of the major findings of the Oregon Cellulose-Ethanol Study, which was completed in June 2000. This Appendix draws from material presented in the final project report.[126] The study reviewed policies that support ethanol industry development, resource availability, cellulose-ethanol technology and economic viability of ethanol manufacturing.

At the time of publication of the study, ethanol was used primarily in EPA oxygenated fuels program areas, including the Portland Metropolitan Area, Klamath Falls and Medford. The oxygenated fuels plan remained in place in Portland because of a state comprehensive air quality plan, even though Portland was reclassified in 1997 as “in-attainment” for EPA air quality standards. The Federal Highway Administration estimated ethanol use in Oregon to be 13.9 million gallons in 1998, though some fuel marketers reported that actual ethanol use may be twice that amount. At the time of the study, there were no ethanol production facilities in Oregon. Most ethanol used in the state comes from the Midwest or the Caribbean.

Some of the policy justifications cited in the study for promoting the production of ethanol from cellulose materials in Oregon included waste reduction, sustainable economic development, greenhouse gas mitigation and provision of a viable alternative to MTBE as an oxygenate for reformulated gasoline. By using waste resources to produce ethanol, Oregon would have an in-

[126] A. Graf and T. Koehler, *Oregon Cellulose-Ethanol Study* (Oregon Department of Energy, June 2000).

state source of renewable fuels and would keep dollars in the state, rather than sending them to out-of-state ethanol manufacturers. Cellulose ethanol manufacturing would likely have a positive effect on rural areas of the state, where economic development needs are most pressing.

The viability of the cellulose ethanol industry depends on the status of cellulose ethanol technology but also on future gasoline and ethanol markets. Cellulose ethanol technology has not yet been demonstrated on a commercial scale, with the exception of one plant that uses sugars from liquid residues from pulp operations. The authors cited a report from the Energy Information Administration that estimated cellulose ethanol manufacturing costs would range from $1.15 to $1.43 per gallon but that technology advances could reduce this cost to $0.69 to $0.98 per gallon over the next two decades. This could make ethanol cost-competitive with wholesale gasoline. Ethanol costs are also dependent on biomass resource costs and availability.

The study found that the biomass resource in Oregon could support a substantial cellulose ethanol industry. More than 8.5 million oven dry tons (ODT) of biomass were generated in 1998 in Oregon, according to estimates provided in the study. This quantity was a gross figure. Some portion of this quantity would not be available for use. However, if it were possible to utilize all of this material, the biomass resource could be used to produce more than 500 million gallons of ethanol per year. The study found that the economically recoverable resource was sufficient to support about 170 million gallons of ethanol manufacturing per year, not including forest residues. If forest residue could be cost-effectively and dependably removed, total potential ethanol production would increase to a total of 364 million gallons per year. In any of these resource scenarios, the resource would support production of all of Oregon's fuel ethanol requirements (based on 1998 usage) and would provide additional ethanol to meet growing ethanol demand in other states.

Agricultural residue, the largest component, represented approximately 49% of the estimated biomass resource, forest residue made up 35%, municipal solid waste (MSW) made up 15% and other sources made up the remaining 1% of the estimated resource.

The total quantity of agricultural residue generated in Oregon could be used to produce over 200 million gallons of ethanol each year (see Table A-15). However, not all of this residue was considered available for ethanol production.

Table A-15. Agricultural residue generation and ethanol potential in Oregon

Residue type	Land area planted (Acres)	Conversion factor (ODT/acre)	Total generation (ODT/year)
Nurseries/Greenhouses	38,100	1	38,100
Grass Seed	461,900	2.1	969,990
Wheat	885,000	2.3	2,035,500
Hay	970,000	0.3	291,000
Potatoes	58,000	1.2	69,600
Pears	17,800	2.3	40,940
Onions	19,500	1	19,500
Cherries	11,000	0.4	4,400
Mint	42,000	1	42,000
Hazelnuts	29,100	1	29,100
Apples	29,100	2.2	64,020
Sweet corn	8,700	4.7	40,890
Beans	95,060	1	95,060
Barley	130,000	1.3	169,000
Oats	54,000	1.2	64,800
Sugar beets	17,500	2.4	42,000
Grapes	7,100	1	7,100
Strawberries	4,440	0.3	1,332
		Total (ODT/year)	**4,024,332**
		Estimated total ethanol potential (Gallons/year)	**201,200,000**

The composition of the statewide biomass resource from the Oregon Cellulose-Ethanol study was similar to the results for the current study in that wheat straw, grass straw and oats are primary constituents of the resource. Hay was not evaluated for the current study, as it was not a major crop in Northeast Oregon.

Table A-16 provides Oregon Department of Environmental Quality data for the biomass components of MSW generated in Oregon in 1998. MSW was not included in the biomass resource assessment for the current study. However, estimated annual biomass fraction of MSW generation for Baker, Union and Wallowa Counties totals 6,184 ODT per year, based on the figures in Table A-16. This relatively small quantity could supplement agricultural and forest biomass in larger biomass energy applications, or it could be used in smaller facility-heating applications.

Table A-16. Cellulosic biomass fractions from MSW recovered in Oregon

County	Maga-zines	Cardboard/ Kraft paper	Phone books	High grade paper	Newspaper	Mixed waste paper	Total paper	Wood waste	Yard debris	Total all
Baker	97.9	993.5	-	35.0	207.8	85.3	1,419.6	14.6	602.8	2,037.0
Benton	25.4	6,381.7	3.5	1,145.4	2,988.3	2,724.2	13,268.5	2,527.5	11,267.2	27,063.1
Clatsop	203.6	2,710.4	4.4	352.0	1,004.4	13.1	4,287.9	322.0	1,338.1	5,948.0
Columbia	146.5	2,054.9	-	1,630.8	658.2	484.4	4,974.8	1,566.4	8.8	6,550.0
Coos	341.8	4,449.5	-	95.5	1,444.8	271.1	6,602.7	1,993.0	875.8	9,471.6
Crook	-	643.1	3.1	42.4	266.8	-	955.5	481.5	-	1,437.0
Curry	93.8	1,522.9	10.0	21.3	532.1	92.3	2,272.4	-	-	2,272.4
Deschutes	714.9	8,226.0	52.4	570.7	2,816.6	253.0	12,633.6	15,979.5	8,726.4	37,339.5
Douglas	312.1	5,475.2	26.4	371.1	1,679.6	183.8	8,048.3	8,799.7	12,058.6	28,906.5
Gilliam	2.8	54.1	-	2.0	39.6	2.7	101.2	-	-	101.2
Grant	11.0	179.4	-	28.0	64.8	5.8	289.0	14.6	-	303.7
Harney	-	197.5	-	10.3	76.7	0.3	284.8	296.2	-	581.1
Hood River	74.8	1,224.9	6.7	47.3	335.8	-	1,689.6	-	55.8	1,745.4
Jackson	514.8	14,427.1	112.8	1,006.8	4,391.5	371.7	20,824.8	25,891.0	13,427.5	60,143.3
Jefferson	17.6	668.6	3.0	40.4	185.4	-	915.0	2,305.5	-	3,220.6
Josephine	4.6	4,013.7	50.5	583.5	1,944.4	10.9	6,607.6	8,247.7	5,119.8	19,975.1
Klamath	52.7	2,664.6	-	238.6	974.9	149.0	4,079.8	2,097.5	2,305.5	8,482.7
Lake	-	135.5	-	7.2	1.4	-	144.1	-	2.5	146.6
Lane	423.0	30,560.7	118.1	5,500.3	13,251.0	8,210.2	58,063.3	49,501.4	20,706.8	128,271.4
Linn	682.2	7,731.3	0.0	1,018.9	4,127.1	1,440.6	15,000.1	4,947.1	8,549.9	28,497.2
Lincoln	127.3	3,782.1	0.1	94.3	1,271.9	1,318.6	6,594.4	59.1	375.1	7,028.6
Malheur	100.2	3,072.1	-	72.1	527.6	-	3,772.0	90.0	-	3,862.0
Metro	20,170.0	179,220.4	1,784.3	51,132.3	98,849.2	59,356.1	410,512.3	176,069.8	148,756.5	735,338.6
Milton & Freewater	11.1	485.8	0.1	23.8	124.8	22.1	667.6	22.0	160.0	849.6
Marion	956.6	19,361.0	155.8	4,008.6	8,401.3	3,019.3	35,902.4	17,854.6	25,887.3	79,644.4
Morrow	-	660.8	-	9.1	101.7	-	771.6	-	-	771.6
Polk	301.6	3,591.2	22.8	651.4	2,136.0	221.3	6,924.3	493.0	3,260.8	10,678.1
Sherman	22.8	48.6	1.0	5.1	59.3	-	136.7	-	-	136.7
Tillamook	106.7	1,105.2	-	39.6	841.1	23.5	2,116.0	-	0.2	2,116.3
Umatilla	103.1	6,661.6	2.5	113.0	759.7	221.6	7,861.5	1,577.4	459.6	9,898.5
Union	181.5	1,886.9	-	35.6	356.8	267.4	2,728.1	539.6	645.0	3,912.8
Wallowa	-	159.6	-	7.0	61.6	-	228.3	2.0	4.0	234.3
Wasco	90.6	1,704.3	-	36.1	698.1	38.9	2,568.0	1,282.5	1,927.0	5,777.5
Wheeler	2.1	23.8	-	1.5	6.0	-	33.4	10.9	7.3	51.7
Yamhill	449.4	5,419.9	10.1	472.3	2,826.8	21.9	9,200.4	3,701.5	12,221.8	25,123.7
Totals	26,342.4	321,498.1	2,367.6	69,449.3	154,013.1	78,809.1	652,479.7	326,687.7	278,750.1	1,257,917.5

Source: A. Graf and T. Koehler, *Oregon Cellulose-Ethanol Study* (Oregon Department of Energy, June 2000), p.16.

Estimates of biomass generation were also developed on a regional level for Oregon. Figure A-6 shows the areas used in the breakdown of regional biomass availability in Oregon. The Eastern Oregon region for this study extends from the north all the way to the southern border of the state and includes Wallowa, Union and Baker Counties.

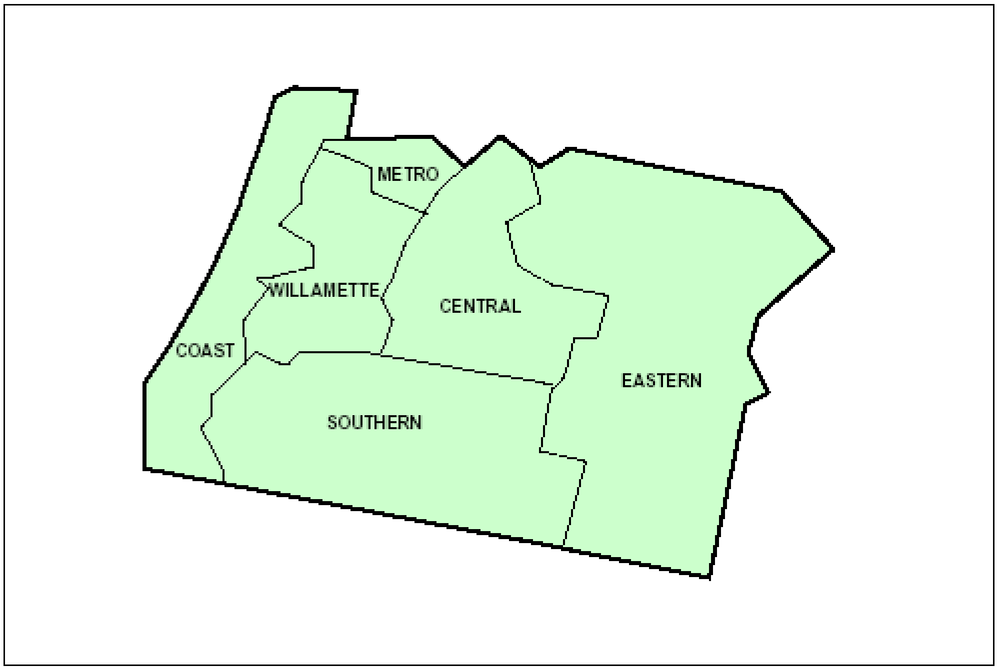

Figure A-6. Regional breakdown for biomass resource estimation

Table A-17 provides estimates of regional biomass generation in Oregon based on the regions delineated in Figure A-5. These estimates exclude biomass potentially recoverable from forest thinning activities.

Table A-17. Estimated feedstock potential by region (ODT/year)

Feedstock	Coast	Willamette	Metro	Central	Eastern	Southern
Mixed waste paper	26,848	138,359	412,203	18,115	6,583	39,705
Yard debris	3,941	79,025	176,070	20,060	2,535	45,036
Green waste	0	148,812	10,661	1,711	0	2,598
Wheat straw	0	81,894	0	0	2,100,000	32,914
Grass straw	0	1,000,000	0	0	0	0
Paper sludge	73,584	91,980	18,396	0	0	0
Total	**106,971**	**1,391,258**	**755,481**	**48,836**	**2,110,829**	**117,655**

Note: Other agricultural residue is not shown. In addition, there are an estimated 2.9 million tons of forest thinnings potentially available. However, further research is necessary to determine the location and amounts of recoverable thinnings.

APPENDIX B. BIBLIOGRAPHY OF BIOMASS STUDIES

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x							x		3	Barbour et al., *Forest Resources in Eastern Oregon – Developing tools for assessing disturbance, succession, and management opportunities into the future* (http://www.oregonforestry.org/sustainability/symposium/barbour_files/frame.htm, 2001 Oregon Forest Sustainability Summit).
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APPENDIX C. BIOMASS ESTIMATE TABLE

Table C-1. Estimated annual forest biomass generation (GT/year) – High and low values reflect variability in annual management intensity

Landowner/ treatment type	Fuels reduction yield 10 GT/acre			Fuels reduction yield 5 GT/acre			Fuels reduction yield 15 GT/acre		
	Avg.	High	Low	Avg.	High	Low	Avg.	High	Low
USFS									
Fuels treatment[a]	42,405	66,940	17,870	21,203	33,470	8,935	63,608	100,410	26,805
Non-commercial thinning[b]	33,710	35,670	31,750	16,855	17,835	15,875	50,565	53,505	47,625
TSI [b]	79,120	94,900	61,980	39,560	47,450	30,990	118,680	142,350	92,970
Timber residues	99,447	176,432	53,468	99,447	176,432	53,468	99,447	176,432	53,468
State									
Timber harvest residues	1,247	2,015	392	1,247	2,015	392	1,247	2,015	392
Industrial private									
Timber residues	176,027	239,988	117,329	176,027	239,988	117,329	176,027	239,988	117,329
Fuels treatment	16,402	6,561	24,603	8,201	3,280	12,302	24,603	9,841	36,905
Nonindustrial private									
Timber residues	100,509	155,968	38,517	100,509	155,968	38,517	100,509	155,968	38,517
County/municipal									
Timber residues	694	2,086	19	694	2,086	19	694	2,086	19
Totals									
Fuels treatment, non-commercial thinning	92,517	109,171	74,223	46,259	54,585	37,112	138,776	163,756	111,335
TSI	79,120	94,900	61,980	39,560	47,450	30,990	118,680	142,350	92,970
Timber residues	377,925	576,488	209,725	377,925	576,488	209,725	377,925	576,488	209,725
Total - all sources	549,562	780,559	345,928	463,743	678,524	277,826	635,380	882,595	414,029

[a] Source: U.S. Forest Service, GEOMAC National Fire Plan Maps. On-line: http://wildfire.geomac.gov/NFPmaps/viewer.htm?extent=Oregon. Accessed March 19, 2003. 2000 -2001 National Fire Plan Fuels Reduction Project data for Congressional District 4102.
[b] U.S. Forest Service Monitoring Reports for Wallowa-Whitman and Umatilla National Forests: 1998-2000.

APPENDIX D. LIST OF POTENTIAL CONVERSION SITES

County	Site notes	Include as site?	Site name	Address	City	Lat	Lon
Baker	Too far from forested areas	N	Ash Grove Cement Co.	33060 Shirt Tail Creek Rd.	Durkee	44.32000	(117.24550)
Baker	In urban boundary	N	Behlen Manufacturing	4000 23rd St.	Baker City	44.79498	(117.85791)
Baker	Not enough information	N	Bourne Mining Corporation - Cracker Creek Gold Mine		Bourne	44.83167	(118.20000)
Baker	Next to airport	N	Farwest Concrete	Airport Lane	Baker City	44.78010	(117.82863)
Baker	Not enough information	N	Northwest Pipeline Corporation			44.79841	(117.73607)
Baker	In urban boundary	N	Triple C Redi Mix	42434 Attwood Rd	Baker City	44.78010	(117.82863)
Baker	Not enough information	N	UNC Cornucopia Mining CO, Inc.		Halfway	45.01022	(117.19500)
Baker	Good potential site	Y	Ellingson Lumber S. Baker		Baker City		
Baker	Prior cogen location (1980s	Y	Former Ellingson Lumber site	3000 Broadway	Baker City		
Baker	Rural site	Y	Former Ellingson Lumber site	38350 Sawmill Cutoff Rd	Halfway		
Union	In urban boundary but with rail access, industrial area, land availability questionable	N	Del Monte Corporation	1621 Spruce	La Grande	45.31660	(118.08130)
Union	1 mile south of La Grande on 84 - current use unknown	N	RD Mac	60831 McCalister Rd	La Grande	45.30787	(118.04508)
Union	Not enough information	N	Teague Mineral Products		Malheur	45.08000	(118.16190)
Union	Near airport	N	Union County Airport Industrial Site		La Grande		
Union	Too small	N	Union Industrial Park		Union		
Union	Near airport	N	USFS La Grande Air Tanker Base	60131 Pierce Rd	La Grande	45.28417	(118.00083)
Union	Not enough information	N	Western Farm Service/Crop Production Services Inc	64325 Booth Lane	La Grande	45.36300	(117.99920)
Union	Bought by ethanol develope	Y	Baum Industrial Park		La Grande		
Union	Yes	Y	Boise Cascade Elgin Complex	90 S. 21st St	Elgin	45.55667	(117.91278)
Union	Yes	Y	Boise Cascade La Grande Sawmill	Jackson and Willow St	La Grande	45.31472	(118.05167)
Union	Yes	Y	Boise Cascade Particleboard Island City	62621 Oregon Hwy 82	La Grande	45.32778	(118.02140)
Union	Yes	Y	Borden Chemical Co Inc	62675 Oregon Hwy 82	La Grande	45.35930	(118.00950)
Union	University	Y	Eastern Oregon State College	1 University Blvd	La Grande	45.31667	(118.08444)
Union	Maybe	Y	Elgin Industrial Park		Elgin		
Union	New industrial park	Y	Gelmekern Industrial Park		La Grande		
Union	Retired biomass power plant	Y	Idaho Timber Corporation		North Powder	45.05631	(118.04508)
Union	Shut down - no heat load	Y	North Powder Lumber Co.	105 2nd St	North Powder	45.03320	(117.90740)
Union	In urban boundary but with rail access, industrial area, land availability questionable	Y	Oregon Trail Electric Coop	2408 Core Ave	La Grande	45.32574	(118.06874)
Union		Y	Western Ag Services	Oregon Hwy 82	Alicel		
Wallowa	Very small bronze casting	N	Joseph Bronze	83365 Joseph Hwy	Joseph	45.36194	(117.25528)
Wallowa	Very small bronze casting	N	Parks Bronze	331 Golf Course Rd	Enterprise	45.43639	(117.28639)
Wallowa	Very small bronze casting	N	Valley Bronze of Oregon	307 W Alder	Joseph	45.36667	(117.16667)
Wallowa	Yes	Y	Bates mill site		Wallowa		
Wallowa	Yes	Y	Great Western Pellet Mill	708 Golf Course Rd	Enterprise	45.43370	(117.28940)
Wallowa	No sewer	Y	Joseph mill site		Joseph		
Wallowa	Yes	Y	Wallowa Forest Products LLC	Lower Diamond Prairie Rd		45.34000	(117.30460)

APPENDIX E. PERMITTED BOILERS IN STUDY AREA

Name	Manufacturer	Fuel	Capacity	Units	Use	Notes
Eastern Oregon University, La Grande						
21508	Cleaver Brooks	NG	25.1	MMBtu/hr	9 months	
21510	Cleaver Brooks	NG	25.1	MMBtu/hr	9 months	
41812	Kewanee	NG	3.35	MMBtu/hr	3 months	
41817	Kewanee	NG	0.95	MMBtu/hr	3 months	
67713	Lochivar	NG	0.5	MMBtu/hr	12 months	
2703	AO Smith	NG	0.9	MMBtu/hr	12 months	
28834	Aerco	NG	1	MMBtu/hr	3 months	
65463	PVI	NG	0.5	MMBtu/hr	12 months	
Boise Cascade, La Grande						
#1	Cleaver Brooks	NG	20.7	k#/hr	12 months	323.7 Mft3 NG/yr for all boilers
#2	Cleaver Brooks	NG	20.7	k#/hr	12 months	350 Mlb steam/yr all boilers
#3	Cleaver Brooks	NG	20.7	k#/hr	12 months	in 1997 had 11 hog fuel boilers
No name						1-10 dutch ovens 40k#/hr
No name						11 Stearling 12.5k#/hr
No name						
Joseph Timber, Joseph						
No name	ABCO	bark	15.9	k#/hr	6424 hrs	60.342Mlb#/yr
No name						installed 1978
No name						source tested July 2001
No name						rated at 25k#/hr
No name						
Marvin Wood Products, Baker City						
4 boilers		NG	2	MMBtu/hr /hr	17838hrs	hrs for all four boilers
No name						permit limit 18 Mft3/yr
Borden Chemical, Island City						
#1		NG & H2	20	k#/hr	7887hrs	41.662 Mft3 NG/yr
#2		NG	30	k#/hr	8688 hrs	18,193 tons H2/yr
Johnson Lumber, Wallowa						
No name	Wellons	hog fuel	16	k#/hr		20.9 MMBtu/hr fuel input
No name						installed 1991
No name						78 M#/yr in 2002
No name						former Wallowa Forest Prod
No name						source tested 1999 7,700 #/hr
No name						1997 burned 14k hog fuel
Boise Particle Board, Island City						
#1		NG/sander dust	28	k#/hr		162M#steam/yr
#2		NG/sander dust	28	k#/hr		
Boise Elgin						
#1		hog fuel				332,503 M lb steam/yr
#2		hog fuel	50.941	k#/hr		303,751 M lb steam/yr
No name						# 2 source tested 9/18/02

Source: Oregon Department of Environmental Quality. Note: k#/hr = thousand lb/hour, M lb = million lb, Mft3 = million cubic feet, NG = natural gas

APPENDIX F. SUSTAINABILITY FOCUS GROUP MATERIALS

AGENDA

Date:	**November 21, 2002**
Time:	**12 PM to 5 PM**
Location:	**Grande Ronde Model Watershed Offices, La Grande, OR** **10901 Island Avenue La Grande, OR 97850 Phone: 541-962-6590**

12:00 – 12:10 Welcome and introductions

12:10 – 12:30 Project review (Scott Haase and Tim Rooney, McNeil; Jim Kerstetter, Consultant

Session 1: Forest biomass supply sustainability

12:30 – 1:00 Overview of forest sustainability criteria & indicators

This presentation will present an overview of forest management priorities and the results of existing efforts to evaluate forest sustainability in Northeastern Oregon.

1:00 – 2:30 Questions for discussion

- How can biomass utilization affect forest sustainability in Northeastern Oregon? *(review pros and cons in light of Montreal Process criteria and indicators, Forestry Program for Oregon objectives)*
- How can foresters optimize the benefits and minimize negative impacts of biomass collection and utilization? *(See Oregon Forest Practice Rules)*
- How can forested areas best be prioritized as candidates for treatment and biomass removal in Blue Mountains region? (*see Blue Mountains Demonstration Area Restoration Strategy*)
- What characteristics would exclude forested areas as candidates for management? (*see Blue Mountains Demonstration Area Restoration Strategy*)
- What legal, regulatory and economic issues affect the potential for biomass utilization? *(see Forestry Program for Oregon)*

2:30 – 2:45 Summary

2:45 – 3:00 Break

Session 2: Agricultural biomass supply sustainability

3:00 – 3:30 Overview of agricultural sustainability in Northeastern Oregon

This is an overview of agricultural practice standards, key issues for sustaining agricultural land in Northeastern Oregon, and potential economic and environmental impacts of biomass utilization.

3:30 – 4:45 Questions for discussion

- How does crop residue utilization affect agricultural sustainability in Northeastern Oregon? *(see Burn or bale: effect on biomass and nutrient and Farming with the Wind)*
- What site criteria limit the potential to collect and utilize crop residues (e.g., slope, soil type, water quality, soil erosion potential, soil productivity, crop cover type, residue yield)?
- What practices can producers use to optimize the benefits and minimize negative impacts of crop residue collection and use? *(See Farming with the Wind, Nitrogen uptake and utilization by Pacific Northwest Crops, Oregon NRCS Residue Management Practice Standard 344)*
- What legal, regulatory and economic issues affect the potential to collect and use crop residues?

4:45 – 5:00 Summary, conclusions and next steps

Recommended reading in preparation for focus group

Forest Biomass

Forest Restoration Strategies

- Blue Mountains Demonstration Area. BMDA Restoration Strategy. Joint project: U.S. Forest Service, EPA, NOAA, FWS, BLM and the Oregon Governor's Office. On-line at: http://www.fs.fed.us/bluemountains/docs/restoration_strategy.htm

Forest Policy

- Oregon Board of Forestry. Forestry Program for Oregon (1995 and draft 2003 version). On-line at: http://www.oregonforestry.org/fpfo/1995/default.htm
  (2003 version still under development)

Assessing Forest Sustainability

- Oregon Report on Montreal Criteria and Indicators. Oregon Department of Forestry. On-line: http://www.oregonforestry.org/sustainability/first_approximation_report.htm. (see also: Montreal Process Criteria and Indicators, under "National/international assessment of sustainability " heading in "References for additional information"). These Montreal Process criteria are a widely used basis for establishing a framework to discuss sustainability in forest and other resource management practices.

Agricultural Biomass

Crop Residue Utilization – Sustainability

- Douglas, Clyde L. Jr. and Stephen L. Albrecht. Burn of Bale: Effect on Biomass and Nutrients. In: Columbia Basin Agricultural Research Annual Report. Spec. Rpt. 1012, pp. 46-50. 2000. Oregon State University, in cooperation with USDA Agricultural Research Service, Pendleton, OR.
- Farming with the Wind, "Managing Soil Cover and Roughness" Chapter 4, soil loss ratio, wind erosion, estimating surface cover, residue retention and tillage, Northwest Columbia Plateau Wind Erosion/Air Quality Project, 2002. Online at: http://pnwsteep.wsu.edu/winderosion/index.htm
- Nitrogen Uptake and Utilization by Pacific Northwest Crops. On-line: http://eesc.orst.edu/agcomwebfile/EdMat/PNW513.pdf A Pacific Northwest Extension Publication. PNW 513.
- Oregon NRCS Residue Management Practice Standard 344. On-line: ftp://ftp.or.nrcs.usda.gov/pub/fotg/FOTG-Oregon/Section-4/Standards/344std.doc or for all Oregon NRCS Practice Standards: http://www.or.nrcs.usda.gov/fotg/sec4updated.htm

References for additional information

Oregon/regional information/ guidance on forest sustainability

Legal/regulatory/policy framework

- Oregon Forest Practices Act ORS 527. 610 - .770 & .990 - .992. On-line at: http://www.leg.state.or.us/ors/527.html
- Oregon Forest Practice Rules (legal authority taken from Oregon Forest Practices Act. On-line at: http://arcweb.sos.state.or.us/rules/OARS_600/OAR_629/629_tofc.html
- Assessing Forest Sustainability in Oregon. Brown, James, Oregon Department of Forestry. October 21, 2001. On-line at: http://www.oregonforestry.org/sustainability/symposium/brown_files/frame.htm
- Working Together To Facilitate Change: 2001 Pacific Northwest Community Forestry Public Lands Policy Organizing Meeting. Wallowa Resources and Sustainable Northwest. December 12-14, 2001. Portland, Ore. On-line: http://www.hfhcp.org/policy/121202.pdf

Regional assessments of sustainability

- 2001 Oregon Forest Sustainability Summit On-line: http://www.oregonforestry.org/sustainability/symposium/presentations_long.htm
- Forest Resources in Eastern Oregon – Developing tools for assessing disturbance, succession, and management opportunities into the future. Barbour et al. At 2001 Oregon Forest Sustainability Summit. On-line at: http://www.oregonforestry.org/sustainability/symposium/barbour_files/frame.htm

National/international assessment of sustainability

- Montreal Process Criteria and Indicators for the Conservation and Sustainable Management of Temperate & Boreal Forests. On-line at: (http://www.sustainableforests.net/C&I_workshops/Criteria&Indicators.htm)
- Roundtable on Sustainable Forest Management (http://www.sustainableforests.net/) – U.S. Federal government (12 agencies) working toward Winter 2002/2003 release of comprehensive "National Report on Sustainable Forests"
- USDA Forest Service Local Unit Criteria and Indicators Development Project (http://www.fs.fed.us/institute/lucid/)

Data sources

- Federal Geographic Data Committee Sustainable Forest Data Working Group http://www.pwrc.usgs.gov/brd/sfd.htm
- Interior Northwest Landscape Analysis System – developed by USFS PNW Research Station in cooperation with a wide group of scientists (http://www.fs.fed.us/pnw/lagrande/inlas/) – Uses Upper Grande Ronde watershed as a study area to assess succession and disturbance patterns under various policy and management regimes – builds on CLAMS project. Contact Pete Bettinger, OSU Department of Forest Resources 237 Peavy Hall Corvallis, Ore. 97331-5703 Phone: (541) 737-8549 E-mail: pete.bettinger@orst.edu
- Forestry Sciences Laboratory at Oregon State University (http://www.fsl.orst.edu/) Coastal Landscape Analysis and Modeling Study (CLAMS)
- USDA PNW Ecosystem Management Decision-making Systems. Knowledge Based Decision Support for Ecological Assessment http://www.fsl.orst.edu/emds/ - multiple data sources. Forest sustainability database/GIS data permit the Evaluation of forest ecosystem sustainability on a national and regional scale based on the criteria and indicators of the Montreal Process. Contact: Keith Reynolds – Corvallis Forest Sciences Lab, PNW Research Station, USFS. E-mail: kreynolds@fs.fed.us

Table F-1. Focus group attendees

Name	Affiliation	E-mail	Phone
Dale Case	Agriculture	sandridgeag@hotmail.com	541-663-1806
John Manwell	Boise Cascade Corp.	John_Manwell@bc.com	541-962-2045
Jim Kerstetter	Consultant	jimkerstetter@attbi.com	360-753-7433
Vernon Tritchka	Eastern Oregon Economic Development Group (EOEDG)	vernon@engineer.com	541-963-4433
Brett Brownscombe	Hells Canyon Preservation Council	brett@hellscanyon.org	541-963-3950
Lisa Dix	Hells Canyon Preservation Council	ldix@hellscanyon.org	541-963-3950
Scott Haase	McNeil Technologies, Inc.	shaase@mcneiltechco.com	303-273-0071
Tim Rooney	McNeil Technologies, Inc.	trooney@mcneiltechco.com	303-273-0071
Angie Johnson	Oregon Department of Forestry	ajohnson@odf.state.or.us	541-963-3168
Diane Partridge	Oregon Department of Forestry	dpartridge@odf.state.or.us	541-963-3168
Rick Wagner	Oregon Department of Forestry	rwagner@odf.state.or.us	541-963-3168
John White	Oregon Department of Energy	john.white@state.or.us	503-378-3194
Brett Kelver	Oregon Rural Action	brett@oraction.org	541-975-2411
David Whitson	Oregon Rural Action		541-663-1841
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Ron Eachus	SED Inc.	re4869@attbi.com	503-361-0116
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APPENDIX G. STATE FARM WILDFIRE PROGRAM

State Farm's Wildfire Program:

Taking Steps to Protect the Property
and Lives of our Policyholders

Program Goals:

While wildfire risk has always been a part of the Arizona landscape, it has become an increasing hazard over the last several years due to drought conditions, record low snow pack, fuel buildup and growing development in the wildland urban interface. To address these concerns, State Farm created a program that will be implemented in Arizona, Nevada, New Mexico, Utah, Colorado, and Wyoming. It will:

1) Protect the homes, personal property and lives of our customers.
2) Create a safer environment for the fire and emergency officials who respond to wildfires.
3) Educate our customers who live in the interface areas about the dangers associated with wildfires and how they can better protect their property and themselves.
4) Reduce the potential for and severity of future financial losses caused by these types of tragedies.

State Farm's hope is not to lose any customers because of the program.

Wildfire Program Details:

Over the next three years, 22,000 homes within the states of Arizona, Nevada, New Mexico, Colorado, Utah, and Wyoming will be surveyed. The surveyors will conduct an outside inspection of the home to identify whether or not any additional steps need to be taken to help better protect the property from future wildfires.

The homes were selected because they are in the highest hazard wildfire prone areas. This was determined by a combination of factors: vegetation or fuels, topography (slope and aspect), population density, lightning strike density, and the proximity of roads and railroads.
Each homeowner in the areas State Farm has identified as part of the program will receive a letter approximately one to two weeks prior to the survey, making him or her aware that it is going to take place. Because the survey is exterior only, the homeowner is not required to be on site.

During the survey, the vendor will identify possible hazards on the property. If the steps necessary to fix the hazards are minor in nature, we will send a letter to the customer approximately two to four weeks following the inspection, listing the items to address and notifying the homeowner that he or she has up to two years to correct those items.

If the property requires significant measures to address the hazards, we will send the customer a letter asking that he or she contact local fire officials to arrange to have an expert visit the property and develop a plan to better protect his or her property. The letter will also advise the customer that he or she will have 18-24 months to obtain the plan and complete the items noted on the plan. Any charges assessed for the help of a local fire or emergency management official is the responsibility of the customer.

Our customer's State Farm agent will follow-up to verify that the recommended measures are completed or are underway. If a homeowner chooses not to complete these safety measures, putting his or her property and the lives of fire officials at greater risk, we would look at options including the non-renewal of his or her property.

QUESTIONS AND ANSWERS:

Q. Is State Farm surveying all of the homes you insure in the wildfire areas?

A. No, we are surveying only a percentage of the homes we insure in the wildfire areas. We are concentrating on those homes in the highest hazard wildfire areas in Arizona, Nevada, New Mexico, Colorado, Wyoming and Utah.

Q. Will State Farm cancel the insurance of customers who refuse to complete the recommended mitigation work?

A. We hope that working with these customers in the highest hazard wildfire areas over the period of 18-24 months will encourage them to take the appropriate action on their property. However, if some refuse to do any work, putting his or her property and life at risk, as well as the lives of local fire officials, we would look at options to address the situation, including non-renewal.

Q: Who will pay for any charges assessed by local fire or emergency officials asked by a State Farm customer to survey the property and create an extensive plan to better protect the property?

A: Any payments for these or other related services would be the responsibility of our customer.

Q. What if one of your customers cannot afford to do the work?

A. There are many national, state and local grants and cost-share programs that may be able to provide funds to homeowners or communities. Many of these can be found by calling the local district office of the state forest service or a local fire authority. These offices also have lists of FireWise contractors who can be contacted regarding their services.
For additional information about the program, please contact Jordan Marsh at (480) 293-6520. Media inquiries should be directed to May Hendershot at (970) 395-5401.

APPENDIX H. SUMMARY OF BIOMASS INCENTIVES

1. FEDERAL BIOMASS HEAT AND POWER INCENTIVES

Section 45 - Renewable Energy Production Tax Credit

Section 45 of the Internal Revenue Code permits taxpayers to take a credit of 1.5 ¢/kWh for electricity generated from "closed-loop biomass" projects, adjusted periodically for inflation. In 2003, the tax credit amount was 1.8 ¢/kWh. In the fall of 1999, Congress amended Section 45 to let facilities using poultry waste for energy take advantage of the tax credit. The new rule also extended the "placed-in-service" date for qualifying facilities to December 31, 2003.[127]

The proposed Energy Policy Act of 2003 included a provision that would open the biomass credit to allow existing and new biomass plants to claim the credit for using biomass resources such as forest thinnings and mill residue and extend the eligibility date for facilities. However, Congress had not approved this legislation as of the date of this report.

Renewable Energy Production Incentive (REPI)

Section 1212 of the 1992 Energy Policy Act allows DOE to make incentive payments, adjusted annually for inflation, for electricity generated and sold by qualifying facilities. Qualifying facilities are eligible for annual incentive payments of 1.5 cents/kilowatt-hour expressed in 1993 dollars and indexed for inflation for the first ten year period of their operation, subject to the availability of annual appropriations in each Federal fiscal year of operation. The REPI authorizes direct payments to project owners from annual Congressional appropriations. Payment depends on availability of funds.

Qualifying electric production facilities are those owned by state and local government entities (such as municipal utilities) and not-for-profit electric cooperatives that started operations between October 1, 1993 and September 30, 2003. Provisions to extend this credit were contained in the Energy Policy Act of 2003, but Congress had not approved the legislation as of the date of this report. Qualifying facilities must use solar, wind, geothermal (with certain restrictions as contained in the rulemaking) or biomass (except for municipal solid waste combustion) generation technologies. Additional criteria for qualifying facilities and application procedures are contained in the rulemaking for this program.

The regulations for the administration of the REPI program are contained in Title 10 to the Code of Federal Regulations, Part 451 (10 CFR 451). The final rulemaking, which contains clarifying supplementary information, is contained in 60 CFR 36959.

Although the REPI is comparable in amount to the Section 45 production tax credit, congressional appropriations have not been adequate to fully fund payments to qualifying facilities. Because of this uncertainty, developers have been cautious in counting on REPI payments when assessing project economics.

Additional information on REPI can be found at: http://www.eere.energy.gov/power/repi.html.

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[127] North Carolina Solar Center, *DSIRE: Renewable Energy Production Credit* at: http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=US13F&State=Federal&currentpageid=1

Special Depreciation Rules for Biomass Energy Facilities

Short depreciation lives are available for certain biomass energy facilities. A five-year tax life applies to biomass power facilities with a capacity of 80 megawatts or less. [128] A seven-year tax life applies to property used in biomass conversion to a solid, liquid or gaseous fuel.[129]

Tax-Exempt Financing

Assuming that the facility has more than 10% private business use, a biomass project can qualify for tax-exempt financing if it fits into one of two categories: 1) the project supplies gas or electricity to an area no larger than two contiguous counties or one city and a contiguous county, or 2) the facility is a solid waste disposal facility.[130]

Sulfur Dioxide Emission Allowances

The Clean Air Act Amendments of 1990 allow public utilities to receive one emission allowance per ton of SO_2 emissions avoided through energy efficiency or renewable energy projects. This program includes a bonus pool of emissions allowances to reward utilities for new renewable energy projects. Co-firing biomass with coal is one way that utilities can reduce SO_2 emissions from coal-fired power plants and qualify for emissions allowances.[131]

Carbon Offsets

The Energy Policy Act of 1992 contains provisions that allow public utilities to voluntarily report actions taken to reduce or sequester greenhouse gas emissions.[132] The U.S. Climate Leaders Program (http://www.epa.gov/climateleaders), sponsored by the EPA, provides industry with tools to help them reduce greenhouse gas emissions. Biomass energy projects are one way in which companies can reduce greenhouse gas emissions.

Green tag credit

Green tag values are not a government incentive but are instead based on market conditions and negotiated agreements between the buyer and seller. Values for green tag transactions range from $0.001/kWh to $0.04/kWh. For additional information on green tags, see: http://www.resource-solutions.org/TRCs.htm.

2. FEDERAL ETHANOL INCENTIVES

Federal Regulatory Programs Requiring Ethanol Use

Federal regulatory requirements for cleaner burning fuels have played a significant role in developing ethanol markets. In addition, these requirements have resulted in tax incentives being developed to help alleviate the costs of complying with federal air quality regulations. For these

[128] U.S. Department of Energy, Energy Efficiency & Renewable Energy, Biopower Program, *Biopower – Policy – Federal Tax Credits* (http://www.eere.energy.gov/biopower/policy/po_ftc.htm#ftc1).
[129] Oregon Department of Energy, *Biomass Energy Incentives* (http://www.energy.state.or.us/biomass/Incentive.htm).
[130] U.S. Department of Energy, Energy Efficiency & Renewable Energy, Biopower Program, *Biopower – Policy – Federal Tax Credits* (http://www.eere.energy.gov/biopower/policy/po_ftc.htm#ftc1).
[131] Oregon Department of Energy, *Biomass Energy Incentives* (http://www.energy.state.or.us/biomass/Incentive.htm).
[132] Oregon Department of Energy, *Biomass Energy Incentives* (http://www.energy.state.or.us/biomass/Incentive.htm).

reasons, it is useful to provide some background on the regulatory requirements that have so greatly influenced the development of the fuel ethanol industry in the U.S.

The Clean Air Act of 1970 authorized the EPA to promulgate regulations regarding the quality of conventional fuels. In 1990, the Act was amended to include establishing air quality standards related to vehicle emissions. The EPA subsequently established the National Ambient Air Quality Standards (NAAQS) covering carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter, ozone and lead. Urban areas were required to use cleaner burning fuels if they did not meet the clean air standards. Adding oxygen to gasoline improves combustion efficiency, thereby reducing a variety of air emissions. Ethanol contains 35% oxygen. Substituting ethanol for gasoline results in a reduction of CO, volatile organic compounds and NO_x emissions.[133]

The EPA established a winter oxygenated fuels program for CO nonattainment areas and a year-round reformulated gasoline program for ozone nonattainment areas. For the winter oxygenated fuels program, the minimum oxygen requirement was equivalent to a 7.7% ethanol blend. Ozone nonattainment areas were required to use reformulated gasoline to lower volatile organic compounds by 15% in 1995 and 25% in 2000. Reformulated gasoline must contain a minimum equivalent of 5.7% ethanol by volume. This regulation is applicable only in the summer months, whereas air toxins regulations apply year-round. The Phase II Reformulated Gasoline standards specify maximum benzene content, minimum oxygen content and performance standards for volatile organic compounds (VOCs) in the summer and nitrogen oxides and toxic air pollutants year-round. Refiners must make reductions against a 1990 "baseline gasoline."[134]

Demand for ethanol increased as a direct result of these federal programs. According to a recent study, "The majority of the increase in ethanol demand in the past 10 years has resulted from these programs. Since 1990, the nation's ethanol production capacity has more than doubled from 850 million gallons/year to 1.779 billion gallons in total production capacity in 1999."[135] In addition, the recent phase-out of methyl tertiary butyl ether (MTBE) in California as a fuel additive has increased demand for ethanol. This has led to a need for increases in production capacity. For ethanol to fully replace MTBE, the demand for ethanol in California could reach 550 million gallons per year.[136]

Oregon developed an oxygenated fuels program as part of its comprehensive air quality maintenance plan in response to the national Clean Air Act Amendments of 1990. While Oregon has met air quality standards, it continues to implement the program to sustain its air quality.

Federal Tax Credits for Blenders

The Energy Tax Act of 1978 established a tax exemption for gasohol containing 10% ethanol. The amounts of the tax exemption for blends of less than 10% ethanol (7.7% and 5.7%) are prorated. There are two ways a blender can take advantage of this tax credit: a federal excise tax exemption or an income tax credit.[137] These tax credits were recently extended until 2007. Gasoline refiners, marketers and users (not ethanol producers) are eligible for these tax credits.[138]

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[133] A. Graf and T. Koehler, *Oregon Cellulose-Ethanol Study* (Oregon Department of Energy, June 2000), pp. 70-71.
[134] Graf and Koehler, 71.
[135] Graf and Koehler, 71.
[136] Graf and Koehler, 5.
[137] IRS, Publication 510 (http://www.irs.gov/publications/p510/ar02.html#d0e2693).
[138] Renewable Fuels Association, *The Federal Ethanol Program* (http://www.ethanolrfa.org/leg_position_fed.shtml).

Federal Excise Tax Exemption for Gasohol

Gasoline is taxed at 18.4 cents per gallon. Ethanol fuel blends sold by refiners or marketers are taxed at a reduced rate, thereby helping ethanol be more cost competitive. The DOE Energy Information Administration (EIA) predicted that an extension of the tax exemption would increase the ethanol production capacity from grain and cellulose biomass to 2.8 billion gallons per year.[139] Current ethanol production capacity is 2.9 billion gallons per year.[140] Table H-1 shows the 2003 excise tax reduction for the production of gasohol.

Table H-1. Federal excise tax rate reduction in 2003[141]

Ethanol blend (% by volume)	**Tax reduction** (cents/gallon)
10	3.734
7.7	2.804
5.7	2.031

Income Tax Credits

Under the Crude Oil Windfall Profits Action of 1980, it became possible to receive an income tax credit instead of the excise tax forgiveness. The blender must have a tax liability to which the credit can be applied. The income tax credit is applicable to the use or sale of straight alcohol as a fuel (ethanol or methanol) and alcohol mixtures.[142]

Table H-2 shows the amount of this income tax credit for straight ethanol and ethanol blends.

Table H-2. Federal income tax rate reduction for ethanol in 2003[143]

Ethanol blend (% by volume)	**Tax reduction** (cents/gallon)
100	52.000
10	5.200
7.7	4.004
5.7	2.964

Small Ethanol Producer Tax Credit

Small ethanol producers, defined as a producer with an annual production capacity of 30 million gallons or less, are allowed a 10 cents/gallon income tax credit for the first 15 million gallons produced annually.[144]

Deductions for Clean-Fuel Vehicles and Refueling Property

In 1992, the Energy Policy Act (EPACT) required government and private fleets (having 20 or more vehicles in metropolitan areas with more than 250,000 people) to include alternative fuel

139 Graf and Koehler, 9.
140 Renewable Fuels Association, *U.S. Fuel Ethanol Production Capacity* (http://www.ethanolrfa.org/eth_prod_fac.html).
141 IRS, *Form 720 – Quarterly Federal Excise Tax Return* (http://www.irs.gov/pub/irs-fill/f720_d.pdf).
142 IRS, *Alcohol Fuel Credit* (http://www.irs.gov/publications/p378/ch04.html).
143 IRS, *Form 6478 – Credit for Alcohol Used as Fuel* (http://www.irs.gov/pub/irs-pdf/f6478.pdf).
144 Renewable Fuels Association, *Modifications are Needed to Make the Small Ethanol Producer Credit Workable for Farmer* (http://www.ethanolrfa.org/leg_position_smallproducer.shtml).

vehicles in their fleets. The requirement ranges from 30% to 90% of fleet vehicles. The requirement may be met by using fuels containing at least 85% alcohol by volume. Other possibilities include: natural gas, propane, hydrogen, liquid fuels from coal and electricity.

Individuals and businesses are eligible for tax deductions of $2,000 for cars and up to $50,000 for certain types of trucks and vans. The deduction will be gradually phased out by 2005. Property used to store or dispense clean fuel is deductible up to $100,000.[145]

Corporate Alcohol Fuel Credit

Businesses that sell or use alcohol fuels or fuel blends may qualify for an income tax credit. Credits range from $0.3926 to $0.60/gallon, depending on the proof and type of alcohol. [146]

3. FEDERAL BIOMASS TECHNICAL AND FINANCIAL ASSISTANCE PROGRAMS

In addition to offering tax and other production incentives for biomass power and biofuels production, the federal government offers a wide variety of technical assistance and financial assistance in the form of grants for feasibility assessment, research and development, technology demonstration and other efforts aimed at commercializing biomass technology. This section reviews some of the key programs that offer these types of support.

USDA/DOE Joint Biomass Research and Development Initiative

The Biomass Research and Development Initiative supports the advancement of biobased products and bioenergy in order to further the goals of strengthening farm income, creating new jobs in rural communities, enhancing energy security and reducing pollution. The vision that DOE and USDA have set forth for biobased products and bioenergy is to increase the share of biomass power to 5%, transportation fuels to 20% and biobased products to 25% of their respective markets by 2030.[147] The Initiative sponsors programs to support research and development, commercialization and public education efforts. Moreover, programs have been developed to provide technical and financial assistance for producers of bioenergy products. See the Biomass Research and Development Initiative (http://www.bioproducts-bioenergy.gov/) for more information about grants and other funding opportunities.

USDA Value-added Agricultural Producer Grants

An additional $27.7 million was available in FY 2003 through USDA's Value-Added Agricultural Producer Grants program to support feasibility assessments, business planning and working capital for new value-added agricultural products.[148] For more information about this program, contact the Oregon representative for USDA for the program, Robert Haase, via phone: (541) 926-4358 x 124 or e-mail: bob.haase@or.usda.gov.

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[145]North Carolina Solar Center, *DSIRE: Incentives by State* at: http://www.ies.ncsu.edu/dsire/library/includes/incentive2.cfm?Incentive_Code=US30F&State=Federal&currentpageid=1 .

[146]North Carolina Solar Center, *DSIRE* at: http://www.ies.ncsu.edu/dsire/library/includes/incentive2.cfm?Incentive_Code=US30F&State=Federal&currentpageid=1

[147]National Biomass Coordination Office, *Feedstock Map Released,* (http://www.bioproducts-bioenergy.gov/news/DisplayRecentArticle.asp?idarticle=115, January 2004).

[148] USDA Rural Business Cooperative Services, *Value-added Producer Grants* (http://www.rurdev.usda.gov/rbs/coops/vadg.htm).

USDA Rural Business-Cooperative Service

There are a handful of programs under the USDA Rural Business-Cooperative Service that broadly support the development of rural businesses. Fiscal year 2003 funding for the Rural Business-Cooperative Service was as follows:

- Business and Industry Guaranteed - $900 million plus $309 million carryover
- Intermediary Re-lending Program - $40 million
- Rural Business Enterprise Grant - $47.99 million
- Rural Economic Development Loan - $15 million
- Rural Economic Development Grant - $4 million
- Rural Business Opportunity Grant - $4 million[149]

Loan guarantees for biomass conversion into bioenergy are available under the Business and Industry Guaranteed Loan Program. The objective is to create employment in rural areas by expanding the lending capacity of commercial lenders. Up to 90% of a loan made by a commercial lender can be guaranteed, and the maximum loan size is $25 million.[150]

The Intermediary Relending Program provides financing to business facilities and community development projects through intermediaries. The intermediaries establish revolving loan funds for this purpose.[151]

The Rural Business Enterprise Grant program provides funds to public bodies, nonprofit organizations and Indian Tribal groups to finance small business enterprises in "urbanizing areas" outside cities with populations of over 50,000. Grant funds are not provided directly to the business.[152]

Rural Economic Development Loans can be provided at 0% interest to electric and telephone utilities. The utility must re-lend the money at 0% interest to a third-party for the purpose of job creation. Priority is given to areas with populations of less than 2,500 people.

Rural Economic Development Grants are available for rural economic development purposes. Grants are provided to electric and telephone utilities and are used to establish revolving funds. The utility must contribute 20% of the funding for each grant administered.[153]

The Rural Business Opportunity Grant program seeks to promote sustainable economic development in rural communities with exceptional needs. Grants cover the costs of economic

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[149] USDA Rural Business Cooperative Services, *Business Programs* (http://www.rurdev.usda.gov/rbs/busp/bprogs.htm).
[150] USDA Rural Business Cooperative Services, *Business & Industry Guaranteed Loans* (http://www.rurdev.usda.gov/rbs/busp/b&I_gar.htm).
[151] USDA Rural Business Cooperative Services, *Intermediary Relending Program* (http://www.rurdev.usda.gov/rbs/busp/irp.htm).
[152] USDA Rural Business Cooperative Services, *Rural Business Enterprise Grants* (http://www.rurdev.usda.gov/rbs/busp/rbeg.htm).
[153] USDA Rural Business Cooperative Services, *Rural Economic Development Grants* (http://www.rurdev.usda.gov/rbs/busp/redg.htm).

planning, technical assistance for rural businesses and training for rural entrepreneurs or economic development officials.[154]

USDA Renewable Energy Systems and Energy Efficiency

USDA's Renewable Energy Systems and Energy Efficiency Improvements programs assist rural small businesses in developing renewable energy systems and making energy efficiency improvements to their operations. Grant funding was available in the amount of $22 million in FY 2003 for projects that derive energy from wind, solar, biomass, geothermal or hydrogen.[155] For more information about eligible grant recipients, projects and funding guidelines, visit the program website: http://www.nrel.gov/usda/.

USDA Agricultural Research Service Bioenergy & Energy Alternatives Program

The USDA manages several programs designed to increase the use of agricultural crops as feedstocks for biofuels. The Bioenergy and Energy Alternatives Program (under the Agricultural Research Service) conducts research in ethanol, biodiesel, energy alternatives for rural practices and energy crops. Emphasis is on developing or modifying technologies, developing energy crops and improving process economics.[156]

USDA CSREES Agricultural Materials Program

The USDA Cooperative State Research, Education and Extension Service (CSREES) advances research and development in new uses for industrial crops and products through its Agricultural Materials program, National Research Initiative, Small Business Innovation Research Program and other activities. Areas of interest include paints and coatings from new crops, fuels and lubricants, new fibers and biobased polymers from vegetable oils, proteins and starches.[157]

DOE Regional Biomass Energy Program

The Department of Energy sponsored the Regional Biomass Energy Program (RBEP) since 1983. This program sought to increase the production and use of bioenergy resources through technical and financial assistance.[158] In the past, the RBEP has maintained a network of regional offices throughout the United States, and Oregon was part of the Pacific Regional Bioenergy Program (http://www.pacificbiomass.org). Many of the past projects and information are still available on-line. However, the program functions have been assigned to a regional biomass partnership funded for FY 2004. In the future, many of the technical transfer and outreach functions will be performed by DOE regional offices.[159] Key program contact information for the new partnership is on-line at: http://www.ott.doe.gov/rbep/organization.html.

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[154] USDA Rural Business Cooperative Services, *Rural Business Opportunity Grants* (http://www.rurdev.usda.gov/rbs/busp/rbog.htm).
[155] USDA, *USDA Farm Bill Section 9006: What is the USDA Farm Bill Section 9006?* (http://www.nrel.gov/usda/what_is.html).
[156] USDA, Biobased Products and Bioenergy Coordinating Council (BBCC), *BBCC Member Agencies* (http://www.ars.usda.gov/bbcc/USDA_BBCC.htm).
[157] USDA CSREES (http://www.reeusda.gov/).
[158] U.S. DOE Office of Transportation Technologies, *What is the Regional Biomass Energy Program* (http://www.ott.doe.gov/rbep/what.html).
[159] U.S. DOE Biofuels Program, *Who We Are* (http://www.ott.doe.gov/biofuels/who_we_are.html).

USFS Small Diameter Utilization Program

The Forest Service, private forestry groups, non-profit orgaizations, states and universities are cooperating under the Small Diameter Utilization Program (http://www.fs.fed.us/fmsc/sdu/index.php). The objective is to provide information in areas such as technology transfer, logging systems, forest products and manufacturing, biomass and marketing.[160]

USFS Economic Action Program

The USFS Economic Action Program provides a range of assistance to rural communities. Program areas included: fuel reduction and utilization projects, bioenergy feasibility studies, wood product utilization and market feasibility studies, support to modify or develop long-range fuels hazard reduction and community economic development planning that expands and diversifies the use of forest products. More information about the Economic Action Program is available on-line at: http://www.fs.fed.us/r6/coop/programs/rca/economic.htm. As an alternative to the Internet, you can contact Charlie Krebs, Program Director via phone: (503) 808-2340 or e-mail: ckrebs@fs.fed.us.

Healthy Forests Restoration Act of 2003 (signed into law on December 3, 2003)

At the time of this writing, the Healthy Forests Restoration Act (HFRA) had recently been signed into law. The interested reader is referred to the following website for a summary of the House and Senate conference report on the HFRA. This website was available as of December 3, 2003. http://capwiz.com/wwipo/webreturn/?url=http://thomas.loc.gov/cgi-bin/bdquery/z?d108:h.r.1904:

The House and Senate conference report findings suggest that funding resulting from the HFRA will provide incentives for the development of outlet markets for biomass, including energy. Title II, Section 2 of the House bill authorizes appropriations of $25,000,000 for FY 2004 through 2008 for grants to improve the commercial value of forest biomass and monitoring for program participants. Sections 203 and 204 of the Senate bill contain comparable funding authorizations. The Senate bill authorizes an additional $5,000,000 for FY 2004 through 2008 for programs that facilitate small business use of biomass.

4. OREGON STATE AND LOCAL INCENTIVES

Pollution Disclosure Requirement

Since March 1, 2002, major electricity suppliers have been required to disclose their fuel mix and emissions using a format prescribed by the Oregon Public Utility Commission. Power source and environmental impact information must be provided to all residential consumers at least quarterly. Renewable resources are reported as "other fuels" unless they comprise over 1.5% of the total fuel mix. Environmental impact information is reported in lbs/kWh. Pollutants that must be disclosed include carbon dioxide, sulfur dioxide and nitrogen oxides.[161] This requirement does not apply to publicly-owned utilities in Oregon.[162]

[160] National Fire Plan (http://www.fireplan.gov/reports/perf_rpt_2002/9-16.pdf, accessed September, 2003).
[161] North Carolina Solar Center, *DSIRE* at:
http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=OR11R&state=OR&CurrentPageID=1
[162] Oregon Secretary of State, State Archives, *Oregon Administrative Rules Division 38: Direct Access Regulation, Section 0300*, OAR 860-038-0300 Electric Company and Electricity Service Suppliers Labeling Requirements (http://arcweb.sos.state.or.us/rules/OARS_800/OAR_860/860_038.html).

Portland Green Power Purchasing

The City of Portland aims to produce or purchase all of its power through renewables. Among other projects, the City is installing four 30-kW bio-gas microturbines at the Columbia Boulevard wastewater treatment plant. The City is also purchasing more than 600,000 kWh/year of renewable resources from the grid. The Office of Sustainable Development is promoting green power purchases to other City bureaus, local businesses and other institutions.[163]

Business Energy Tax Credit Program

Current law provides a 35% tax credit for renewable energy investments. The credit is taken over five years. Unused credit can be carried forward up to eight years. The tax credit can also be transferred to a partner in exchange for cash payment. This allows tax exempt entities to benefit from undertaking projects.[164]

Recent legislation removed the $40 million limit on the annual amount of total projects qualified for the credit program and replaced it with a maximum of $10 million qualified cost per project each year. More than 6,500 credits have been awarded in the areas of energy conservation, recycling, renewable energy resources and less-polluting transportation fuels.[165]

Residential Energy Tax Credit

Homeowners and renters are eligible for a tax credit if they purchase alternative fuel vehicles and charging or fueling systems. The tax credit is 25% of the cost of the vehicle and/or device, not to exceed $750. The tax credit may be claimed for a vehicle and a charging or fueling system for a total of $1,500.[166]

Property Tax Exemptions

Oregon offers incentives for new businesses and property tax exemptions. The Oregon Enterprise Zone Program offers incentives for businesses to create new jobs by encouraging business investment in economically lagging areas of the state. Locating a facility in this zone would allow new construction and most of the equipment installed a 100% property tax abatement for a minimum of three years. Thirty-seven areas in Oregon have been designated as enterprise zones.

The Enhanced Enterprise Zone Program was developed to spur major industrial investments in rural areas of the state with high rates of unemployment. The incentive provides 15 consecutive years of full relief from assessment of all local property taxes at the investment site. Credit equal to gross payroll is applied against state corporate income tax liabilities.

New commercial facilities are exempt from property taxes while they are under construction and may continue the exempt status for two years if they are manufacturing projects.

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[163]North Carolina Solar Center (http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=OR17R&state=OR&CurrentPageID=1).
[164]Oregon Department of Energy, *Oregon Business Energy Tax Credit* (http://www.energy.state.or.us/bus/tax/taxcdt.htm).
[165]Ibid.
[166]Oregon Department of Energy, *Oregon Residential Energy Tax Credit Program* (http://www.energy.state.or.us/res/tax/taxcdt.htm).

Environmental Tax Credits

Oregon provides tax credits to companies that meet or exceed the EPA and Oregon Department of Environmental Quality clean air requirements. A facility may take 50% of the qualified cost of an installation designed to meet state or federal regulations as a tax deduction, subject to a variety of requirements.[167]

Energy Facility Siting Process

Small ethanol production and other biomass facilities producing a fuel product capable of being burned to produce the equivalent of less than six billion Btu/day are not subject to the siting process of the state Energy Facility Siting Council. This would equate to a cellulose ethanol facility of about 28 million gallons per year. In addition, there is an exemption in industrial zones for certain ethanol facilities that produce fuel from gain, potatoes or whey. To qualify for the exemption, the facility must meet certain criteria, but there is no capacity limitation.

Small Scale Energy Loan Program

Renewable energy projects are eligible to receive low interest loans from the Small Scale Energy Loan Program. Businesses, individuals, counties, public agencies, tribes and non-profit organizations may be eligible. Existing renewable energy facilities may qualify for financing for an energy improvement or energy project expansion.[168]

Funding is provided by the sale of bonds is on a periodic basis and, occasionally, to accommodate a particularly large loan request. Although there is no maximum loan size, the largest single loan has been $16.8 million.

General Business Financing

Revolving loans and bonds are available through the Oregon Economic and Community Development Department. The purpose of these loans is to facilitate the creation of employment. Other programs are in place to increase the availability of loans from banks.[169]

Project Development Assistance

The Special Public Works Fund provides Oregon Lottery money for public infrastructure supporting business development projects that create or retain jobs. Eligible applicants include water and sewer districts, cities and counties. If a site under serious consideration needs additional infrastructure, this fund can provide the resources for such improvements.[170]

5. NON-PROFIT ORGANIZATIONS

Non-profit organizations can provide a great deal of in-kind support in getting renewable energy programs up and running through consumer outreach and education and market analysis. The following organizations are supportive of development of renewable energy resources.

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[167] Oregon Department of Environmental Quality, *Pollution Control Facilities Tax Credit Program* (http://www.deq.state.or.us/msd/taxcredits/txcp.htm).

[168] North Carolina Solar Center, *DSIRE* at: http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=OR04F&state=OR&CurrentPageID=1).

[169] Oregon Economic & Community Development Department, *Financing Services* (http://www.econ.state.or.us/financeb.htm).

[170] Oregon Economic & Community Development Department , *Special Public Works Fund* (http://www.econ.state.or.us/spwf.htm).

The Bonneville Environmental Foundation (BEF)

The Bonneville Environmental Foundation (BEF) funds renewable energy projects located in the Pacific Northwest. Project areas include: solar photovoltaics, solar thermal electric, solar hot water, wind, hydro, biomass and animal waste-to-energy.[171]

Funding is provided in the form of grants, loans, convertible loans, guarantees and direct investments in renewable energy projects. BEF renewable energy grants and investments may range from a few thousand dollars for small installations to significant investments in central station grid-connected renewable energy projects. If a BEF grant is requested for a generating project, the BEF share will not exceed 33% of total capital costs and 0% of operating costs.[172]

The Energy Trust

The Energy Trust of Oregon (Energy Trust) was created in March 2002 to invest public purpose funding for energy efficiency and renewable energy in Oregon. Its goals include displacing 300 MW through energy efficiency improvements and helping Oregon meet 10% of its energy needs through renewable energy resources by 2012.[173] In 2003, the Energy Trust budgeted $925,000, or approximately 10% of its Renewable Program budget, for its Open Solicitation, which supports unsolicited renewable energy projects in the areas of small wind, solar photovoltaics, biomass and geothermal. The Energy Trust is funded through a public purposes charge to customers of the two investor-owned electric utilities in Oregon (Portland General Electric and Pacific Power) and NW Natural, a natural gas company.[174]

Renewable Northwest Project

Renewable Northwest Project (http://www.rnp.org/) is a coalition of public interest groups and energy companies that is promoting the development of wind energy and other renewable energy resources. Renewable Northwest works with local organizations and energy companies to put projects on the ground, encourages utilities and customers to invest in renewable energy technologies and promotes renewable energy market development.

NW Energy Coalition

The NW Energy Coalition (http://www.nwenergy.org/) is an alliance of environmental groups, civic organizations, businesses and utilities in Alaska, Idaho, Montana, Oregon, Washington, Montana and British Columbia. The Coalition promotes energy conservation and renewable energy use, consumer protection and fish and wildlife protection on the Columbia and Snake Rivers.

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[171] BEF, *About BEF* (http://www.b-e-f.org/about/index.shtm).
[172] BEF, *BEF Renewable Energy Project Criteria and Proposal Process* (http://www.b-e-f.org/grants/docs/renewable_grant_guide.pdf).
[173] Energy Trust of Oregon, *About Energy Trust: Who We Are* (http://www.energytrust.org).
[174] Energy Trust of Oregon, *Renewable Programs – Open Solicitation* (http://www.energytrust.org).

APPENDIX I. OVERVIEW OF GASIFICATION TECHNOLOGY

UPDRAFT GASIFIER

The simplest gasifier is the updraft, fixed-bed gasifier. This gasifier pulls hot air from the bottom of the container up through the fuel material, drying it in the process. As the fuel sinks, pyrolysis occurs, producing liquid methanol, acetic acid, tars and solid charcoal. Then the liquids and tars enter a reduction zone, in which a reduction reaction takes place, producing carbon monoxide and hydrogen. These combustible gases can be used for heating or power generation. Lastly, in a high-temperature oxidation zone, hydrocarbons are oxidized to generate energy to run the reduction and pyrolysis reactions. The gas produced is normally a low-Btu gas (150 Btu/cubic foot) that contains residual tars and moisture. Figure I-1 shows a schematic of an updraft gasifier.

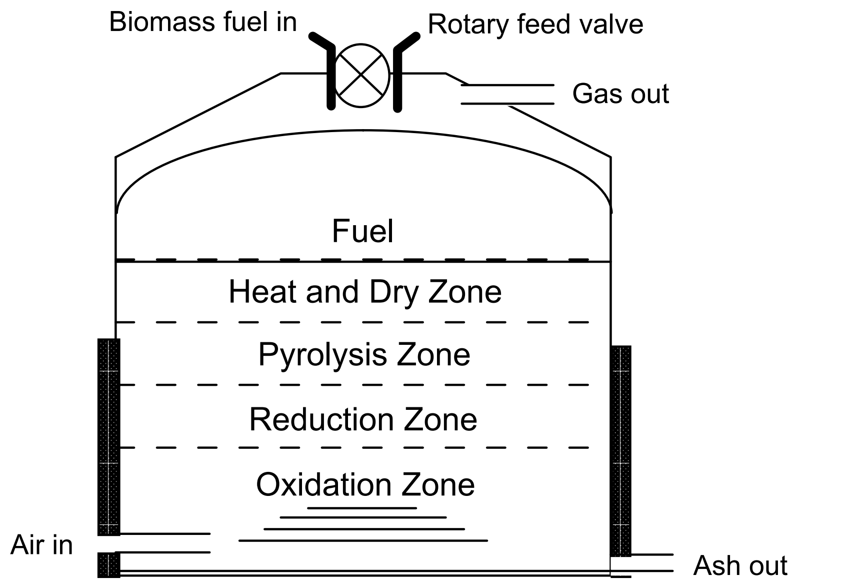


Figure I-1. Updraft gasifier

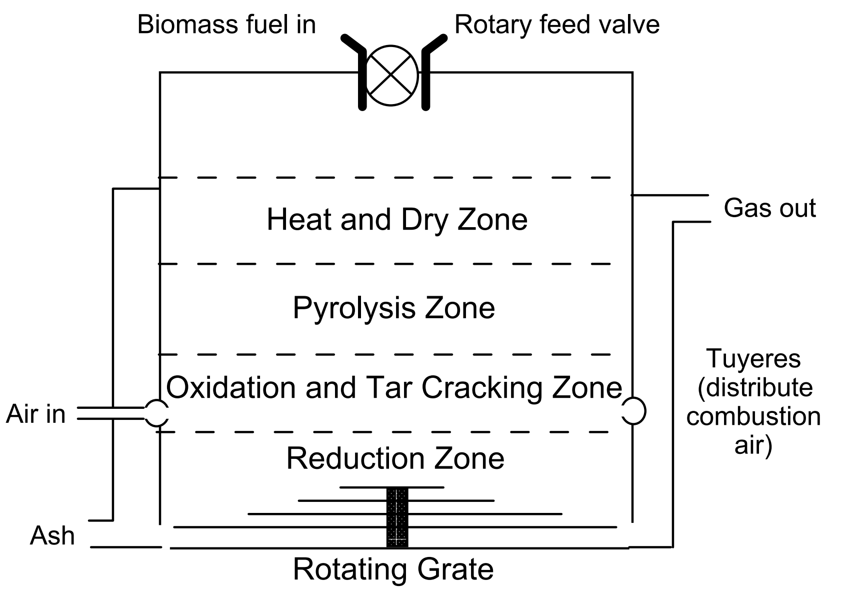
There are a few advantages with this gasifier design. First, the gasifier can be made in a variety of sizes. These sizes can range from small "household" units to large 8,000 lb/hour units. The large units are constrained by the possibility of unmixed areas occurring in the reacting mass. A second advantage is that the low-carbon ash produced does not present a disposal problem.

A disadvantage of updraft gasifiers is that the gas produced cannot be transported through a pipeline because the tars and non-reacted solids will condense. Several proprietary modifications and additions have been made to updraft gasifiers in order to clean the gases so they can be used as engine fuel or transported by pipeline. This "cleanup" results in tar residues that pose a disposal problem.

Also, updraft gasifiers do not give simultaneous control over fuel and air. The lack of simultaneous control over fuel and air results in the development of a combustion zone within a portion of the gasifier. Pyrolysis is not a combustion process, and development of a combustion zone in the gasifier reduces the energy output from the gasifier and can cause slagging with certain feedstocks. This means that updraft gasifiers have a difficult time handling certain slagging-type fuels such as agricultural residues.

DOWNDRAFT GASIFIERS

Although the downdraft gasifier differs only slightly from the updraft gasifier, the differences are important. As in updraft gasification, fuel materials are added to the top of the container. The material is heated to evaporate water, and the pyrolysis process occurs. However, with downdraft gasification, the high temperature oxidation process occurs after the pyrolysis rather than after the reduction stage. This allows the tars and oils from the gasification process to be filtered with the char in the reduction stage. As a result, the low-Btu gas that is produced is very clean and can be used for boilers, furnace fuel or for internal combustion engines. Figure I-2 shows a schematic of a downdraft gasifier.



Source: Biomass Energy Project Development Guidebook

Figure I-2. Downdraft gasifier

The advantages of sizing and low ash content mentioned for the updraft gasifier are also available with the downdraft gasifier. However, the downdraft gasifier has the additional advantage of producing clean gas that can be transported by pipeline. Disadvantages of downdraft gasifiers include the fact that they are very sensitive to moisture and cannot handle fuels that contain more than 30% water. Also, downdraft gasifiers have a hot zone and do not give simultaneous control of fuel and air. The lack of simultaneous control over fuel and air results in the development of a combustion zone within a portion of the gasifier. The combustion zone is an unwanted characteristic of this type of gasifier that reduces the gas output of the system and can result in slagging on the inside of the gasifier with certain types of biomass feedstock. This means that downdraft gasifiers cannot be used with certain slagging-type fuels such as most agricultural residue.[175]

[175] This was demonstrated by John Goss at the University of California, Davis, and quoted in Dr. Wayne LePori's (Texas A&M University) May 22, 1993, letter to NEOS Corporation.

FLUIDIZED BED GASIFIERS

Figure I-3 shows a schematic of a fluidized bed gasifier. In this type of gasifier, the bed is continually mixed. The mixing results in relatively uniform temperatures and fuel composition throughout the fluidized zone. The gas produced by an atmospheric-type fluidized bed gasifier generally is a low-Btu gas of approximately 150 to 200 Btu/cubic foot at standard conditions. However, pressurized beds or use of oxygen rather than air can increase this to roughly 500 Btu/cubic foot.

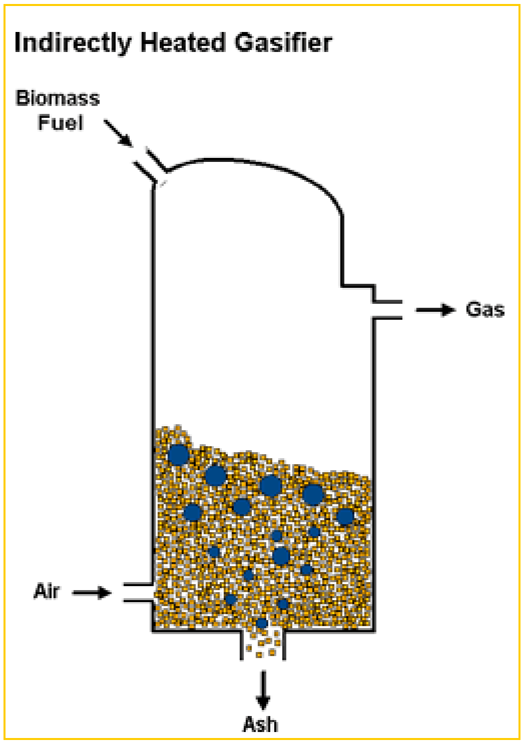


Figure I-3. Fluidized bed gasifier

There are some major differences between the fluidized bed gasifiers and the updraft or downdraft gasifiers described previously. Because pyrolysis occurs very rapidly, fuel residence time is short. This means that the fluidized bed gasifier offers the potential to produce a larger quantity of gas than other types of gasifiers.[176] The gas produced by fluidized bed gasifiers is relatively clean and can be used in an engine, a gas turbine or as boiler fuel, although gas cleanup is still required. Fluidized beds are less sensitive to particle size than other thermal systems. They will accept almost any size particle that can be fed into the unit. In addition, fluidized bed gasifiers can utilize feedstocks that contain more contaminants (such as salt, dirt and high ash content feedstocks) than can normally be gasified in other systems. Fluidized bed gasifiers develop an isothermal zone that is low temperature and deficient in oxygen. An isothermal zone is an area of consistent temperature within the gasifier. This low-temperature, oxygen-starved zone creates a reducing atmosphere, and full combustion (and hence slagging) does not occur.

[176] J. Vranizan et al., *Biomass Energy Project Development Guidebook*, Chapter 4 - Conversion Technologies.

HOT GAS CLEANUP

When many biomass fuels are converted to gas, ash is entrained in to the gas stream. Before the gas is used, the ash must be removed to prevent slagging. Preferably, the removal should take place at the temperature of the hot gas (1,200 degrees F to 1,400 degrees F) so that heat is not lost during the process. The temperature at which the solids separation takes place can be lower, but it should be higher than 800 degrees F to prevent tar condensation. Removing ash prior to combustion requires smaller solids separation equipment than would be necessary if the solids were removed after it is burned in a gas engine, gas boiler or other energy conversion device, because the volume of gas is much greater following combustion. A smaller solids separation device is a significant advantage of gasification over direct combustion, because it can significantly reduce the costs of particulate matter emissions control.

SUMMARY OF GASIFICATION

To prevent ash slagging, most high-ash, high-alkali fuels must be converted into a gas in a reduced (oxygen-starved) atmosphere at a temperature less than 1,450 degrees F during the entire process. It is important to maintain this reducing atmosphere. If the reaction is allowed to shift to combustion within the gasifier, slagging will most likely occur. The fluidized bed gasifier is the only gasifier that presently meets these requirements.