OREGON CELLULOSE-ETHANOL STUDY

An evaluation of the potential for ethanol production in Oregon using cellulose-based feedstocks

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Purpose of the Study

The State of Oregon Office of Energy commissioned this study to evaluate the near-term potential of an Oregon cellulose-based ethanol industry. This report contains a review of national and state policies that support the development of the ethanol industry. It also contains an overview of cellulose feedstock availability and viability. It discusses the status of cellulose-ethanol technology and the economic feasibility of a cellulose-ethanol facility in Oregon. In addition, the report provides an evaluation of regional markets for ethanol and its co-products.

A major objective of this study is to identify critical barriers and assess perceived risks to the development of commercial ethanol production facilities in Oregon. This report addresses possible methods to overcome obstacles through the utilization of low-cost indigenous resources in Oregon. The report suggests public policy initiatives and identifies market opportunities.

Ethanol is a clean-burning, renewable and biodegradable fuel that could be produced from biomass resources in nearly every region of the country. Oregon timber and agricultural industries generate substantial quantities of biomass residues and by-products. Potentially, these materials could supply feedstock for commercial-scale ethanol production.

The U.S. Department of Energy's Office of Fuels Development (OFD) has identified the conversion of cellulose biomass materials to ethanol as a technology that holds the promise of meeting future demand for ethanol. The OFD has concluded that the use of lower-cost feedstocks is key to expanding the production potential of ethanol in the near-term and lowering the cost of ethanol production through the application of new biotechnology tools in the long-term.

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Executive Summary

Over the past 20 years, the U.S. ethanol industry has grown into the transportation fuels market as a fuel extender, octane enhancer, and oxygenate. Ethanol's use has grown from a mere 200 million gallons per year (gpy) in the early 1980s to more than 1.5 billion gpy today. It is expected to grow another billion gallons as methyl tertiary butyl ether (MTBE) is taken out of reformulated gasoline market. California has already initiated this process by banning MTBE after 2002. However, efforts to eliminate the oxygen requirement in reformulated gasoline could have a significant negative impact on ethanol market growth.

The Federal Highway Administration estimated ethanol use in Oregon to be 13.9 million gallons as reported in 1998[1]. However, according to some fuel marketers, actual ethanol use may be double that amount[2]. Ethanol's primary market in Oregon is in the U.S. Environmental Protection Agency (EPA) oxygenated fuel program areas, which include the Portland Metropolitan region, Klamath Falls, and Medford areas. In 1997, Portland achieved air quality standards set by the EPA and was reclassified as "in-attainment." However, as part of the comprehensive air quality maintenance plan developed by the state, the oxygenated fuels program remains in place. Beyond that, there are no other public policy initiatives currently in place to encourage the market growth of ethanol.

There are no ethanol production facilities in Oregon. Therefore, ethanol demand must be met by outside sources. Until sufficient production capacity is developed in the Pacific Northwest, most ethanol will arrive from producers located in the Midwest and from the Caribbean via ships to Portland.

Oregon has an abundant amount of cellulose feedstocks, which could potentially be used for ethanol production. Preliminary results from the resource assessment completed as part of this study indicate that more than 8.5 million bone-dry tons (bdt) of cellulose feedstocks were produced in 1998. This is the gross amount, which means that not all of this quantity is available for collection. If it were possible to economically collect and use all of the available materials, Oregon would have the potential to produce over 500 million gpy of ethanol. Given the current estimates of economically available feedstock, it appears there would be sufficient material to support about 170 million gallons of ethanol production annually.[3] If policies are put in place to insure adequate long-term supplies of forest residues, this number could be increased by nearly 194 million gallons, creating a total production capacity of over 364 million gallons annually.

In spite of Oregon's large forested areas, the most readily available biomass feedstocks are agricultural residue. Agricultural residues comprise about 49 percent of the total resources, followed by forest residues at 35 percent and municipal solid waste at 15 percent. The remainder includes other feedstocks such as pulp and paper mill residue. Feedstocks

[1] The amount of ethanol reported to the Federal Highway Administration is from an October 1999 survey. The amount is estimated from gasohol tax collections, refunds, and credits reported by the Internal Revenue Service, U.S. Department of the Treasury.
[2] Based on confidential survey information from two ethanol marketers in the Northwest.
[3] This number is based on the available wheat straw after soil needs are met, half the available grass straw, paper mill sludge, and urban green waste.

were reviewed for current market demand and uses, cost, collection potential, qualities and geographic concentrations.

An economic analysis conducted by the National Renewable Energy Laboratory showed potential returns on investment using forest thinnings and wheat straw of 19 percent and 18 percent respectively with a natural gas fired boiler. The analysis showed a return of roughly 13 percent with a biomass-fired boiler. The latter is the most likely scenario based upon the limited markets for the lignin created in the cellulose conversion process.

While Oregon's forest and agricultural residues have the potential to be used for ethanol production, near-term economic feasibility depends largely on what happens to the price of gasoline and the demand for ethanol. In addition, proof of economic viability of the cellulose-to-ethanol technology in a successful commercial facility would substantially improve the outlook for the development of cellulose-ethanol production in Oregon.

A recent report by the Energy Information Administration[4] estimates that the current cost of producing ethanol from cellulose is $1.15-$1.43 per gallon. However, advances in feedstock processing and biotechnology could reduce cellulose-ethanol costs to $.69-$.98 per gallon over the next two decades. This will enable cellulose-ethanol to compete with wholesale gasoline, which is currently at $.80-$.90 per gallon. The extension of the 54-cent federal excise tax exemption would further help this case for nearer-term ethanol growth, in regards to both ethanol demand and cost.

State programs designed to achieve public economic and environmental benefits could boost the development of a cellulose-based ethanol industry in Oregon. The following three examples could provide multi-level benefits by creating public policy choices:

1. As MTBE is phased out in California and nationwide, clean air and clean water benefits would be achieved through increased use of ethanol to add oxygen to gasoline. Widespread replacement of MTBE with ethanol would increase demand for production capacity and price stability. Conversely, if Congress were to repeal the oxygen standard, that action would send a negative signal to potential cellulose-ethanol development as ethanol demand would drop and become less certain. By maintaining the oxygen requirement in gasoline, or establishing a renewable fuels requirement, Oregon can encourage the development of a biomass industry.
2. A forest management strategy to promote ecosystem sustainability would address excessive accumulation of biomass fuel in some locations. Selective thinning operations would increase the availability and quantity of feedstock for ethanol production.
3. Growing public concern about climate change could encourage strategies to reduce greenhouse gas emissions. A renewable fuel requirement would reduce life-cycle carbon dioxide emissions and enhance market demand for ethanol.

Although significant quantities of cellulosic feedstock are available in Oregon, external factors such as market economics and advancements in technology will affect the timetable

[4] J. DiPardo, *Outlook for Biomass Ethanol Production and Demand*, Energy Information Administration, April 2000.

for development of a cellulose-to-ethanol industry in the state. The choices that are being made now in the public policy arena can make a critical difference in how soon commercial cellulose-ethanol production becomes a reality.

I. Overview of Policy Rationales for a Cellulose-Ethanol Industry in Oregon

Important drivers for promoting and supporting the development of a cellulose-ethanol industry in Oregon include greenhouse gas mitigation, clean water, sustainable economic development and waste reduction. Economic gains can be realized using cleaner Oregon-grown fuels by converting cellulosic biomass resources, such as forestry and agricultural residues, into ethanol, thereby promoting economic development in their respective industries and communities.

By producing ethanol from waste resources, Oregon would have the ability to produce an in-state supply of renewable fuels versus exporting dollars to import its transportation fuel supply. In-state ethanol production would reduce the burden on landfills because it would divert the biomass fraction of the waste stream to an ethanol facility. This has been a motivating factor for several proposed ethanol projects around the country.

Ethanol is currently being imported into the state for use in Oregon's oxygenated fuels program. The oxygenated fuels program is part of the federal Clean Air Act Amendments of 1990 to reduce carbon monoxide emissions from mobile sources. Even though most areas in Oregon have now attained federal clean air standards, the state continues to implement the program to sustain its air quality. Ethanol is the primary oxygenate used in this program.

A. Climate Change

Since the beginning of the industrial revolution, human activities have been adding measurably to levels of greenhouse gases. The burning of fossil fuels (coal, oil and natural gas) for energy is the primary source of emissions. Fuel burned to run cars and trucks, and to heat homes and businesses, are responsible for about 80 percent of global carbon dioxide emissions, 25 percent of U.S. methane emissions and about 20 percent of global nitrous oxide emissions. In 1994, the U.S. alone emitted about one-fifth of total global greenhouse gases.

The effects of increased greenhouse gas emissions have been felt in Oregon. For example, over the last century, the average temperature in Corvallis has increased 2.5 degrees Fahrenheit and precipitation has increased by up to 20 percent in many parts of the state, except along the leeward side of the Cascades where precipitation has fallen by 20 percent.[5]

Changes in global temperatures could affect the availability of arable land, water resources, air quality, forest productivity, and the sustainability of human and animal health. The Kyoto Protocol was advanced in 1998 to address these problems. The Clinton Administration committed to reducing greenhouse gas emissions to 7-percent lower than 1990 levels by the reporting period 2008-2012. However, the US Senate has not yet ratified the Kyoto Protocol, and without that ratification, a workable, on-going program of greenhouse gas reductions may not be possible.

[5] Climate Change and Oregon, U.S. Environmental Protection Agency, EPA 236-F-98-007u, September 1998.

Ethanol has been proven to reduce carbon dioxide emissions in a full fuel cycle analysis conducted by numerous studies including those prepared by the Argonne National Laboratory and the National Renewable Energy Laboratory (NREL). NREL estimates that ethanol derived from cellulose decreases CO_2 emissions by 90 percent compared to gasoline.[6]

B. MTBE Water Issue

Ethanol is one of two main oxygenates used in reformulated gasoline to improve combustion and provide clean burning dilution of other dirtier hydrocarbons. The other major competing oxygenate is methyl tertiary butyl ether (MTBE). MTBE recently has been found to be a suspected carcinogen in animals and a highly persistent contaminant in water.[7] It smells and tastes like turpentine, and very small amounts render water resources undrinkable. Because of adverse effects, the State of California has issued an executive order to phase out MTBE use in gasoline by 2002.

Ethanol is the only known viable alternative oxygenate. Recently, the State of California Governor's Environmental Policy Council concluded that ethanol is safe and a preferred alternative to MTBE. If ethanol were to fully replace MTBE at its current level of use, the demand for ethanol could potentially reach as much as 550 million gallons per year, presenting Oregon with a large nearby export market if ethanol were produced in-state.

C. Economic Development

Cellulose-ethanol offers economic development opportunities for the State of Oregon, particularly in rural parts of the state where the economy is somewhat depressed. A recent study by Northwestern University[8] concluded that the existing ethanol industry, which produces 1.5 billion gpy, has beneficial economic impacts. The study found that the industry: increases net farm income more than $4.5 billion; boosts total employment by 192,000 jobs; improves the balance of trade by over $2 billion; adds over $450 million to state tax receipts; and results in net federal budget savings of over $3.5 billion. This kind of economic impact could also happen in the Northwest if a cellulose-ethanol industry flourished in the region.

D. Environmental Mitigation and Waste Reduction

Rye grass straw, wheat straw, pulp and paper sludge, mixed waste papers and forest residues can all be converted into ethanol. By doing so, waste and environmental problems are addressed in a manner that creates economic development and supports environmental health. For example, greater use of forest residues would address disease and excess fuel loading problems that characterize many western forests, including some forests in Oregon.

Fuel loading is a condition created by forest management practices, in part by the resistance to conduct controlled burns and the public's insistence to extinguish forest fires at any cost, even when they are started by nature. The expansion of residential dwellings into forested areas puts enormous pressure on the Forest Service to handle wild fires as quickly as possible. As a result, forest undergrowth (fuel loading) has dramatically increased in the last

[6] Telephone conversation 4/5/00 with John Sheehan, NREL.
[7] The State of California instituted a ban on MTBE starting 1/1/2003 because of the water contamination that it causes.
[8] 1997, Michael Evans – Kellog School of Economics, Northwestern University.

100 years from 10-20 large trees per acre at the turn of the century to as many as 500-700 trees per acre today. This dense undergrowth creates the potential for almost uncontrollable wildfires and the dangerous spread of disease.

A cellulose-ethanol facility offers an opportunity to help alleviate the threat of forest fires and disease, while creating rural economic development by turning the forest thinnings and other waste materials into feedstocks for ethanol production.

II. Status of Commercial Cellulose-Ethanol Developments in the United States

Most ethanol today is produced by yeast fermentation of sugar from cane or starch from grains. Advancements in biotechnology will soon enable ethanol to be produced from non-traditional cellulose-based resources such as forestry and agricultural residues, municipal solid waste, and dedicated energy crops.

Only one facility in the United States today produces ethanol from a cellulosic feedstock, Georgia Pacific in Bellingham, Washington. Georgia Pacific produces 6.3 million gallons per year (mgpy) of ethanol from sugars contained in sulfite liquor, a wood pulping byproduct.

There are several cellulose-ethanol projects proposed or under way across the United States. Cellulose-ethanol plants are under consideration in Louisiana, Pennsylvania, New York, Alaska and California (see **Table 1**). In addition, several studies have been conducted by both private and government organizations to assess and determine cellulose-ethanol production potential in various parts of the country using local feedstocks, such as forestry and agricultural residues in the Black Hills region, Montana and Idaho, Northeastern California, and elsewhere.

At the time of this report, there are no cellulose-ethanol production projects operating or under development in Oregon. However, Cascade Grain Products is proposing to build an 80 million-gpy corn and wheat ethanol plant in western Oregon on the Columbia River, close to Pacific Gas & Electric’s Beaver power plant near the town of Clatskanie. The plant would produce other products such as food grade fiber, wheat gluten, animal feed, wheat bran and flour. The corn processed at the plant would be shipped in from the Midwest and the wheat from eastern Washington. The Cascade project supporters include Enron North America Corporation, Delta-T, Foster Farms, Fagan Inc., and Hartford Steam Boiler Insurance. The developers are in the process of obtaining necessary financing, permits and anticipated state production incentives.

Table 1: Proposed Cellulose-Ethanol Plants in the United States

Company	Location	Feedstock	MGPY	Proposed Start-up
BC International	Jennings, LA	Bagasse/rice hulls	20	2002
BCI Collins Pine	Chester, CA	Wood waste	20	2002
BCI Gridley	Oroville, CA	Rice Straw	20	2002
Arkenol/Sacto Ethanol Partners	Sacramento, CA	Rice Straw	4	2001
MASADA	Middletown, NY	Municipal Solid Waste	6.6	2001
	Birmingham, AL	Municipal Solid Waste	13.5	2002
Sustainable Energy Development	Central Region, OR	Wood Waste	30	unknown
Sealaska	Southeast Region, AK	Softwood residues	6-8	2003
Standard Energy	Philadelphia, PA	Municipal Solid Waste	unknown	unknown

Source: Bryan & Bryan Inc., April 2000

A. Review of Current Cellulose-Ethanol Projects

Sealaska Corporation (Sealaska), a Native American-owned corporation based in Alaska, is in the process of evaluating the technical and economic feasibility of a cellulose-ethanol production facility in southeast Alaska using wood residues. Sealaska Timber Corporation, a subsidiary of Sealaska, is a wood processing operation that is striving to improve the utilization and value of wood fiber. One way to add value to its wood processing operations is to convert the currently unmerchantable residues, such as sawdust, bark and other wood wastes, into ethanol. Preliminary findings, based on a study conducted by the National Renewable Energy Laboratory (NREL), indicate that the plant would process about 96,000 dry tons per year of wood residue to produce 6 million gpy of ethanol.

Alabama-based Masada Resource Group has plans for a waste-ethanol facility in Middletown, New York. Masada processes and converts municipal solid waste (MSW), sewage sludge and wastewater into a variety of industrial products. In the future, these products will include ethanol. Masada is planning to build an ethanol plant on the site of a closed landfill and process 178,000 tons of MSW and 215,000 tons of sewage sludge into 6.6 million gallons of ethanol annually. This facility will also recover glass, plastic and metals for recycling.

Masada has made a similar proposal to the City of Birmingham, Alabama, to build an ethanol facility adjacent to the city’s landfill. Masada would produce 13.5 million gallons of ethanol per year from MSW. Both of these projects will use Masada’s patented OxyNol technology, a concentrated acid hydrolysis process, to convert the cellulose sugars from the MSW and sludge for ethanol production.

BC International (BCI) in Dedham, Massachusetts, has several cellulose-ethanol projects in the planning and development stages. The project closest to completion is in Louisiana, which is expected to begin production in 2001. BCI purchased a former molasses and grain-ethanol plant in Jennings, Louisiana, to retrofit into a cellulose-ethanol production facility. The feedstock will be sugarcane bagasse. BCI will produce 20 million gallons of ethanol per year from 300,000 dry tons of sugar cane bagasse using a two-stage dilute acid hydrolysis process and a genetically engineered bacterium to ferment both five and six carbon sugars.

BCI is planning a second cellulose-ethanol facility in the rice-growing region of California's Sacramento Valley. This project will use a two-stage dilute acid process like the Jennings plant. In 2003, California law will ban the burning of rice straw. This will create a low-cost waste resource for ethanol production as an alternative to landfill disposal. The City of Gridley, a local rice straw cooperative, NREL and other stakeholders are working with BCI to develop the project that would produce 23 million gpy of ethanol using 250,000 tons of rice straw annually. This production facility may process wood waste as a supplemental feedstock.

A third BCI project is in cooperation with the Collins Companies, a large private timber firm. Collins has a wood processing plant in Chester, California, with an adjacent 12.5 MW biomass power plant. The Collins Pine project would utilize softwood residues collected from forest thinnings, a management practice used to reduce the risk of forest fires. A forest management plan in Plumas and Lassen National Forests could provide up to 1.4 million dry tons per year of woody material, yielding an estimated 119 million gpy of ethanol. BCI tentatively plans to use enzymatic technology to convert the feedstocks for ethanol production at the proposed Collins Pine facility.

Arkenol, based in Mission Viejo, California, has plans to build an ethanol plant that produces 4 million gpy of ethanol plus citric acid, another fermentation product, from rice straw using its proprietary concentrated acid hydrolysis process. The facility would be located in Sacramento, near a major rice-growing region. Arkenol also has another project under development in Los Angeles to produce 25 million gpy of ethanol from MSW.

NREL recently entered into a new Cooperative Research and Development Agreement and licensing agreement with Arkenol to develop new strains of genetically-altered bacteria for fermenting sugars from rice straw for ethanol production. NREL will develop improved strains of *zymomonas mobilis* bacterium that could increase the amount of biomass material that can be converted into ethanol by up to 40 percent, substantially improving the economics of ethanol production from cellulose. Arkenol will be allowed to use this technology at its proposed ethanol facility in Sacramento.

In Canada, Iogen Corporation is building a commercial-scale cellulose-ethanol plant using proprietary enzymatic hydrolysis technology. In 1997, it entered into a partnership with Petro-Canada to produce cellulose-ethanol beginning with a 1 million gallon per year ethanol plant, located at its headquarters in Ottawa, using corn stover and switchgrass. This project is co-funded by the Canadian government. Iogen plans to begin production in August 2000.

The success of these projects will have substantial impacts on the progress of the cellulose-ethanol industry. One of the major challenges that exist at this time is the technology to economically convert and ferment cellulosic feedstocks. Once technology has been proven commercially viable, nearly every region around the nation and worldwide will have the ability to produce ethanol from cellulosic feedstocks. An overview of cellulose-ethanol technologies is summarized in Appendix B.

B. Outlook for Cellulose-Ethanol Production

The continued development of technology to produce ethanol from cellulosic feedstocks could significantly reduce the cost of production and lead to an increase in ethanol demand and production over the next two decades. In addition to the advances in technology, increased ethanol production depends upon whether current Federal ethanol incentives are extended. A summary of Federal ethanol incentives is provided in Appendix D. These incentives help make ethanol, from any biomass resource, more competitive with gasoline.

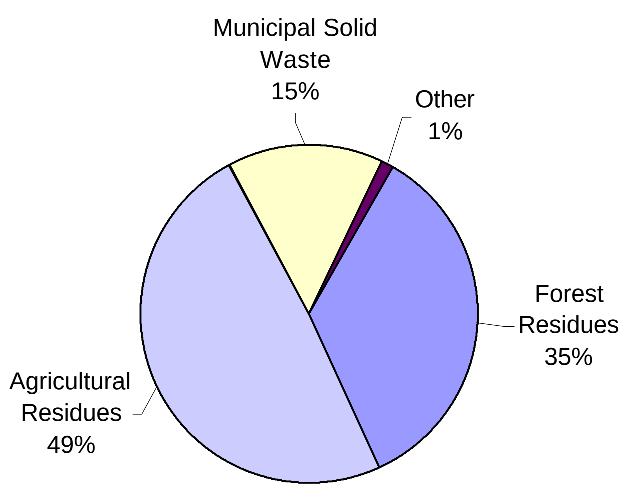
According to a recent report issued by the Energy Information Administration (EIA), "Outlook for Biomass Ethanol Production and Demand," the advances in cellulose-ethanol technology over the next twenty years could reduce the cost of producing cellulose-ethanol to \$0.69-0.98 per gallon. The EIA report also concluded that if the 54-cent per gallon Federal subsidy for ethanol were extended through 2020, ethanol production capacity from grain and cellulose biomass would increase to 2.8 billion gallons per year by 2020.

Corn-ethanol is currently less expensive to produce than cellulose-ethanol. Even though cellulose feedstocks such as forest residues, agricultural residues and municipal solid wastes are lower cost than corn, they are more costly to process into ethanol. When this barrier is overcome, future ethanol demands will be met largely by low-cost cellulosic feedstocks because corn-ethanol is not expected to fall much below \$1.10 per gallon.

III. Preliminary Feedstock Assessment for Cellulose-Ethanol Production in Oregon

Oregon has an abundance of potential cellulose feedstocks for ethanol. Feedstocks available in Oregon are characterized as agricultural residues, forestry thinnings, municipal solid wastes and other materials (**Diagram 1**). The resource assessment conducted with this study catalogued over 8.5 million bone dry tons (bdt) of cellulose materials available in Oregon in 1998. If it were possible to economically collect and utilize all of the materials available, Oregon would have the potential to produce over 500 million gallons per year (gpy) of ethanol. This level of production would be enough to blend ethanol in every gallon of gasoline consumed in the state and help supply emerging markets, such as California's reformulated gasoline program.

Diagram 1: Cellulosic Biomass Generated in Oregon



The 8.5 million tons available is the gross amount, which means that not all of this quantity would be available for ethanol production because of practical and economic reasons. However, it is a useful gauge to help measure the abundant resources available in the state. Feedstocks were reviewed for current market demands and uses, cost, collection potential, qualities, and geographic concentrations. Available quantities of feedstocks and ethanol production potential were estimated (**Table 2**) based on data gathered from U.S. and State Forest Services, Oregon Department of Agriculture, state and municipal waste management agencies, industry associations, and private organizations. The National Renewable Energy Laboratory (NREL) provided the estimated ethanol yield per dry ton.[9]

Table 2: Gross Ethanol Production Potential in Oregon from Cellulosic Feedstocks

Feedstock	Bdt Per Year	Percent of Total Feedstocks*	Ethanol Yield (gallons/bdt)	Ethanol Potential (million gpy)
Greenwaste[10]	278,750	3 %	46.6	12.9
Mixed Waste Paper[11]	652,536	8 %	54	35.2
Wood and lumber[12]	326,688	4 %	45.6	14.9
Paper mill sludge[13]	183,960	2 %	66.6	12.3
Grass Straw[14]	1,000,000	12 %	60.6	60.6
Wheat Straw[15]	2,100,000	25 %	60	126
Forest residues[16]	2,940,000	35 %	66	194.1
Agricultural residues[17]	1,018,842	12 %	50	50.9
TOTAL	**8,500,776**			**506.9**

*Total is greater than 100 percent due to rounding.

A. Agricultural Residues

Agriculture is one of Oregon's top three industries in total economic impact, contributing $3.4 billion dollars per year to the Oregon economy. Agricultural residues account for over 4 million bdt per year of potential feedstock for ethanol production.

Two main agricultural feedstocks have significant quantities available for cellulose-ethanol production: grass seed residues in the Willamette Valley and wheat residues in Eastern Oregon. Other agricultural residues as shown in **Table 3** could be used as supplemental ethanol feedstocks.

Table 3 lists the quantities of agricultural residues produced in Oregon and the acres planted for each crop in 1998. This chart applies a conversion factor to estimated quantity of residue (bone dry tons) each crop produces per acre. As an example, in 1998 there were

9 NREL has yield estimates of different materials based upon testing in its lab. Mark Yancey of NREL provided these estimates.
10 Oregon Department of Environmental Quality, Peter Spendelow, Manager, Solid Waste.
11 1998 Oregon Material Recovery Survey Report, www.deq.state.or.us/wmc/solwaste/mrs1998tbl8.html.
12 Ibid.
13 Paul Coscrove, NW Pulp and Paper Association, Assessment of Potential for Conversion of Pulp and Paper Sludge to Ethanol Fuel in the Pacific Northwest – Jim Kerstetter.
14 Jim Nelson, Oregon Grass Seed Commission.
15 Oregon Wheat Growers League, Daren Coppock, Executive Vice President.
16 Oregon Department of Forestry (www.odf.state.or.us/faq.htm) and Nils Christoffersen, Wallowa Resources.
17 Oregon Department of Agriculture.

19,500 acres of onions planted. The conversion ratio for onions is 1. Therefore, the onion crop in 1998 produces 19,500 bdt of residues. NREL provided conversion factors for this table.[18]

Table 3: Agricultural Residues in Oregon for Ethanol Production

Residues	Acres planted	Conversion Factor	BDT/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 BDT/Year	**4,024,332**
		Estimated GPY of Ethanol	**201,200,000**

1. Wheat Straw

Last year, according to the Oregon Wheat Growers League, there were over 44 million bushels of wheat harvested in the state – primarily in Eastern Oregon. Each bushel of wheat weighs roughly 60 lbs. The Oregon State Extension Service and the Oregon Wheat Growers League estimate that for every ton of wheat harvested there is about 1.6 tons of wheat straw produced.

Currently, most of the wheat stubble is left on the field and later tilled in when preparing for the next planting. A small fraction – Oregon State Extension Service estimates 5 percent – is burned. If all the wheat straw were harvested for ethanol production, the potential would be over 120 million gallons per year. However, in many areas a portion of the wheat straw needs to be returned to the fields for soil conservation practices. A rough estimate of the ethanol production potential of wheat straw available after the soil needs are met is roughly 90 million gallons of ethanol per year. This estimate is based on the Agricultural Statistics Service numbers of yields per acre and subtracting an average of 1.6 tons per acre that is needed for soil enhancement.

[18] NREL has estimated on a dry ton basis what each agricultural crop generates per acre of residue. These estimates were provided by Mark Yancey of NREL.

The soil enhancement requirement is based on the Soil Conditioning Index used by the USDA National Conservation Service. The average is an estimate of the amount of organic matter needed for the soils in Eastern Oregon. Actual requirements could be lower or higher depending on temperature, slope, and soil type. However, this amount appears to be a reasonable estimate based upon the index.[19]

Table 4: Available Wheat Straw in Oregon After Soil Conditioning[20]

Region	Acres Planted (average yield)	Total residue[21] (pounds)	Soil Needs[22] (pounds)	Available dry tons
North Central	447,900 – 59 bu./acre	2,770,300,915	1,202,650,915	601,325
Northeast	342,200 – 66 bu./acre	2,367,651,686	1,169,951,686	584,975
Southwest	900 - 61 bu./acre	5,755,276	2,605,276	1,302
Northwest	51,800 - 71 bu./acre	385,551,130	204,251,129	102,125
Southeast	56,900 - 103 bu./acre	614,388,902	415,238,902	207,619

Suitability: Wheat straw is suitable for ethanol production with a near term yield estimated by NREL of over 60 gallons per ton. The amount of wheat straw available will depend on a regional, site-by-site evaluation of soil needs.

Competing uses: Some manufacturers in the Midwest have developed a technology for converting wheat straw into fiberboard. This potential competing use currently does not exist in Eastern Oregon. In general, wheat straw is used for soil conditioning and typically half of it is left on the field for this purpose.

Challenges and Barriers:

- **Cost of removing the straw and storage:** The cost of removing the straw needs to be minimized in order to maximize the economic yield of the resource. The Oregon Wheat League estimates the collection cost for the straw to be between $25-$35 a ton. Because of the seasonality of the crop, storage will be required. Currently no cost data exists for storage of wheat straw. Storage of the crop for use as a feedstock will need to be investigated to understand the viability.

2. Grass Seed Straw Residues

According to the Oregon Grass Seed Commission, there are about 1 million bdt per year of grass seed straw generated in Oregon. Oregon is the largest producer of grass seed in the world. About 500,000 acres per year of grass seed are planted and cultivated in the Willamette Valley. Roughly half of the straw is bailed and exported to Japan for livestock feed purposes. The current market for this export of grass seed straw, according to the Oregon Grass Seed Commission, ranges between $40-$50 dollars per ton.

About 500,000 tons per year is either burned or chopped into the field. It is possible that this portion would be available for ethanol production. However, the cost of bailing is estimated to be about $30-$35 dollars per ton transported to a nearby site.

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[19] Steve Campbell, from USDA Soil Conservation Service, Portland Oregon, supplied the index and the REV's (residue equivalent values) of 42 Oregon climate stations across Oregon.

[20] Based on 1998 data collected from USDA Agricultural Statistics Service (www.oda.state.or.us/oass/oass.html).

[21] Acres × bushels per acre × 60 lbs × 1.6 (residue factor) × 1.092 (residue factor for plant roots).

[22] Amounts based on Soil Conditioning Index.

Suitability: Grass straw residues are well suited for conversion to ethanol. NREL estimates that, in the near term, yields of rye grass could reach 60 gallons per bone dry ton.

Competing uses: The majority of the straw is either exported or mulched back into the field. There are some potential local markets being developed for grass straw such as cardboard production. Weyerhaeuser Corporation has been researching the possibility of pulping rye grass straw in Oregon for several years. The price being paid for the straw as a pulping material would most likely be tied to the prevailing price for pulp, which fluctuates radically. According to the Beck Group, a consulting firm on forest product material, the price of pulp over the last three years has ranged from a low of $25 dollars per ton to a high of over $125 per ton.

Challenges and Barriers:

- **Cost of collecting residues in the field:** It costs $30 to $35 per ton to collect agricultural residues. It is unclear what the profit margin must be before farmers would be motivated to provide straw to an ethanol facility. Even at $30 to $35 per ton, incentives may be needed to make ethanol from wheat straw more economical.
- **Past promises:** In the past, other technology providers have made promises to the grass seed farmers regarding their straw by-product, but other than a small export market, nothing has materialized. A strong sense of cynicism exists that will have to be broken before the farmer is willing to develop a working relationship with the ethanol facility. This could be averted if a co-op of growers is formed and becomes part-owner in a facility.
- **Seasonality of feedstock:** As with wheat straw, seasonality and storage are of concern with grass straw. The efficiency and cost effectiveness of storage and collection will need to be carefully considered before the economics of using grass seed straw can be accurately assessed.
- **Competing uses:** Exports and potential fiber markets will continue to increase the market value of the feedstock. An expansion of these markets would create upper pressure on the price for the feedstock.

B. Forestry Residues

According to the Oregon Department of Forestry (ODF), over 28 million of the state's 62 million acres of land base are forests. This represents about 46 percent of the total land base in Oregon. ODF estimates that at least 25 percent of the forested land (area/acres) has severe health problems and is in need of thinning.[23] Most of these forests are in Eastern and Southern Oregon.

The current state of forest health in Oregon is a result of both human and natural influences. The practice of fire suppression has led to severe fuel loading. There is a consensus in the forestry industry that careful, but intensive, thinning management practices are necessary because of the high risk of severe forest fires. ODF estimates that annual fires have cost the state over $25 million dollars a year, an annual cost that is increasing as the health of the forests becomes worse.

[23] Oregon Department of Forestry (www.odf.state.or.us/faq.htm).

The entire state has forested areas in need of thinning. If public policy were in place to facilitate the active management of areas with poor forest health, at a rate of just 2 percent per year, the quantity of small diameter wood thinned could produce nearly 200 millions gallons of ethanol.

The assumption of thinning 2 percent per year is a conservative approach in contrast to estimates prepared by the Quincy Library Group (QLG).[24] The QLG assessed forests in Northern California that are similar to those in Eastern Oregon. The QLG proposed thinning 5 percent per year. By ODF's estimate, there are 7 million forest acres in Oregon that need thinning. At the rate of 2 percent per year, an estimated 140,000 acres could be thinned on an annual basis.

According to a USDA Forest Service report prepared for Jackson County and Wallowa Resources, it is estimated that a normal thinning would generate about 21 bdt per acre[25]. A total of 140,000 acres per year, generating 21 tons per acre, equals 2.9 million bdt per year. NREL estimates that 2.9 million bdt could yield nearly 200 million gallons of ethanol per year. However, until policies are put in place to allow for the consistent thinning of these lands, the available feedstock for ethanol production will be severely limited.

Suitability: Forest thinnings are suitable for ethanol production. The estimated ethanol yield for forest thinnings is over 66 gallons per bone-dry ton.

The cost to remove and deliver forest thinnings to a site within a 50-mile radius ranges between $28 and $40 per bone-dry ton. The Quincy Library Group's study estimates $40 per bone-dry ton. Private mill owners in Oregon estimate between $28 and $35 per bone-dry ton.

Competing uses: Depending upon the uniformity and quality of the forest thinnings, this feedstock could be used as pulpwood, hog fuel for boilers, and biomass derived electricity. According to the Beck Group, a consulting firm in the forestry industry, the pulpwood market fluctuates from a low of $25 per bone-dry ton to a high of $125. The price as of today is about $60 per dry ton.[26]

According to the ODF, however, most of the thinnings have no current market because of a lack of conformity of product. For example, the Blue Mountain demonstration project is a small-scale forest health project in the Blue Mountains of Oregon sponsored by the USDA Forest Service. The project is currently evaluating a section of forests in need of thinning but has not been able to find a market for the residue.

Challenges and Barriers:

- **Lack of a coherent policy concerning forest health:** Although there is consensus among foresters and policymakers that something needs to be done to protect forest health, no comprehensive, coherent policy exists to carry out a maintenance program. Hence, many acres of forests are being left to die from overcrowding and disease.

[24] The Quincy Library Group (QLG) is a 30-member steering committee formed to establish a common ground between environmentalists, forestry industry and the public to improve forest management practices in the Lassen, Plumas and Sierra counties of northeastern California.

[25] 12/1/99 letter to Jackson County Commissioner Susan Kupillas, from J. Michael Lunn, Forest Supervisor, Rogue River National Forest.

[26] The Beck Group, Forest Resource Consultants, Portland, Oregon.

Until a clear policy is set in motion, the availability and cost of the feedstock from this source will be in question.

- **Potential environmental opposition:** One of the biggest forest management challenges is to assure the environmental community that selective thinning is a viable option. A major concern is that forest health thinning practices will turn into over-cutting of the forests and that economics, rather than sound science, will dictate the level of cutting to supply the raw material needs of future ethanol plants.[27]
- **Funding for removal of excess forest fuel:** Public funding would help reduce the cost of feedstock delivery and could be a part of a coherent strategy to deal with the fuel loading and forest health management.
- **Competing uses:** Potential competing markets, such as pulpwood, present a potential challenge to the economics of using thinnings as a feedstock. It will be important for a prospective ethanol facility to determine the quantity of thinnings suitable for pulpwood, which is a premium market, and the remaining thinnings, which could be sold at an economical price for ethanol production. Inconsistency of the quantity and quality of forest thinnings needs further examination on a site-by-site basis.

C. Municipal Solid Wastes

According to the Oregon Department of Environmental Quality, Oregon disposed of over 4.3 million tons of solid waste in 1998. Nearly half of the waste is generated in the tri-county metropolitan area of Portland. Table 5 shows the waste recovery figures for the cellulose fractions of MSW by county.

MSW collection facilities in the tri-county Portland area may be potential sites for collaboration or joint ventures with an ethanol facility. Much of the cellulosic materials could be recovered if the price paid justifies the expense of sorting.

Tipping fees in the Portland metropolitan area are typically about $25 per wet ton. However, markets that currently exist for recovered papers, such as mixed waste paper, exceed the value that would be economical for an ethanol facility. According to the Metro Waste Management Division (Metro), prices for recycled and mixed waste papers range from $60 to $125 a dry ton. Because of the higher value of paper, the most promising feedstock of the municipal solid waste stream for ethanol production is urban greenwaste.

There are over 270,000 bdt of urban greenwaste generated per year in Oregon. According to the Oregon Department of Environmental Quality, over half of the greenwaste is generated in the Portland metropolitan area. Metro estimates that most of the greenwaste collected is currently composted and sold for garden use. Only a fraction of the waste is used as hog fuel for boilers.

According to Metro, the current “tipping fee” – the price charged for disposal – for a ton of greenwaste is $15, making it a potentially economical feedstock for ethanol production. Because of its relatively small quantities and low yields, urban greenwaste would most likely be a supplement to an alternate feedstock stream for cellulose-ethanol production.

[27] A recent fund-raising letter by The Wilderness Society criticizes the forest service for logging and thinning more than appropriate.

Table 5: Cellulosic Biomass Fractions from MSW Recovered in Oregon

	County	Cardboard/Kraft paper (OCC)	High Grade Paper (HI)	Magazines (MAG)	Phone Books (PB)	Mixed Waste Paper (MWP)	Newspaper (ONP)	Total Paper	Wood Waste (WW)	Yard Debris (YD)	Total All
BA	Baker	993.548	35.041	97.934	0.000	85.342	207.766	1,419.631	14.629	602.770	2,037.030
BE	Benton	6,381.697	1,145.373	25.395	3.519	2,724.151	2,988.317	13,268.452	2,527.454	11,267.176	27,063.082
CL	Clatsop	2,710.415	352.005	203.590	4.415	13.067	1,004.405	4,287.897	321.966	1,338.137	5,948.000
COL	Columbia	2,054.934	1,630.761	146.454	0.000	484.418	658.212	4,974.779	1,566.397	8.823	6,549.999
COO	Coos	4,449.509	95.489	341.833	0.000	271.132	1,444.785	6,602.748	1,993.017	875.813	9,471.578
CR	Crook	643.140	42.439	0.000	3.105	0.000	266.790	955.474	481.479	0.000	1,436.953
CU	Curry	1,522.948	21.300	93.785	10.000	92.287	532.101	2,272.421	0.000	0.000	2,272.421
DE	Deschutes	8,225.972	570.718	714.886	52.414	252.976	2,816.602	12,633.568	15,979.500	8,726.430	37,339.498
DO	Douglas	5,475.221	371.059	312.098	26.427	183.816	1,679.639	8,048.260	8,799.667	12,058.568	28,906.495
GI	Gilliam	54.053	1.994	2.844	0.000	2.660	39.600	101.151	0.000	0.000	101.151
GR	Grant	179.414	28.046	10.965	0.000	5.822	64.784	289.031	14.629	0.000	303.660
HA	Harney	197.481	10.349	0.000	0.000	0.311	76.697	284.838	296.234	0.000	581.072
HR	Hood River	1,224.942	47.327	74.807	6.701	0.000	335.799	1,689.576	0.000	55.800	1,745.376
JA	Jackson	14,427.117	1,006.832	514.835	112.832	371.709	4,391.472	20,824.797	25,891.034	13,427.490	60,143.321
JE	Jefferson	668.637	40.370	17.634	3.001	0.000	185.380	915.022	2,305.535	0.000	3,220.557
JO	Josephine	4,013.690	583.543	4.621	50.467	10.855	1,944.445	6,607.621	8,247.674	5,119.758	19,975.053
KL	Klamath	2,664.648	238.585	52.673	0.000	148.957	974.898	4,079.761	2,097.493	2,305.494	8,482.748
LAK	Lake	135.513	7.195	0.000	0.000	0.000	1.389	144.097	0.000	2.500	146.597
LAN	Lane	30,560.685	5,500.340	422.954	118.057	8,210.202	13,251.036	58,063.274	49,501.394	20,706.777	128,271.445
LIN	Linn	7,731.299	1,018.893	682.231	0.018	1,440.635	4,127.069	15,000.145	4,947.119	8,549.887	28,497.151
LNC	Lincoln	3,782.141	94.326	127.319	0.090	1,318.637	1,271.911	6,594.424	59.128	375.089	7,028.641
MAL	Malheur	3,072.129	72.079	100.181	0.000	0.000	527.640	3,772.029	90.000	0.000	3,862.029
MAR	Marion	19,360.954	4,008.606	956.561	155.781	3,019.292	8,401.251	35,902.445	17,854.609	25,887.297	79,644.351
ME	Metro	179,220.395	51,132.308	20,170.009	1,784.269	59,356.146	98,849.210	410,512.337	176,069.757	148,756.531	735,338.625
MF	Milton Freewater	485.803	23.751	11.065	0.057	22.075	124.813	667.564	22.000	160.000	849.564
MO	Morrow	660.772	9.092	0.000	0.000	0.000	101.694	771.558	0.000	0.000	771.558
PO	Polk	3,591.209	651.383	301.560	22.841	221.309	2,135.990	6,924.292	492.999	3,260.829	10,678.120
SH	Sherman	48.598	5.059	22.777	1.000	0.000	59.297	136.731	0.000	0.000	136.731
TI	Tillamook	1,105.155	39.563	106.715	0.000	23.497	841.077	2,116.007	0.000	0.246	2,116.253
UM	Umatilla	6,661.559	112.957	103.136	2.500	221.644	759.706	7,861.502	1,577.430	459.565	9,898.497
UN	Union	1,886.892	35.582	181.461	0.000	267.388	356.824	2,728.147	539.629	645.000	3,912.776
WAL	Wallowa	159.630	7.011	0.000	0.000	0.000	61.624	228.265	2.000	4.000	234.265
WAS	Wasco	1,704.280	36.098	90.629	0.000	38.910	698.052	2,567.969	1,282.500	1,926.998	5,777.467
WH	Wheeler	23.825	1.512	2.100	0.000	0.000	6.000	33.437	10.930	7.310	51.677
YA	Yamhill	5,419.916	472.328	449.379	10.059	21.889	2,826.844	9,200.415	3,701.457	12,221.841	25,123.713
	Totals	321,498.121	69,449.314	26,342.431	2,367.553	78,809.127	154,013.119	652,479.665	326,687.660	278,750.129	1,257,917.454

Suitability: Urban greenwaste is suitable for ethanol production but has lower yields than other feedstocks. The average yield, according to NREL, is about 46 gallons per bone dry ton. Because of its negative feedstock price, urban greenwaste is attractive. There is also a transportation infrastructure in place as all municipalities have greenwaste collection programs for residential customers.

Competing use: Competing markets for urban greenwaste are organic material for composting facilities and hog fuel for boilers. The 1998 Metro Recycling Guide lists 22 facilities that collect greenwaste in the Greater Portland Metro area. This number is expected to decrease because of the current trend to consolidate these facilities, according to the Metro Waste Management Division. Larger recovery facilities could potentially integrate an ethanol facility in their existing operations.

Challenges and Barriers:

- **Need for supplemental feedstock:** Finding other viable feedstocks to supplement greenwaste will be critical because of the relatively small quantities of greenwaste available. It is not clear that the small quantities and lower yields of urban greenwaste could be profitable as the principal feedstock for a production facility. In addition, there will be variations in supply due to seasonality issues.
- **Inconsistent availability:** Greenwaste is collected from many individual sites; therefore, consistency of availability is often hard to predict.
- **Low ethanol yields:** According to NREL, greenwaste has the lowest potential per ton ethanol yield of all the feedstocks analyzed for Oregon. The ethanol yield per dry ton of greenwaste is about 46 gallons.

D. Pulp and Paper Mill Sludge

According to the NW Pulp and Paper Association, there are 10 paper and pulp mills operating in Oregon. Quantities of sludge generated at each mill are not available because the industry is reluctant to report actual figures for competitive reasons. However, based on industry averages, an estimated total amount of sludge produced by these mills is about 183,900 bdt per year.

Like urban greenwaste, sludge would make a good supplemental feedstock to an existing ethanol operation. The economics associated with collection of the feedstock are favorable because at present there is a cost (tipping fee) associated with sludge disposal. However, according to the NW Pulp and Paper Association, there are many alternative disposal methods and uses for the sludge. It is burned in on-site boilers, disposed of in landfills, used as an agricultural supplement, used for dairy bedding and used as a material for kitty litter.

Current cost of disposal ranges from $0 to $70 per wet ton depending on the application or market. From interviews conducted with several mills, it is evident that a cellulose-ethanol option would be welcomed if reliable disposal of the sludge were offered.

Suitability: Paper sludge is suitable for ethanol production and is available year-round. However, because of its limited quantity, it most likely will be a supplemental feedstock to an existing facility. The estimated yield for pulp and paper sludge on average is 66 gallons per dry ton according to NREL. A recent study determined that a paper mill would have to have a negative feedstock cost in order to receive a positive return on investment in an ethanol facility.[28]

Competing uses: The major competing uses for sludge is as boiler fuel, soil amendment, and animal bedding. No markets exist that pay for the true cost of handling the sludge by the mills.

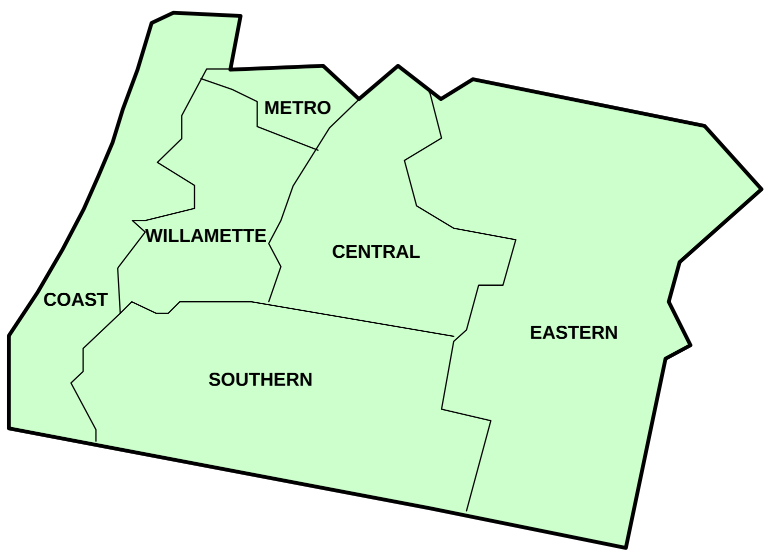
Challenges and Barriers:

- **Need for supplemental feedstock:** The main challenge and barrier with paper and pulp mill sludge as a cellulose feedstock for ethanol is the lack of quantity to justify a stand-alone facility. Because of the negative cost to an ethanol facility, sludge would be promising as a supplemental feedstock. The facility, however, must be located within close proximity to the mill because of the high water content of the sludge, making it a relatively expensive feedstock to transport.

E. Feedstock Potential by Region

The following **Table 6** shows the potential quantities of feedstock available in Oregon by region. Agriculture is the predominant industry in the Eastern, Central and Willamette regions, while forestlands are concentrated in the Metro and Coast regions.

Map 1: Regions in the State of Oregon



[28] Kerstetter, Lynd, Lyford and South, *Assessment of Potential for Conversion of Pulp and Paper Sludge to Ethanol Fuel in the Pacific Northwest* (NREL, March 1997).

Table 6: Estimated Feedstock Potential by Region (dry tons)

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	2,598	0	148,812	10,661	1,711	0
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 residues are not shown. In addition, there are an estimated 2.9 million tons of forest thinnings. However, further research is necessary to determine the location and amounts of recoverable thinnings.

IV. Economic Analysis of Cellulose-Ethanol Production in Oregon

The National Renewable Energy Laboratory (NREL) has spent the last ten years testing and analyzing the efficiencies and economics of cellulosic feedstock conversion to ethanol. NREL conducted an economic pre-feasibility analysis on the most attractive feedstocks in Oregon. NREL's detailed analysis commissioned for this report is in Appendix A.

NREL ran data collected from the feedstock assessment in a model used to estimate the return on investment employing various production scenarios for each feedstock type at different feedrates.[29] The feedrates are the amount of biomass converted each day by the facility. The following shows six feedstocks and respective feedrates used in NREL's economic model.

Table 7: Cellulosic Biomass Feedstocks and Feedrates for an Ethanol Facility in Oregon

Biomass Feedstock	Feedrate (dry tons/day)
Forest Residue	1,369
Mixed Waste Paper	682
Ryegrass Seed Straw	1,232
Wheat Straw[30]	2,739 and 1,600
Pulp and Paper Sludge	180
Urban Greenwaste	400

The model predicts energy and mass flows and a detailed equipment list for purchasing and installation. Once the capital and operating costs are established for the plant, a discounted cash flow analysis is used to determine the project's IRR (Internal Rate of Return) assuming a set selling price of ethanol. The ethanol price for this analysis was $1.25 per gallon; however, the sensitivity analysis also implemented price ranges from $1.10 to $1.40.

Feedrate inputs used in the model were based on data gathered from in-state industry sources and identified feedstock concentrations. Cellulose-ethanol technology used for each feedstock was two-stage dilute acid hydrolysis. NREL conducted a sensitivity analysis on production parameters including capital costs, ethanol selling price, lignin byproduct price and feedstock cost.

[29] "Feedrate" is the quantity of feedstock demand based on the capacity of the plant and feedstock availability. Feedrate figures were estimated from the preliminary feedstock assessment.

[30] Two numbers are shown for wheat straw to bracket the economics better. The initial number was considered too optimistic after feedstock availability was more fully assessed.

Two scenarios were initially modeled: in one, the ethanol plant uses a boiler fueled with the lignin byproduct. In the other, the plant uses a natural gas boiler and sells the lignin byproduct. The natural gas boiler scenario gave the best IRR. However, since finding a market for the lignin is very uncertain at this time, the biomass boiler scenario, which burns the lignin produced on site, was used as the base case. The modeling results in **Table 8** show that forest residues, wheat straw and urban greenwaste residues produced the highest IRR – 19.0 percent, 18.3 percent and 14.0 percent respectively. The wheat straw scenario with a lower feedrate produced an IRR of 7.0 percent.

Table 8: NREL Pre-Feasibility Results Using Natural Gas Boiler Design

Oregon Project Results

As of: 1/11/2000

Feedstock	Forest Residue	Wheat Straw	Urban Greenwaste	Mixed Waste Paper	Rye Grass Straw	Paper/pulp Sludge
Boiler Model Used	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	
Model	A9912H2	A9912H4B	A9912H7	A9912H3	A9912H5	Not Modeled
Feedrate (BDT/day)	1369	2739	400	682	1232	180
Feedstock Cost ($/BDT)	$28	$30	-$20	$20	$35	$10
Ethanol Plant Capital Cost ($ MM)	$50.1	$74.5	$30.5	$34.7	$47.7	
(denatured) Ethanol Sales Price ($/gal)	$1.25	$1.25	$1.25	$1.25	$1.25	$1.25
Ethanol Yield (Gal/BDT feed)	58	53	40	55	53	
Ethanol Production (MM gal/yr)	29	54	6	14	24	
IRR	***19.0%***	***18.3%***	***14.0%***	***7.0%***	***-1.3%***	***??***
Other Results:						
Electricity Demand (kW)	9,519	17,102	4,000	5,310	8,621	
Natural Gas Demand (lb/hr)	13,664	23,534	4,500	7,093	10,254	
Flow to WWTP (gpm)	700	1,340	250	375	620	
Wastewater COD (ppm)	232	305	260	172	365	
Lignin-residue Heating Value (MM BTU/hr)	615	1,006	205	291	447	
Makeup Water Flow (gpm)	1,150	2,000	380	600	850	

A. Sensitivity Analysis for Forest Residue/Natural Gas Boiler Scenario

The NREL model shows four key parameters that have a significant impact on the viability of a project: lignin residue utilization/revenue, feedstock delivered price, percent of project debt financing, and ethanol selling price. A brief summary of the sensitivity results from the natural gas boiler scenario, which delivered the most favorable results, is explained below. (See Appendix A for a detailed summary.)

1. Lignin Residue

The natural gas boiler model assumes that the lignin by-product is sold to other enterprises that would use it as boiler fuel. This analysis assumed that the price of lignin as a boiler fuel would be equal to the cost of other raw fuel materials, such as wood, on an energy basis for the ethanol facility. In the case of the forestry residue scenario, the assumed value of the lignin byproduct is $24 per ton, reflecting an incentive for lignin to be purchased over the raw material. The actual market price of lignin will affect the IRR on an ethanol project. For example, if the price of the lignin were half of the assumed value ($12 per ton) then the IRR for the project would drop to only 8 percent. Any prospective project must carefully analyze this aspect of the economics.

2. Feedstock Costs

Feedstock costs are critically important to production economics, whether in cellulose or grain-based ethanol facilities. In the case of forestry residue, the feedstock was assumed to be delivered to the facility at a cost of $28 per ton. This estimate was based on discussions with a mill operation owner in Eastern Oregon. If the price of delivered feedstock increases to $40/ton, then the IRR drops to 6.6 percent. If policies were implemented to provide subsidies for forest thinnings, dropping the price per ton delivered to $10, then the IRR would be 35 percent.

3. Project Financing

Interest rates and equity investment also can have a significant impact on the viability of a project due in large part to the high capital cost of building a cellulose-ethanol facility. Lowering the interest rate from 8 percent to 3 percent can increase the IRR from 19 percent to 35 percent. Although an 8 percent interest rate is relatively low, such rates can be found. A current project of BCI in Jennings Louisiana has been financed through bonds at 8 percent.[31]

4. Ethanol Price

The ethanol selling price assumption is critical. An ethanol selling price of $1.25 was assumed, based on a projected high demand scenario. The phasing out of MTBE should put upward pressure on ethanol's selling price. In the last three years, the average ethanol selling price in Oregon has been between $1.08 and $1.20.

Because ethanol is the main revenue generator of a cellulose-ethanol facility, the price of ethanol will have a large impact on the IRR. An ethanol selling price at $1.10 will provide an IRR of 10 percent. Should higher selling ethanol markets develop and the total ethanol price becomes $1.40 per gallon, then the IRR would increase to 27 percent.[32]

B. Economic Challenges and Barriers

1. Financing

Many of the emerging cellulose-to-ethanol development companies are small and will require large amounts of financing for their projects. The estimated capital cost of these projects

[31] According to Mark Yancey of NREL via email, 4/13/00.
[32] These figures were based on the natural gas boiler; using the biomass boiler model would give similar scale of changes.

is over $100 million for a 20 to 25 million gallon per year plant, in many cases, with construction costs ranging from $5 to $10 per production gallon. The need for financing for an untested technology creates a significant challenge and barrier. At the projected IRR that this study calculates, it is highly unlikely that investors will invest capital on an untested technology.

2. Market Uncertainty

The uncertainty of the ethanol market also creates a major challenge. Because the ethanol market is so closely tied to federal tax and air quality policies, major investment in new technologies will be limited until there is a strong signal that the ethanol market will grow substantially and securely.

3. Feedstock Supply

Securing long-term contracts with favorable economics for feedstocks is also a considerable challenge and a current barrier to developing a cellulose-ethanol industry in Oregon. Although this report catalogues numerous potential feedstocks, securing them with long-term contracts at a relatively stable price is necessary to attract major capital investment.

4. Production Technology

None of the current cellulose-ethanol technologies available to date has been commercially proven. Until one facility and technology is commercialized, there will be a great reluctance to invest major capital in a cellulose-ethanol facility. Process guaranties from qualified engineering firms may be necessary to overcome this challenge.

C. Economic Conclusions

The economics of a cellulose-ethanol industry in Oregon appear to be possible for the long term but not overwhelmingly positive for the short term. Most investors in new technologies are looking for returns greater than 13 percent. This is especially true when the risks of investing in "new" technology are considered. It is important to note that currently no cellulose-ethanol plants have been built anywhere in the country. When this happens, and the technology and returns are better known, then investors might be more inclined to take advantage of Oregon's enormous cellulose feedstock base.

Of all the feedstocks considered, forest residues, wheat straw and greenwaste show the best returns. More research needs to be done on the net availability and price of specific feedstocks in a concentrated area before a more accurate IRR can be predicted.

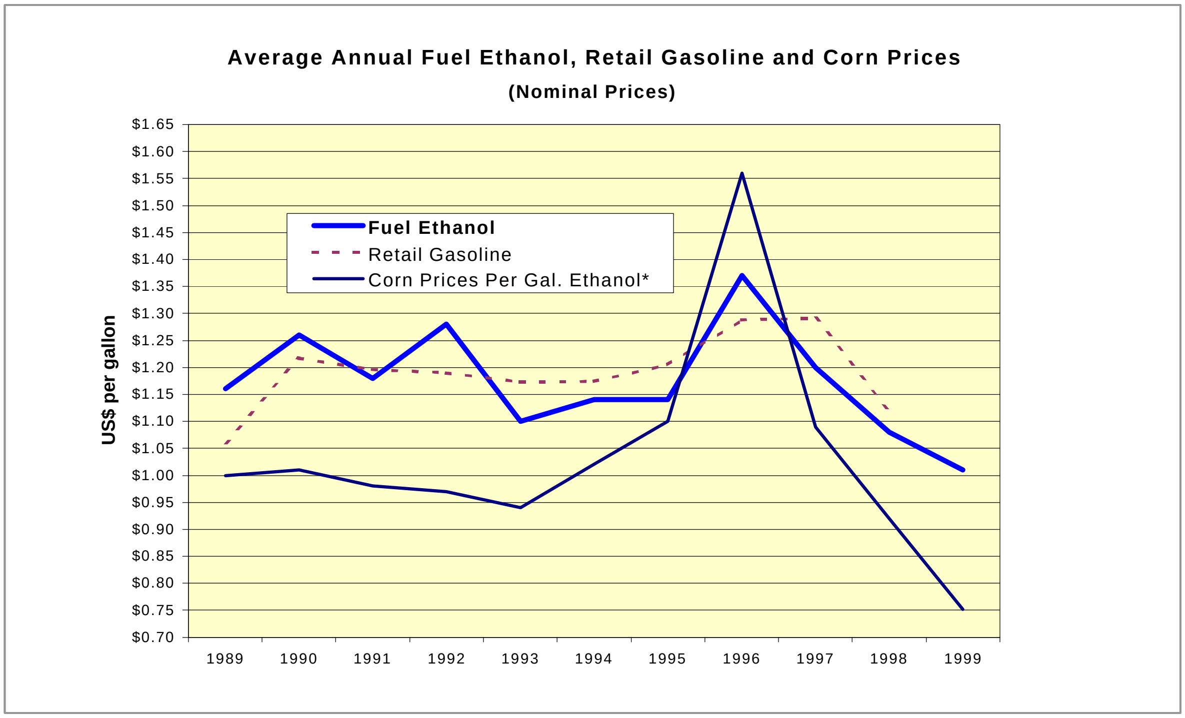
Low cost loans with extended terms offered by the state of Oregon enhance the economics considerably. Finally, a degree of certainty needs to exist on the long-term outlook of ethanol prices and the demand for ethanol in order for large investments to be made in a cellulose-ethanol production facility. This certainty can only come about by positive policy initiatives on the federal and state level that would ensure a growing market for ethanol over the next 10 to 20 years.

V. Ethanol Market in Oregon

A. Price Factors

Until sufficient ethanol production capacity is developed in the Pacific Northwest, most ethanol will be shipped from producers located in the Midwest and the Caribbean. The price of ethanol is reflected by the current ethanol price, FOB Midwest plants, plus transportation costs. Midwest ethanol price is historically near the unleaded gasoline rack gasoline price plus $0.54 (the federal incentive). See **Diagram 2** for average annual ethanol, gasoline and corn prices.

Diagram 2:



Retail Gasoline Data Source: Energy Information Administration (EIA). The data for 1999 are not yet available from EIA.
*Ethanol and Corn Data Source: Hart's Oxy-Fuel News
Prepared by Bryan & Bryan Inc.

The rack price of gasoline is typically higher on the West Coast (see **Table 9**) due to supply/demand tightness in California, the recent complications MTBE has imposed on the environment, and stringent fuel formulations. The phase-out of MTBE would not only eliminate the availability of a significant fuel supply (15-percent blend in gasoline) but a major octane component as well. If the rack gasoline price differential between Midwest and West Coast markets continues, it may provide a continuous blend margin for ethanol.

Table 9: West Coast Ethanol Prices

West Coast Biannual Ethanol Prices 1989-1999 ($/gallon)				
Date	**Avg. Eth.**	**Los Angeles**	**San Francisco**	**Seattle**
Jan-89	$1.11	$1.05	$1.05	$1.24
Jul-89	$1.24	$1.20	$1.20	$1.32
Jul-90	$1.22	$1.20	$1.20	$1.27
Jan-91	$1.11	$1.10	$1.10	$1.14
Jul-91	$1.12	$1.11	$1.11	$1.15
Jan-92	$1.22	$1.17	$1.17	$1.31
Jul-92	$1.35	$1.32	$1.33	$1.39
Jan-93	$1.33	$1.31	$1.31	$1.36
Jul-93	$1.17	$1.16	$1.15	$1.20
Jan-94	$1.10	$1.10	$1.08	$1.13
Jul-94	$1.19	$1.20	$1.20	$1.18
Jan-95	$1.33	$1.31	$1.35	$1.34
Jul-95	$1.15	$1.15	$1.15	$1.16
Jan-96	$1.28	$1.28	$1.28	$1.28
Jul-96	$1.42	$1.41	$1.42	$1.42
Jan-97	$1.24	$1.25	$1.25	$1.21
Jul-97	$1.17	$1.17	$1.17	$1.17
Jan-98	$1.22	$1.23	$1.23	$1.20
Jul-98	$1.08	$1.07	$1.08	$1.08
Jan-99	$1.02	$1.03	$1.01	$1.02
Jul-99	$1.00	$1.00	$1.01	$1.00

Price data source: Hart's Oxy-Fuel News.

B. Potential Demand

The use of ethanol in Oregon exceeds the minimum required to satisfy its requirements under the clean air regulations due to the overlap of service areas and blending economics. The total market for ethanol is price sensitive, depending on the relationship between ethanol and rack gasoline. The actual market demand is difficult to quantify because of a lack of reporting, but ethanol use is about 30 million gallons of ethanol per year according to fuel marketers in the Northwest. The Federal Highway Administration estimates that ethanol use in Oregon is 13.9 million gallons in 1998. This figure is based on gasohol tax collections, refunds, and credits reported to the Internal Revenue Service.

Federal and state designations for air quality standards in a specific jurisdiction may vary from non-designated to moderate and severe, with each designation changing from year to year. In addition, air quality programs may be mandated as a control measure or just maintained as a contingency.

The following list of locations includes all Oregon areas that have been designated as having air quality concerns and are, or may be, part of a winter oxygenate program:

- Grants Pass, Josephine County
- Central Business District, Klamath Falls, Klamath County

- Medford Urban Growth Boundary, Jackson County
- Portland Metropolitan Area

C. Distribution

There are no refineries in the state of Oregon. Instead, the state is served primarily by the refineries in Washington and to a lesser degree from northern California. Major terminals are located in Portland, which is serviced by tanker, barge, pipeline or rail. Eugene is served by pipeline or rail. Branded gasoline retailers of fuels include Texaco, Cenex, Chevron, Tosco and Tesoro.

VI. Overview of Possible Sites for an Ethanol Facility

Overall, industrial land is available and plentiful in every region throughout Oregon. The state is committed to sustainable development and economic prosperity for all of its prospective businesses and citizens. The Oregon Economic Development Department (OEDD) focuses on industry development and assists companies that are considering Oregon when siting a facility. If a company were to provide them with specific requirements, the department will seek out the information from each region to find the best fit. This process is extremely expedient, averaging around two weeks.

Land opportunities across the state are vast, and each parcel offers something unique, including access, infrastructure, building costs and environment. In addition to the state incentives, each region offers incentives to siting a facility. The following is a sample of possible industrial sites for an ethanol facility in the state.

Hood River

Hood River has property available in its waterfront district. The property has access to freeway, port, water and rail. The property is conducive to the development of an ethanol plant. It is close to Interstate 84 and served by the Union Pacific. However, with only 5 acres available, it could be a tight fit for an ethanol facility. The waterfront property has been created with fill. It has supporting infrastructure, including rail service. It is adjacent to other facilities, such as Full Sail Brewing.

North Central

The Port of The Dalles owns a ready-to-go site that has road availability. The property and the city, however, are not centrally located to other parts of Oregon. The Dalles is located on I-84 and on the railroad line.

Hepner offers industrial land that has sufficient water and sewer access. The Port of Morrow researched the possibility of locating an ethanol plant at this site in the early 80s. Morrow County is second in the state for wheat production. The Port of Morrow has over 4000 acres. It has water supplies and sewage treatment facilities. It has a highway exit from I-84, rail access to the Union Pacific, and is the largest inland river port for barges (in tonnage) in the country. It is the site of a proposed ethanol plant sponsored by Oregon Ethanol, LLC. There are three major potato processors at the port and additional potato residues available from other plants in the area. There is a 700,000-bushel Cargill elevator.

Southeastern

Both Malheur and Harney counties have industrial land readily available that has been zoned, plotted and graded. Because it is close to Idaho, there are potato residues available, along with onions, sugar beets and corn. Malheur County has rail access. Given the region's low population density, it is questionable whether the existing infrastructure and wastewater treatment facilities could support an ethanol plant.

South Central

The Klamath Basin has a number of different factors that come into play and make it an attractive place to site a facility. The three major crops in the Klamath Basin are sugar beets, potatoes and barley. Klamath County has ready access to major highways and freeways, railroads, and California.

A 600-acre industrial site in Klamath Falls has its own rail served by Burlington Northern and a switching agreement with Union Pacific. Collins Pine has signed a lease with the city for use of portions of this land, and the city is in the process of developing a cogeneration facility.

There are two other industrial parks in the City of Klamath Falls. One is owned by the city, which offers various incentives depending on how many jobs are created. This industrial park has a switching yard and a rail spur. The other industrial park is privately owned.

Lake County has a 40-acre industrial park with its own rail. There are a number of other sites in this region available as well. These sites are already zoned.

Southern

Southern Oregon has some of the largest ready-to-go industrial facilities in the state. Class-A rail service runs directly through the region and up to the Columbia Basin. This is the largest wheat producing area in the state. The region is located along Interstate 5, which is the primary route, running north to south between the major cities in Oregon.

Grants Pass offers facilities at around $3.75 a square foot. White City, about 10 miles east of Medford, has rail service and offers some of the best industrial sites ranging from $1.25 to $2.50 a square foot. White City serves heavy industries and major corporations such as Kodak.

There are some industrial sites available around the Roseburg area, including a 40-acre site east of town under redevelopment for an industrial park. The Oregon Department of Transportation (ODOT) and OEDD funds have been set aside for street improvements. This public/private partnership is in a State Enterprise Zone; thus, tax incentives are given for siting in this area. This site is close to I-5 and has natural gas, although it does not offer rail service. There are four other industrial parks around Douglas County. Each site has at least fifteen acres.

Southern Oregon Coast

Reedsport in Douglas County has a number of developed industrial sites available with rail and highway/freeway access. Its wastewater system, however, would have difficulty with the volume an ethanol plant would create, especially during the winter months when storm water takes up most of the system. The capacity would have to be upgraded, and the city would have to seek out funds to do this. This is not completely out of the question, although the process would be time consuming.

The City of North Bend would have the same wastewater problem. Ethanol production would increase wastewater volume by 25 percent. Coos Bay offers some facilities located adjacent to the bay area. One 13-acre parcel has a rail line running along the property. These sites are located along Highway 101 and are adjacent to rail lines and barge access. Coos Bay, therefore, is the most feasible location on the Southern Oregon Coast.

Willamette Valley/Central Coast

There are several ready-to-go sites available in the Millersburg area, which is located north of Albany along Interstate 5. These sites are served by the City of Albany for wastewater treatment. If wastewater is pre-treated, Millersburg can release its wastewater into the river without wastewater costs. Millersburg has no city property taxes.

There are several sites available within Lane County. The properties located in Springfield are under an Enterprise Zone, which abates property taxes for a few years for new development. Cottage Grove and Oakridge are two rural communities that have property available.

Three sites in Eugene could accommodate an ethanol plant. However, Eugene has a “toxic right to know” law that requires extensive reporting procedures that a company should be aware of if looking to locate in the community. Major land, rail and airport routes intersect the Eugene area. Power and water are plentiful in this area and inexpensive. Natural gas and steam are available as well.

Eugene/Springfield began operating its wastewater treatment plant in 1984. The facility has an average dry weather capacity of 49 million gallons per day (mgd) and wet weather capacity of 175 mgd. The plant is currently operating at about half its rated capacity.

Benton County has an industrial site containing 700 acres. Portions of this property are owned by the City of Corvallis and can be leased for long term monthly at $225 an acre. This property currently has six other companies on its site and is near the municipal airport. The rail runs north and south and is served by Willamette Pacific, which is contracted with Union Pacific. The major crop in this area is grass seed.

VII. Conclusions

Oregon has the feedstock potential to support a commercial-scale cellulose-ethanol industry in the long-term (in 10 to 20 years), based on anticipated advancements in technology, current feedstock costs and projected ethanol market growth. According to the Energy Information Administration, advancements in technology could decrease the cost of cellulose-ethanol from $1.43 per gallon to an estimated $0.69 to $0.96 per gallon by 2020. Before then, however, the industry will rely on the extension of the federal tax incentives beyond 2007 for market security and project financing.

The preliminary feedstock assessment showed that wheat straw and forest residues (primarily from forest thinning) provided the greatest potential based on quantity available, feedstock cost and ethanol production technology. Estimated ethanol production potential from wheat straw, after soil needs have been met, is about 90 million gallons per year (gpy), and estimated potential from forest thinnings is about 194 million gpy. While forest thinnings may provide greater initial production capability, the collection and processing of the thinnings will likely be more difficult and costly than for wheat straw.

The economic viability for a cellulose-ethanol facility in Oregon depends upon the cost of the feedstock, processing costs, ethanol yield and ethanol selling price. Based on a given set of assumptions, NREL's economic analysis assumes that a commercial ethanol facility requires a feedstock cost of less than $28 to $30 per ton and an ethanol selling price of $1.25 per gallon. Factors such as processing costs, capital costs, ethanol yield and economies of scale were also important considerations for determining the viability of a cellulose-ethanol facility. Modeling results were based on plant capacity of 54 million gpy for wheat straw and 29 million gpy for forest residues, both using natural gas-fired boilers. A site-specific feasibility analysis is required to provide a more accurate picture of the economic viability of a cellulose-ethanol facility in Oregon. This would include a detailed assessment of feedstock concentrations, methods and costs for storage and collection, and processing costs.

Environmental regulations play an important role both where feedstock availability is concerned and in the increasing market for ethanol. Regulations affecting forest management strategies, which address fuel loading, would increase the quantity of feedstocks available for ethanol, through forest thinning practices. The continuation of the federal oxygenated fuels program and the banning of MTBE will substantially increase the demand for ethanol over the next couple of decades.

A. Policy Strategies for Near-Term Cellulose-Ethanol Industry Development in Oregon

For a cellulose-ethanol industry to exist in Oregon in the near term, an aggressive set of state policies must be implemented. Such policies would encourage market development and price stability. The industry must first demonstrate the viability of commercial-scale ethanol production using cellulosic feedstocks. Then, national policies and programs must be extended in order to secure financing. To expedite cellulose-ethanol industry development in Oregon, this study recommends four policy strategies.

1. Oxygen Standard

Support of an oxygenated fuels requirement would provide market security for ethanol, which will significantly help the cellulose-ethanol industry overcome the investment risks associated with new technology. Today, the reformulated gasoline oxygen requirement creates the single largest potential market nationwide for ethanol. This requirement may be eliminated because of the adverse effects of MTBE. The repeal of the oxygen requirement would send a negative market signal to the ethanol industry, including the emerging cellulose-ethanol industry. The continuation of the federal mandate or implementation of a state-wide oxygenate standard would be beneficial to the progress toward near-term cellulose-ethanol production in Oregon, resulting in expanded rural development, enhanced waste stream mitigation, and improved air quality.

2. Renewable Fuels Standard

A minimum renewable fuels standard (1 to 2 percent of the total fuel consumed) is a policy option that would increase the market for ethanol, reduce greenhouse gas emissions, improve rural economic development, expand and diversify fuel supplies, and advance new technologies. A renewable fuel standard would require that a percentage of the fuel consumed derive from renewable resources. As a result, Oregon would acquire a new market for forestry residues, agricultural crops and residues, urban greenwaste and other plant-based resources. Since plants are renewable, the state would have a perennial supply of resources for fuel production plus a means to mitigate carbon dioxide emissions from mobile sources.

3. Greenhouse Gas Emission Standard

A policy approach that could be implemented jointly with the renewable fuels standard or as a stand-alone policy is a greenhouse gas emission standard for all energy sources. This policy would help ensure a market for renewable fuels in ongoing climate change programs. It would require that all fuel industries meet targeted greenhouse gas reduction goals through a minimum use of renewable fuels. The standard may be a complement to the Kyoto Protocol agreement or an autonomous progressive statewide program. Several organizations such as the Tellus Institute and the Union of Concerned Scientists have advocated such a policy.

4. Forest Management and Climate Change Policy

A large cellulose-ethanol opportunity exists in the collection of forest thinnings, which some forestry experts believe to be necessary to ensure forest health and reduce the risk of catastrophic fire. The potential for ethanol production is quite large – nearly 200 million gpy if a supported effort to collect forest thinnings were implemented. A policy that linked forest health to the production of positive climate change fuels, such as ethanol, would do two things. First, it would ensure that a reliable source of cellulose was available for a commercial ethanol plant. Second, by linking the forest health issue to greenhouse gas reduction, the possibility exists to broaden the support for a policy on forest health management. Cellulose-ethanol has the potential to be a unifying mechanism in the forest health debate.

B. Recommendations

While the feedstock availability exists in Oregon for the development of a substantial cellulose-ethanol industry, the actual building of a facility may be premature. The technology for cellulose-ethanol simply has not yet progressed to a stage of commercially viability. However, several projects are in progress or on the drawing board to demonstrate commercial-scale cellulose-ethanol production, with the first one expected to start production in the summer of 2000.

Because cellulose-ethanol technology is advancing rapidly, it may be prudent to proceed with legislative efforts designed to improve the viability of a cellulose-ethanol industry for near-term production. These steps may include:

- Legislation to improve forest health through thinning practices, which will increase feedstock availability.
- Re-designating at least a portion of the funds dedicated to forest fire containment to forest management instead, including fire protection measures such as mechanical thinning of overstocked forestlands.
- Tax incentives for ethanol production to secure project financing and reduce long-term debt.
- Legislation emphasizing the use of renewable fuels, such as ethanol, to promote the reduction of greenhouse gases and maintain clean air standards.

Finally, the data collected for this report provides a basis for site-specific study focused on the development of a cellulose-ethanol facility using forest residues or wheat straw. A site-specific study would include a detailed business plan and pro-forma.

Cellulose-ethanol is the next generation of ethanol production. Steps taken now are essential for realizing near-term commercial cellulose-ethanol production in Oregon, benefiting agricultural and forestry economies, local communities, and air and environmental quality, while supplying in-state fuel demands for the long-term.