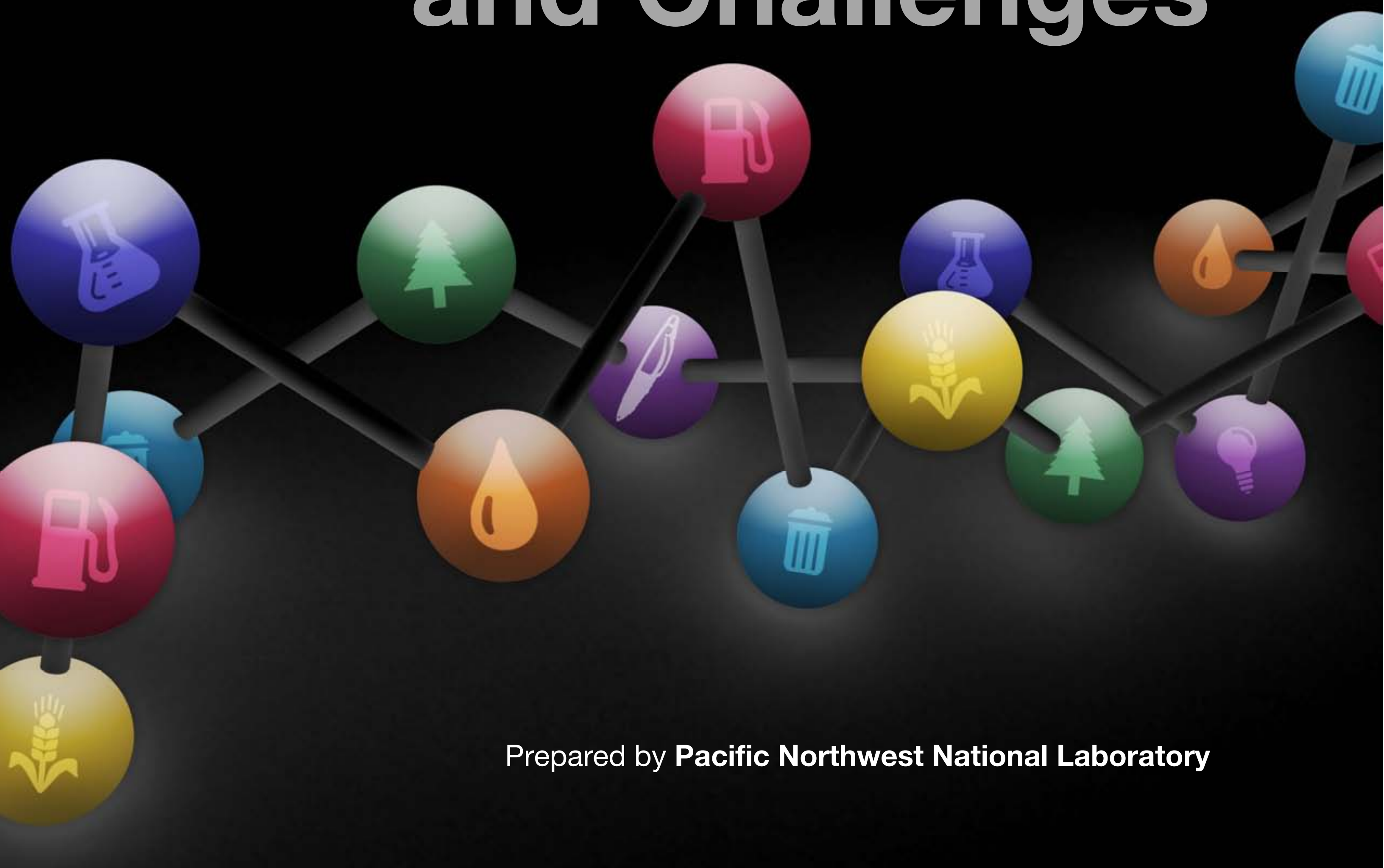
PNNL-17351

Biofuels in
Oregon and Washington

A Business Case Analysis of Opportunities and Challenges



Prepared by **Pacific Northwest National Laboratory**

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Biofuels in Oregon and Washington: A Business Case Analysis of Opportunities and Challenges

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February 2008

This report was funded in part by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, Office of Biomass Programs

Prepared by
Pacific Northwest National Laboratory

Forward

Study Objectives

The subject of biomass-derived fuels is attracting the interest of agribusiness, forest products businesses and investors in Oregon and Washington, particularly in light of the recent growth experienced by the biofuels industry in the Midwest. Policymakers in both Oregon and Washington are seeking to advance the development of a biofuels industry in their states, desiring benefits that include reduced consumption of fossil fuels, reduction of greenhouse gas emissions and creation of new economic opportunity in rural areas. However, there is increasing recognition that these Northwestern states face a different set of opportunities and challenges than other regions, and there is a growing sense that different approaches may be required to create an environmentally and economically sustainable biofuels industry that contributes significantly to the region's energy supply.

The purpose of this report is to assemble the information needed to estimate the significance of the opportunity for producing biofuels in the region as well as the associated challenges. The report reviews the current state of the industry, the biomass resources that are available within current production practices, and the biofuels production technology that is available within the marketplace. The report then seeks to identify the areas in which alternative approaches or strategies, or technological advances, might offer an opportunity to expand the Northwest biofuels industry beyond its current state.

The report draws heavily upon a number of other reports that have explored the regional biomass and biofuels opportunity, including excellent studies by Washington State University, Oregon State University and the U.S. Department of Agriculture that examined the potential biomass resource in the region. The information provided by this prior research is integrated with new data compiled or developed by Pacific Northwest National Laboratory to provide a complete and balanced characterization of the region's assets, opportunities and challenges. This characterization is not meant to suggest a particular answer or approach. Rather, it is intended to provide a body of knowledge from which the business community, policymakers and research institutions can base their respective efforts to foster an economically and environmentally sustainable biofuels industry that serves the needs and interests of Oregon and Washington.

Acknowledgements

The authors would like to thank Mr. J. Michael Davis, Associate Laboratory Director for Energy & Environment at the U.S. Department of Energy's Pacific Northwest National Laboratory, for recognizing the need for this regional assessment, his guidance throughout the analysis and the financial support provided by his organization. The authors also would like to thank the Department of Energy's Office of the Biomass Program within the Office of Energy Efficiency and Renewable Energy, particularly Mr. Zia Haq, for co-funding the analysis.

The authors gratefully acknowledge the many contributions made by our colleagues and friends in the region, particularly Drs. Steve Petrie and Russ Karow (Oregon State University), Dr. Ralph Cavalieri (Washington State University) and Dr. Gary Banowetz (U.S. Department of Agriculture, National Forage Seed Production Research Center) for their substantial contributions to the resource analysis and for reviewing numerous versions of the report. Special thanks go to Dr. Tom Binder (Archer Daniels Midland Company), Mr. Gerson Santos-Leon (Abengoa Bioenergy) and Dr. Denny Hunter (Weyerhaeuser Corporation) for providing technical review of the process and economic information used throughout the report. Finally, we thankfully acknowledge the team of Ms. Dawn Zimmerman, Ms. Virginia Sliman, Mr. Chris DeGraaf, Ms. Rose Watt and Mr. Mike Parker for their work in editing, formatting and visually enhancing this document.

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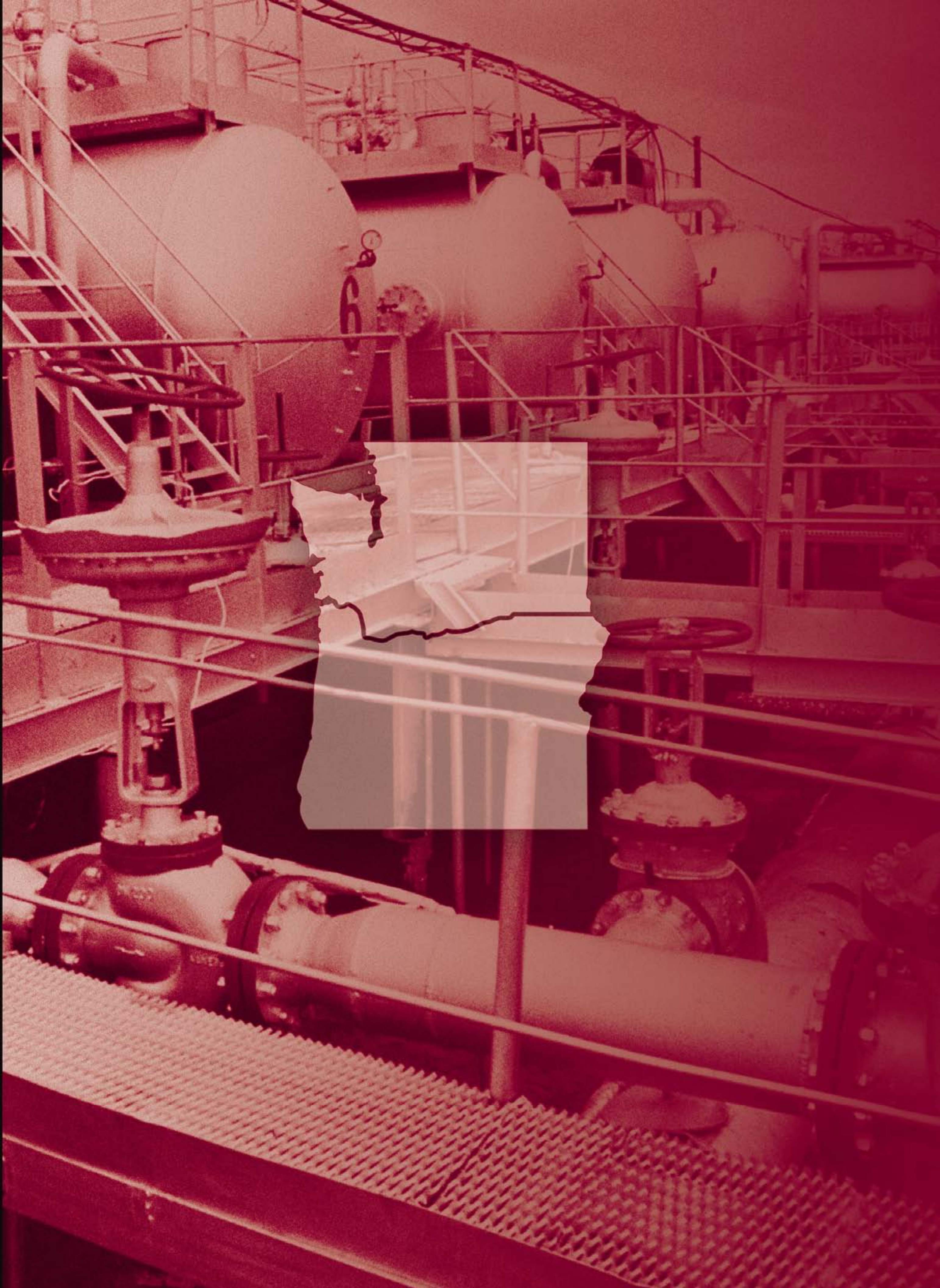
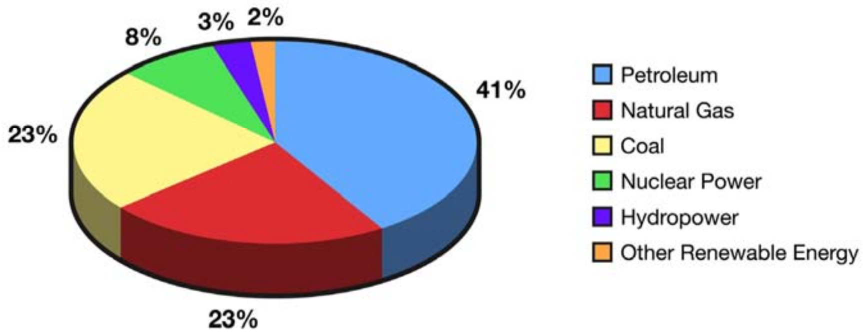


CHAPTER ONE

Together, Oregon and Washington consume more than 7 billion gallons of transportation fuel each year.

Fuels: A National and Regional Perspective

Energy is essential to the U.S. economy and a reliable supply is critical to the nation's quality of life. The total energy needs of the United States are met through a mix of resources, shown in Figure 1, with petroleum supplying more than 40 percent of the energy used in the nation. Demand for petroleum largely is driven by use of transportation fuels, which account for approximately 65 percent of U.S. consumption of petroleum. Of the total petroleum required to meet current demand, more than 65 percent is imported. According to the Energy Information Administration (EIA) U.S. petroleum consumption is projected to increase by about 25 percent by 2030 (EIA-AER 2007), further increasing dependence upon foreign supplies and potentially resulting in supply uncertainties and price volatility (Scott 2006). Compounding the challenge are the environmental impacts associated with consuming petroleum, particularly carbon emissions.



Note: Chart developed from data provided in Reference 1.

FIGURE 1. United States Energy Portfolio (billion Btu, 2006)

Source: Energy Information Administration

In response to these challenges, it is important to displace imported petroleum with reliable domestic resources, to use renewable resources where possible, and to develop technologies that mitigate the environmental impacts of producing and consuming energy. Biomass is one part of this strategy because it represents a renewable resource that can be substituted for petroleum in production of transportation fuels and chemicals. The national goal is to produce 30 percent of today's fuel needs, or approximately 60 billion gallons per year, from biomass by 2030 (U.S. Department of Energy 2007). Implementing the national goal at the regional level (i.e., using biomass to supply as much as 30 percent of the fuel consumed in Oregon and Washington) would equate to a need for more than 2 billion gallons of liquid fuel from biomass annually. This chapter describes the current liquid fuel market in Oregon and

Washington and the product distribution infrastructure that serves this market to better understand how a new biofuels industry might integrate with them.

Regional Fuel Consumption

In 2005, the most recent year for which U.S. Department of Energy statistics are available, Oregon and Washington together consumed more than 7 billion gallons of gasoline, distillate and jet fuels, as shown in Table 1. Use of petroleum for transportation fuel represents roughly 40 percent of the combined Oregon and Washington energy consumption. In addition, fuel use increased by 5 percent between 1990 and 2003 (EIA-SEP 2007).

TABLE 1. Petroleum Product Consumption (billion gallons per year, 2005)

Product	Washington	Oregon	Total
Gasoline	2.74	1.57	4.31
Distillate Fuels	1.04	0.75	1.79
Jet Fuel	0.78	0.23	1.01
TOTAL	4.56	2.55	**7.11**

Source: Energy Information Administration

Other fuel products used in the region include small amounts of compressed or liquefied natural gas and propane, limited (but growing) quantities of ethanol and biodiesel, as well as marine and other specialty fuels.

Regional Petroleum Product Supplies

There are five refineries located in Washington state (Table 2) and in 2003 these refineries operated at greater than 94 percent of capacity, producing 24.2 million gallons of product per day, representing a net annual market value of $7.3 billion. As shown in Figure 2, gasoline is by far the largest product category and accounted for 50 percent of the total output value. Together, these refineries employ 1,750 people with an average annual wage of $80,357 (twice the Washington average), supply more than 80 percent of the fuel consumed in Washington, more than 90 percent of the fuel consumed in Oregon, and export products to other states as well. The balance of Oregon and Washington supplies are sourced from refineries in California, Montana and Utah (Washington Research Council 2004).

TABLE 2. Washington State Crude Oil Refineries (2003)

Firm	Built	Location	Major Products	Capacity
BP Cherry Point	1971	Ferndale	Gasoline, diesel oil, jet fuel, coke	**9.5 million gal/day**
Conoco Phillips	1954	Ferndale	Gasoline, diesel oil, jet fuel, liquefied petroleum gas, residual fuel oil	**3.9 million gal/day**
Shell Oil	1957	Anacortes	Gasoline, diesel oil, jet fuel, propane, coke, sulfur	**6.1 million gal/day**
Tesoro	1955	Anacortes	Gasoline, diesel oil, turbine & jet fuel, liquefied petroleum gas, residual fuel oil	**4.8 million gal/day**
U.S. Oil	1957	Tacoma	Gasoline, diesel oil, jet fuel, marine fuel, oils, emulsifiers and asphalt	**1.9 million gal/day**

Source: Washington Research Council

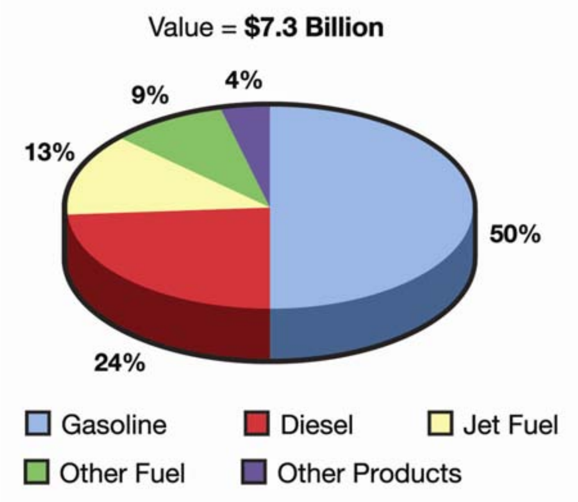


FIGURE 2. Washington Refinery Fuel Production Value (2003)

Source: Washington Research Council

The Pacific Northwest has no indigenous source of oil, so Washington refineries draw on other sources, shown in Figure 3. Alaska supplies more than 80 percent of the crude oil processed in Washington (delivered by tanker ships) with the balance imported from Western Canada via the Trans Mountain pipeline. Crude oil rarely is purchased from other regions, except when Alaskan or Canadian crude is in extremely short supply.

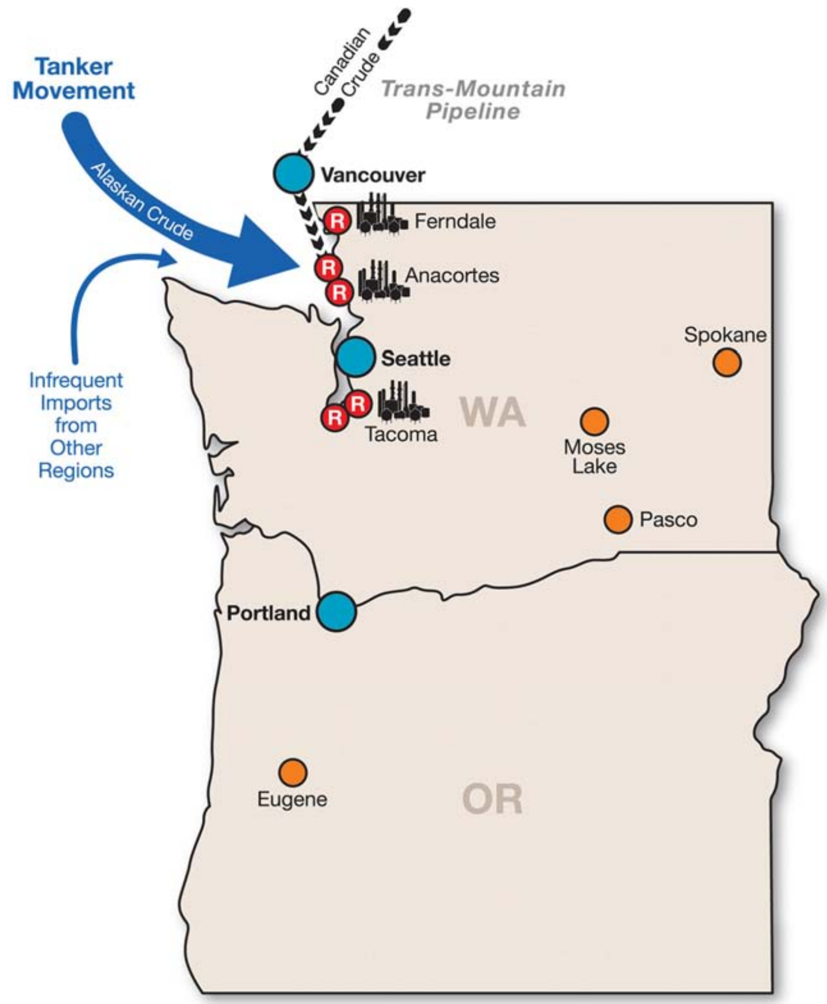


FIGURE 3. Petroleum Supply to Washington Refineries

Source: Washington Research Council

The Northwest is not significantly dependent upon foreign supplies of oil or finished products. However, Alaskan production is expected to decline in the future so Washington refineries will either look to Canada to replace this supply, or to sources in South America, Asia or the Middle East. However, the ability to source crude oil from regions that typically deliver petroleum using supertankers may be limited by the 1977 Magnusson amendment to the Marine Mammal Protection Act which restricts the size of oil tankers entering the Puget Sound, effectively preventing the use of supertankers for transporting oil to Washington refineries and limiting the expansion of Puget Sound refinery capacity, except as needed for in-state consumption. Therefore, as regional populations grow, these states may become increasingly dependent upon other states for fuel unless other means can be developed to deliver crude to these refineries or alternative fuel production options are developed.

Petroleum Fuel Distribution Infrastructure

Half of all fuel products refined in Washington are transported from the refineries by pipeline, shown in Figure 4, which is the lowest-cost means of transportation. The Olympic pipeline, the largest in the region, delivers to terminals in Seattle, Tacoma and Portland for distribution, while smaller branches along the north-south Olympic pipeline deliver petroleum products directly to large users such as SeaTac Airport and McCord Air Force Base. These pipelines are heavily utilized and operate very near capacity. Another 40 percent of Washington's refined product is shipped by water, primarily to Portland, and the balance is transported by other modes (mostly truck) for short distances.

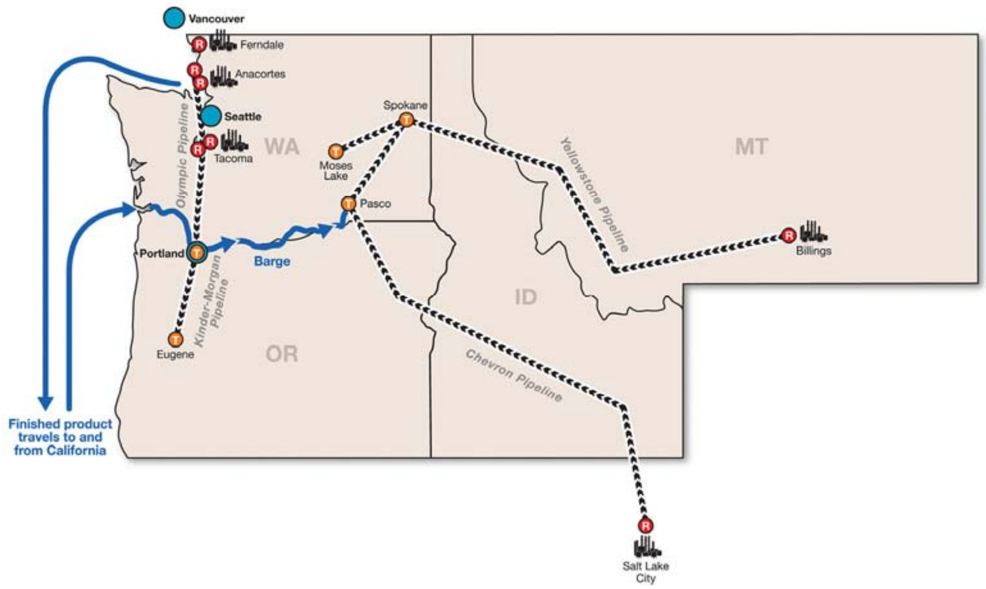


FIGURE 4. Petroleum Fuel Distribution Network

Source: Washington Research Council

Portland is a major fuel distribution hub, receiving fuels from Washington and California, then moving finished products either through the Kinder-Morgan Pipeline south to Eugene, or east through the Columbia and Snake River barge system. The Columbia-Snake system stretches more than 500 miles inland from the Pacific Ocean and enables low-cost barge service to river ports within Washington, Oregon and Idaho, including delivery of 4.5 million gallons per day of petroleum products to distribution terminals in Washington and an additional 1.2 million gallons per day delivered to Idaho ports on the Snake River. Barges transporting petroleum products comprise 65 percent of all upriver traffic (U.S. Army Corps of Engineers 2004). These containers are returned downriver empty, which could present a low-cost transportation opportunity for eastern producers of biofuels that are compatible with this shipping mode. Other distribution installations are located in Pasco, Spokane and Moses Lake at the terminals of the Yellowstone and Chevron pipelines. The pipelines are heavily utilized and operate very near capacity.

Petroleum Product Price Estimates

The final cost of gasoline or any finished petroleum product reflects crude oil purchase, transport and storage costs; refining costs; and finished product storage and delivery to retailers. Addition of federal tax ($0.18.4) and state tax ($0.24 and $0.34 for Oregon and Washington, respectively) to each gallon forms the basis for estimating the wholesale cost of fuel. Various studies estimate that oil will trade within a range of $50-$75 per barrel, with an average price of $65 per barrel, through the decade (Edwards 2006 and EIA-AEO 2007). When refining and transportation costs as well as taxes are added, results indicate an estimated average wholesale price of approximately $2 per gallon for both gasoline and diesel in the region.

Clearly prices for both petroleum and finished products will fluctuate, with crude oil trading well above $65 per barrel in certain circumstances and with wholesale fuel prices likely to spike above $2 per gallon in select circumstances, perhaps even for extended periods. However, these estimates provide a benchmark for biofuels, which must compete based upon realistic price projections. Historically, ethanol prices have been tied to wholesale gasoline prices, averaging a premium of $0.40 per gallon above the wholesale gasoline price. This, in turn, sets the value of the biomass purchased for biofuel production.

Summary

Oregon and Washington consumed a combined 7.1 billion gallons of transportation fuel in 2005 and this consumption is expected to grow as the populations of both states expand in the coming decades. While the region is presently not dependent upon foreign sources of oil to produce this fuel, the Alaskan crude oil production that is the source of most of the region’s fuel is expected to decline in the future and there will be a need for replacement supplies that do not require supertankers for delivery. Clearly, growing demand and constrained petroleum supplies present an opportunity for a biofuels industry. However, in order to make a significant contribution to the region’s needs, a new industry must be built that can reliably supply significant quantities of fuel, perhaps the equivalent of more than 2 billion gallons per year, on a sustainable basis. Further, to be financially viable, the fuels produced by that new industry will need to be competitive with petroleum, most likely reflecting an average price of $65 per barrel for crude oil and with wholesale prices of approximately $2 per gallon for finished fuel products. Building a new industry to that level is a major challenge, but it is a goal that is supported through both national and local policies, which are addressed in the next chapter.

CHAPTER TWO

Federal, state and local initiatives seek to create new markets for biofuels.

Policies Encouraging Biofuels

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A number of federal, state and local policy initiatives have been created to promote use of biomass-derived fuels. Such programs generally seek to create new markets for biofuels and encourage industry growth. This chapter summarizes the most prominent national and regional policy initiatives in place today and explores how such incentives might influence the development of a biofuels industry in Oregon and Washington.

National Policies and Programs

There are a number of federal policies that seek to encourage production of renewable, biomass-derived fuels. These programs are intended to support the national effort to reduce the country's dependence on imported petroleum, improve air quality and diversify farm economies. Production of ethanol in particular has received long-standing support through federal policy.

The earliest market for ethanol was as an additive to increase the octane of gasoline. A new ethanol market was stimulated by 1994 amendments to the Clean Air Act, which required use of oxygen-carrying additives (oxygenate additives) in many parts of the country to reduce smog-forming emissions. Initially, the preferred oxygenate additive was methyl tertiary butyl ether (MTBE) because MTBE was cheaper and could be blended with gasoline at the refinery. Ethanol was used only on a limited basis because it was more expensive than MTBE, not yet widely available and could not be shipped through pipelines with gasoline. However, discovery of MTBE in ground water resulted in declining use of the additive nationally and its total elimination in many states, led by California. The continued requirement for oxygenated fuel, combined with reduced use of MTBE, provided a key new market for ethanol. In 1997, the Environmental Protection Agency estimated that 800 million gallons of ethanol were used for octane improvements and 600 million gallons of ethanol were used for emissions control, compared to more than 7 billion gallons of MTBE used at that time (Environmental Protection Agency 1999). By 2006, U.S. ethanol production had grown to nearly 5 billion gallons, driven in large part by replacement of MTBE.

Support for ethanol production also has also been the focus of energy policy, beginning with the Energy Tax Act of 1978, which established a federal tax credit for production of gasoline blends containing 10 percent ethanol (E10). This credit is available to producers of the finished ethanol-gasoline blend (therefore labeled the "blender credit") through either an income tax credit or an excise tax exemption. This provision has been amended and extended a number of times over the years, most recently in 2004. These latest amendments provide a tax credit to blenders equivalent to $0.51 per gallon of ethanol used and extend this credit through 2010. An additional credit, enacted in 2004 and expanded by provisions of the Energy Policy Act of 2005, provides a "producer" tax credit of $0.10 per gallon for the first 15 million gallons produced at smaller facilities (those with total production of 60 million gallons per year or less).

Also enacted in 2004 is a tax credit for biodiesel, providing a blender credit of $1 per gallon for biodiesel made from virgin vegetable oil or $0.50 per gallon if made from recycled oil (e.g., used cooking grease). The federal tax code also includes other incentives for production and consumption of alcohol fuels, including an income tax deduction for purchasing flexible fuel vehicles (FFVs) equipped for E85 and an alternative fuels production tax credit.

In addition to expanding tax credits, the Energy Policy Act of 2005 also sets a renewable fuels standard (RFS) for the United States that starts at 4 billion gallons in 2006 and grows to 7.5 billion gallons by 2012. This legislation creates a national market that is nearly double the volume of ethanol and biodiesel production capacity in place at the time the act was passed. The act also specifies that a minimum of 250 million gallons of ethanol will be produced from lignocellulosic resources by 2013; this provision is intended to broaden the resource base for biofuels production.

The 2002 Farm Bill also supports biofuel production through the U.S. Department of Agriculture. Through the Rural Development office, the USDA awards grants to rural communities to evaluate and design biomass projects and to businesses in eligible areas to develop renewable energy projects, including biofuels. The USDA also provides loan guarantees for selected eligible capital projects, including biofuels production plants. Together, the programs are intended to support development of a new industry in rural communities and to provide a new market for agricultural products.

In addition to these federal policies, at least 23 states offer some form of excise tax exemption and/or producer credits for biofuels and a growing number are considering or have implemented renewable fuel standards. Both Oregon and Washington recently have enacted legislation aimed at encouraging the development of a local biofuels industry based upon regional resources.

Oregon State Programs

Oregon has a number of state-wide programs that are intended to create a market for renewable energy and stimulate investment in renewable energy businesses. The most significant reflection of this broad commitment to renewable energy is the Oregon Business Energy Tax Credit, which offers a 35 percent credit against Oregon corporate taxes (up to a $10 million total tax credit) for qualifying renewable energy projects, including biofuels and bio-power projects. If a project developer does not have sufficient Oregon tax liability, this credit can be passed through to a partner and the developer can receive the net present value of the credit up front. Other programs include the Small Scale Energy Loan Program, which provides low interest loans and engineering assistance to qualifying renewable energy projects. In addition, the Energy Trust of Oregon, a private non-profit trust funded by a 3 percent fee on electrical rates, offers programs through which all or part of the above-market costs for renewable energy projects can be offset[1].

In 2007, Oregon enacted new legislation focused specifically on biofuels, seeking to create a market, stimulate utilization of local resources and facilitate construction of new facilities. The first element of the legislation is an RFS, which implements a state-wide sales requirement of E10 as soon as in-state ethanol production reaches 40 million gallons per year. The RFS also requires a 2 percent blend of biodiesel (B2) for all diesel sales as soon as in-state biodiesel production reaches 5 million gallons per year. The biodiesel requirement will be expanded to B5 when in-state production reaches 15 million gallons.

The E10 requirement creates a market of at least 150 million gallons per year and the biodiesel requirements create a market of approximately 10 million (B2) to 26 million gallons per year (B5). However, legislation stipulates that enactment of the biodiesel RFS requires in-state production based upon resources grown within Oregon, Washington, Idaho or Montana. Therefore, biodiesel produced using resources imported from other states or countries (e.g., using soybean oil from the Midwest, palm oil from Asia, or Canola oil from Canada) would not satisfy

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[1] Awards to date have supported wind and wood combustion electricity projects.

2

the in-state production requirement and the RFS would not come into effect.

The 2007 biofuels legislation also provides a number of tax credits as incentives for production and collection of resources within Oregon. These include $0.05 per pound for oilseed; $0.10 per gallon for used cooking oil; $0.90 per bushel for grain; $10 per green ton for woody materials and straw; $10 per wet ton for waste water solids; and $5 per green ton for yard waste and manure. Finally, the legislation provides property tax exemptions for rural area renewable energy development zones, defines a streamlined process for issuing state permits for biofuel plant operations and offers income tax credits for purchasing FFVs.

In addition to the state-wide RFS, the city of Portland also has enacted a renewable fuels requirement in an effort to improve air quality and develop a market for biofuels. As a result of this ordinance, all retail diesel sales within the city limits must be B5 or higher by August 15, 2007, with this minimum requirement increasing to B10 by July 1, 2010. The Portland RFS also requires that all retail gasoline vendors provide an E10 blend for sale by November 1, 2007. City officials estimate that this will create a reliable demand of 16 million gallons per year of ethanol and more than 4 million gallons of biodiesel.

Washington State Programs

In March 2006, the Washington legislature enacted a state-wide renewable fuel standard with the intention of “spurring the market” for biofuels within the state (Engrossed Substitute Senate Bill 6508 2006). This legislation requires that all motor fuels include a minimum 2 percent biofuel blend by November 30, 2008, or earlier if the Washington Director of Agriculture determines that Washington feedstock can support production of 2 percent of the fuel requirement. Further, the legislation requires that all state government fleet vehicles use B20 by June 1, 2009, and requires the Director of Agriculture to monitor biodiesel and ethanol supplies until the state’s long-term attainment goals of B10 and E20 are met.

The initial E2/B2 requirement would result in a need for more than 50 million gallons of ethanol and approximately 15 million gallons of biodiesel per year. The biodiesel requirement increases to B5, approximately 38 million gallons, when the Director determines that there is an in-state oilseed crop and crushing capacity sufficient to supply at least 3 percent of the diesel fuel demand. Further, when sufficient raw materials are available in Washington to support economical production of ethanol at higher levels, the Director can raise the ethanol blend requirement to E10, which would raise the ethanol requirement to more than 265 million gallons per year. Any of the RFS requirements can be suspended by an executive order from the governor if attaining target production is deemed to be infeasible.

2

Summary

The federal, state and local policies described in this chapter have been effective in creating widespread interest in developing businesses to produce and supply biofuels to Oregon and Washington. In particular, the RFS requirements create new markets for ethanol and biodiesel, as shown in Table 3. The demand represented by these RFS requirements, combined with the other tax credits, grants, and loans, has been effective in stimulating plans for new production capacity, which is addressed in the next chapter.

TABLE 3: Market Created by State-wide RFS Requirements (million gallons per year, based upon 2005 consumption reported by EIA)

Consumption	Oregon	Washington
Gasoline	1,570	2,740
Distillate fuels	750	1,040
Estimated RFS Requirement*		
E2	NA	55
E10	157	274
B2	15	21
B5	38	52


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87
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89
E85
MINIMUM 85% ETHANOL

CHAPTER THREE

Current Biofuels 3

Biofuels currently comprise a small portion of the fuel supply in the Northwest, but production capacity is expanding.

Current Role of Biofuels

Biofuels have historically been a very small portion of the fuel supply for Oregon and Washington. Both ethanol and biodiesel, the only biofuels available with defined product standards for modern motors, are used in the region. However, these biofuels have comprised less than 2 percent of the region's total fuel consumption and until recently there has been very limited local production of biofuels. However, the state and local policy initiatives described in Chapter 2, combined with growing popular interest in biofuels, have created market conditions that are resulting in new production capacity. This chapter explores the current consumption and production of biofuels within the region, plans to expand production, and some of the initial challenges that must be overcome to achieve a sizeable biofuels industry that uses local resources.

3

Ethanol

Ethanol is the most widely used biofuel in the United States. Nearly all of the current U.S. ethanol production involves fermenting the starch fraction of corn, with 1 bushel of corn producing at least 2.8 gallons of ethanol (Iowa Corn Promotion Board 2006). The U.S. ethanol industry will consume approximately 2 billion bushels of corn to produce more than 5 billion gallons of ethanol in 2007, accounting for approximately 18 percent of the U.S. corn harvest (National Corn Growers Association 2007).

Ethanol is an alcohol that burns cleanly, producing fewer smog-forming carbon monoxide and nitrogen oxide (NO_x) emissions, and 12 to 19 percent less greenhouse gas emissions than gasoline. It also has approximately 30 percent less energy content per gallon than gasoline. Ethanol usually is blended with gasoline and any gasoline engine can burn blends that contain low percentages of ethanol, but engines need some modifications to use fuel blends containing more than 10 percent ethanol (known as E10). All American automobile manufacturers have been producing specially equipped vehicles, called flexible fuel vehicles (FFVs), which are capable of burning both regular gasoline and gasoline-ethanol blends of up to 85 percent ethanol (E85) and a number of import manufacturers plan to introduce FFVs in the future.

Ethanol – Regional Markets and Production

Until recently, Oregon and Washington represented a very minor ethanol market. In 2005, the two states consumed only 92 million gallons of ethanol, according to the Energy Information Administration (EIA), and there was no ethanol production in the region as recently as 2005 (EIA-SEP 2007). The emerging regional market spurred by the state Renewable Fuel Standards (RFS) and growing popular interest in renewable fuels in both Oregon and Washington have resulted in plans for a number of new ethanol production facilities. The first new plant in Oregon began operation in October 2007 (Pacific Ethanol in Boardman, 40 million gallons per year capacity) and the second is expected to begin production early in 2008 (Cascade Grains in Clatskanie, 113 million gallons per year capacity). The first new plant in Washington is under construction (Northwest Renewables in Longview, 55 million gallons per year capacity) and applications for construction permits have been filed for five more plants in Washington, which would add at least 200 million gallons per year of production capacity.

Together, the operating plant, plants under construction, and the facilities presently seeking permits, would produce enough ethanol to meet 9 percent of the region's current gasoline demand if operated at design capacity and would nearly satisfy the market created by the recent RFS legislation passed in both Oregon and Washington. Other facilities have been proposed or considered, but growing beyond the 10 percent of regional fuel supply will require either new infrastructure or creation of new markets.

As of 2005, there were only 16,300 FFVs in Oregon and Washington (EIA-SEP 2007), a small percentage of the current vehicle fleet. A growing number of new vehicles will be FFVs, but it will still take many years for existing vehicles to be retired and replaced with FFVs. Further, only a small percentage of the nearly 5,000 filling stations in Oregon and Washington have E85 pumps, so this is an additional investment that must be made to expand the local ethanol market beyond E10. These infrastructure factors may limit the near-term, local market for ethanol.

However, biofuel production in Oregon and Washington may not be constrained by the local market. Both states are well situated to produce ethanol for export to a growing California market, capitalizing on the railroad infrastructure that already delivers large quantities of grain to the deepwater port in Portland. In addition, the availability of barge systems for transportation of biofuels via the Columbia River system and down the Pacific coast to California may enable the Northwest ethanol industry to be competitive with producers in the Midwest and to grow more quickly than would be expected based solely upon local demand.

Ethanol – Regional Feedstock Supply Limitations

While a regional ethanol industry is emerging and could grow as demand within the region and in California expands, a limited portion of ethanol production will be derived from feedstocks grown in the region. All of the current ethanol plants that are in construction or that have filed for construction permits plan to start production using corn imported from the Midwest and are sited specifically to capitalize upon the large volume of corn brought into the region by rail.

Oregon and Washington agriculture does produce cereal grains that could substitute for corn. Together the two states grow more than 200 million bushels of wheat and about 40 million bushels of barley annually, and both wheat and barley are suitable sources of fermentable sugars. However, these grains also have higher value in the food market than corn does in the fuel market. In particular, the export value of wheat, which historically has averaged about $3 per bushel and recently exceeded $6 per bushel at the Portland commodity market, makes wheat a more expensive source of starch than corn, typically trading about 25 percent higher than corn. Barley, which at times has a market value closer to that of corn, would be a comparable source of fermentable sugars, but the limited barley crop in Oregon and Washington would not provide a significant supply for biofuels production. In fact, replacing corn imported from the Midwest for all of the planned ethanol production in the region would consume more than 30 percent of the combined wheat and barley crops of Oregon and Washington, driving prices for those crops higher and diverting them from the human food supply. It is possible to grow some corn within the region, but this requires irrigation and only a relatively small portion of the region's agricultural land is irrigated. Further, the revenue potential of corn grown for fuel is lower than the revenue potential of other food and forage crops that are usually produced on the same irrigated acres (e.g., potatoes and other vegetable crops, or alfalfa). In years where corn prices are unusually high, such as the 2007 crop year, a limited number of acres can be expected to be converted to corn production, but again this is unlikely to result in a significant and sustained local grain supply. As a result, until other resources are found, corn grown outside of the region likely will be the preferred feedstock for the majority of the ethanol produced in Oregon and Washington.

Biodiesel

Another biofuel used in the region is biodiesel, which is produced from vegetable oils and animal fats. The production process involves addition of an alcohol (usually methanol) to the fatty acid in the presence a catalyst, with extensive mechanical mixing of the products. The finishing steps require recovery of the catalyst materials, separation of the by-product glycerol, and removal of all water and any contaminates (e.g., soap, which is formed if water is present in the process) from the diesel stream. Capital costs for biodiesel plants are attractive and the overall process is reasonably simple to operate, although considerable care is required to ensure that the biodiesel produced conforms to strict industry standards.

Biodiesel can be blended with petroleum diesel and is used in ranges from 5 percent blends (B5) up to 85 percent (B85), or even as pure biodiesel (B100). There are many advantages of blending biodiesel into petroleum diesel – carbon monoxide, particulate and total hydrocarbon emissions are reduced by blending and the biodiesel improves the lubricity of low-sulfur diesel. Biodiesel also is safer to store than petro-diesel and is biodegradable, which may make B100 attractive for use in marine and other sensitive environments, such as national parks. However, higher biodiesel blends can increase NO_x exhaust emissions and some petroleum fraction is usually necessary to control fuel changes that occur at lower temperatures – referred to as “cold flow properties” – which can affect engine performance.

Biodiesel – Regional Production and Supply Limitations

Feedstock generally comprises 75 percent or more of the product cost for biodiesel. As a result, many early production plants utilized the used cooking oil and waste fats collected at restaurants, which were available as a low-cost waste product. However, there is a relatively small supply of yellow grease and the bulk of the resource produced in urban centers now is consumed for biodiesel production in Oregon and Washington (Lyons 2005). In order to increase production, regional biodiesel producers have had to seek other feedstocks, typically vegetable oils such as soybean or canola oil, or tropical oils such as palm. Because there is very limited local production of oil crops in Oregon and Washington, most of the feedstock must be imported from other regions. Further, due to the value of vegetable oil in the food market, it has been difficult for these facilities to acquire oils at prices that enable production of biodiesel at a cost that is competitive with petroleum diesel.

These factors have constrained total production capacity within the region. Two small facilities in Oregon currently produce 1 million gallons per year at each plant (National Biodiesel Board 2007). In Washington the existing production capacity is larger, reported to be between 25 million gallons per year (National Biodiesel Board 2007) and 40 million gallons per year (Washington State University Extension Energy Program 2007). There are a large number of facilities being considered in both states, but the most significant increase in production capacity has been the recent construction of a 100-million-gallon-per-year plant by Imperium Renewables (formerly Seattle Biodiesel) in Grays Harbor, Washington. Initially, only 1 percent of the vegetable oil supplying that facility will be derived from crops grown in Washington, but that 1 percent of capacity will consume a significant fraction of the oilseed crop produced in the region. The balance of the oil will be imported, either Canola oil purchased in Canada or palm oil imported from Malaysia and Indonesia.

Summary

A biofuels industry is emerging in Oregon and Washington, building facilities that will produce ethanol and biodiesel. As shown in Table 4, facilities that already are operational, under construction, or well into the permitting process in both states will provide enough biofuel capacity to approximately match the initial markets created by RFS legislation in both states. Further, the regional ethanol production capacity could experience further growth, driven by the opportunity to export to other nearby markets, particularly California.

TABLE 4. Expected Biofuel Production Capacity vs. Consumption and Estimated RFS Requirements (million gallons per year, consumption and RFS estimates based upon 2005 EIA data)

Consumption	Oregon	Washington
Gasoline	1,570	2,740
Distillate fuels	750	1,040
Estimated RFS Requirement*		
E2	NA	55
E10	157	274
B2	15	21
B5	38	52
Estimated Near-term Production Capacity		
Ethanol	153	255
Biodiesel	2	125

However, the attendant desire to produce these biofuels using local resources, thereby creating greater opportunities for Oregon and Washington farmers and rural communities, will be difficult to realize in the near term. While a number of small biodiesel facilities currently use locally generated feedstock, the majority of the current biodiesel production is based upon oil supplies from outside the region and all of the planned ethanol capacity is based upon corn imported from the Midwest. The emerging industry is dependent upon imported feedstocks for production and will remain so because the crops that have traditionally supported these products are not currently available in the region in sufficient quantities to support a large biofuels industry. This limitation indicates the need to search for alternative biomass resources within the region, the subject of the next three chapters.

3

CHAPTER FOUR

Resource: **Agriculture** 4

The current U.S. biofuels industry has drawn almost exclusively on agricultural resources – this may not be possible in Oregon and Washington.

Regional Resource Potential: Agriculture

The existing national biofuels industry has drawn almost exclusively on agricultural resources, creating new markets for corn grown in the Midwest. It is reasonable to ask whether the Oregon and Washington agricultural industry could similarly provide a significant, sustainable resource for production of biofuels. However, many factors specific to the region must be taken into account to adequately gauge the true potential for regional agriculture to provide a sustainable resource of sufficient size to supply a major biofuels industry.

In particular, the Midwest produces two main crops, corn and soybeans, which primarily find low value in the livestock feed and food product markets and which are grown at high yields per acre without irrigation. In contrast, the agricultural systems of Oregon and Washington are more diversified, with the limited irrigated acreage used to produce high value food, seed and ornamental crops on relatively small farms with intensive management. Intermediate value cereal crops are grown on large farms without irrigation and at relatively modest yields. Further, the regional livestock feed markets, which are relatively small, are served primarily by forage crops rather than grain crops.

In addition, while agriculture is a key industry in both Oregon and Washington (see sidebar) the combined agricultural land base of 29 million acres is relatively small (about 3 percent of total U.S. agricultural acreage) and a significant portion of that land base is not highly productive. Based upon 2004 statistics[1], 16.1 million acres (56 percent of agricultural land in the region) were used for range or pasture, 10.2 million acres were cultivated to produce crops, 1.5 million acres were fallow and 1.5 million acres were enrolled in the Conservation Reserve Program (CRP). Because the range, pasture and CRP lands typically have low biomass productivity, this chapter focuses on the more productive cultivated land, which offers the highest biomass production potential. Further, this chapter focuses on three of the five leading crop categories, shown in Table 5. These three categories—cereal grains, hay and forage, and grass seed—present either an opportunity to utilize residuals associated with current land use practices or might support substitution of an alternative energy crop on these acres.

[1] Agricultural statistics presented in this chapter were obtained from the Oregon State University Extension, Oregon Department of Agriculture, and National Agricultural Statistics Service – Washington unless otherwise noted.

Agriculture in Oregon and Washington is a diverse industry,

producing more than 220 different commodities on 74,000 farms and employing 97,000 people. Regional agriculture sales totaled $9.7 billion in 2004, with the leading products listed here accounting for 85 percent, or $8.3 billion, of that revenue.

Oregon	
Greenhouse & nursery	$739
Cattle & calves	$592
Vegetable, berry crops	$524
Grass seed	$351
Dairy	$327
Orchard, vineyard crops	$238
Hay & forage	$226
Farm woodlots	$204
Wheat & barley	$195
Christmas trees	$143

Washington	
Apples, cherries, pears	$1,337
Dairy	$861
Wheat & barley	$525
Cattle & calves	$476
Potatoes	$460
Hay & forage	$376
Greenhouse & nursery	$329
Farm woodlots	$130
Grapes	$127
Hops	$ 80

Leading Agriculture Product Sales in 2004 (million $)

Source: Oregon Department of Agriculture, National Agricultural Statistics Service

TABLE 5. Leading Uses of Cultivated Agricultural Land

Product	Acres
Cereal grains	3,775,500
Hay & forage crops	2,444,500
Vegetables & berries	745,700
Grass seed	620,500
Orchards & vineyards	606,000

Source: ODA, NASS

Cereal Grains

While some limited ethanol production could be based upon cereal grains produced within the region, the expectation is that the primary value of Northwest grains will continue to be found in food markets. However, the straw residue associated with current cereal crops represents a near-term potential resource. Further, it is possible that new energy crops could be developed and grown in rotation with the traditional cereal grain crops. These potential strategies for capturing biomass from the 3.8 million acres used for cereal grain production are addressed in this chapter.

Grass Seed

Production of grass and alfalfa seed is an important regional industry, particularly in Oregon where more than 500,000 acres were planted to grass seed in 2004. Several companies contract with Oregon farmers to grow proprietary seed lines, a major business for Willamette Valley agriculture. The seed is separated from the straw in the field and until about 1990, the residual straw was burned to clear the field, prevent disease, rid pests, and remove thatch. Air quality restrictions now limit burning to about 40,000 acres each summer and there is continued pressure to reduce burned acreage further. While much of the straw has found use as livestock feed, this biomass is often identified as a resource for biofuels, a prospect explored in this chapter.

Hay and Forage Crops

The hay and forage segment of the agriculture industry is of interest because these acres are already dedicated to production of biomass, providing more than 4.5 million tons of biomass annually as forage crops. The livestock feed value of this biomass averages $100 per ton and has recently sold for $150 per ton, making it too expensive for production of biofuels. However, new biomass crops might be developed that could be substituted for livestock forage crops on these acres in a way that could provide a supply to support a biofuels industry, while providing comparable revenues for farmers. This concept also is explored in this chapter.

The remaining cultivated acres are excluded from consideration in this chapter because the vegetable and fruit crops represent relatively high gross revenue potential (ranging from $1,000 to $6,000 per acre), so it is unlikely that these acres would be converted from production of the current primary crops to produce energy crops – there is simply not the same revenue potential – except as part of a normal rotation strategy. Further, while these vegetable and fruit crops generate small quantities of secondary biomass per acre, these residuals represent a relatively small, and very dispersed, potential resource, even in those instances where collection of the residual biomass could be compatible with standard production practices. As noted earlier, corn already is grown in limited acreage as part of rotation strategies but it is unlikely that this segment of the agricultural industry will add significant biomass resources beyond the current practice.

Potential Biomass Resource: Current Crop Residues

Cereal Grain Straw

Several studies have estimated the amount of straw that is produced as part of the annual wheat, barley and oat grain crop in Oregon and Washington. The most extensive studies estimate total straw production at between 10 million tons per year (Banowetz et al. 2007) and 12 million tons per year (Kerstetter and Lyons, January 2001), depending upon the methodology used. Most farmers currently leave all of this straw in the field, except in limited parts of the region that enjoy higher rainfall (more than 18 inches per year), and therefore much higher wheat yields (more than 100 bushels per acre). In those areas, there is often a need to remove straw because it does not fully decompose within a year and it interferes with field preparation and seeding, and because these farmers do not need to leave their fields fallow for a year to accumulate soil moisture. This high-yielding, annually cropped area represents only about 20 percent of the total wheat acreage in the region. Within this limited area, some straw is baled and removed, but this has been done on a very limited basis because historically there have been limited markets for the straw (e.g., as a substitute for grass hay, bedding for dairy cattle or mulch for mushroom growers). This would indicate that there is potential to remove some of the residual straw for use in production of biofuels, but there are competing uses that consume a portion of the supply under some market conditions.

Cereal Grain Straw – Supply Limitations

There are many incentives for farmers to leave straw in the field, including reducing soil erosion, retaining soil moisture, maintaining soil organic matter and desirable soil biological, chemical and physical properties. Such sustainable practices are reinforced by conservation payments from the United States Department of Agriculture (USDA) for most regional grain growers and by legislation for land that is designated as highly erodible.

The USDA Natural Resource Conservation Service guidelines for good conservation practices indicate that no straw should be removed from land yielding less than 60 bushels per acre and that at least 3,000 pounds of straw per acre should be left in place, with 4,000 pounds per acre being more desirable, and some indication that 5,000 pounds per acre would be ideal. If farmers follow these guidelines, the amount of available straw is dramatically reduced. The Kerstetter and Lyons (January 2001) analysis calculated that leaving 3,000 pounds per acre would reduce the estimated 12 million tons of total straw to an available amount of 5.9 million tons per year (4.3 million tons in Washington, 1.6 million tons in Oregon). In the USDA analysis, leaving 4,000 pounds of straw per acre reduces the estimated 10 million tons per year total straw production to an available amount of 3.8 million tons per year (3 million tons in Washington, 0.8 million tons in Oregon). While other studies have estimated the available straw as slightly higher for Oregon—2.1 millions tons (Graf and Koehler 2000), and slightly lower for Washington—1.6 million tons (Frear et al. 2005), the USDA estimate (Banowetz et al. 2007) is a reasonable characterization of the cereal straw theoretically available for other uses after sustainable agricultural guidelines are satisfied.

It is important to note the uncertainty of this prospective resource. Clearly a drought would reduce the available biomass for at least a year, while early fall rains could result in wet material that is difficult to collect and store, or affect the straw quality. Also, changing agricultural practices might have significant impacts, as illustrated by a separate study in which Kerstetter and Lyons (January 2001) indicated that adoption of the recommendation to retain 5,000 pounds per acre in Washington would reduce the available straw in that state to less than 700,000 tons per year, limited only to the highest rainfall band of eastern Washington. Finally, development of new markets, or periodic increases in the livestock feed value of the straw, could create competing uses with shorter transportation distances and reduce the amount of straw available for fuels production.

Cereal Grain Straw – Logistical Limitations

The concerns related to the size of the potential resource are matched by issues related to logistics. The first hurdles will be associated with obtaining a resource that currently isn't collected and that may require development of new technology and new grain production practices. For example, if combines leave tall standing stubble, can the straw be windrowed, or will operators need to change practices? Will it be necessary to develop new equipment and field practices to enable collection of the straw while ensuring that the desired 4,000 pounds are left in place (or 3,000 or 5,000, depending upon the selected guideline)? Such questions must be addressed by public and private research before growers and businesses can decide to make significant investments.

There also are potentially daunting business considerations that require study. For example, if farmers collect the straw, will they require a purchase contract from the biofuels facility prior to making the capital investment in new equipment? Based upon a review of farm size and straw distribution in the high-yield area of eastern Washington (the area with the greatest straw density), Kerstetter and Lyons (September 2001) estimated that a small facility (200,000 tons per year) would need to sign contracts with at least 150 different farms in order to ensure sufficient straw supply. Expansion of the secondary industry that provides on-farm straw collection and subsequent storage and transportation would simplify the interface for the biorefinery, but raises other questions as well. Would such companies be willing to share any of the straw revenues with the farmers? Because the motivation of such firms would be to maximize straw delivery to the biorefinery, can the farmer be sure that straw removal will be done in a manner that doesn't deplete the soil to a degree that requires adding nutrients at a cost to the farmer or lead to elimination of conservation payments?

Cereal Grain Straw – Cost Limitations

Finally, there is the question of feedstock cost. Graf and Koehler (2000) estimated that on-farm collection would cost $25-$35 per ton and personnel at the Oregon State University and Washington State University experiment stations confirm that $35 per ton would be a typical cost to bale and collect straw on the farm. Kerstetter and Lyons (January 2001) estimated that storage costs between $7 and $25 per ton (uncovered stacks vs. a covered pole barn), and transportation of 50 miles adds another $10 per ton. It is not clear what payment would need to be made to the farmer as some growers in the high-yield areas may benefit from removal of "excess straw" while other growers may look for a price at least comparable to the nutrient value of the straw, which has been quoted as low as $7 per ton and as high as $40 per ton. Collectively, these factors indicate a minimum delivered feedstock cost of $40-$45 per ton, with significant risk that costs could be much higher. This is reflected in the supply curves produced by Kerstetter and Lyons (January 2001), which show that the higher resource availability estimates were only reached at delivery costs of $70-$80 per ton. The cost of collection and delivery, the overall supply uncertainty, and the logistical difficulty of obtaining this resource will prove to be significant limitations to developing major biofuels capacity based upon use of cereal grain straw. Still, the recent tax incentives enacted in Oregon (see Chapter 2) may make straw collection and delivery more attractive in that state.

Grass Seed Straw

The total straw produced in association with the Willamette Valley grass seed harvest is between 0.8 million and 1 million tons annually. A secondary industry has developed to collect, bale and remove the straw from the farms, temporarily store the bales, then transport the bales to the port of Portland where they are loaded into containers for shipment to Japan, Korea and Taiwan as animal feed. Prices paid f.o.b. Portland range from $75 per ton to more than $100 per ton, depending upon the grass species. Approximately $50 per ton is distributed among the various collection/storage, transportation and brokerage companies, with growers receiving nominal payments ($10 per ton or less) at best. Approximately 50 percent of the grass straw produced in the Willamette Valley (639,000 tons in the 2004 growing season) currently is delivered to the Portland export market. The remaining portion (more than

200,000 tons in 2004) is either annual rye grass straw, which is not a suitable livestock feed, or is too distant from Portland to be transported economically. Some of this remaining resource is burned, some goes to local markets, and the rest is chopped and left in the fields.

Grass Seed Straw – Competitive Market Limitations

In the near term, the feed market appears more attractive than a biofuels market unless biofuels companies can afford to pay $50 per delivered ton or more at locations very near farm production, and will continue to consume the bulk of the grass straw resource. Consequently, the current resource available to a biofuels industry would be limited to the 200,000 tons of straw that is not exported -- enough to support one very small (20 million gallons per year or less) fuel production facility. It is possible that the value of straw for export could decline significantly if Australia and China enter the market, which some economists believe is quite probable. Further, rising costs of shipping containers (caused by increased exports from Portland to Asia) could price Oregon grass straw out of the export market. In either case, much more of this very concentrated resource would become available to the biofuels market, possibly at prices at or near the cost of collection and transportation, which could be as low as $35 per ton for short hauls (Graf and Koehler 2000). However, even if all of the straw produced in the Willamette Valley were diverted from the export and local feed markets, it would still comprise a very small biofuels resource and the fuel value of the straw would represent a "disposal" option for farmers, not a major new market opportunity.

Summary: Straw as a Current Resource

This analysis suggests that in spite of an apparent abundance, straw actually represents a rather limited biomass resource. As shown in Figure 5, the total straw production in Oregon and Washington is estimated to be between 10 and 12 million tons. However, when accounting for competing uses, particularly the need to leave a significant portion of cereal grain straw in the field as part of sustainable agricultural practices and the current value of grass straw in livestock feed markets, the truly available amount is reduced by approximately 50 pecent. When factoring in the cost of collection, storage, and transportation and applying the supply curves developed by Kerstetter and Lyons (January 2001), the amount that would be available at a cost commensurate with the value of biomass in the biofuel market, the available resource is approximately 1 million tons.

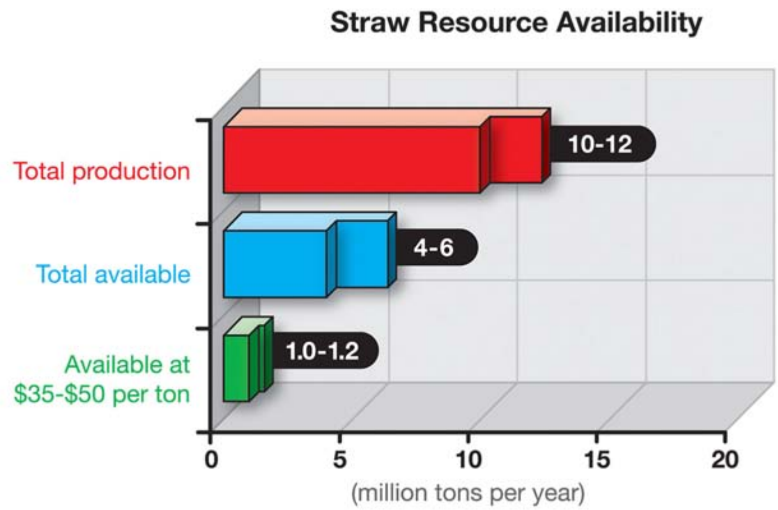


FIGURE 5. Straw: Total Production Versus Availability

In addition, the analysis conducted by Kerstetter and Lyons (January 2001) indicates that the lower-cost ($35 and $50 per ton) cereal grain straw resource is distributed in such a way that this biomass would be divided between five facilities. These facilities would be clustered in the higher-yield areas of northeastern Oregon and eastern Washington. Each facility could draw about 150,000 to 300,000 tons of dry straw each year. When combined with the available grass straw in the Willamette Valley, this indicates that at best the straw resource could supply six small facilities that collectively could produce approximately 100 to 120 million gallons of biofuel annually. This small array of facilities could add to the biofuel production base in the region, but the facilities would still fall short of the goal of creating an industry that meets a significant fraction of the region's fuel demand. Further, these facilities would do little to provide economic opportunity for farmers. This indicates a need to develop alternative means of producing biomass, perhaps by growing new energy crops in rotation with cereal grains or forage crops.

Developing New Biomass Resources for the Future

The remainder of this chapter explores ways to develop a more significant biomass resource by using new crops that might be deployed on the largest portions of the agricultural lands in Oregon and Washington. Options currently being discussed within the region include introducing oil seed crops and high-yield herbaceous energy crops that might be grown in rotation with current crops.

Oil Seed Grains in Rotation with Cereal Grain or Grass Seed Crops

There is a longstanding interest around the region in growing oil seed crops for either food markets or for industrial markets such as biodiesel production. The latter potential market has resulted in renewed regional interest in *Brassica spp.* such as canola, rapeseed or mustard. Ideally these crops could be grown without irrigation in rotation with wheat and grass seed and possibly in rotation with some irrigated crops, both as an alternative in years when market prices are low for the primary crop and as part of sustainable agricultural practices. There have been a number of research trials involving these crops and a few farmers are now experimenting with canola. However, while there is a great deal of interest, there are still a number of uncertainties and limitations that must be addressed to enable production at a significant scale.

The *Brassica* crops have been studied most extensively because they are better suited to the region than sunflower or safflower, which would require irrigation, or soybeans, which are not viable in the region except in extremely limited acreage. Canola has been of particular interest because canola used in rotation with wheat may offer a number of agronomic benefits, including reducing the incidence of certain pests, permitting use of a different spectrum of herbicides for weed control and breaking up compacted soil. Under ideal conditions winter canola can be fall planted in dryland wheat areas or in the non-irrigated land west of the Cascades. Either winter or spring canola could be grown on irrigated land throughout the region. Yields of winter canola usually are significantly greater than spring canola. Test plantings of winter canola in the eastern regions of Oregon and Washington indicate that yields between 1,500 and 1,800 pounds per acre could be expected (Hinman et al. 2003). Trials without irrigation in the Willamette Valley averaged 2,300 pounds per acre and irrigated trials throughout the region have averaged 3,400 pounds per acre, with the promise of yields approaching 4,000 pounds per acre (Karow and Auyong 2006).

Oil Seed Grains – Production Limitations

Although canola holds considerable promise, there also are risks and limitations that need to be addressed through additional research. One limitation is that state agricultural regulators currently do not permit growing canola in Oregon's Willamette Valley or several counties of western Washington because of the risk of cross-pollination with, or contamination of, the high-value vegetable seed crops grown in these areas. More study is required to determine appropriate separation distances and other control measures before these restrictions will be lifted or applied in more limited areas. Another significant limitation is that these crops are not ideally suited for areas receiving less than 12 inches of annual precipitation and planting must follow a fallow cycle for soils receiving between 12 and 18 inches of annual rainfall, greatly reducing the acreage available for planting. In addition, winter canola productivity has proven to be highly variable in dry-land production, with crop establishment greatly impacted by fall weather or fall rains that are too late. Severe cold in late winter, or severe heat in early summer, can also dramatically reduce yields. Due to these factors there currently is no significant dryland production in the region although there is some limited production with irrigation. More work is needed to develop varieties suited to regional weather patterns and to dryland production before there can be a major supply for a regional biofuel industry.

Oil Seed Grains – Production Cost Limitations

Perhaps the most important limitation is production cost. The generally accepted break-even price for canola with current yields and production practices is between $0.13 and $0.16 cents per pound (Hinman et al. 2003), even when factoring in “credits” for avoided costs and possible rotation benefits. This break-even price is about 40 percent higher than the target price desired by biodiesel producers, indicating that higher yields are needed for canola to be competitive in a large fuel market. Even if the cost of production could be reduced, the revenue potential associated with growing canola for fuel would be less than the revenue potential for growing wheat on the same acres. In the near term, it is conceivable that a limited number of acres could go into production, serving regional biofuels producers who have access to markets that are not price sensitive. Therefore, these producers could pay a limited number of farmers a price above their break-even cost. However, given the production restrictions in western Oregon and Washington, the variability and risks of dryland production, and the yield improvements required to lower the break-even price even for irrigated canola, considerable research will be required before large-scale production occurs in the Northwest.

Reflecting upon the research effort required to create new seed lines that can address all of the issues discussed above, as well as the gap between the break-even production cost and the prices that can be paid for these crops to be competitive in the fuel market, it seems that a more valuable research investment might be development of oil seed crops with desirable human nutrition traits that could command a premium in the food market. Although this approach does not specifically advance a regional biofuels industry, such a higher-priced food market appears to deliver much more value for farmers and could result in more oil seed production, with a by-product portion potentially being useful for the biofuels industry. An example might be camelina, which produces high levels of omega-3 fatty acids and a number of valuable phytosterols. This oil seed variety also seems suitable to production in the Northwest although more research is needed to fully ascertain the suitability of this crop.

New Herbaceous Energy Crops

In addition to oil seed crops, there may be other opportunities to produce crops explicitly for an energy market, using a portion of the acres currently used to produce grains or forage crops. It is conceivable that herbaceous crops could be grown in rotation with current crops on either dryland or irrigated acreage, given the right economics. The next section explores some advancements that might enable introduction of dedicated energy crops to Northwest agriculture.

New Energy Crops – Dryland Cropping

In order to substitute for wheat in the farmer's production plan, an energy crop would need to provide revenues comparable to those that could be realized from growing wheat on the same acres. For the high-yield areas of the region, especially those that produce wheat annually (without a fallow year) and where the net annual revenue potential is high ($350 to $550 per acre using a price of $4.50 per bushel and a yield of 80 to 120 bushels per acre), it is very difficult to envision how this could be accomplished. In the drier areas where a fallow year is required and the annual revenue potential is closer to $150 or $160 per acre (based on $4.50 per bushel and a yield range from 35 to 70 bushels per acre, divided by two to reflect the fallow year), it is conceivable that the right energy crop strategy might be competitive.

In these areas, the approach would involve growing a plant, or mix of plants, specifically selected to make the best use of the available soil moisture for maximum biomass production per acre. By comparison, wheat has been selectively bred, and production practices optimized, to make the best use of water to produce maximum grain per acre, not total plant biomass. A perennial that requires few, if any, inputs to reach optimal tonnage per acre and that reliably produces for a three or four year span might be an example of how an entrepreneurial farmer could contract to produce an energy crop on part of the farm.

However, the financial hurdle is very high for dryland production of energy crops. Assuming a target delivery price of $35 per ton to the biorefinery, practices that enable collection and delivery of the biomass at $25 per ton, and allowing for a $10 per ton payment to the farmer while still meeting the delivery price, new dryland energy crops would have to produce at least 15 tons per acre annually to equal the revenue potential of current crops. As a benchmark to illustrate how high this hurdle is, the regional lands removed from wheat production and enrolled in the CRP typically produce 0.5 tons per acre of native grasses, and wheat that yields 100 bushels of grain per acre only generates 8 tons of biomass (straw) per acre. A great deal of research would be required to overcome the hurdles associated with dryland production of biomass crops.

New Energy Crops – Irrigated Land

Producing energy crops on irrigated acres that currently are used to raise forage crops is another option to consider. In this case, the threshold likely would be the value of alfalfa ($100 to as much as $150 per ton) with productivity of 8 tons per acre with three cuttings per year. Assuming that the same equipment can be used to produce and harvest the new energy crop, yields would have to be at least three to five times higher for each cutting in order to generate the same gross revenue per acre, reflecting the lower market value of biomass for fuel.

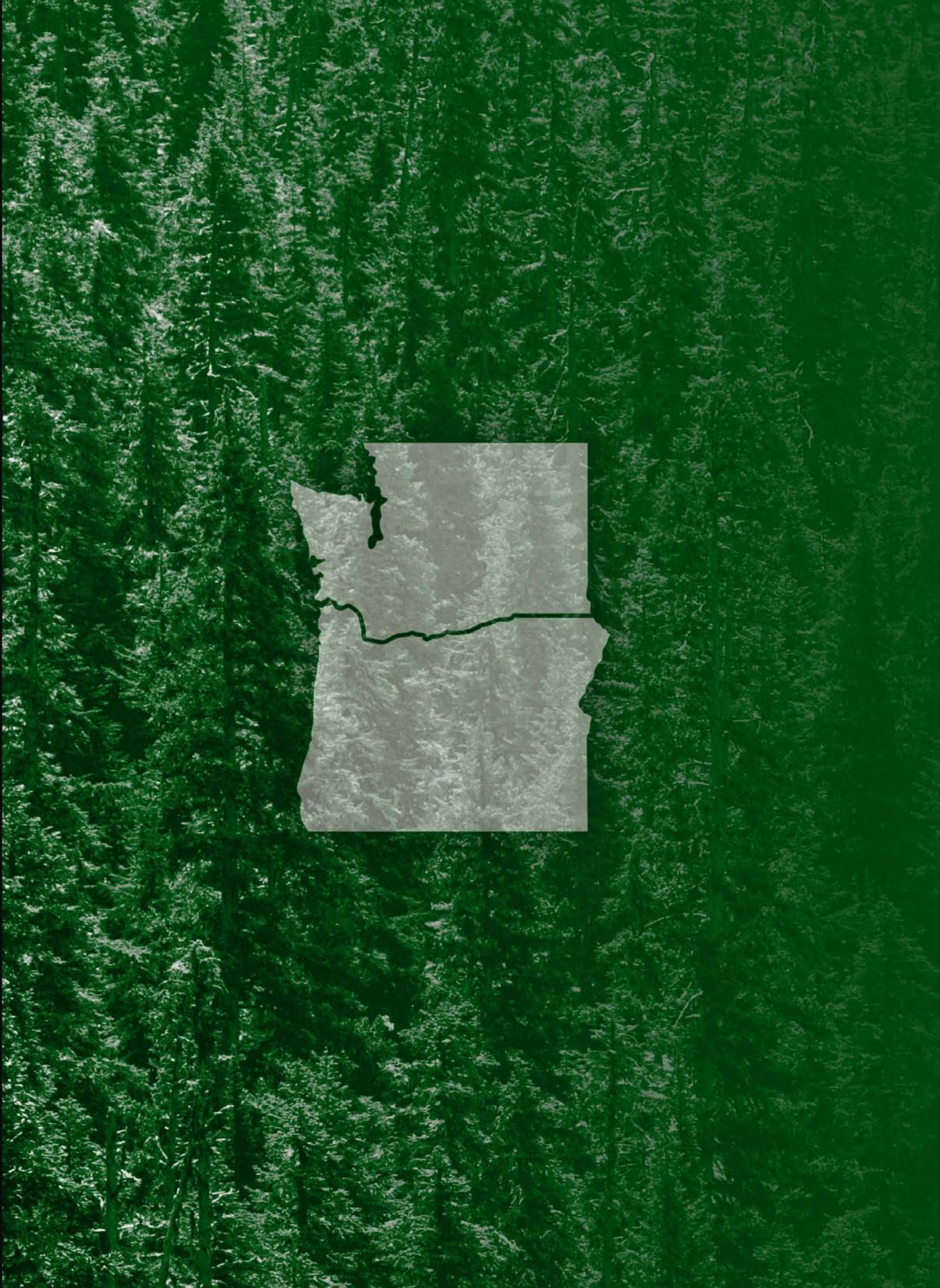
Researchers at USDA and regional universities are exploring potential herbaceous plants that could be developed to that level of productivity in the Northwest, including native perennial grasses as well as non-native species. Candidates include high-yield prospects such as *Arundo donax* (reported to produce up to 25 tons per acre) or *Miscanthus spp*. (reported to yield approximately 10 tons per acre), illustrating the potential promise of such plants. If energy crops yielding 15 tons per acre could be produced on one-third of the acres currently used to produce hay/forage, this would translate to a biomass supply of 12 million tons per year – a significant fraction of the resource required to support a large biofuels industry.

However, much research remains to understand these plants, assess the potential invasive risks of non-native candidates, select and breed plant lines suitable for the region and develop the accompanying production practices for the varied soils and climatic conditions of the Northwest. Energy crop development lines will require an intensive, long-term effort consistent with past efforts that developed the cereal grain and turf grass varieties currently grown throughout the region. Fortunately, new genomics, bioinformatics, and other advanced biotechnology tools are available today and could enable development of high-yielding new crop lines, perhaps within one or two decades given intense effort. Further, there is a wealth of capability in agricultural science and plant biotechnology in place within the region's two land grant universities. Researchers at these universities and at USDA research stations located in both states have a demonstrated track record of translating science to agricultural practices that can be adopted by farmers throughout the region.

Resource Summary

The analysis presented in this chapter indicates that the current agricultural industry has limited ability to provide the resources needed to supply a major portion of the region's fuel requirement in an economically and environmentally sustainable manner. This reflects the productivity of the majority of agricultural acres in the eastern two-thirds of the region, as well as the export value of the food and feed crops that have been adapted for production in the region. The most significant existing resource – residual straw from cereal grain and grass seed production – is limited by competing uses (sustainable agricultural practices, feed markets), and by the cost of collection, storage and transportation.

It is conceivable that in the future a fraction of the region's cultivated acres could be used to produce other energy crops, either in rotation with cereal grains or hay/forage, potentially providing a much more significant resource. In particular, developing herbaceous energy crops suitable for irrigated production on land currently used to produce forage crops could be a major future resource. If energy crops yielding 15 tons per acre could be produced on one-third of the acres currently used to produce hay/forage, this would translate to a biomass supply of 12 million tons per year – a significant fraction of the resource required to support a large biofuels industry. Developing the new plant lines and associated production practices may be difficult, particularly in the case of new herbaceous crops, and success is uncertain even for the promising oil seed crops, but the capabilities and biotechnology tools certainly exist within the region's universities and USDA laboratories to address these challenges. If support for a biofuels industry is a priority, these options should be explored as a means of developing a local resource for the future.



CHAPTER **FIVE**

Resource: **Forestry** 5

Forests comprise 47 percent of the land mass in Oregon and Washington.

Regional Resource Potential: Forestry

The other major natural resource base in the region, timber production from the 49 million acres of timberland within the borders of Oregon and Washington, is also a promising source of biomass. Forests comprise 47 percent of the land mass of the two states and these lands produce more than 2 million cubic feet of harvested timber annually. While the region's forest lands are largely federal – 59 percent of the acreage is managed by the U.S. Forest Service, Bureau of Land Management or the U.S. Park Service – private ownership accounts for 36 percent of the acres and supports 84 percent of the region's timber harvest. The private timberlands are located primarily in the western third of both states, areas with higher rainfall and higher annual productivity, while the federal lands are concentrated in the drier eastern sections of both states.

These features present two different opportunities. The first is to capitalize on the resources associated with current timber production and affiliated wood products industries. One immediate resource opportunity could be collection of the residues associated with timber harvesting, such as branches, tree tops, small diameter trees and other materials currently left in the forest. Biomass also is generated as a by-product of downstream processing operations at sawmills and other facilities that convert harvested timber into lumber and other building products. Both current resource options are explored in the first section of this chapter.

The second section of the chapter explores potential resource options that might arise in the future under different land use practices. One such opportunity often discussed within the region is the possibility of removing dense accumulations of small diameter trees and underbrush from federal forests to eliminate the fuel that increases the threat of major forest fires. Such a thinning strategy would result in accumulation of logs and other biomass that otherwise has limited utility in current wood products markets. Another possibility would be purpose-grown energy crops cultivated on forest lands, or even conversion of agricultural land to production of woody biomass.

Resource Potential: Current Industries

Timber Harvesting Residues

The most abundant potential resource associated with forestry may be the materials that are left behind in the course of harvesting timber. These materials include the tops of trees, limbs removed after the trees are felled, small diameter trees, culled logs and the other brush that is removed during harvesting. Estimates of the total potential resource exceed 5 million tons per year. In ideal conditions, these materials could be accumulated in piles near loading sites, chipped using mobile equipment with the chips then hauled to centralized sites for processing. However, cost-effective collection would require mechanization, which is not practical on very steep slopes with today's technology, and the terrain also may limit the equipment that can be used to transport the chips for processing. Factoring in these limitations, the resource that is actually available will be less than the full 5 million tons per year.

The most comprehensive region-wide analysis of realistically available timber harvesting residue was completed by the Washington State University Energy Program (Kerstetter and Lyons, January 2001). This study provided a very thorough analysis of the conditions under which the material could be collected in the harvest areas, applied reasonable limits to collection methods (e.g., eliminated collection on very steep slopes, limited skidding distances, etc.), and evaluated road conditions and transportation distances. Based upon this evaluation, the Kerstetter and Lyons study (January 2001) estimated the available resource as 2.1 million tons per year – 1 million tons per year in Oregon and 1.1 million tons per year in Washington.

The Kerstetter and Lyons (January 2001) analysis also provided a detailed estimate of the costs associated with collecting, processing and transporting the materials. These costs were used to develop supply curves, which the authors used to identify the resource centroids where biofuel facilities might be sited. Four locations were identified as centroids with resources that could support 300,000-ton-per-year facilities (Aberdeen and Longview in Washington, Springfield and Roseburg in Oregon), while two in Washington (Everett and Port Angeles) were identified as centroids that could support 100,000-ton-per-year facilities. The total quantity of material that could be delivered to those centroids was estimated at 1.5 million tons per year. It is conceivable that a small regional industry could be developed based upon this resource. However, the supply curves developed in the Kerstetter and Lyons (January 2001) assessment also indicate that the price required to achieve this level of resource collection would be $70 to $80 per ton, which is $40 to $50 a ton higher than the target per ton price required to make biomass cost competitive with petroleum. These supply curves also indicate that at prices of $50 per ton, the total available resource dropped to only 500,000 tons per year and only four very small facilities could be supported.

The thorough analysis provided by Kerstetter and Lyons (January 2001) offers a benchmark for understanding the limited potential of timber harvesting residues as a resource for a biofuels industry – unless conditions change significantly. Such changes might include introduction of new technology that enables collection and transportation of these residues at greatly reduced cost, although the steep terrain of western Oregon and Washington, as well as the long transportation distances, are significant challenges. Given the expected fuel markets and the costs associated with collection, this resource does not appear to be a viable near-term option for biofuel production. [1]

Primary Mill Residuals

Sawmills and other primary timber processors generate significant quantities of sawdust, wood chips, bark and other wood by-products. The total potential resource represented by this product is significant, estimated at 6.8 million tons in Oregon (OFRI 2006) and 5.3 million tons in Washington (Frear et al. 2005) in 2002. However, much of this material has value for competing uses, as illustrated by the disposition of the 6.8 million tons generated by the Oregon mills:

- 4.4 million tons (64 percent) were sold for use in building products (e.g., oriented strand board, particle board) or pulping
- 1.7 million tons (25 percent) were used to produce steam for 49 operations and combined heat and power for six other facilities

[1] Several other studies also have looked at this resource and have estimated the available resource to be slightly higher than the Kerstetter (January 2001) analysis, adding as little as 300,000 tons to the total annual resource, or as much as 900,000 tons. These reports also indicated that the "average" delivery cost would be $60 per ton, with delivery costs ranging as much as 50 percent above that average (see OFRI, CH2M-Hill, Frear et al.). These alternative studies do not significantly change the conclusion that timber harvesting residue is a limited biomass resource.

- the remaining 0.7 million tons found uses as landscape bark, mulch or bedding (valued at $15/ton or less), or had no use at all.

The total traded value of this resource was $222.6 million in 2002. The highest value use of the resource is for pulp, where the market price for sawdust and chips was $60-$62 per ton in 2002. Pulpwood prices have ranged as high as $120 per ton in the last decade although prices in the past also have been well below $60 per ton. Prices paid for fiber used in wood products were lower, ranging between $25 and $45 per ton.

The ability of any individual producer to obtain the higher prices is dependent upon location – the cost of transporting this low bulk density product requires close proximity to a market. However, even in isolated locations that are distant from pulp or fiberboard markets, or in areas where fiber supply exceeds demand, the residual is worth $15 to $25 per ton as a fuel for combustion to produce process steam and power. This is driven by the industry’s desire to be energy self-sufficient in the face of fluctuating costs for electricity and natural gas in the last decade. Further supporting the value of wood for combustion are renewable energy programs promoted by many of the region’s utilities, which place a premium on electricity produced by wood combustion. Two combined heat and power plants in Oregon and two more in Washington already generate surplus electricity to sell to the grid using mill residuals and several new wood combustion plants are being constructed or planned in both states to supply renewable energy. Growth of this industry is likely to keep a solid floor on fiber prices.

The current competing uses described above are likely to consume the majority of the primary mill residuals, leaving limited opportunities for use of this resource to produce transportation fuel. In particular, the interdependency of the wood products companies seems to preclude diversion of these products to new uses.

Resource Potential: Future Alternatives

Timber Thinning

A potential future resource often mentioned in the region is the removal of small diameter trees and underbrush from forests as part of a forest fire control strategy. This strategy has been variously studied by the

Forest Service, the Bureau of Land Management and the Oregon Department of Forestry, with a comprehensive analysis completed for the drier forests in 20 counties of eastern and south-central Oregon (OFRI 2006). The Oregon Forest Resources Institute (OFRI) study in particular provides a detailed assessment of 14.9 million acres (70 percent federal, 30 percent private), excluding all parks, monuments, wilderness and roadless areas, and concludes that 7 million acres (100 percent federal) were overstocked and in need of thinning to control fires and disease. When harvest estimates were restricted to areas with hauling distances of no more than 75 road miles to a potential processing facility, the estimated potential resource dropped to approximately 1 million tons per year, assuming a 20-year harvest campaign. Two specific sites were studied as potential locations for a wood-to-energy facility based upon these initial analyses – Klamath Falls (potential for 20.8 million tons in the plant lifetime, 75-mile radius) and LaGrande (potential for 2.6 million tons lifetime, 50-mile radius). Further, the OFRI (2006) report estimated the average delivery cost for the biomass as $59 per ton, as long as a significant quantity of merchantable timber also is harvested, providing revenue to the contractor that defrays the overall cost of the thinning operation. Even if the thinning concept meets with public acceptance, which may be questionable given the need to remove merchantable timber, the cost of the biomass is about twice the delivered cost needed to be competitive for production of liquid fuels.

Similarly, Washington has forests in the central and northeastern parts of the state that are identified as needing thinning for fire control. The Washington State University Energy Extension Program estimated the sustainable resource available as a result of thinning these forests is more than 500,000 tons per year (Kerstetter and Lyons, January 2001). This estimate is considered conservative and it is likely that the biomass resource associated with thinning for fire suppression in Washington is comparable to Oregon's.

It is important to note that biomass from timber thinning is a resource that is largely contingent upon a change in land use policy. Thinning as a fire control strategy in federal or state forests is not currently a common practice although some foresters believe that thinning would be half the cost of fighting fires and would yield a more sustainable forest. However, adoption of such a policy is uncertain, as is possible public acceptance of such a policy, although focus groups have indicated that broad support could be developed and several environmental groups have publicly expressed openness to the idea (OFRI 2006). Further, funding for thinning Northwest forests is not currently included in the budgets for either the U.S. Forest Service or the Bureau of Land

Management and it is not clear that Congress would be willing to appropriate funds for a 20-year thinning campaign.

Plantation Production

Another option that increasingly captures the imagination of the region is plantation production of trees on land outside of the current forest production system. A number of experiments have been conducted in both Oregon and Washington focusing on hybrid poplar clones and at least one company has a large number of acres of poplar under active management. The initial target market was as a source of chips for the pulp and paper industry or for medium density fiber board. In later years the poplars have been harvested as saw logs for use in cabinetry and finish/trim wood products. These uses represent the highest revenue potential for the plantation poplars, but as with other timber products there are residues and unusable fractions of the harvest that could represent a source of biomass for biofuels.

There also is interest at Washington State University (WSU) in developing clones that are optimized for biofuel production, as well as developing clones that can reach optimal productivity with fewer nutrients, water and other inputs (WSU College of Agricultural, Human, and Natural Resources 2007). Plantation production of poplars offers the promise of lower production, harvesting and transportation costs, and the biomass production per acre can be quite high, potentially resulting in an attractive biomass per metric ton. While the best use of this material will probably still be found in the structural materials or pulping market, production of hybrid poplars as a source of biomass for biofuels warrants careful study and continued support of research that could improve the productivity and overall economics of growing poplars.

Summary

This analysis indicates that the forestry and forest products industries of Oregon and Washington currently present a limited biofuels resource. Under normal market conditions, higher value uses exist for the bulk of the mill residual materials, while the cost of collection and transportation make harvest residues impractical for biofuels production. At best, there might be some limited collection of harvest residues in areas where the terrain is not a limiting factor and transportation distances are very short, as indicated in the Kerstetter and Lyons (January 2001) analysis. Similarly, there might be some opportunity for one or two biofuel facilities to purchase limited amounts of primary mill residuals that would otherwise be used as landscaping mulch or for electricity generation, at prices around $30 per ton. Figure 6 shows the amount of biomass that could be expected to be available to a biofuels industry at a suitable delivery cost, relative to the total resource.

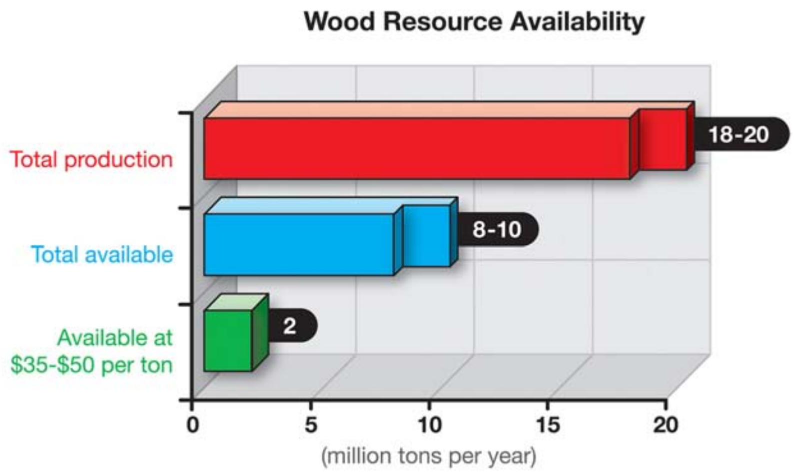


FIGURE 6. Current Availability of Wood Resources for Fuel Production

Of course, new circumstances could expand this resource. Clearly a change in federal policy that embraces timber thinning to reduce forest fire risks would add to the available resource. Similarly, major changes in markets, such as a significant increase in petroleum prices or a long-term reduction in demand for pulp fiber, could motivate the largest producers of saw logs or the operators of sawmills and pulp mills to use the overall resources differently. If fuel values become considerably higher than recent averages, it is conceivable that timberland owners could incorporate short rotation woody crops into their long-term management regime, or expand plantation production of such crops.

There are a number of ways in which research might enable greater utilization of the forestry resource in the future. For example, research that explores new, lower cost recovery technology, as well as alternative transportation modes, could enable cost-effective collection of a greater portion of timber harvesting residues. Research related to poplar production also could be very important over time, with new clones that provide higher growth rates, greater disease resistance, and greater biomass density per acre contributing to introduction of a new resource. Again, now that the poplar genome is available, a number of advanced biotechnology tools could greatly accelerate this research. Poplar-related research also needs to be matched with projects aimed to optimize production practices for the varying climatic zones around the

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region, define ideal rotation practices, and develop lower cost harvest technologies. Finally, it seems that additional research to explore the possibility of purpose-grown woody crops mixed with saw timber production might be a valuable addition to future land use options on private forest lands.

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CHAPTER SIX

Resource: **Waste** 6

The organic portion of municipal solid waste constitutes 70 percent of the biomass resource currently available in the region.

Regional Resource Potential: Waste Products

Given the limited volume of the existing biomass resources reviewed so far, it seems clear that a biofuels industry of any size will need to draw upon other resources, ideally resources that would be far cheaper than those reviewed in previous chapters. The search for additional biomass resources, and materials available at lower cost, forces an evaluation of biomass that has traditionally been managed as waste, especially those products that also are supported by a collection and handling infrastructure. The most prominent potential resource is the solid waste already routinely collected and managed by municipalities, as well as any organic wastes handled by industry and agriculture. This chapter explores the volume of material that might be available as an additional resource for a biofuels industry.

Municipal solid waste (MSW) consists of everyday items such as packaging, clothing, bottles, food scraps, newspapers and appliances – all of the items that households and businesses rely upon municipalities to remove on a regular basis. Approximately 60 percent of MSW is organic material, such as paper. In 2004, Oregon and Washington residents generated 8.2 pounds and 7.5 pounds of MSW per person per day respectively and the municipal infrastructure of these states handled 13.6 million tons of material. Recycling and other programs diverted 6.1 million tons of material, while the remaining 7.5 million tons of waste was sent to one of the 54 permitted regional landfills for disposal (Oregon Department of Environmental Quality [DEQ] 2006 and Washington State Department of Ecology [WSDOE] 2004).

Diverted Waste

Both states are trying to increase recovery and recycling, but the rate of recovery has been static in both states for many years (45 percent in Oregon, 35 percent in Washington). The recovered material is primarily glass, aluminum, paper, yard waste, construction debris, land-clearing debris and other wood waste. Of the total recovered material, biomass comprises as much as 60 to 70 percent and many individual recovered streams are entirely biomass (e.g., yard waste and land-clearing debris). Of the 6.1 million tons of recovered MSW, 0.8 million tons were used in one of the five combustion energy facilities in the region, approximately 2.4 million tons were composted, and the balance found other uses as recycled fiber or were exported for recycle (Oregon DEQ 2006 and WSDOE 2004).

Based upon this data, it seems that production of liquid transportation fuels would be a higher value use for a significant fraction of the diverted biomass handled by municipalities in Oregon and Washington, perhaps as much as 3 million tons per year.

Disposed Waste

The disposed waste represents an even larger potential resource. Larger municipalities in the region are increasingly challenged in finding disposal options, indicating that perhaps the time is right to consider other uses for this material. While there are currently a large number of landfills operating, only a few have permitted capacity extending beyond the end of the decade and more than 85 percent of disposal is already concentrated at nine primary landfills (WSDOE 2004). In particular, two private operations dominate disposal in the region. The largest facility, the Roosevelt Landfill in Klickitat County, Washington, represents 81 percent of the permitted disposal capacity in Washington and is increasingly the disposal site of choice for the state, receiving waste from 34 of Washington's 39 counties and accepting waste from Oregon, Alaska and British Columbia. Three unit trains (100 rail cars each) of MSW arrive at Roosevelt every day (Washington State Department of Transportation 2006) and 1.9 million tons were delivered for disposal at Roosevelt in 2003 (WSDOE 2004). The other large regional facility, the Columbia Ridge Landfill near Arlington, Oregon, also accepted 1.9 million tons of waste from Oregon counties, several cities in Washington, and from California and Idaho in 2001(Oregon DEQ 2006). Seven other facilities located close to the larger municipalities of Western Oregon and Washington disposed of another 3.5 million tons (WSDOE 2004 and Oregon DEQ 2006). As the number of permitted options for disposal decrease, there is a commensurate increase in disposal costs throughout the region. For example, the Portland metropolitan area reports that the rates paid for disposal increased from $15 per ton in 1985 to $70 per ton in 2001 (Metro Regional Government 2007). These costs are in addition to the cost of collecting, packaging, storing and transporting the MSW to a disposal site.

Industrial Waste

This resource also could be augmented by industrial wastes that are currently disposed in licensed private landfills. For example, the pulp and paper industry generates by-product materials that are disposed in landfills or composted, representing a resource that is already collected and is in a form that could be processed readily. This industry used private landfills for disposal of 550,000 tons of waste pulp, paper and wood in 2001 – 250,000 tons in Oregon (Oregon DEQ 2006) and 300,000 tons in Washington (WSDOE 2004). Other waste streams that might augment the available resource include food processing waste, solids from municipal waste water treatment facilities and manure solids from large-scale animal operations although such resources would be difficult to transport for any distance and would require development of conversion technologies that can be installed and operated on site at these generators.

Resource Summary

Figure 7 illustrates the potential biomass resource represented by MSW. This resource appears even more important considering factors such as the increasing cost of disposal, the significant fraction of the waste that is organic, the concentration of the material in a very small number of locations and the existing infrastructure that is in place to handle the materials. Given the potential magnitude of MSW as a resource compared to the resource potential from current agricultural and forestry practices, further study is warranted to understand what innovations are required for MSW to realize its potential.

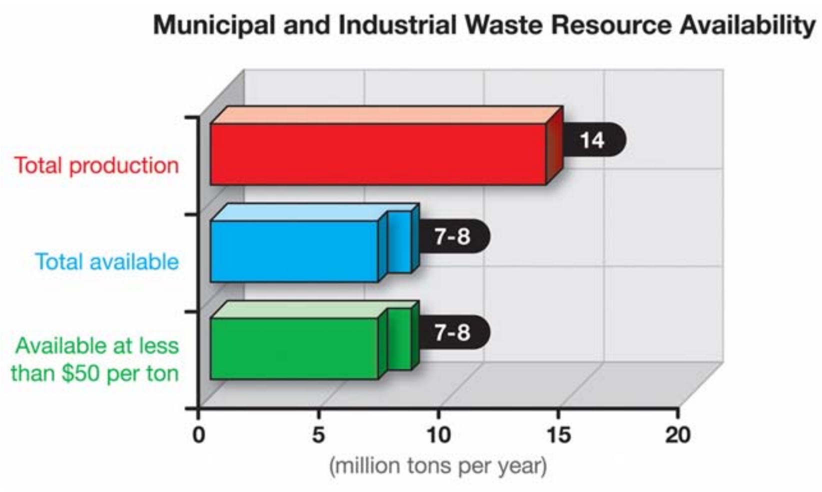

FIGURE 7. Organic Material Available In Municipal Solid Waste

Figure 8 shows that a significant biomass resource could be available in Oregon and Washington if the organic content of municipal and industrial solid waste streams is combined with the currently available straw and wood resources. When this currently available resource is expanded

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through possible future innovations (e.g., forest thinning, hybrid poplar production, or introduction of herbaceous energy crops), there is a real prospect that biomass could make a significant contribution to the fuel requirements of the region if there are technologies available that enable cost-effective conversion of these resources to fuels. That is the subject of Chapter 7.

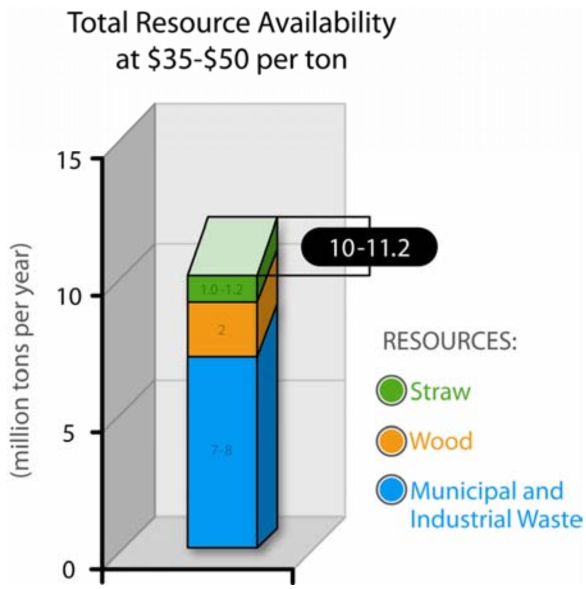

FIGURE 8. Total Available Regional Biomass Resource

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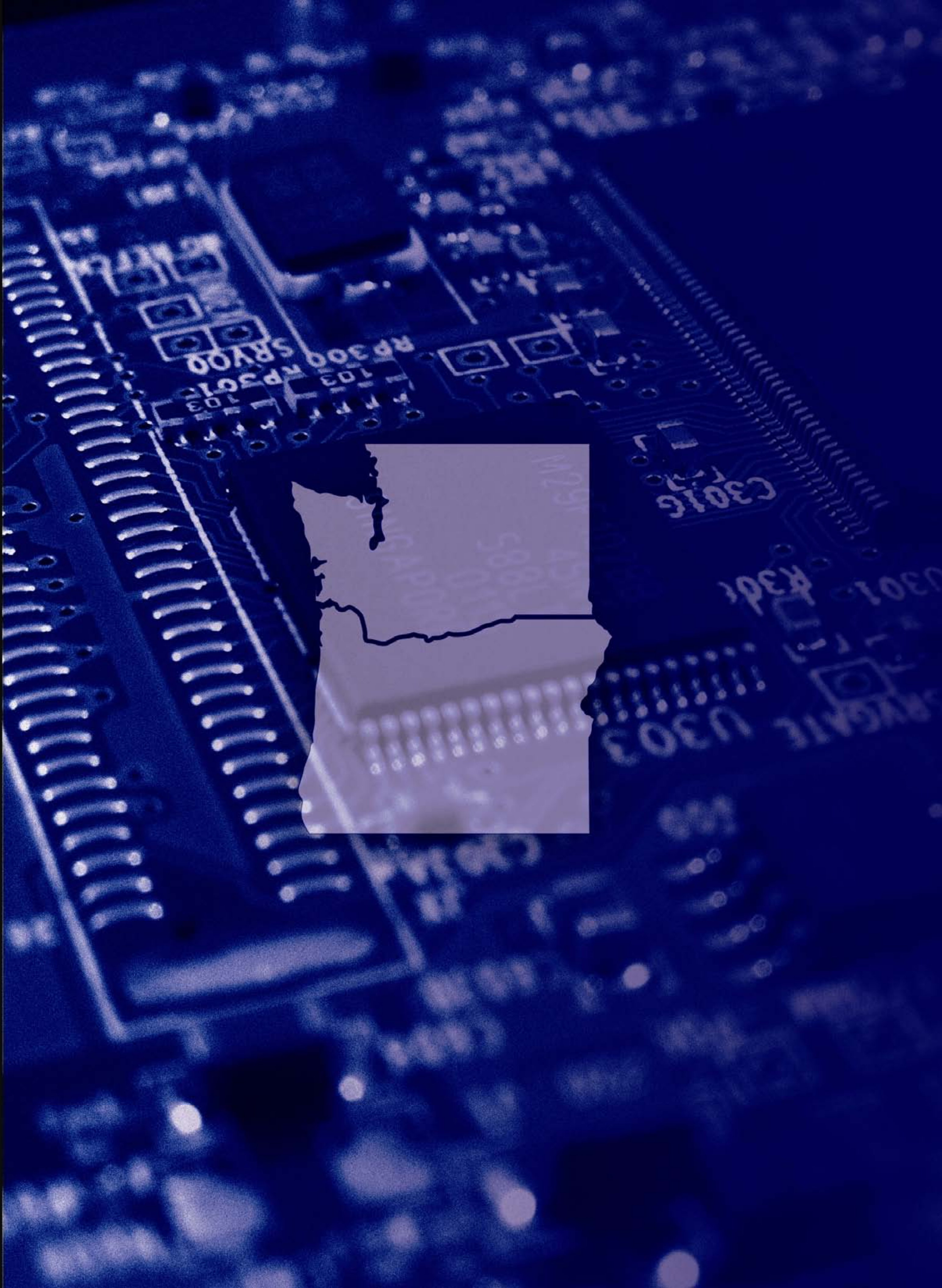
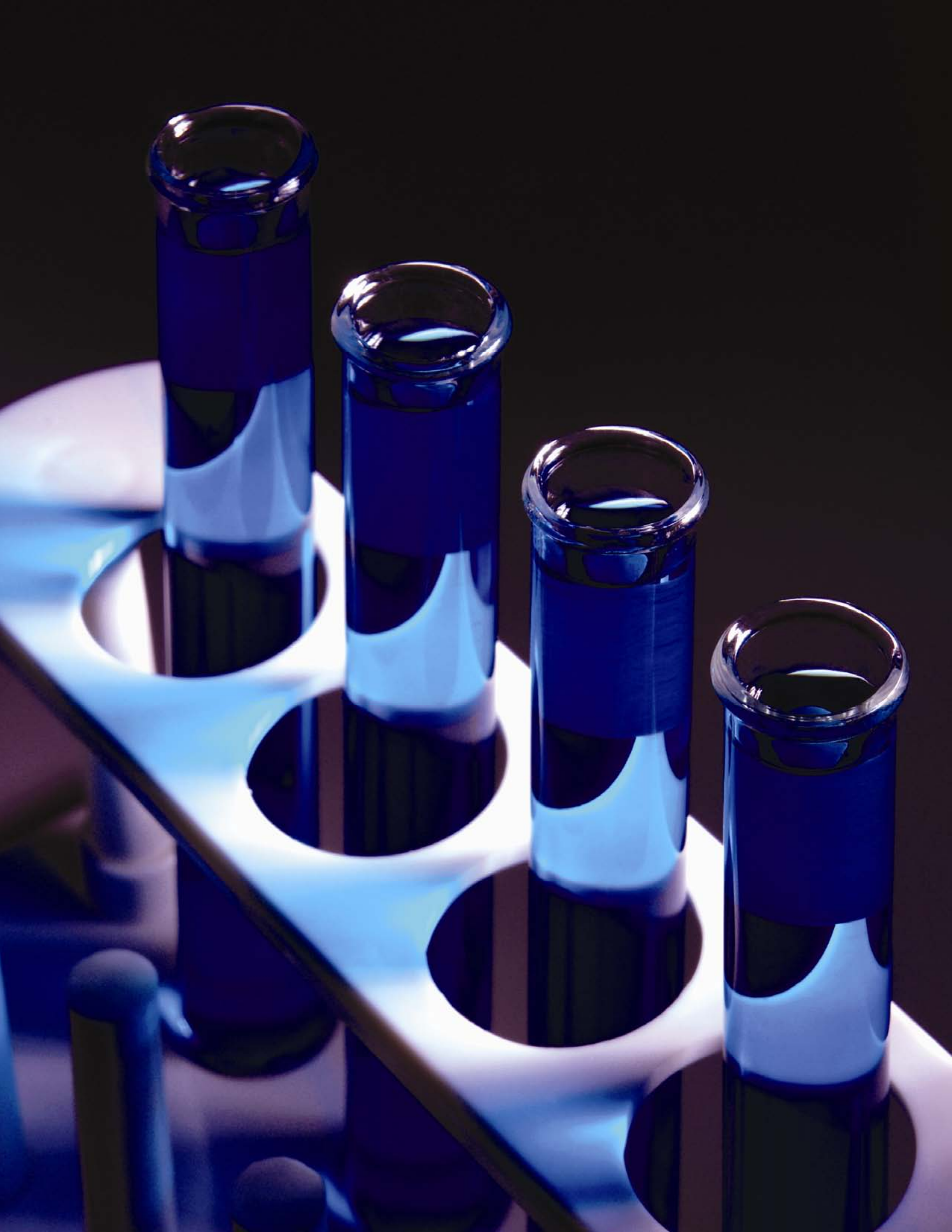


CHAPTER SEVEN

New process technology will be needed if a regional biofuels industry is to draw on locally produced resources and achieve significant production volumes.



Technology and Product Options

This chapter focuses on process options that might be suitable for conversion of Oregon and Washington biomass resources to transportation fuels. The most significant available biomass resources are comprised almost exclusively of complex lignocellulosic materials, rather than the grain crops that have been the basis for the U.S. biofuels industry so far. Consequently drawing upon locally produced resources will require use of conversion technology that is different from the facilities that have been constructed in the Midwest. A number of strategies for conversion of complex biomass have been studied during recent decades. These strategies, illustrated in Figure 9, include both biological and thermochemical technologies.

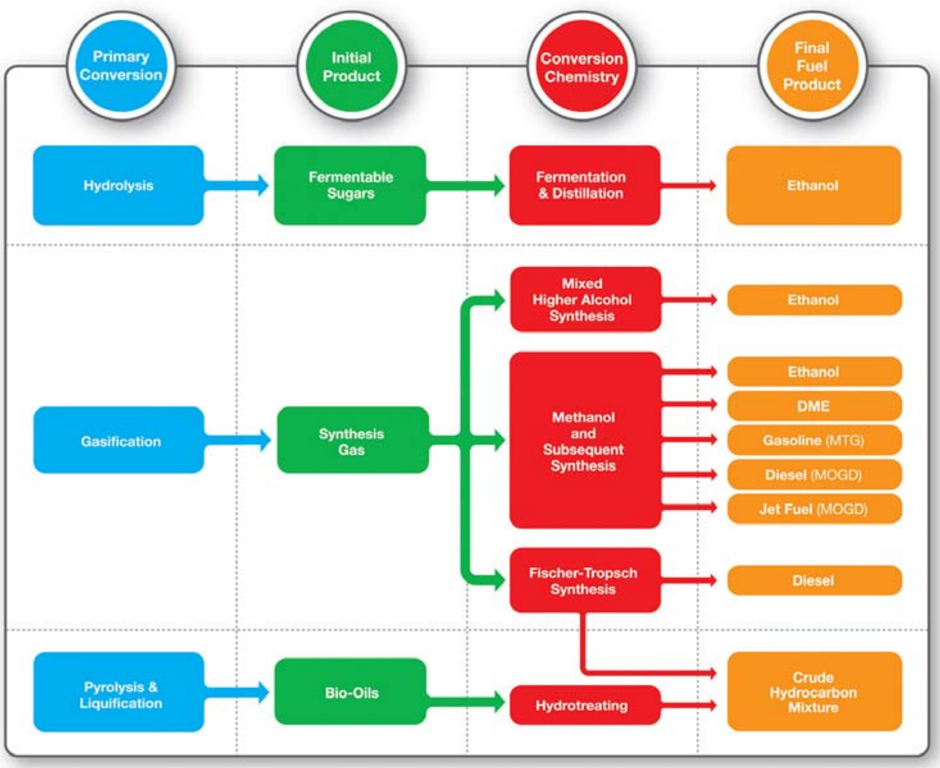


FIGURE 9. Lignocellulosic Biomass Conversion Strategies

Early research efforts were focused on the thermochemical conversion strategies, but recently the research emphasis has been directed more to applications of biotechnology. The biological strategy has generally emphasized hydrolyzing the biomass to produce sugars that can be

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fermented to ethanol. Recent research efforts are expanding the product options by developing fermentation processes to produce butanol and hydrocarbon products. Gasification, the second pathway illustrated in Figure 9, involves partial oxidation of the carbonaceous portion of the biomass to produce a gaseous product – synthesis gas (or "syngas") – which consists primarily of hydrogen (H_2) and carbon monoxide (CO). Syngas chemistry provides a platform for a number of product options, including ethanol, as well as hydrocarbons that could be used within the existing refining and fuel infrastructure. In addition to producing gases, thermochemical processing of biomass also can produce useful liquid oils, or bio-oils, the final conversion strategy shown in Figure 9. Bio-oils are a complex mixture of as many as 400 different compounds. Some bio-oils can be used directly as boiler fuel and with additional chemical upgrading processes these bio-oils can become a direct substitute for petroleum in existing refining processes.

None of the conversion strategies illustrated in Figure 9 are practiced commercially today, in spite of many years of public and private research. The following sections evaluate the potential readiness of the current generation of these technologies, compare the relative advantages or disadvantages of each process strategy for Oregon and Washington, and identify the most important advances that might close the gap between today's technology and the requirements of a viable regional industry. The evaluation of these conversion strategies again reflects a high-level synopsis of a number of technology assessment reports and design studies published by other authors. This published information is supplemented by information developed by Pacific Northwest National Laboratory using process simulation and cost estimating models, providing a framework for comparison of all of the approaches on a consistent basis. The result is intended to illustrate the array of options that might be considered within the region.

Fermentation Processes

Extensive research has been conducted over the last decade to develop processes to convert biomass to sugars that can be fermented to ethanol (the first pathway in Figure 9). The primary process options currently available use either chemical hydrolysis to derive the sugars, or a combination of chemical and enzymatic steps. In either case, the recovered glucose (and ideally the xylose) is converted to ethanol via fermentation. The lignin and other residual products can be combusted for heat and power or may require some other means of disposal. The hydrolysis and fermentation process strategy has been widely reviewed and a very detailed process design report and accompanying cost analysis has been developed by the National Renewable Energy Laboratory (Aden et al. 2002). While several elements of the process are still in the research stage and the complete process has yet to be commercially demonstrated, the technology is expected to be competitive within a decade.

This option may be suitable for some of the resources available in Oregon and Washington, most notably cereal and grass straws. It can be assumed that, once demonstrated, conversion of straws via this process could be a logical extension of feedstock for the grain ethanol facilities currently being constructed in the region. While the straw comprises a relatively small fraction of the available resource, this technology platform would enable more production of ethanol using local resources, but would require some adaptation of the production facilities to accommodate the different process. The hydrolysis and fermentation strategy may also be applicable for some wood biomass, the cellulosic by-product streams associated with regional pulp mills, and some segregated municipal solid waste (e.g., paper waste or yard waste). However, use of these materials will require alternative pretreatment technologies and development of additional enzyme cocktail combinations, or refinement of acid hydrolysis processes that avoid use of enzymes (saving cost) but that currently yield co-products that adversely impact the performance of the fermentation organism.

Gasification and Related Product Options

Gasification technology is practiced commercially around the world using petroleum and coal as feedstocks and syngas chemistry is used to make a number of chemical products, as well as liquid fuel from stranded natural gas. Although gasification of biomass was used to produce fuel for more than a million vehicles in Europe during World War II, this has not been practiced commercially since then. Although there are no modern biomass gasification facilities producing transportation fuels, several biomass demonstration systems have made syngas suitable for producing fuels. Additionally, the Schwartz Pumpe gasification facility in Germany currently produces methanol for the chemical market from resources that include municipal solid waste (Faaij 2006).

The general biomass gasification process, shown in Figure 10, involves drying the biomass, mechanical processing to achieve uniform biomass particle size, feeding the particles to the reactor, gasification and gas conditioning. Once the ideal syngas makeup has been achieved, there are a number of chemistries available to produce liquid fuels, including mixed alcohol synthesis, methanol synthesis and related conversions, and Fischer-Tropsch processes.

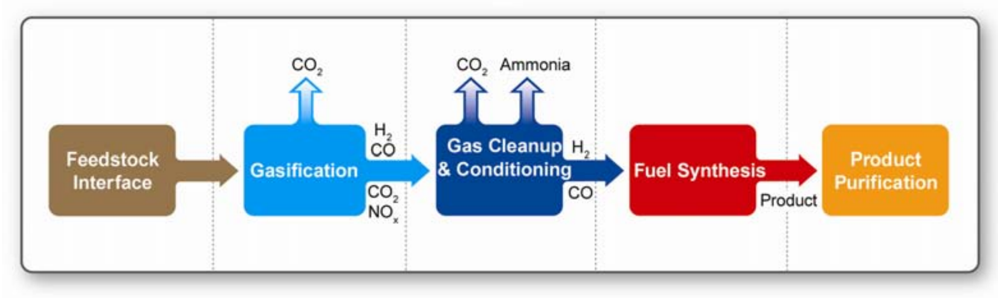

FIGURE 10. General Gasification Process

The gasification reaction is a complex thermochemical reaction in which the heated biomass rapidly decomposes into vapors and char. Pyrolytic decomposition and partial oxidation of the vapors yields a mix of CO, CO_2, H_2, methane and other gaseous hydrocarbons, while the char can be reacted further by introducing moisture or oxygen into the system, contributing additional CO and hydrogen. The heat to drive the gasification reaction can be generated in two ways. A directly heated gasifier derives heat by partially combusting the biomass with blown oxygen (which is separated from air). In an indirectly heated gasifier the heat is generated outside of the reactor and transferred into the gasifier (and the biomass) via a medium such as a moving sand bed with the addition of steam, eliminating the expense associated with the oxygen separation unit. The product gas characteristics depend upon the gasification medium used as well as the stoichiometry and temperature of the gasification process. Impurities commonly found in the gas stream include nitrogen-containing gases, sulfur gases, alkali metals, tar (organic hydrocarbons) and particulates. Much of the complexity, and a significant portion of the expense associated with gasification involves dealing with these impurities and achieving the ideal synthesis gas makeup required for the downstream process chemistry (Spath and Dayton 2003).

Products of Synthesis Gas Chemistry

Synthesis gas provides a platform for a number of product options, including ethanol and other alcohols, hydrocarbon fuels and chemicals. A great deal is known about product chemistry based upon synthesis gas, but a number of persistent process challenges remain that have proven difficult to overcome.

Mixed Alcohol Synthesis

The product of this synthesis pathway includes ethanol, but also other higher alcohols (n-propanol, n-butanol, n-pentanol). Producing ethanol and higher alcohols from syngas has been recognized and studied since the early 1900s, but the synthesis mechanism involves a complex set of numerous reactions that has proven difficult to optimize. Current technology provides relatively low total yields of ethanol from the biomass feedstock, reflecting issues associated with thermal efficiency and carbon conversion in the gasifier, inefficiencies in the subsequent tar reforming and gas conditioning, and suboptimal selectivity to ethanol in the synthesis step. Further, these inefficiencies (i.e., low per-pass conversion rates) result in the need to recycle a large portion of the feed gas, requiring a synthesis reactor that is relatively large, adding to capital costs. Although a number of processes have been studied, none are practiced commercially yet (Spath and Dayton 2003).

In spite of the relative inefficiency of the current technology, mixed alcohol synthesis appears to be quite close to financial viability. Based upon published results (Spath and Dayton 2003, Faaij 2006) as well as process models developed by PNNL, the estimated cost of producing ethanol via this process route is approaching the long-term forecast rack price of gasoline. Innovations that reduce the capital cost associated with gasification and syngas conditioning, as well as improvements in the mixed alcohol synthesis process, would make this a competitive option. The National Renewable Energy Laboratory (NREL) has designed a process optimized for ethanol production, based upon a comprehensive review of past research and the best technology currently available. NREL also has identified the research and development efforts required to address the limitations of current technology (Aden et al. 2005). The U.S. Department of Energy supports many elements of this research and intends to demonstrate an improved gasification and mixed alcohol synthesis process within the decade.

Methanol Synthesis

Methanol is a commodity chemical currently produced from natural gas, but also could be produced from biomass (in fact, methanol originally was produced from wood). With appropriate engine modifications, methanol can be used as a clean burning fuel. For example, neat methanol (M100) currently is used in high-performance race cars and airplanes. There has been interest in M85, and cars have been produced that operate on M85 with a limited number of fleets operating using M85 on a test basis. However, methanol has not yet been accepted as a transportation fuel in the United States and higher blends would encounter the same infrastructure challenges associated with ethanol. However, there are several alternative fuels that can be derived from methanol that would be more compatible with the existing infrastructure if they could be produced at a competitive cost (Keil 1999). These options include:

- ***Dimethyl ether*** *(DME), a product currently made from methanol and used as an aerosol propellant but which could also substitute for liquid petroleum gas or liquid natural gas as a fuel. DME shows great promise for use in diesel engines due to its high cetane number, indicating potential value in developing methanol-derived DME as a diesel alternative. Large-scale use of DME would require storage and distribution infrastructure development.*
- *MTG (methanol-to-gasoline), a hydrocarbon produced from methanol that can substitute for gasoline and has been shown to deliver comparable performance in fleet trials involving U.S., European, and Japanese manufactured vehicles. The original MTG process was discovered by Mobil Oil.*
- *MOGD (Mobil olefins-to-gasoline/diesel), a process for production of olefins from methanol with subsequent conversion to a gasoline/distillate stream, enabling production of gasoline, diesel, and jet fuel from methanol. This process was also developed by Mobil Oil.*

None of these methanol-derived fuels are in commercial use today, although Mobil ran a plant producing MTG in New Zealand from 1985-1997 and a pilot facility producing MOGD in Germany in the 1980s (both using natural gas). The MTG and MOGD products have the advantage of producing fuels that are compatible with the existing vehicle fleet and the existing distribution infrastructure. In addition, they have the value of being able to supply all of the products sold in the current fuel market, including jet fuel.

Methanol production from syngas already is already a very efficient, high-yield process that is practiced commercially using syngas derived from natural gas. Production of methanol could be competitive in the near-term using biomass, but the downstream conversion of methanol to hydrocarbon fuels appears to be too costly to be competitive with gasoline or diesel using the technology available today. However, technological innovations that streamline the methanol-to-hydrocarbon process by combining unit operations would substantially improve the cost of these products, enabling production of non-alcohol fuels at a cost competitive with petroleum fuels. Given the potential value of a biomass-to-fuels option that is compatible with the current distribution infrastructure and vehicle fleets, as well as the prospect that this option also could be employed using domestic resources (e.g., coal), these options are quite attractive and warrant vigorous investigation.

Fischer-Tropsch Processes

The formation of hydrocarbons from syngas was discovered early in the 1900s. Throughout the 1920s and 1930s research teams led by Franz Fischer and Hans Tropsch developed a number of catalyst formulations, reactor designs, and process conditions that inform this field of chemistry to the degree that the collection of work today is referred to as Fischer-Tropsch synthesis. In the past, Germany (during World War II) and South Africa used gasification and Fischer-Tropsch synthesis to convert coal and biomass to liquid fuels when petroleum was not available to these countries. More recently, Fischer-Tropsch synthesis has been successfully used to convert natural gas to liquid fuel at commercial scale and one facility, a pilot-scale plant in Freiburg, Germany, currently is seeking to demonstrate production of diesel from gasified biomass using Fischer-Tropsch synthesis.

Current state-of-the-art processes use clean syngas to produce liquid fuels through different process routes leading to either diesel or gasoline products. If diesel is the desired product, a low temperature reaction with a cobalt catalyst is used to maximize yield of high molecular weight waxes (C20 and higher) that can be upgraded to diesel. Different reactor designs, iron catalyst formulations and high temperatures yield low molecular weight olefins (C3-C11) that can be upgraded to gasoline (Spath and Dayton 2003). Unfortunately, neither fuel can be made selectively without also producing a significant amount of undesired by-products, resulting in reduced product yield. Research has not yet provided catalyst formulations that successfully tune the product selectivity to achieve theoretical yields and these yield limitations are expected to present a significant economic hurdle for biomass-to-fuels using this process until better catalyst formulations are developed (Faaij 2006 and Huber et al. 2006).

Another option is to operate the Fischer-Tropsch process to optimize yields by producing a crude liquid that is not directly suitable as a fuel but is low in aromatics and free of sulfur, resulting in a product with properties and value similar to light, sweet petroleum crude. This product, which would serve as a biomass-derived substitute for crude oil, would then be sent to a petroleum refinery for production of gasoline, diesel or jet fuel.

The production of Fischer-Tropsch fuel seems to be the most challenging of the options discussed in this chapter, driven in part by the low product yields from biomass and the efficiency of the Fischer-Tropsch synthesis. Fuels using the best Fischer-Tropsch technology available today would not be competitive with petroleum fuels, based upon models developed by PNNL. Production of Fischer-Tropsch crude is more attractive but additional development is also needed to make that option competitive with petroleum. However, gasification of a low-cost resource available in quantities that would enable economies of scale, a resource such as municipal waste, could be an option in this region because of the existing refining infrastructure,

Other Synthesis Gas Product Opportunities

While production of fuels from lignocellulosic biomass is important, and will be a viable option in the future, it is also possible to produce a number of chemicals from synthesis gas. Several product options from the biomass-gasification-to-methanol platform, shown in Figure 11, illustrate this opportunity. In addition to methanol, derivative product options include formaldehyde, acetic acid, vinyl acetate and olefins. These methanol-to-chemical conversion technologies are known processes and the products have global markets. Producing these products from biomass might have fewer technical and financial risks compared to fuels.

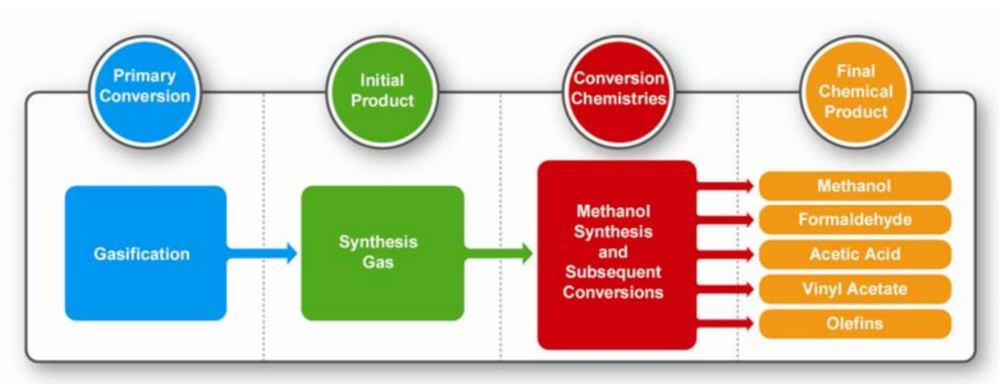

Figure 11. Methanol Products for a Chemical Market

Based upon models developed by PNNL, supplemented by cost information from the SRI Process Economics Program Yearbook (SRI Consulting 2003), production of methanol and related chemicals from biomass appears to be an option that is nearly cost-effective with today's technology. Modest improvements in the biomass gasification technology could make these products competitive with the petrochemical industry in the near term and potentially even offer a cost advantage compared to petrochemical routes. Further, a significant fraction of the methanol and methanol-derived chemicals currently used in the United States are imported, so this could create a reliable domestic supply.

Improving Gasification and Related Syngas Chemistry

Capital cost may be the most significant initial barrier to commercial biomass gasification and fuel production. Installation of a stand-alone gasification and synthesis system is estimated to range from $350 million to $450 million at the 2,200 short-ton-per-day scale. This capital investment (reflected in depreciation cost) comprises approximately 50 percent of the product cost in each case modeled by PNNL. Further, the estimated product cost is very sensitive to assessing a rate of return for investors; Figure 12 illustrates that a 30 percent return on investment (ROI) doubles the product cost. Capital cost reductions of 30 percent to as much as 50 percent may be required to bring product costs into a competitive range.

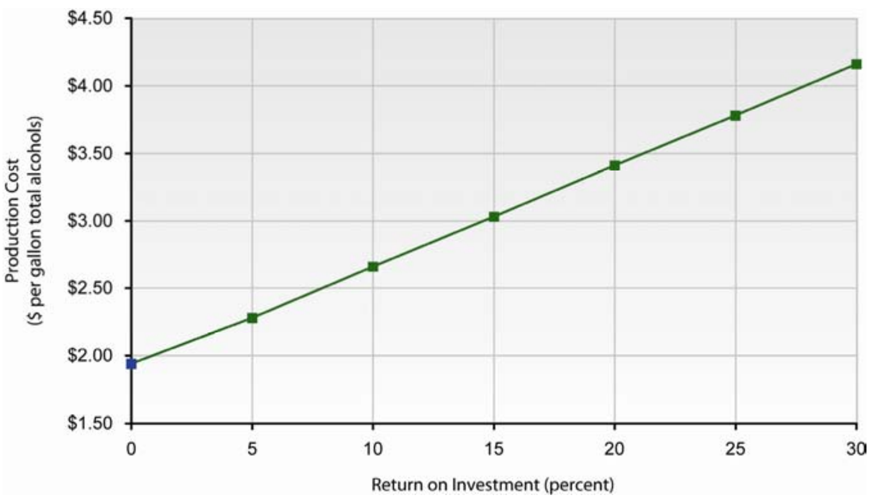

FIGURE 12. Effect of Return on Investment. ($440 million capital expenditure)

Increased production scale ameliorates the impact of capital cost somewhat, shown in Figure 13. However, the 2,200 short-tons-per- day scale is near a break in the scale curve; doubling production only reduces product cost by about 15 percent. In addition, achieving economies of scale would require greater aggregation of biomass feedstock within an area, which may be difficult to accomplish within Oregon and Washington without increasing the delivery cost of the resource. Figure 14 illustrates the trade-off between advantages of scale and potential changes in feedstock cost, indicating that even at 5,500

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short tons per day, the delivered feedstock cost will likely need to be less than $35 per ton to maintain product costs in a range competitive with petroleum and to accommodate a reasonable ROI for investors. This casts municipal and industrial solid waste in a new light as this resource already is collected and aggregated at a level that could support large-scale production and could be available for less than $35 per ton, delivered cost.

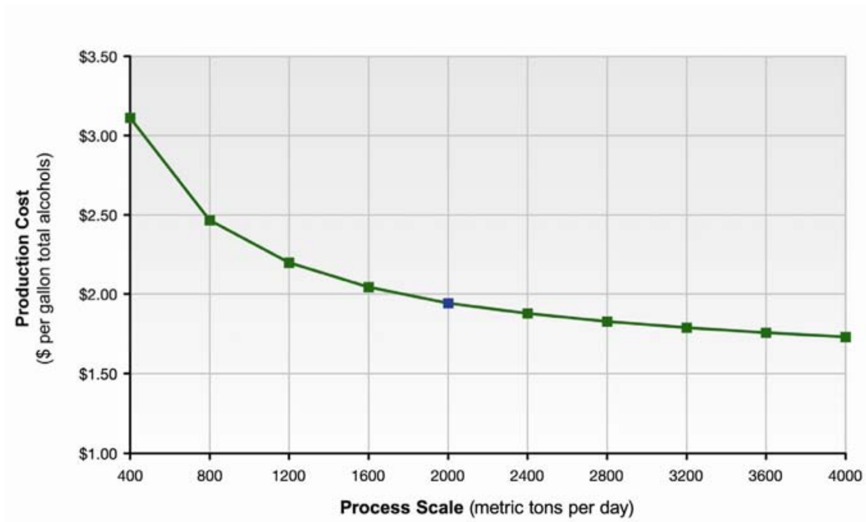

FIGURE 13. Effect of Process Scale

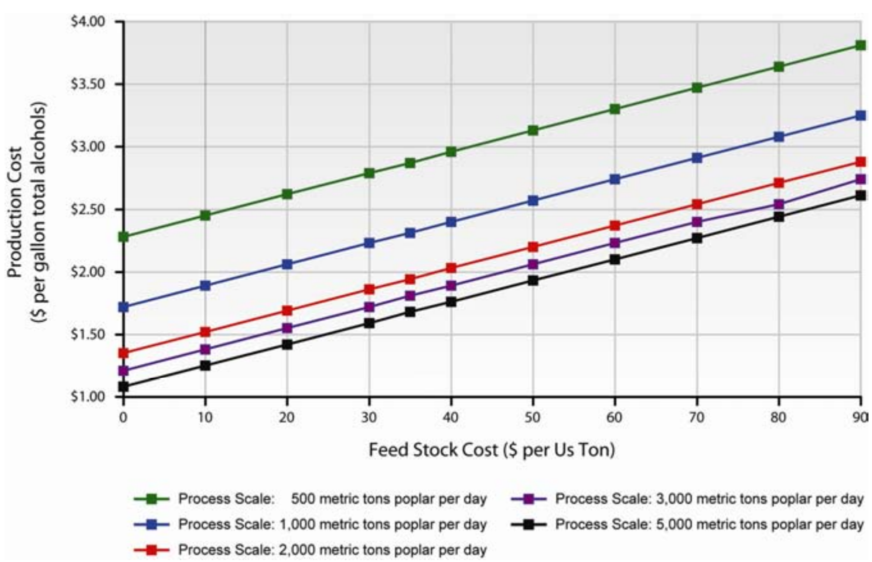

FIGURE 14. Effect of Biomass Costs and Process Scale

Technological innovations that improve the performance of the combined gasification and syngas conditioning operations, and reduce the capital cost of these units, would make a significant contribution to the viability of biomass-derived fuels. For example, operation of the gasifier at elevated temperatures compared to past designs could lead to an increase in biomass conversion to carbon monoxide and hydrogen and reduced tar production. This would increase the overall yield of biomass to product and possibly reduce the capital associated with tar cracking and recycling. For treatment of the remaining tars, combination of the tar-cracking and steam-reforming steps into one unit operation would lead to a significant reduction in capital cost. Such strategies for combining unit operations are being investigated by NREL, with promising results. These improvements, either singly or in combination, would reduce the capital investment required for gasification, making all of the product platforms much more competitive. These improvements also could be supplemented by enhancements to the mixed alcohol synthesis, methanol conversion, and Fischer-Tropsch crude synthesis processes.

Pyrolysis and Liquefaction (Bio-Oils)

As noted earlier in this chapter, bio-oils also could be used as a means of displacing petroleum. The two primary technologies used to produce bio-oils are liquefaction and pyrolysis. Both technologies have seen limited practice in production of fuel for boilers or stationary power but these oils also could be upgraded to be suitable for use in producing liquid transportation fuel. This option is attracting increased attention, but had not been pursued aggressively in the United States until recently.

Both processes are capable of processing lignocellulosic biomass and can convert the bulk of the biomass material to final product. The pyrolysis process is performed rapidly and at atmospheric pressure, but requires a dry biomass feedstock. According to Ringer et al. (2006), hydrothermal liquefaction involves a lengthy dwell time (approximately 20 minutes) to convert pressurized (200 atm) biomass slurries to bio-oil. Liquefaction also requires at least some moisture content in the biomass feedstock. The oil product yields are relatively high, but have differing characteristics. As a result, the process required to upgrade the two different product bio-oils for further conversions requires a different process configuration, but involves the same general hydrogenation chemistry (hydrotreating). Both approaches offer the prospect of small-scale distributed processing of lignocellulosic biomass with the resulting bio-oil being transported to an intermediate facility for upgrading, and the hydrotreated oil subsequently delivered to an existing refinery for conversion to liquid fuels and other products (Ringer et al. 2006).

To assess the potential for this approach in Oregon and Washington, a pyrolysis unit processing 550 dry tons (short) of wood per day was modeled, assuming $35-per-ton delivered cost for the wood. The hydrotreating facility was modeled as a hydrodeoxygenation reaction using commercially available hydrotreating catalysts. This process, which increases the stability of the bio-oil, removes the entrained water and increases the hydrogen content of the bio-oil, was modeled at 2,200 tons-per-day capacity, which would upgrade the product from at least four pyrolysis facilities. A separate model has not yet been developed for hydrothermal liquefaction, but the overall performance and cost of this approach should be comparable to pyrolysis even though the specific operations are different. Again, process and economics models, as well as model results, were made available to industry for peer review.

The model results indicate an installed cost of $35 million for the pyrolysis units with these units producing approximately 700,000 barrels of bio-oil per year (assuming 90 percent on-stream efficiency) at a product cost of about $25 per barrel. The capital cost of the installed hydrotreating facility is approximately $40 million dollars and the cost of the upgraded product is about $80 per barrel, before adding an appropriate return on investment and accounting for the cost of transporting the upgraded product to the refinery. Clearly, this product cost is higher than the target delivery cost of $65 per barrel and significant advancements are needed for this strategy to be competitive. In fact, there are a number of opportunities to improve both the pyrolysis and hydrotreating technologies. Given the potential value of a distributed processing strategy, these improvement opportunities warrant thorough investigation.

In the pyrolysis process, advancements that increase the total yield of bio-oil from the biomass input by decreasing gas formation and production of char production would decrease product cost. In addition, bio-oil can be unstable and the characteristics of the bio-oil can change during shipping or storage, so producing a more stable bio-oil would allow more reliable transportation and processing. Further, optimizing the characteristics of the bio-oil mixture could have significant beneficial impacts on the hydrotreating step and could lead to higher yields and potentially lower capital cost in the hydrotreating operation. Finally, there has been limited engineering research associated with scaling of pyrolysis systems. However, scaling systems up to 250-to-500-tons-per-day while reducing the capital cost from the current $35 million installed cost would support implementation at an industrial scale.

The biggest economic gains can be made by developing new catalysts that dramatically improve the hydrotreating operation. Currently, the space velocity in the hydrotreater is relatively low and the process pressures are quite high. Developing catalysts that double or triple space velocity while performing at process pressures below 100 atm would reduce the size of the hydrotreater, thereby decreasing the cost of hydrotreating by 50 percent. Catalyst improvements leading to increased product yield would reduce the product cost even further. Finally, recovery and utilization of some of the by-products from pyrolysis (e.g., lignin fractions or light oxygenates) for the production of higher value products also would make the process economics more attractive.

Summary

The most significant biomass resources available in Oregon and Washington are comprised of complex lignocellulosic materials. Thermochemical process alternatives seem to be best suited to convert these resources to fuels and these technologies also open the door for product options beyond ethanol and biodiesel, including hydrocarbon fuels that substitute for gasoline and diesel as well as hydrocarbon products that substitute directly for crude oil in existing refining processes. Strategies that pursue these options could accelerate adoption of biofuels because these products are compatible with the existing vehicle fleet and the current fuel distribution system. New strategies may also leverage the existing petroleum refining infrastructure, thereby avoiding capital investment in new production capacity.

Gasification systems are capital intensive and therefore the economics tend to favor larger-scale production, but the technology could be suitable for resources that already are collected and aggregated, such as municipal solid waste. A concerted research and development effort resulting in gasifier capital cost reductions of 30 to 50 percent, combined with targeted improvements in synthesis chemistry, would bring product costs into a range competitive with petroleum fuels and provide an attractive ROI in large-scale, centralized production facilities. The methanol synthesis pathways offer the greatest opportunity to leverage the existing infrastructure and the innovations required to make this technology ready for deployment seem to be within reach. Further, biomass gasification and methanol synthesis could enable a regional chemical industry that supplies products that compete favorably with imports and require fewer technology innovations to be economically attractive.

For those resources that are distributed throughout the region and where collection and transportation costs present a major hurdle, deployment of smaller-scale, less capital-intensive process units that can be located nearer to the biomass resource is a compelling strategy. One option could be distributed production of bio-oils with centralized hydrotreating to upgrade the bio-oils to make a crude feedstock that is acceptable for existing petroleum refinery processes, avoiding the need for capital investments in stand-alone fuel production facilities. The lower capital threshold, combined with improvements in both the pyrolysis/liquefaction and bio-oil hydrotreating technologies, could make this strategy financially competitive within a decade. An alternative approach, currently being investigated by the U.S. Department of Agriculture (Banowetz et al. 2007), involves small-scale gasifiers combined with new, small-scale chemical synthesis reactors. Given the potential value of a distributed processing strategy, these opportunities seem to warrant thorough investigation.

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CHAPTER EIGHT

New approaches and technologies will be required to build a sustainable, economically viable biofuels industry that contributes significantly toward meeting the region's increasing fuel needs.

Conclusions

There is little doubt that the Northwest states will have a biofuels industry. In fact, there are currently plans to construct eight ethanol plants with a capacity of more than 400 million gallons per year, as well as plans for biodiesel production capacity totaling 127 million gallons per year. If these facilities are constructed and operated at capacity, these plants would provide approximately 8 percent of the combined Oregon and Washington total annual transportation fuel need and would very nearly satisfy the E10 and B5 targets defined in the renewable fuel standards recently enacted in both states. However, these fuels will be produced almost entirely from crops grown elsewhere. The ethanol production will rely primarily on corn imported from the Midwest and most of the biodiesel production will rely on imported vegetable oil. So, while renewable fuel standards and other policies have incentivized biofuel production in the region, fundamental market and technological barriers must be overcome to create an opportunity to utilize regional biomass resources for biofuel production and to create new markets for in-state natural resource industries.

A clear challenge for Oregon and Washington, therefore, lies in identifying local biomass resources that can support further growth of the industry in a way that realizes the in-state production goals of both states. The current regional agricultural and forestry resource base could provide a limited supply of biomass, and this resource could be expanded by identification and development of new energy crops. Additionally, utilization of municipal solid waste (MSW) could provide a major near-term resource. However, producing biofuels from the majority of the biomass available in the region (primarily "lignocellulosic" biomass) will require conversion technologies that are not yet commercially available. This indicates that the second challenge for the region is development of conversion technologies that are appropriate for the resources available in the region. Further, while production of biofuels is an important goal, it is also important that the region's research institutions identify bioproducts and other uses of agricultural and forestry resources that can provide higher market value than fuels.

Current Indigenous Resource Availability

If Oregon and Washington biofuel production capacity is to double or triple from levels currently planned without increasing feedstock imports, a regional biomass resource must be identified that can reliably and sustainably supply 10 to 20 million tons of biomass at a delivery cost of less than $50 per ton. A natural assumption has been that the region's agricultural and forestry resources are more than sufficient to provide for such near-term growth. However, this is not the case in today's land use practices.

The current agriculture system has limited ability to provide additional resources at a significant scale. This is primarily due to the competing food and feed value of the crops that currently are produced from the region's cultivated land—simply put, farmers can get more for their crops as food than as feedstock for fuel.

Alternative options, such as using crop residues or introducing new oilseed lines, would enable only a minor incremental expansion of biofuel production, not a doubling or tripling of supply. Crop residues could be counted on as only a modest resource due to the relatively low productivity of the dryland production that dominates the region. More importantly, the straw that is processed for fuel will represent a disposal option for farmers, not a major source of new revenue. And, while a small number of farmers may find localized "boutique" markets for oilseed crops and biodiesel profitable in the near term, in the long term the fuel market value of oilseed grains does not provide a significant margin for farmers compared to crops currently grown.

The timber industry represents an additional resource, but in current market conditions much higher value uses exist for the majority of the available resource that is currently collected, and the region's rugged terrain limits expansion of the resource via increased collection of timber harvesting residues. Timber thinning to reduce the fire danger on federal forest land could almost double the available wood resource, but requires both new land use policy and public acceptance.

The volume and cost limitations of regional agricultural and forestry resources lead to the consideration of biomass that has traditionally been managed as waste. Municipal and industrial solid waste is in abundant supply and it appears that production of liquid transportation fuels would be a higher value use for as much as 7 million tons per year within the region that are currently buried. Solid wastes seem even more promising when considering the increasing cost of waste disposal, the significant fraction of the waste that is organic, the concentration of the material in a small number of locations, and the existing infrastructure in place to handle the materials. While technological challenges must be addressed, the potential of this abundant resource should be thoroughly assessed.

Expanding Resource Availability

If a majority of MSW can be utilized, in combination with the agriculture and forestry resources available based upon current land use practices, it is conceivable that indigenous biomass resources could produce between 10 and 15 percent of the region's fuel needs. However, expanding beyond that level will require development of new energy crops and production strategies that will enable the region's farmers and foresters to sustainably produce, harvest and collect these new crops.

The region's land grant universities, experiment stations and U.S. Department of Agriculture research centers are well qualified to undertake such an effort. They can develop new crop lines and related agronomic and silviculture practices that allow energy crops to be grown in rotation with dryland wheat, in conjunction with saw timber in forest lands, or cost effectively on irrigated agricultural lands, all adding to the available resource. Research is already underway in the region, exploring the potential role of herbaceous energy crops such as switch grass or arundo donax, advancing oilseed production, and developing hybrid poplars for fiber production. The hurdle is high, but regional research institutions have delivered new high-yield crops and cost-effective production practices in the past and could do so again with a sustained effort.

Other Possible Biomass Strategies

Expanding the regional biofuels industry is a worthy effort and such efforts may be necessary to increase the ability of the United States to satisfy its transportation fuel needs with domestic resources. However, given that the fuel value of biomass is generally quite low, production of biomass for biofuels is only one potential strategy that should be pursued locally in the quest to create new jobs and provide economic opportunities for farmers and rural communities. Oregon and Washington also need to pursue other research and business options for developing new bio-based products that have greater value than the current grain and forage crops grown in the region or that offer new markets for the natural resource industries of the Pacific Northwest.

For example, a number of advances are required to reduce the cost of growing canola to reach the low costs commensurate with the market value of canola oil as a feedstock for biodiesel. Such advances include improving canola yield, improving crop hardiness, and reducing the break-even cost by at least 30 percent. Even then, the end result is an oilseed grown as a rotation crop for the fuel market that will generate less revenue per acre than the cereal grain or grass seed normally grown on those acres.

An alternative, and possibly much more valuable, research investment would be development of a crop that can be grown in the same rotation but has higher value in the human food market due to specific product content. For example, camelina is an oilseed plant that shows greater potential for adaptation to dryland production in the Northwest and also produces an oilseed with high omega-3 fatty acid content, which is desirable in the food market for reducing the risk of heart disease. Such a crop could provide greater revenue for farmers in the food market than in the biofuel market. In addition, there are many potential opportunities outside of the traditional food and feed markets, such as oils, extracts and other bio-based products for use in personal care, pharmaceuticals and specialty industrial chemicals.

Examples of recent or ongoing research that illustrate the potential of bio-based products research include development of natural rubber-producing crops (U. S. Department of Agriculture, Agricultural Research Service 2007), development of Meadowfoam as a new crop with high-value oils for personal care applications (Oregon State University Extension 2005), and identification of plant-derived compounds with anti-cancer properties (Washington State University Agricultural Resource Center 2007). Given these developments, the region's research institutions should not abandon their long-standing and valuable research dedicated to developing new and more profitable crops for food, feed, and fiber markets, even as they pursue new industrial markets such as biofuels and renewable chemicals.

Technology Options

Almost all of the Northwest biomass resources that could be available to support a biofuels industry are far more complex than the starch and vegetable oil that form the basis for the existing biofuels industry. Even the grass and cereal grain straws available from current agricultural production, or the new herbaceous energy crops that might be grown in rotation with irrigated forage crops, are "lignocellulosic" biomass that requires more advanced conversion processes. Other resources such as forest residues and other wood, or MSW also require different technologies than those developed for the existing biofuels industry and many of the potential process options have not been the primary focus of research efforts over recent decades. Development and demonstration of new conversion strategies is a critical component in enabling expansion of a biofuels industry. Further, such conversion strategies need to consider the geography of the region, the existing infrastructure of the region, and market needs.

For resources that are collected and concentrated, such as MSW, a gasification strategy could achieve the desired economies of scale needed to be competitive with petroleum fuels. Ideally, with advances in synthesis chemistry, these resources could be used to produce finished fuel products that are directly compatible with the existing distribution infrastructure and vehicle fleets. Of course, a concerted research and development effort is needed to reduce gasifier capital cost by 30 percent, perhaps up to 50 percent. When combined with targeted improvements in synthesis chemistry, this would bring the cost of most products into a range that is competitive with petroleum fuels and provide an attractive return on investment.

The second potential conversion strategy, based upon small-scale, distributed process technologies, would be aimed at resources that are distributed throughout the region and where collection and transportation costs present a major hurdle. These technologies seem well suited to make use of resources such as cereal grain straw and timber harvesting residues, and perhaps even some municipal and industrial wastes (e.g., MSW from small municipalities, food processing waste streams, or even manure solids from large livestock operations). One such strategy could be distributed production of bio-oils with a number of larger-scale facilities centrally located to upgrade these bio-oils to make a crude feedstock that is then transported to existing petroleum refineries. This strategy expands the crude supply for the region's refineries, avoids the need for capital investments in stand-alone fuel production facilities and enables production of all of the fuel products currently used in the market. Development of small-scale gasification and fuel synthesis systems also could be an alternative, as well as hydrolysis and fermentation to ethanol, as additional process "trains" at existing ethanol facilities[1]. Again, the technology requires additional development to be competitive, but maturation, demonstration and deployment could be accelerated with the support and involvement of regional industry.

Summary

In conclusion, new approaches and technologies are required to build a sustainable, economically viable biofuels industry that contributes significantly toward meeting the region's increasing fuel needs. In

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[1] This option is being explored at a small scale at Pacific Ethanol's plant in Boardman, Oregon. Funds to support this 10% scale demonstration are provided in part by the U.S. Department of Energy, Office of the Biomass Program.

particular, new resources such as MSW or purpose-grown energy crops must be evaluated to secure the quantity of biomass required to meet the needs of such an industry and to meet the cost target of $35 per delivered ton of biomass. Further, the next generation of conversion technologies must be developed in order to ensure that the industry can be competitive and financially viable in the long term. These technologies must be scaled to reflect the distributed nature of some biomass resources and the potential to aggregate others. Finally, regional efforts must be expanded beyond the limited opportunities associated with regional ethanol and biodiesel production. The technology, product, research and policy strategies should address the complete fuel needs of the region (i.e., replacements for gasoline, diesel and jet fuel) and the economic potential of bio-based products other than fuels in order to ensure maximum benefit for the region.

References

Aden A., M. Ruth, K. Ibsen, J. Jechura, K. Neeves, J. Sheehan, B. Wallace, L. Montague, A. Slayton, and J. Lukas. 2002. *Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover.* National Renewable Energy Laboratory. Golden, Colorado. Report No. NREL/TP-510-32438.

Aden A., P. Spath, B. Atherton. 2005. "The Potential of Thermochemical Ethanol Via Mixed Alcohols Production." *Milestone Report*, National Renewable Energy Laboratory. Golden, Colorado.

Banowetz, G.M., B. Akwasi, J. Steiner, V. Sethi, and H. El-Nashaar. 2007. *Potential for On-Farm Thermochemical Conversion of Straw to Bioenergy in the Pacific Northwest.* U.S. Department of Agriculture, Agriculture Research Service, National Forage Seed Production Research Center. Corvallis, Oregon.

CH2M Hill. 2005. *Sizing and Characterizing the Market for Oregon Biopower Projects: Phase II Market Assessment.* Prepared by CH2M Hill for the Energy Trust of Oregon, Inc. Available at http://energytrust.org/RR/bio/MarketAssessment2/01_Table_Contents.pdf (February 2008).

Edwards A.G. 2006. *Analysis of Global Petroleum Markets and Pricing Trends.* AG Edwards and Sons, Inc. Securities Research. St. Louis, Missouri.

EIA-AEO—Energy Information Administration. 2007. *Annual Energy Outlook 2007.* Energy Information Administration, U.S. Department of Energy. Washington, D.C. Available at http://www.eia.doe.gov/oiaf/archive/aeo07/index.html (February 2008).

EIA-AER—Energy Information Administration. 2007. *Annual Energy Review 2007.* Energy Information Administration, U.S. Department of Energy. Washington, D.C. Available at http://www.eia.doe.gov/emeu/aer/contents.html (February 2008).

EIA-SEP—Energy Information Administration. 2007. *State Energy Profiles.* Energy Information Administration, U.S. Department of Energy. Washington, D.C. Available at http://tonto.eia.doe.gov/state/ (February 2008).

Engrossed Substitute Senate Bill 6508. 2006. 59th Legislature. Available at http://apps.leg.wa.gov/billinfo/summary.aspx?bill=6508&year=2006 (February 2008).

Environmental Protection Agency. 1999. "Use of Fuel Oxygenate Additives by Region." U.S. Environmental Protection Agency, Washington, D.C.

Faaij, A. 2006. "Modern Biomass Conversion Technologies." *Mitigation and Adaptation Strategies for Global Change*, 11:335-367. Springer, Netherlands.

Frear C., B. Zhao, G. Fu, M. Richardson, S. Chen, and M.R. Fuchs. 2005. *Biomass Inventory and Bioenergy Assessment: An Evaluation of Organic Material Resources for Bioenergy Production in Washington State*. Washington State University. Pullman, Washington. Report prepared for the Washington State Department of Ecology. Available at http://www.ecy.wa.gov/biblio/0507047.html (February 2008).

Graf A. and T. Koehler. 2000. *Oregon Cellulose-Ethanol Study.* Bryan & Bryan Inc., 5015 Red Gulch, Cotopaxi, Colorado. Prepared for the Oregon Office of Energy. Available at http://www.ethanol-gec.org/information/briefing/20a.pdf (February 2008).

Hinman H., D. Pittman and D. Roe. 2003. "Cost of Producing Canola and Mustard Oilseeds in Eastern Washington and North Central Idaho." *Farm Business Management Reports.* Washington State University Cooperative Extension. Pullman, Washington. Available at http://www.farm-mgmt.wsu.edu/nonirr.htm (February 2008).

Huber G.W, S. Iborra and A. Corma. 2006. "Synthesis of Transportation Fuels from Biomass: Chemistry, Catalysts, and Engineering." *Chem. Rev.* 106, 37(52): 4044-4098. American Chemical Society.

Iowa Corn Promotion Board. 2006. Ethanol Facts. Des Moines, Iowa. http://www.iowacorn.org/ethanol/ethanol_3a.html (February 2008).

Johnson J.D. 2000. "Hybrid Poplars in the Pacific Northwest: Culture, Commerce, and Capability." Symposium Proceedings. April 7-9, 2000. Washington State University. Pullman, Washington. http://cahnrs.wsu.edu/ag/archives/2007/johnson-poplar-2007-09.html

Karow R. and J. Auyong. 2006. *Growing Canola as a Feedstock for Biofuels in Oregon: A Fact Sheet*. Oregon State University, College of Agricultural Sciences. Corvallis, Oregon.

Keil F.J. 1999. "Methanol-to-Hydrocarbons: Process Technology Review." *Microporous and Mesoporous Materials* 29:49-66. Elsevier Science.

Kerstetter, J.D., L. Lynd, K. Lyford, and C. South. 1997. *Assessment of Potential for Conversion of Pulp and Paper Sludge to Ethanol Fuel in the Pacific Northwest*. Report for the National Renewable Energy Laboratory, Golden, Colorado. Washington State University Cooperative Extension Energy Program. Olympia, Washington.

Kerstetter J.D. and J.K. Lyons. January 2001. *Logging and Agricultural Residue Supply Curves for the Pacific Northwest.* Prepared for the U.S. Department of Energy. Washington State University Cooperative Extension Energy Program, Olympia, Washington. Available at http://www.energy.wsu.edu/documents/renewables/SupplyCurveReport.pdf (February 2008).

Kerstetter J.D. and J.K. Lyons. September 2001. *Wheat Straw for Ethanol Production in Washington: A Resource, Technical, and Economic Assessment.* Prepared for the Washington State Office of Trade and Economic Development. Washington State University Cooperative Extension Energy Program. Available at http://www.energy.wsu.edu/documents/renewables/WheatstrawForEthanol.pdf (February 2008).

Lyons J.K. 2005. *Biodiesel in Washington: A Snapshot.* Prepared for Washington Community Trade and Economic Development Department. Washington State University Energy Program. Available at http://www.cted.wa.gov/DesktopModules/CTEDPublications/CTEDPublicationsView.aspx?tabID=0&ItemID=3180&MId=863&wversion=Staging (February 2008).

Metro Regional Government. 2007. Available at http://www.metro-region.org/index.cfm/go/by.web/id=24197.

National Biodiesel Board. 2007. "Commercial Biodiesel Production Plants." Updated version available at http://biodiesel.org/buyingbiodiesel/producers_marketers/ProducersMap-Existing.pdf (February 2008).

National Corn Growers Association. *World of Corn, 2007.* Saint Louis, Missouri. Available at http://www.ncga.com/worldofcorn/2007/production1.asp (February 2008).

OFRI (Oregon Forest Resources Institute). 2006. *Biomass Energy and Biofuels from Oregon's Forests*. Oregon Forest Resources Institute.

Oregon Department of Agriculture. 2007. *The State of Agriculture: Report to the Governor and the Oregon Legislature*. Oregon Department of Agriculture. Salem, Oregon.

Oregon DEQ (Department of Environmental Quality). 2006. *2004 Oregon Material Recovery and Waste Generation Rates Report.* State of Oregon DEQ, Land Quality Division. Salem, Oregon.

Oregon State University Extension. 2005. *2004 Oregon County and State Agricultural Estimates*. Special Report 790/04. Oregon State University Extension Service. Corvallis, Oregon.

Ringer M., V. Putsche and J. Scahill. 2006. *Large-Scale Pyrolysis Oil Production: A Technology Assessment and Economic Analysis.* National Renewable Energy Laboratory. Golden, Colorado. Report no. NREL/TP-510-37779.

Scott, R.E. 2006. *Trade Picture*. Economic Policy Institute. Washington, D.C.

Spath P., A. Aden, T. Eggeman, M. Ringer, B. Wallace, J. Jechura. 2005. *Biomass to Hydrogen Production Detailed Design and Economics Utilizing the Battelle Columbus Laboratory Indirectly-Heated Gasifier.* National Renewable Energy Laboratory. Golden, Colorado. Report no. NREL/TP-510-37408. Available at http://www.nrel.gov/docs/fy05osti/37408.pdf (February 2008).

Spath P.L. and D.C. Dayton. 2003. *Preliminary Screening – Technical and Economic Assessment of Synthesis Gas to Fuels and Chemicals with Emphasis on the Potential for Biomass-Derived Syngas.* National Renewable Energy Laboratory. Golden, Colorado. Report no. NREL/TP-510-34929.

SRI Consulting. 2003. Wang S., ed. *Process Economics Program Yearbook International: Vol. 1E United States (English Units)*. SRI Consulting. Menlo Park, California.

U.S. Army Corps of Engineers. 2004. *Final Waterborne Commerce Statistics for Calendar Year 2004, Waterborne Commerce National Totals and Selected Inland Waterways for Multiple Years.* Institute for Water Resources, Navigation Data Center, U.S. Army Corps of Engineers. Waterborne Commerce Statistics Center.

U.S. Department of Agriculture. 2005. *2004 Washington Annual Statistical Bulletin*. National Agricultural Statistics Service, Washington Field Office. Olympia, Washington.

U.S. Department of Agriculture, Agricultural Research Service. 2007. *Development of Domestic Natural Rubber-Producing Industrial Crops Through Biotechnology.* (Research Project). Project No. 5325-41000-043-00.

U.S. Department of Energy. 2007. *Biomass Multiyear Program Plan.* Office of the Biomass Program, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy. Washington, D.C. Available at http://www1.eere.energy.gov/biomass/pdfs/biomass_program_mypp.pdf (February 2008).

Washington Research Council. 2004. *Washington State's Petroleum Refining Industry Economic Contribution*. Seattle, Washington.

WSU (Washington State University) College of Agricultural, Human, and Natural Resources. 2007. "WSU Researcher Wins Grant to Research Poplar Wood Biofuel Feasibility." Washington State University. Pullman Washington. Available at http://cahnrs.wsu.edu/ag/archives/2007/johnson-poplar-2007-09.html (February 2008).

WSDOE (Washington State Department of Ecology). 2004. *Solid Waste in Washington State: Thirteenth Annual Status Report.* Washington

State Department of Ecology. Olympia, Washington. Available at http://www.ecy.wa.gov/biblio/0407018.html (February 2008).

Washington State Department of Transportation. 2006. *Transportation Plan Update.* State of Washington, Department of Transportation. Olympia, Washington. Available at www.wsdot.wa.gov/planning/wtp/documents/freight.htm. (February 2008).

Washington State University Agricultural Resource Center. 2007. *Research in Agricultural, Human, and Natural Resource Sciences: Annual Research Impact Report 2007*. Available at http://arc.wsu.edu/researchimpacts/ (February 2008).

Washington State University Extension Energy Program. 2007. *Biofuel Development in Washington*. Olympia, Washington. Available at http://www.bioenergy.wa.gov/documents/biofuelactivities.pdf (February 2008).