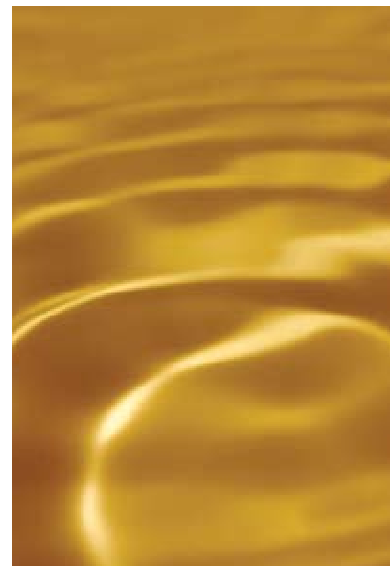
FUELING OREGON *with* SUSTAINABLE BIOFUELS



A REPORT BY THE OREGON ENVIRONMENTAL COUNCIL

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Fueling Oregon with Sustainable Biofuels

by Daniel Gilman

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OREGON ENVIRONMENTAL COUNCIL

About the Oregon Environmental Council

The Oregon Environmental Council safeguards what Oregonians love about Oregon – clean air and water, an unpolluted landscape and healthy food produced by local farmers. For nearly 40 years we've been a champion for solutions to protect the health of every Oregonian and the health of the place we call home. We work to create innovative change on three levels: we help individuals live green; we help businesses, farmers and health providers thrive with sustainable practices; and we help elected officials create practical policy. Our vision for Oregon includes solving global warming, protecting kids from toxins, cleaning up our rivers, building sustainable economies, and ensuring healthy food and local farms. Join thousands of Oregonians by becoming a member today at www.oeconline.org.

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Our continued dependence on imported fossil fuels – primarily petroleum – to meet America's energy needs is increasingly putting our nation's economy and security at risk. Petroleum is a non-renewable resource that will persist in driving up energy costs as global production declines. The burning of fossil fuels, long recognized as having impacts on human health and the environment, is also the primary contributor to escalating global warming.

In July 2007, Oregon became the first state in the nation to provide incentives for the local production of feedstocks for alternative, renewable fuels. Oregon also joined a handful of other states, including its neighbor Washington, in enacting a statewide renewable fuels standard, requiring the blending of biodiesel and ethanol in all diesel and gasoline sold at the pump.

In tandem with a new standard to meet 25% of the state's electricity needs from renewable energy by 2025, Oregon's investment in renewable fuels development constitutes a forward-thinking strategy that will lead us to a cleaner, more sustainable energy future.

Energy derived from biofuels, wind, solar, geothermal, and wave technology produced in Oregon can serve as a driver of economic development across the state, creating new industry and jobs, reducing energy costs and stabilizing local energy supply. By investing in these renewable resources now, Oregon is positioning itself to be on the leading edge of an emerging low-carbon economy and an exporter of clean energy technologies necessary now and over the long term to combat climate change.

In particular, the establishment of incentives and a stable market for biofuels empowers Oregon farmers and businesses to develop these renewable fuels locally. In many cases, renewable fuels development can provide growers an added income stream, strengthening Oregon's agricultural sector.

With emerging opportunities to develop and market new clean fuel technologies, renewable fuels development can foster new Oregon-grown industries. These businesses will not only create jobs, but also ensure that an increasing share of our energy dollars (running in the billions of dollars per year) are invested in the local economy, rather than sent out of state or overseas.

While Oregon has an historic opportunity to be on the leading edge of a clean energy future, it should endeavor to do so responsibly, keeping not only economic, but also environmental and social, goals in mind. To maximize greenhouse gas benefits, energy output and efficiency, the conservation of natural resources, environmental protection, public health and other social benefits, the entire biofuels production process must be taken into account – from the fields where the feedstock is planted, through the processing plant, all the way to the tank. *Fueling Oregon with Sustainable Biofuels* discusses the pitfalls that exist along the way, from water polluted by excess chemical inputs during feedstock production to the release of greenhouse gases from biofuels processing facilities powered by coal.

These pitfalls can be avoided. Biofuels production in Oregon should be geared toward those feedstocks and processing technologies where our state can leverage the maximum environmental and social benefits and competitive edge. The matrix in section 6.4 of this report summarizes the positives and negatives of a variety of fuels based on the feedstock used to produce them.

As Oregon moves forward with renewable fuels development, the following principles will help ensure that the biofuels produced and used in Oregon will live up to their potential as clean, renewable fuels.

- **Support only biofuels that reduce greenhouse gas emissions on a life-cycle assessment basis**: To ensure that biofuels are in fact reducing global warming pollution, the full greenhouse gas impact of specific biofuels needs to be accurately assessed using a methodology that is updated as the science improves. To the extent possible, agricultural emissions and land use changes need to be fully accounted for. Biofuels should be required to reduce greenhouse gas emissions compared to petroleum in order to qualify for state incentives, and an incentive system that will encourage the development of increasingly more climate-friendly biofuels should be put in place.

- **Process biofuels with minimum fossil fuel inputs**: Incentives to encourage plants to use biomass, wind, solar or other renewable energy should be put in place. No state incentives should be available for biofuels plants that rely on coal to power their facility.

- **Protect air and water quality**: Careful monitoring of both tailpipe emissions and localized impacts of biorefinery operations on air and water quality will be required. State policies should be informed by the evolving understanding of these impacts.

- **Grow biofuel feedstocks using sustainable agricultural practices**: To avoid negative impacts on water and soil quality, farmers should use best agricultural practices – including minimal chemical fertilizer and pesticide inputs, buffer zones on waterways, and conservation tillage.

- **Conserve water**: The total water use for plants and irrigation should be carefully considered before sourcing feedstocks or locating biofuels production facilities. Incentives to encourage water conservation should be implemented, and research should be done to identify and develop drought-resistant feedstocks.

- **Protect biodiversity**: Biofuel and bioenergy production poses a range of threats to biodiversity if habitat is disturbed. Impacts on native species should be carefully considered as the industry develops.

- **Avoid conversion of native ecosystems**: Converting native grasslands or forests to agriculture, short-rotation woody crops, or tree plantations eliminates any greenhouse gas benefits from even advanced biofuels and does serious harm to biodiversity.

- **Support socially responsible and locally owned biofuels production**: Local communities have the greatest investment in their environment. Encouraging local input, ownership and control of biofuel production will help ensure real sustainability.

- **Provide consumer information**: Biofuel producers should be required to provide sufficient information on feedstocks and production practices to allow consumers to make an informed decision about which biofuels they purchase. Ideally, there would be a system of either voluntary or mandatory labeling that indicates the greenhouse gas balance, if not more detailed environmental and social criteria.

Both public and private institutions have a role to play in promoting these best practices to maximize the social, economic and environmental benefits of renewable fuels development. First and foremost, Oregon should adopt a Low-Carbon Fuel Standard (LCFS). A LCFS requires all fuel providers to gradually reduce the greenhouse gas intensity of the fuels they sell, but doesn't mandate how they meet the standard. It creates a high-value market for renewable fuels that provide the highest greenhouse gas improvements and associated environmental benefits. An Oregon LCFS would focus technological innovation on sustainability and increase Oregon's already strong comparative advantage in renewable fuels development and a clean energy future.

Besides a Low-Carbon Fuel Standard, *Fueling Oregon with Sustainable Biofuels* recommends a number of other policies that will put Oregon at the forefront of sustainable biofuels production. These policies are summarized in Appendix I.

Oregon is uniquely positioned to become a leader in the development of sustainable biofuels. The Oregon Environmental Council hopes that this report will provide Oregon government, agriculture, business and citizens some of the analysis and tools needed to take advantage of this opportunity.

The Oregon Environmental Council contracted with Daniel Gilman to write this report. The executive summary was written by Lindsey Capps and Chris Hagerbaumer of the Oregon Environmental Council.

INTRODUCTION

The current explosion of interest in biofuels is driven by a range of factors, primarily concerns about high oil prices, national security and the increasing pace of global warming. Technological advances have also given new steam to what is actually an older technology, dating back to some of the earliest internal combustion engines.

Yet in the space of a few years, as US biofuel production has soared to over five billion gallons a year (a figure that is expected to double by 2009[1]), more and more concerns about the environmental impacts of biofuels have been raised. These environmental concerns range from pesticide and water use associated with feedstock production to the potential for slightly higher emissions of some air pollutants. This report makes the case that biofuels can and must be produced – from "field to wheel" – with environmentally and socially sound practices.

Oregon is particularly well-suited to benefit from developing a renewable fuel industry. Oregon's diverse agricultural industry and strong environmental policy framework make it uniquely placed to become a leader in the development of sustainable biofuels.

Oregon has the potential to produce renewable fuels locally to replace a small, but not insignificant, portion of its petroleum use in the near-term,[A] and production is expected to expand significantly as cellulosic ethanol and other advanced biofuels become cost-effective to produce. Unlike dollars spent on gasoline or diesel, money spent on locally produced biofuels will circulate in local communities, boosting Oregon's economy. Developing a renewable fuels and biomass energy industry will also create new markets for Oregon farm and forest products.

Perhaps most critically, if renewable fuels are produced sustainably, they can generate substantial reductions in greenhouse gas emissions and improvements in air and water quality. The converse is also true – if farmers, foresters and biofuels processors use unsustainable practices, we will end up with fuels that harm, not help, our environment.

BIOFUELS ARE AN ARROW IN THE QUIVER

Reducing the overall demand for oil by increasing the energy efficiency of our economy and finding new ways to conserve energy should be the nation's and Oregon's first priority. To meet the *remaining* demand for oil and help fight global warming, sustainably produced renewable fuels also play a key role.

Transportation's important transition away from oil also includes more fuel-efficient conventional vehicles, hybrids, plug-in hybrids, electric and other alternative fuel vehicles in the near-term and perhaps hydrogen fuel cell vehicles in the long-term.

[A] Production capacity in the Pacific Northwest is expected to trigger Oregon's renewable fuel standard within the next year; the standard requires 2% biodiesel and 10% ethanol to be blended into the diesel and gasoline sold in the state respectively.

OREGON'S POTENTIAL FOR RENEWABLE FUELS

Oregon has very different potential for what are known as first-generation and second-generation biofuels. First-generation biofuels, including ethanol and biodiesel, are those that are produced from food crops. Second-generation biofuels are those that can be produced from inedible cellulosic crops like wheat straw or wood. Second-generation biofuels are expected to become commercially viable over the next five to ten years, although technological breakthroughs could speed this up.

Oregon has substantial potential for an expansion of oilseed production, which could produce 25-50 million gallons of biodiesel a year, around 3-6% of Oregon's diesel consumption.[B] While canola is the main crop being considered as a biodiesel feedstock, developing drought-resistant crops, such as camelina, for use in Eastern Oregon will help expand feedstock production.

After selling into food markets, wheat farmers could direct a good portion of Oregon's large wheat crop to first-generation ethanol production. Smaller quantities of ethanol could also be produced from sugar beets, potatoes, and whey and other agricultural byproducts if it proves economical to construct the plants and infrastructure to do so.

In terms of second-generation biofuels, Oregon's largest potential feedstock is wheat straw and other agricultural residues. However, determining how much residue needs to be left on the field to prevent erosion and preserve fertility is a critical question. Woody biomass, such as forest thinnings, can also be used to produce biofuels, but it is logistically challenging to remove and transport and would have to be done in such a way that improves, rather than impairs, forest health. Finally, hybrid poplar and other short-rotation woody crops may be an important feedstock in the mid-term, although the limited availability of water for irrigation in Eastern Oregon may be an issue. In the long-term, one of the most promising biofuels feedstocks may be algae, although much research remains to be done to prove its feasibility.

Producing Renewable Fuels Sustainably

While renewable fuels are often referred to as "carbon-neutral," this is not quite the case. Although the carbon released when biofuels are burned is the same carbon that was captured by the plant as it grew, agricultural production – particularly through the use of chemical fertilizers – can produce substantial greenhouse gases (GHGs). Bringing new land into agriculture also accelerates global warming because the destruction of forests and grasslands releases large quantities of carbon dioxide and other GHGs within a very short period that had been sequestered in the plants and the soil over decades. Converting carbon-rich natural ecosystems to agricultural land for production of biofuels feedstocks diminishes any value the fuels might have in fighting global warming. Likewise, when biofuels production relies on fossil fuels like coal and natural gas to power the processing plants, the global warming benefits of biofuels decline.

To produce sustainable biofuels, it is important to evaluate the entire biofuels production process, from the fields where the feedstock is planted, through the processing plant, all the way to the tank. Based on this life-cycle analysis, those renewable fuels that provide the highest energy yield, most positive local economic and social impacts, greatest benefit to the environment, and lowest drain on scarce resources should be clearly identified and encouraged.

[B] Oregonians consumed over 750 million gallons of diesel in 2005 according to the US Energy Information Administration.

This report outlines the environmental implications of producing biofuels, both positive and negative, and provides recommendations that will put Oregon at the forefront of sustainable biofuels production.

Some members of the renewable fuels industry question whether they should be held to higher standards than the petroleum industry, particularly when they are just getting off the ground. We propose that there is not only a moral imperative to protect the environment, slow global warming and improve the public's health, but that sustainable biofuels practices make sense from an economic standpoint. Consumers are increasingly demanding sustainably produced products; and citizens are increasingly demanding that government policy support sustainability. Whenever public funds are used to support expansion of an industry on the premise that that industry is providing a public benefit (in the case of biofuels a climate-friendly, environmentally sustainable, and local industry), the industry should meet these goals or government should withdraw its support.

At the 2007 annual Leadership Summit of the Oregon Business Council, much attention was drawn to Oregon's competitive advantage in sustainability, and the biofuels industry was identified as a key growth opportunity for the state. After years of relying on imported fuel, renewable fuels offer the possibility of locally produced, locally consumed energy, which puts money back into the community and, if done right, helps rejuvenate rather then damage the environment. Biofuels are just the beginning. New technologies allowing a full range of bio-products to be produced can help reduce our use of polluting chemicals and reduce the amount of non-biodegradable trash we produce. By encouraging a sustainable biofuels industry today, Oregon can be at the vanguard of an entirely new global economy tomorrow.

THE ENVIRONMENTAL IMPACTS OF OIL

Oil has provided many benefits since significant deposits were discovered in the 19th Century, but every stage in its life cycle, from exploration to use, has harmful effects on our health and the environmental systems on which we and other species depend. A few are outlined below:

- Drilling and extracting oil results in spills and fires, occupational injury and disease, and harm to ecosystems. As one example, offshore oil rigs along the Gulf Coast have contaminated sediments and fish with mercury at levels far exceeding what is considered safe for human consumption.[2]

- Oil leaks and spills cause serious harm to marine life and fisheries. According to the Oil Spill Intelligence Report of 1999, approximately 32 million gallons of oil was spilled in worldwide waters as a result of 257 transport incidents that year.[3]

- Petroleum refineries present major health hazards for those who work in and live near them; oil, its byproducts and the chemicals used in the refining process cause air and water pollution, thermal and noise pollution.

- Combustion of gasoline and diesel releases a variety of air pollutants that can lead to heart and lung disease, cancer and premature death. Combustion of gasoline and diesel also releases embedded carbon which combines with oxygen in the air to produce carbon dioxide, CO_2, the most prolific greenhouse gas in our atmosphere. As levels of CO_2 rise, the world warms, bringing a host of unwanted effects.

2 OVERVIEW OF BIOFUEL TECHNOLOGIES

While the term "biofuels" can include a range of solid, liquid and gaseous fuels derived from organic matter or "biomass," the focus of this report is on the development of liquid biofuels, which can be blended with gasoline and diesel and integrated into the existing infrastructure.

2.1 First-Generation Biofuels

First-generation biofuels are those biofuels in production today that rely primarily on food crops as their primary feedstock.

The primary biofuel produced in the US is ethanol (C_2H_5OH), which is the same alcohol found in alcoholic beverages. Ethanol has traditionally been produced by fermenting sugars or starches, which each require slightly different processing. Over 92% of US ethanol is produced from corn kernels, with production being centered in the Corn Belt of the Midwest. Most of the remaining 8% comes from grain sorghum (milo), wheat, barley or other similar grains, with only about 1% coming from agricultural co-products such as beverage waste, cheese whey, and others.[4]

A 10% blend of ethanol and gasoline (E10) has been certified as a motor vehicle fuel by the US EPA and is covered by warranties from every major car manufacturer, so it can be used in any car on the road today.[C] There are over four million "flex-fuel" vehicles on the road that can run on a blend of up to 85% ethanol (E85),[5] although few gas stations offer E85 fuel as of yet.

As an established technology, which is easily integrated into our current infrastructure, sugar- or starch-based ("first-generation") ethanol is likely to dominate US renewable fuels for at least the next five to ten years. However, it also has several disadvantages. Ethanol has only two-thirds of the energy of gasoline per gallon, thus resulting in lower gas mileage, and can't be transported through conventional oil pipelines.[6] The greatest limit on first-generation ethanol is the availability of sugar and starch feedstocks, however. Nearly 20% of the US corn crop already goes to ethanol production,[D] to meet only a small percentage of our gasoline needs.

The other major renewable fuel available today is biodiesel (fatty-acid methyl ester). There is already 1.85 billion gallons of biodiesel production capacity in the US, with another 1.37 billion gallons in capacity is under construction,[7] although only 250 million gallons of biodiesel was sold in the US in 2006[8] (compared to over 63 billion gallons of diesel sold).[9]

Biodiesel can be produced from any kind of oil or fat, including waste vegetable oils, virgin vegetable oils and animal fats. Unlike ethanol, which is the same molecule with the same properties no matter what feedstock it is produced from, biodiesel has distinct chemical properties depending on what feedstock oil is used. Biodiesel is produced by combining the oil with an alcohol (commonly methanol) in a process called transesterification, which is straightforward enough to be done in a home kitchen.

[C] Cars can likely run with no problems at higher blends of ethanol. Minnesota has passed a law calling for a 20% ethanol blend by 2013, which is predicated on EPA approval of E20 as a vehicle fuel. The assumption is that if EPA certifies E20, vehicle manufacturers will also adjust their warranties. Because the Minnesota law also allows for a waiving of the 20% blending requirement if ethanol is 20% of the total gasoline sold in the state, an increase in E85 vehicles may make this adjustment unnecessary.

[D] About half of US corn is used for animal feed, and around 18% is exported; the remainder is used for food or other industrial uses.

You can use either 100% biodiesel (B100) or any blend of 1-99% biodiesel (B1-B99) with petroleum diesel in standard diesel engines, usually with no modifications required.[E] Biodiesel contains 88-95% as much energy as diesel fuel on average, but its higher cetane rating means there is almost no discernable difference in miles per gallon.[10]

HYDROGENATION-DERIVED "RENEWABLE DIESEL"

The same range of oils and fats that can be used for biodiesel can be fed into a modified hydrotreating unit in a conventional diesel refinery to produce a fuel with very similar properties to diesel, which has been called "hydrogenation-derived renewable diesel" or simply "renewable diesel."[11] Although very similar in terms of its environmental properties to biodiesel, because it can be produced in existing refineries by large oil refiners, the social and economic implications of renewable diesel are different. There is already a vigorous debate on the federal level over whether incentives for biodiesel should be applied to renewable diesel as well, and policymakers in Oregon are likely to have to consider this issue as well.

However, renewable diesel suffers from the main restraint of first-generation biofuels: they depend on types of biomass (oils or sugars/starches) that are both limited in quantity and also used as food.

2.2
Second-Generation Biofuels

There are a range of technologies currently being commercialized that will allow the production of ethanol, biodiesel and other advanced fuels from cellulosic feedstocks, leading to what are often referred to as "second-generation biofuels." Cellulose makes up the majority of plants in nature, and cellulosic feedstocks include corn or wheat stalks, forest thinnings, grasses and bushes: all materials that are potentially available in much greater quantities than first-generation feedstocks and won't compete with food production. Second-generation biofuels are expected to become commercially viable over the next five to ten years, although technological breakthroughs could speed this up.

There are two main groups of technologies for converting cellulose to biofuels: the biochemical (or enzymatic) platform or the thermochemical platform. The biochemical platform uses enzymes to break cellulose down to sugars where it can be converted to ethanol. The thermochemical platform essentially involves heating biomass under conditions of low oxygen. In what is referred to as biomass-to-liquids or BTL, the biomass is gasified and then can be converted into a range of fuels including both ethanol and biodiesel. In fast pyrolysis, biomass is converted directly to a "bio-oil," which can be used for heating of power generation or refined into a vehicle-grade fuel.

There are only a handful of mostly pilot-scale plants using these technologies in the world. In North America there are only two plants, both located in Canada: Iogen's pilot-scale enzymatic cellulosic ethanol plant in Ottawa and Dynamotive's small commercial-scale fast pyrolysis plant in West Lorne, Ontario. The US Department of Energy (USDOE) has just given grants totaling $385 million for six pilot-scale plants using a range of technologies; this, along with a range of other incentives being considered at the federal level,

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[E] The current ASTM standard for biodiesel, D-6751-06a, has the title "Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels." Some states that require that biodiesel meet ASTM standards, such as California, have interpreted this to mean that sales of B100 are allowed only under restrictions as an "experimental fuel." The federal tax credit for biodiesel is also for blends of up to B99, not for B100. There is currently a push to get the restrictions on B100 use removed.

is likely to accelerate the development of cellulosic biofuels considerably. Still, it is likely to be five to ten years before commercial scale production of cellulosic biofuels will really begin to expand.[F]

There is also substantial research going into developing new types of fuels that eliminate some of the disadvantages of ethanol or biodiesel. One of the more promising of these is biobutanol. Unlike ethanol, biobutanol ($C_4H_{10}O$) has nearly the same energy content as gasoline and is less water-soluble and corrosive. This means it could be transported through existing pipelines and blended at a higher level in existing vehicles. BP and Dupont, who have partnered to commercialize biobutanol, are also stating that existing ethanol facilities can be upgraded to produce biobutanol instead, which would eliminate the need for the creation of substantial new infrastructure.[12] Although it looks promising, substantially more study on the possible air and water quality impacts of biobutanol needs to be done before we can be sure of its suitability.

3 KEY ENVIRONMENTAL CONCERNS FOR BIOFUELS

Biofuels are only as sustainable as the agricultural and industrial processes that produce them. Biofuels can clearly provide positive environmental benefits if the environmental consequences of feedstock production and fuel processing are carefully considered and care is taken to mitigate any negative impacts. This section examines a range of environmental concerns – including net energy, greenhouse gas emissions, air quality, water quality, soil erosion, forest health, and biodiversity – and suggests ways to maximize environmental protection.

3.1
Net Energy

One of the more controversial debates surrounding biofuels is the question of net energy: simply put, whether biofuels require more energy to produce than they take to make. On the surface, this seems an obvious consideration. What good is it producing a fuel that requires more energy to make than it produces? Actually, the question of net energy is far more complex than it appears. For example, a USDOE report notes that producing "1 MJ of biodiesel requires an input of 1.24 MJ of primary energy,"[13] which seems to make biodiesel a net loser. However, the term "primary energy" includes the solar energy that is "lost" during plant photosynthesis. What we are actually concerned with is the energy of the fossil fuels that go into producing biofuels. Thus the measurement of how much *fossil fuel* energy is needed to produce a biofuel is usually what people are usually referring to when they talk about net energy.[G]

Even the production of fossil fuels requires the use of fossil fuel energy. For example, to produce a million BTUs of gasoline, you have to use 1.23 million BTUs of fossil fuel energy, mainly natural gas and coal. This applies not only to fuels, but also to electricity. To produce 1 million BTUs of electricity, you need to use 2.34 million BTUs of energy, which usually comes from fossil fuel.

[F] The DOE-funded projects will be completed between 2009 and 2011 and will likely need to run a few years before investors will be willing to put down money for a commercial-scale plant. The plants are Abengoa Bioenergy Biomass in Kansas; ALICO, Inc. in Florida; BlueFire Ethanol, Inc. in Southern California; Broin Companies in Emmetsburg, Iowa; Iogen Biorefinery Partners in Shelley, Idaho; and Range Fuels in Soperton, Georgia.

[G] The net energy measurement does not capture such qualities as how easily the fuel can be transported or converted into other forms. Both gasoline and electricity are higher quality fuels that can be cheaply transported and stored and used for a variety of applications.

The vast majority of studies released have stated that the net energy of biofuels is positive, and the few that do not have been controversial. More important than worrying about what any particular study says is to understand the factors that go into determining what the net energy is, in order to appreciate how to maximize energy gains. A major part of what makes the net energy balance of biofuels positive is the energy credit given for co-products. With all biofuels, including cellulosic technologies, a large portion of the biomass is not converted into fuel but can be converted into other useful co-products, such as distiller's grains, a valuable animal feed. How you measure the value of these co-products and what you do with them have a significant impact on how much fossil fuel you are saving. If you burn the co-products to produce heat or electricity, it is relatively clear what their energy value is; but if you use the co-product as animal feed, it is less clear what the energy credit should be. Do you consider the protein content of the feed, the nutritional qualities, the market value, or the energy it would have taken to produce a similar quantity of feed? While it is clear that if we use them efficiently, we are gaining substantial amounts of energy from the co-products, translating that into a single fossil-fuel equivalent number is challenging.

To show how this breaks down, it is worth examining a 2004 study of wheat ethanol.[14] Wheat ethanol produced in a plant using a natural gas boiler and grid electricity has a net energy of 1.1 GJ/f/GJ EtOH, meaning you are in fact using slightly more fossil fuel energy than you are getting from the ethanol. However, this does not include the possible uses of the distiller's grains that are left after you have produced the ethanol. If you dry the distiller's grains and use them as animal feed, the study includes an energy credit that improves the net-energy balance to .9, meaning a slight gain. If you don't have to dry the grains (an energy-intensive process) and can feed wet distiller's grains to livestock right near the plant, you can save even more energy. The other possibility is to burn the distiller's grains in the ethanol plant to provide heat and power. If you burn the same distiller's dry grains for power, the net energy gain improves radically to .24, although you have now lost any food value from the wheat. In other words, different uses of the co-products can have a dramatic effect on the overall net energy of the ethanol, although with different trade offs. For example you need to consider whether the distiller's grains are more valuable to society as feed or as energy. While distiller's grains are the main co-product of ethanol production, wheat (or corn) production has another important co-product: wheat straw (or corn stover). Just like with the distiller's grains, processing plants can be set up so that they can burn wheat straw to help produce electricity and power for the process. According to the study, if you use wheat straw to generate power in a more efficient plant, you can achieve a net energy gain of .45. In the best case scenario you can not only generate the electricity for the plant but also sell the excess electricity generated back to the grid. In that case, you can not only eliminate fossil fuel use but even displace fossil fuel use elsewhere. These numbers are similar to those the US Department of Agriculture (USDA) has suggested for conventional corn ethanol production.

While advanced biofuels are capable of attaining even more impressive net energy gains, it is probably also possible to produce them at a loss. What is important in determining net energy is not simply the type of fuel and the feedstock (i.e., corn ethanol), but the entire bioenergy system, a point that is particularly true when analyzing greenhouse gas emissions. Therefore, to maximize energy savings and reduce greenhouse gas emissions it is necessary to use co-products in the most efficient way possible, use other renewable energy sources to power the process, and improve the efficiency of agricultural and distribution systems.

3.2
Greenhouse Gas Emissions

The need to reduce our greenhouse gas (GHG) emissions is a major driver of interest in biofuels, and biofuels have been identified as a key part of Oregon's global warming reduction strategy in its *Oregon Strategy for Greenhouse Gas Reductions*.[15]

IMPACTS OF GLOBAL WARMING ON OREGON

The 2004 "Scientific Consensus Statement on the Likely Impacts of Climate Change on the Pacific Northwest"[16] concluded that our region is warming, average annual precipitation has increased, land on the central and northern Oregon coast is being submerged by rising sea level, and the region's snowpack has declined precipitously. These trends are expected to continue.

Global warming comes with a big price tag. Climate change will impact farm and fisheries productivity and hydroelectric energy production. Drier summers will lead to drought stress and vulnerability of forests to fire, disease, and insects.

Global warming will also impact human health.[17] Among the most serious health impacts, Oregon is likely to see an increase in unhealthy air days as hotter summertime temperatures generate more smog; a longer pollen season will make life more uncomfortable for people with asthma and allergies; and such insect-borne diseases as malaria are expected to reappear.

Biofuels are often referred to as "carbon-neutral" fuels, because the carbon and other GHGs released when they are burned are recaptured when the plant is re-grown. Of course this assumes that the plant is re-grown, and to the same size and depth that it was before harvesting. The carbon-neutral statement also ignores the potential loss of carbon from the soil, the fossil-fuel-derived fertilizers and other inputs into growing the plant, and the fuel used in planting, harvesting, transporting and processing. When all of these are added up, biofuels can range from being carbon-negative (in that they are actually sequestering GHGs) to releasing more carbon than fossil fuels.

To accurately calculate biofuels' greenhouse gas emissions, one must use a life-cycle analysis methodology that captures emissions at all stages of production and use. The largest percentage of GHG emissions in the production of biofuels comes from the agricultural production of the feedstock.[18] Unfortunately, agricultural emissions also pose the greatest challenges for accurate accounting due to the range of emission types and the sensitivity to local conditions. While certain emissions from agriculture, like the use of fossil fuels in farm equipment, are easy to understand and quantify, others are not as straightforward. N_2O, which is 296 times as potent a greenhouse gas as CO_2[19], is released from soil as a result of microbial activity and is increased by the application of nitrogen fertilizer. These emissions could account for around 40% of total agricultural emissions,[20] but getting accurate measurements is difficult because "actual emissions…depend on several site-specific factors including agronomic practices, temperature, and moisture."[21]

Carbon sequestration in the soil is also heavily dependent on both the kind of tillage (conventional, conservation or no-till), the soil type, the type of crop, the rotation and use of fallow and a range of other factors.[22] While exact figures for these types of emissions are hard to produce, it is possible to create sufficiently detailed approximations based on readily available data. The upshot of this is that improving agricultural practices will be a key part of ensuring that the climate benefits from biofuels are fully realized.

The next largest percentage of GHG emissions comes from the production of the fuel itself. It depends on the type of fuel that the plant uses and how the plant is designed, for example whether it uses combined heat and power (CHP or cogeneration). While emissions associated with distribution and infrastructure are substantial, both fossil fuels and biofuels have similar requirements, so these factors have relatively little impact when you are comparing biofuels against fossil fuels.[23] However, because biofuels – particularly those derived from bulky cellulosic feedstocks – are likely to be produced in relatively isolated areas, developing an efficient transportation system will be a key aspect of their sustainability.

Changes in land use, particularly conversion of native ecosystems like forests or grasslands to agricultural production, also have serious negative implications for GHG emissions. This is because all of the sequestered carbon, both in the biomass and in the soil, is rapidly released when land is converted, which will overcome any GHG benefits for years to come.

The US Environmental Protection Agency has suggested that biofuels produced from energy crops, including short-rotation woody crops like hybrid poplar, can save 4.8-5.5 tonnes of CO_2 per acre per year by substituting for fossil fuels. On the other hand, deforestation can release 83.7-172.1 tonnes of CO_2 per acre immediately. This means that in the best case scenario it would take 16-35 years before biofuels produced from that land would offset the carbon released.[24] Conversion of wetlands, grasslands, forests, and other carbon sinks would also have a similarly dramatic impact. This also means that because conventional agriculture often produces, rather than sequesters, GHGs, first-generation biofuels could take hundreds of years to offset the GHGs produced by land conversion.

Accurately assessing the climate change impact requires consideration of the entire production process of the biofuel. GHG reductions are not intrinsic to any one product or process but the result of environmentally sound choices being made consistently along the entire value chain. If old-growth forests are clear-cut to plant hybrid poplar and the poplar is grown with excessive chemical inputs then processed into ethanol in a coal-fired plant, there could be little or no improvement in emissions over conventional fuels.

If on the other hand, degraded farmland is converted to perennial energy crops grown with no or minimal chemical inputs then processed into ethanol in a plant powered by natural gas or renewables, GHG benefits will most certainly be positive.

Policy Recommendations – Greenhouse Gas Balance:

Because the GHG balance of renewable fuels is the result of a complex range of factors, policy makers should address the problem in a comprehensive way. One policy solution is a Low-Carbon Fuel Standard (LCFS), such as the one currently being designed for California. A LCFS places a requirement for a gradual reduction in the greenhouse gas intensity of all fuels sold, but doesn't mandate any specific way this has to be reached. The key part of an effective LCFS is to create an incentive for all fuel producers to analyze and report what the real GHG impact of their fuels is. The University of California team advising the state on its LCFS has recommended the use of an opt-in system for reporting. Rather than require mandatory reporting from every single producer, default values will be set that assume worst-case scenarios. If producers are using better practices, they can provide that information and get more credit for GHG reductions. This ensures that best practices are credited and encouraged without providing an unnecessary regulatory burden. The LCFS should also create a market for sustainably produced feedstocks, thus encouraging best agricultural practices. Ideally, the information on overall emissions and environmental impact would also be available to consumers so that they can make informed decisions about the fuels they buy. Oregon should devise and adopt a LCFS based on these principles.

3.3
Air Quality

The original idea of blending ethanol with gasoline was to reduce reduce air pollution, in particular carbon monoxide. However the long-term impact, particularly of ethanol, on air quality is not yet entirely clear. Biofuels reduce emissions of some pollutants, like carbon monoxide, particulate matter and benzene, but may increase emissions of others, like acetaldehyde and nitrogen oxides. Regular monitoring of changes in air quality as increased quantities of biofuels are used in Oregon will be necessary to ensure that there are no unforeseen effects from changes in the fuel mix.

3.3.1
Tailpipe Emissions

Concern for reducing pollution from cars directly led to the first national Renewable Fuel Standard under the Clean Air Act. Much of the incredible growth that has been seen in the ethanol industry has been driven by phasing out MTBE, an oxygenate additive that was found to contaminate groundwater, and replacing it with ethanol. The high level of oxygen in ethanol helps reduce the amount of carbon monoxide produced. Despite this and the other clear advantages that biofuels have over traditional fossil fuels, such as being biodegradable and non-toxic in marine environments, biofuels do not provide air quality benefits across the board. As detailed below, the use of biodiesel results in much lower emissions of almost every pollutant, with the possible exception of nitrogen oxides. The use of ethanol also results in lower emissions of most pollutants, but ethanol can increase emissions of nitrogen oxides, volatile organic compounds – especially at low blends – and can also increase acetaldehyde emissions.

AIR QUALITY IN OREGON

While Oregon's and the nation's air is generally cleaner than it has been in the past, air pollution continues to negatively impact people's health and the environment. In Oregon, air pollutants of particular concern include air toxics, fine particulate matter, and ground-level ozone (also known as smog).

Most Oregon communities consistently meet the current federal standards for ozone and particulate matter set by the US Environmental Protection Agency. This means that levels of these pollutants in Oregon's air are considered low enough to not pose a risk to human health. However, there is still reason to be concerned:

- Klamath Falls and Oakridge occasionally experience dangerous levels of fine particulate matter and are unlikely to meet the federal standards that were revised in 2006.[25]
- Scientific evidence indicates that exposure to smog at levels below the current standards is causing adverse public health effects, particularly in those with respiratory illness.[26]

In addition, it is estimated that there are 16 air toxics in Oregon's air at levels more than 10 times the federally determined safe level, including several associated with vehicle exhaust: diesel, benzene, acetaldehyde, acrolein, formaldehyde, polycyclic organic matter, and 1,3-butadiene. Air toxics are pollutants in the air that are known or strongly suspected to cause serious health problems, including cancer. Diesel emissions alone are known to contain more than 40 air toxics.[27]

Biodiesel

While tailpipe emissions from biodiesel depend on the blend used, the type of biodiesel (since different feedstocks have different properties), and the type of engine, there are some general statements that can be made with certainty. Biodiesel has fewer emissions compared to petroleum diesel of particulate matter (PM), carbon monoxide (CO), and hydrocarbons (HC). The US Environmental Protection Agency estimated that for a soybean-derived B20 blend these could be as much as -10.1% for PM, -21.1% for HC and -11.0% for CO.[28] Higher blends provide greater benefits. Research has also shown that biodiesel reduces emissions of such air toxics as benzene, 1-3 butadiene, acetaldehyde, and formaldehyde.[29]

There has been some disagreement on nitrogen oxide (NOx) emissions from biodiesel with the US EPA study referenced above suggesting that B20 may increase emissions by 2%. However, a 2006 National Renewable Energy Laboratory study concluded that B20 had no net impact on NOx emissions.[30] Recently, the Texas Commission on Environmental Quality delayed implementing a decision to ban the use of B20 (due to concerns over increased NOx emissions) pending the results of further testing.[31] If the NOx issue is resolved through further testing or processing refinements, it is likely that biodiesel can provide major improvements in air quality for all major pollutants. In any case, it is a clear improvement over petroleum diesel.

Ethanol

Unlike biodiesel, ethanol tailpipe emissions do not vary based on the feedstock used to produce the ethanol because the end product is the same chemical compound – C_2H_5OH.

The results of studies of ethanol tailpipe emissions have been mixed, and there are continuing debates on what the long-term impacts are. The Renewable Fuels Association states that “ethanol reduces tailpipe carbon monoxide emissions by as much as 30%, toxics content by 13% (mass) and 21% (potency), and tailpipe fine particulate matter emissions by 50%” and reduces smog formation. Although the US EPA has stressed the air quality benefits from ethanol, particularly in reducing carbon monoxide and smog, their own analysis and literature review shows a more complicated picture than for biodiesel. While different studies show a range of a results, the US EPA model of E10 estimates in some cases a 7.4% reduction in volatile organic compounds (VOCs) and a 11-19% reduction in carbon monoxide (CO), but a 7.7% increase in NOx.[32] Also due to the higher volatility of E10, more evaporation occurs, which results in the release of more VOCs than from the tailpipe alone. The use of ethanol likely also increases acetaldehyde emissions.[33] Research indicates that NOx emissions may be improved by the use of E85 or other higher ethanol blends,[34] and that E85 may

Policy Recommendations – Tailpipe and Evaporative Air Emissions:

It seems likely that increased use of ethanol will lead to at least some increases in NOx emissions, and therefore a possible increase in ozone levels. If biodiesel also increases NOx levels, which may not be the case, this could pose a real concern in Oregon (although US EPA testing has also indicated that the total smog-forming potential of biodiesel is 50% lower than petroleum diesel).[38] The more difficult question may be the impact of evaporative emissions of VOCs from ethanol blends, as the more easily evaporated ethanol carries off compounds from the gasoline during storage. Because different ethanol blends may have very different air quality impacts, both as a result of burning and evaporation, the exact mix of blends used in the state will determine what the impacts are. Overall, while it seems most likely that biofuels will produce air quality benefits, considering the uncertainty in several areas, it would be advisable for the Oregon Department of Environmental Quality to assess the impacts on air quality of increased use of biofuels in the state.

also reduce evaporative emissions compared to low blends.[35] However, a controversial study by an atmospheric chemist at Stanford University has suggested that the increased use of E85 "may increase ozone-related mortality, hospitalization, and asthma,"[36] although he notes that "because of the uncertainty in future emission regulations, it can be concluded with confidence only that E85 is unlikely to improve air quality over future gasoline vehicles." While this report has been widely questioned,[37] what is clear is that ethanol raises more air quality concerns than biodiesel, and that the increased use of ethanol may result in tradeoffs between different pollutants rather than across the board benefits.

3.3.2
Biofuel Refinery Emissions

While air quality concerns stem primarily from the tailpipe emissions from burning biofuels, increased emissions from production facilities are also an issue, particularly for those that use coal. As biofuel production is theoretically displacing oil production, the effect may be negligible or even positive, but localized impacts are important to consider.

Policy Recommendations - Air Emissions from Biofuels Production Facilities:

Biofuel plants should comply with the state's air quality rules. Any attempt to loosen restrictions on emissions from biorefineries could offset tailpipe air quality benefits.

3.4
Water Quality

One of the great advantages of biofuels is that they are biodegradable and pose little risk of directly contaminating water supplies. For example, biodiesel degrades two to three times as fast in water as petroleum diesel and is less toxic.[39] Ethanol also readily degrades and is unlikely to contaminate groundwater sources. Biofuel production, however, can have major impacts on water quality. The two areas that are of greatest concern are impacts from intensified agricultural production and wastewater discharges from production facilities.

3.4.1
Agricultural impacts on water quality

Several water quality concerns relate to agricultural production: nutrient loading from fertilizer runoff, contamination from certain fertilizers and pesticides, and silting and other issues from eroded soil.[41] None of these are unique to growing feedstocks for biofuels, but to the extent that biofuels are based on an expansion of conventional agriculture these water quality impacts pose one of the greatest environmental challenges to sustainable bioenergy.

Agricultural runoff of fertilizers produces blooms of algae that drain all of the oxygen out of large areas of water producing eutrophication and hypoxic zones, including the "dead zone" in the Gulf of Mexico, which is rendered incapable of supporting life for long stretches of the year.[42] Because corn is grown over so much of the area that drains into the Mississippi river and uses so much nitrogen fertilizer, corn production is closely linked with the dead zone. Experts are suggesting that the dead zone may be the biggest ever this year and could reach 8,500 sq miles, which is almost double the average since 1990.[43] While increased rains and other factors may have as much of an impact as increased corn production in the size of the dead zone, agricultural runoff in general is clearly a root cause.[44]

Policy Recommendations - Agricultural Impacts on Water Quality:

Oregon should increase technical assistance and conservation incentives to farmers to help them minimize their impact on water quality through nutrient management planning, minimizing the use of chemical inputs, creating stream buffers, making changes to tillage and rotation, and implementing other techniques as appropriate. Specifically, Oregon should:

- Research and education: Become a leader in interdisciplinary research and education in sustainable farming and energy systems by establishing a Center in the Oregon University System that would provide research on alternative, sustainable production methods, and degree programs and extension outreach on sustainable production methods.
- Technical assistance: Increase funding for technical assistance to improve best management practices on-farm, transition to more sustainable practices (including certification), and restore watersheds and habitats on agricultural lands.
- Financial incentives: Provide state tax credits, payments, grants, or other financial incentives for transition to certification by an independent third party, and annual incentives for best practices or certified acreage.

Soil erosion into streams can also have a profound impact on overall water quality. Fine sediment has been identified as a source of stream impairment in much of Western Oregon's stream basins.[45] Finally, certain herbicides and pesticides can pose a direct threat to the health of both people and wildlife.

Fortunately, all of these problems can be addressed by the adoption of best management practices. The use of conservation tillage, cover crops or better rotations can help cut down on soil erosion and runoff, as can planting buffers of trees or native vegetation along streams. Nutrient management planning, where care is taken not to apply more fertilizer than the plants can take up, or building healthy soil through compost or cover crops to reduce or eliminate the need for chemical fertilizers, can substantially reduce nitrogen runoff. Finally, the use of integrated pest management and other techniques can reduce or eliminate the amount of chemical inputs that are required. Many of these techniques will also reduce the net GHG emissions and improve the energy balance of biofuels as well. These best management practices are applicable to all agricultural crop production, not just the growing of feedstocks for biofuels.

3.5
Water Use

Biofuel production is generally very water intensive. In addition to the irrigation requirements of most current biofuel feedstocks, biofuel plants currently use several gallons of water for every gallon of fuel produced. Because plants are usually placed close to where the feedstock is produced to minimize transportation costs, local water supplies may need to bear the brunt of both increased irrigation and production demands. This is of particular concern when the water is being drawn from sources that are already being depleted and for more arid areas, including much of Eastern Oregon. While oil refineries are probably less water intensive per BTU of energy produced, they do use substantial amounts of water and certainly the extraction and processing of petroleum poses a higher risk of contaminating water

WATER QUALITY IN OREGON[40]

Every two years, the Oregon Department of Environmental Quality develops a list of streams and rivers that do not meet minimum water quality standards (named the 303(d) list after the section of the federal Clean Water Act that requires it). Every single one of Oregon's major rivers is on the most recent 303(d) list (2004) for a variety of pollutants and other water quality problems.

Major pollutants tracked on the 303(d) list and found in Oregon's rivers include fecal coliform bacteria, mercury, dioxin, arsenic, iron, manganese, PCBs, polycyclic aromatic hydrocarbons, pentachlorophenol, and the banned pesticides DDT, DDE, aldrin and dieldrin. Excessive amounts of chlorophyll, nutrients (ammonia and phosphorus), aquatic weeds and algae, and sediment also degrade water quality. Emerging pollutants of concern that are not currently tracked on the 303(d) list include pharmaceutical products, toxic flame retardants, and several additional pesticides.

Water quality is impacted not only by pollution, but also by water flow, temperature, streamside vegetation, and changes to the stream channel.

supplies.[H] Regardless, the full water-use implications of biofuel production for each watershed region need to be carefully considered to ensure that water use is sustainable over the long-term. This is particularly true as global warming is likely decrease snow pack runoff and otherwise affect water tables and precipitation levels in many areas.[46]

3.5.1
Ethanol refinery water use

Ethanol plants use large quantities of water for cooling and wastewater discharge, and although plants recycle water, substantial quantities are lost to evaporation. Improved plant design has resulted in substantial improvements in water needed per gallon of ethanol, from 5.8 gallons of water to produce 1 gallon of ethanol in 1998 to 4.2:1 in 2005, and the current average is probably between three to four gallons per gallon for new plants.[47] That means that a 100 million gallon plant might use 400 million gallons of water per year, which is the same as a town of 10,000 people.[48]

Soybean field irrigation

[H] For comparison purposes several sources have suggested that oil refineries use about .5 gallons of water for every gallon of crude oil refined into gasoline, diesel, kerosene and a range of other fuels, and one technical report suggested that New Mexico refineries used between .25 and 1 gallons of water for every gallon of crude. Ethanol also only contains approximately two-thirds the energy of gasoline, so more needs to be produced to generate the same amount of energy. Sources:
Water use, conservation and wastewater treatment alternatives for oil refineries in New Mexico, 1985 (www.osti.gov/energycitations/product.biblio.jsp?osti_id=5808988);
Water Use in Oil Refineries (http://i-r-squared.blogspot.com/2007/03/water-usage-in-oil-refinery.html); and
Ethanol faces big hurdle: water use, St. Petersburgh Times, May 28, 2007 (http://www.sptimes.com/2007/05/28/Hillsborough/Ethanol_faces_big_hur.shtml)

Policy Recommendations – Water Use:

Oregon should support research and development of drought-resistant biofuels crops, such as camelina, that don't require irrigation. Total long-term water requirements for the region need to be carefully considered when state agencies issue permits for new ethanol and biodiesel plants. Overall, newer designs that are more efficient at water recycling should be encouraged through tax breaks, loan guarantees or other incentives or requirements.

3.5.2
Biodiesel refinery water use

Biodiesel production uses far less water than ethanol, but still about two gallons of water per gallon of biodiesel produced.[49]

3.6
Soil Erosion

Intensified agriculture, particularly using conventional tillage, can result in increased soil erosion and loss of soil fertility. On the other hand, the conversion of agricultural land in annual crops to perennial grasses or trees can stop or even reverse erosion. One of the most promising sources for cellulosic biomass in Oregon is agricultural residues, particularly wheat straw. However, residues left on the field help prevent soil erosion and water loss and maintain soil fertility. Sustainable residue removal rates vary depending on management practices (such as no-till or conservation tillage), soil type and climate. Developing clear guidelines specific to Oregon agriculture for how much residue can be removed without increasing erosion will be a key part of ensuring the sustainable use of this resource. This is discussed in more detail in the section on agricultural residues (6.3.2).

3.7
Forest Health

The use of forest thinnings and other non-merchantable material has been identified as one of the most promising sources of biomass for cellulosic ethanol in Oregon.[50] Particularly in cases where forests are overloaded due to years of fire suppression, thinning can improve forest health; but there are also serious concerns. Woody biomass provides vital habitat for plants and animals and is a critical part of natural forest health. In cases where biomass removal is being added on to clear-cut logging and other more intensive practices there are even greater concerns. These concerns and a policy recommendation are discussed in more detail in the section on woody biomass (section 6.3.3).

3.8
Biodiversity and Ecosystem Conversion

While there has been some research on the use of native grass poly-cultures as feedstocks for biofuels,[51] the vast majority of energy crops – from oilseeds to trees – are likely to be grown as intensely cultivated monocultures. Monocultures are unable to support the biodiversity of natural ecosystems, with major environmental and social implications.

BIODIVERSITY

Biodiversity refers to the total number of species of organisms that exist within an ecosystem. It is the complex interdependencies and interactions between these species that support the broader health of the environment. The role of forests, wetlands and grasslands in protecting water quality, air quality, and soil fertility is inseparable from their role as habitats for diverse plants and animals.

An excellent example of this trade-off is the current debate over the federal Conservation Reserve Program (CRP) and the Oregon Conservation Reserve Enhancement Program (CREP). CRP and CREP, which combined have approximately 541,000 acres enrolled in Oregon, pay farmers to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover, such as native grasses, wildlife plantings, trees, or riparian buffers. Farmers receive an annual rental payment for the term of a multi-year contract which is usually 10-15 years for CRP, and 15 or 30 years for CREP. Cost sharing is provided to establish the vegetative cover practices. CRP supports huge amounts of wildlife and plant species, including millions of birds. There has been some discussion of opening up CRP or other conservation programs to biomass production, but this is likely to have negative implications for biodiversity. The millions of birds and other wildlife that are dependent on CRP grasslands and wetlands or CREP riparian buffers need habitats that are left fallow for five years or more, and will not fare well under a regularly harvested system. Most CRP and CREP lands are small and scattered across the landscape in nowhere near the concentration that would be needed to supply the feedstock for a biofuel plant. Those blocks that are large enough to supply a plant are also disproportionately important to wildlife, particularly migratory waterfowl.[52] While in some cases biomass production from perennial crops can offer improvements in wildlife habitat over annual crops, it is no substitute for areas that are never harvested.

Policy Recommendations - Biodiversity and Ecosystem Conversion:

Bioenergy production needs to be done in a way that doesn't negatively impact biodiversity or rare and threatened ecosystems. In order to discourage the conversion of CRP and CREP land (and other valuable habitat) back into land used for agricultural production, biofuels produced from land that is taken out of these programs early should not qualify for state incentives. While it is likely that higher crop prices will result in some landowners not renewing their contracts after they are up, any attempts to allow an "early out" to the contracts to supply biofuels will do more harm than good. Ideally, these and other conservation programs should receive more funding to help protect ecologically valuable lands and help balance the strain put on agriculture from intensified production of biofuels. Specifically, Oregon should:

- Advocate at the federal level to ensure that early opt-outs from the CRP and CREP Program for the production of biofuel feedstocks are not allowed.
- Not allow biofuels grown on land which has taken an early opt-out from a CRP or CREP contract or other similar conservation programs to qualify for a state Low-Carbon Fuel Standard or other biofuel regulatory or incentive programs.
- Provide strong incentives for farmers to protect habitat, wildlife, and water resources and make sure these incentives are competitive with the incentives provided to farmers to produce biofuel feedstocks.

4 SOCIAL SUSTAINABILITY

Beyond their environmental impacts, the attraction of biofuels for many is the promise of increased opportunities for small farmers and businesses.

The ethanol industry in this country has already developed a split personality. About 40% of US ethanol plants are farmer owned, with a capacity to produce 1.6 billion gallons of ethanol of the 5 billion or so produced this year.[53] Yet a handful of large companies, like ADM and Cargill, own an increasing share of the market and are aggressively expanding. The increase in the size and complexity of ethanol plants from 40 to 100 million gallons per year and up is making it more and more difficult for farmers' co-ops to compete. Similarly, while biodiesel is largely a small-scale local industry, the building of the first 100 million gallons per year plant in Washington, which will be importing much of its feedstock, and the entry into the market of big oil refiners producing hydrogenation-derived renewable diesel, heralds a similar direction in the biodiesel industry.

Brazil has seen a similar development with the ethanol industry, with sugarcane production highly concentrated in the hands of a few players. As their biodiesel industry has developed they have created an innovative program to support local farmers. The Social Fuel Stamp provides tax breaks to biodiesel producers who source their feedstocks from family farms growing appropriate crops in underdeveloped parts of the country. The producer is then allowed to use the Social Fuel Stamp when marketing their product.

For the biofuels industry to provide as much advantage to Oregon farmers as possible, farmers need to be partners in the profits of the industry, not merely suppliers of commodity crops for biofuels production. Co-owned mobile processing units, such as mobile oilseed crushers, are examples of potential value-added enterprises for farmers. Mobile processing units will also increase the efficiency of operations. And local communities will retain more of a consumer's fuel dollar by producing biofuels as well as biofuel feedstocks. In the long-term, small-scale biofuel plants are likely to be a vital part of a more decentralized and robust energy system.

Policy Recommendations – Social Sustainability:

To support locally owned biofuels operations where the greatest value is returned to the local farmer, Oregon could consider a system like Brazil's, which provides tax breaks to biodiesel producers who source their feedstocks from family farms rather than large agribusinesses.

5 BIOFUEL REFINERY DESIGNS AND IMPACTS

Unsurprisingly for what is, of course, an industrial product, many environmental impacts from biofuels arise from the design and management of the processing facilities. Plant design is a primary factor in determining the net energy benefit and up to 50% of the GHG impact. Biofuel refineries also have a range of traditional environmental problems, including water and air pollution. Finally, a major concern for facilities cited in dry agricultural regions is water use. However, with proper design and operation, biofuels refineries can be far more sustainable than petroleum refineries, which have tremendous environmental impacts themselves.

RENEWABLE TRANSPORT FUEL OBLIGATION

Another innovative way to promote sustainable biofuels in a comprehensive manner is the Renewable Transport Fuel Obligation in the UK. Similar to a renewable fuel standard, the Renewable Transport Fuel Obligation initially requires that 5% of road fuel come from renewable sources. To qualify for the mandate, the UK requires that biofuels meet both greenhouse gas and more general environmental and social sustainability requirements, including conservation of biodiversity, sustainable use of water resources, maintenance of soil fertility, good agricultural practices, appropriate land use, and support for workers' rights.[54]

In order to develop and implement these requirements, the UK is first requiring mandatory reporting of GHG variables and sustainability indicators such as agricultural practices. For the first several years, biofuel producers will be required to submit these reports, but not meet any requirements. Then, based on the real-life data accumulated over this period, the UK will phase in mandatory standards.

A key part of this process will be to develop standards that are applicable to a wide range of environments as the UK is expecting to import a substantial amount of feedstocks. This helps address one of the fundamental issues associated with evaluating biofuels, which is the lack of detailed information on what the social and environmental impacts of increased production will be. This approach has the advantage of developing requirements which are both clearly feasible and reflect the actual state of the industry.

5.1 Ethanol Plants

5.1.1 Overview

There are two basic kinds of ethanol plants: wet mills and dry mills. Wet mills soak the corn grains in water and sulfuric acid to separate them into starch, germ, fiber and protein as precursors for making a range of products including gluten, high-fructose cornstarch, and other food products. Ethanol is also produced but is not the primary product of these kinds of mills. Dry mills begin the fermentation process by grinding dry grains and are primarily dedicated to ethanol production. Most new mills being built in the US are dry mills as they are less expensive.

Like any industrial facility, ethanol plants can produce a range of pollution, particularly if they are not properly monitored and held fully accountable to existing environmental standards. The range of problems that Iowa, home to the largest number of ethanol plants, is dealing with is indicative of this. From 2001-2007, Iowa had 397 instances of major pollution spills or violations of environmental regulations at ethanol plants. These covered a full range of air and water issues with a majority coming from failure to meet sewage pollution standards or standards for discharges into waterways. As a biofuel industry develops in Oregon it will be important to compile detailed information on all types of emissions and to carefully monitor impacts.

The biggest difference between ethanol plants in terms of their environmental impact is what energy source they use for heat and power generation. The second biggest factor has to do with the overall efficiency of energy use. There has been increased interest in using combined heat and power (CHP or cogeneration), where both electricity (which can be sold to the grid) and heat are produced as part of an integrated process. A CHP plant can improve overall energy efficiency by about 10%, and can be incorporated into plants using a variety of fuel types.

5.1.2
Natural gas-fired ethanol plants

The standard corn ethanol plant in the US uses natural gas for heat and grid electricity for power (similar to the wheat ethanol case examined in the section on net energy) and has an average capacity between 40 and 100 million gallons per year. These plants produce large quantities of distiller's grains and drying the distiller's grains for preservation and transport is also done with natural gas.

Greenhouse gas impacts: Natural gas is a relatively clean-burning fuel and most lifecycle GHG analyses of corn and wheat ethanol use natural gas as a model. A UC Berkeley study using Illinois corn and a baseline of 32.330 Btu of natural gas per gallon ethanol found that GHG emissions were 31% lower than gasoline at baseline,[55] which is slightly better than the 18-29% average range for corn ethanol suggested by the National Renewable Energy Laboratory.


An Iowa ethanol plant

5.1.3
Coal-fired ethanol plants

As natural gas prices have risen there has been an increase in the construction of ethanol plants that can use less expensive coal.

Greenhouse gas impacts: Coal, which is mostly composed of carbon, is one of the leading sources of GHG emissions in the world, and one that may pose an even greater problem over the long-run as developing countries like China build coal-fired power plants to satisfy their electricity needs. Even with CHP (cogeneration), the UC Berkeley study calculated that emissions from coal-fired ethanol facilities wipe out any GHG gains from displacing gasoline with ethanol, meaning that ethanol produced from coal-fired facilities is just as bad as gasoline from a global warming perspective.[56] Combining this with the serious environmental impacts that come from conventional grain production, particularly corn, coal-fired corn ethanol is an absolute loss from an environmental perspective. Ideally, coal-fired plants or ethanol produced in coal-fired plants would not be eligible for any state or local incentives. A good example of this in Oregon is legislation passed in 2007 which precludes coal-fueled ethanol and biodiesel production facilities from the state's site certification exemption criteria.

5.1.4
Biomass-powered ethanol plants

It is possible to convert natural gas facilities to use biomass gasification systems for their heat generation. Gasification systems can be used to convert a wide range of cellulosic feedstocks into a clean burning syngas that can substitute for natural gas for heat generation. This allows the plant to be powered by corn stover, distiller's grains, waste wood or other agricultural wastes that are available in the region. This not only reduces most of the need for fossil fuels, producing a greatly improved net energy balance, but also dramatically cuts GHG emissions. Ethanol from a Minnesota ethanol plant that uses biomass gasification was modeled to have a 53% reduction in GHG emissions.[57] As mentioned previously, most cellulosic ethanol plants are being designed to use the large amount of leftover lignin produced to provide heat and power for the plant, in some cases even generating excess electricity to sell back to the grid. This accounts for a large portion of both their energy and GHG benefits in most calculations.

5.1.5
Biogas and integrated feedlots

The E3 Biofuels-Mead ethanol plant in Nebraska has pioneered another innovative way to reduce fossil fuel use and emissions from ethanol production. The plant is integrated with a cattle feedlot, which allows the wet distiller's grain to be fed directly to the cattle without requiring energy-intensive drying. That alone reduces the energy requirements by nearly half. The manure and other waste products from the plant are put into an anaerobic digester to produce biogas, which is then used to provide heat for the plant. Without counting the avoided GHG emissions from the methane released by the manure (a major source of GHG emissions globally), ethanol from the plant was calculated to have 40% lower GHG emissions.[58] On a less dramatic scale, many new mills are incorporating "bio-methanators," which produce methane from wastewater in the ethanol plant to substitute for a portion of natural gas use.[59]

5.2
Biodiesel Plants

As biodiesel production is a far less heat- and energy-intensive process than grain ethanol, emissions from energy are much less of a problem. There are a range of innovative options for reducing the energy footprint of biodiesel even further, including using geothermal[60] or other renewable power, or integrating biodiesel and ethanol facilities to better use excess heat and power produced from biomass firing.

Policy Recommendations - Ethanol and Biodiesel Plants:

State incentives to encourage the use of renewable energy and process efficiencies in new plants will pay substantial environmental dividends. Providing incentives for ethanol plants to employ biomass gasification would be a cost-effective way to reduce fossil fuels, promote real energy independence and reduce GHGs, while maximizing agricultural resources. (Financial incentives may be necessary because of the substantial up-front capital cost of biomass gasification systems.) There are a range of other process changes that can be utilized in first-generation plants to substantially improve energy efficiency, including not drying the distiller's grains. The Pacific Ethanol plant in Boardman, Oregon is already moving in this direction.

6 BIOFUEL FEEDSTOCKS IN OREGON

Oregon, as one of the US's most diverse agricultural and forest product producers, has a range of options for developing a domestic biofuels industry. Due to the complexity of environmental, technical and economic factors involved, it is very difficult to put an exact number on what Oregon's full biofuel potential is, but clearly, Oregon has a wide range of available and potential feedstocks. In the short run, Oregon has substantial potential for developing oilseeds for biodiesel and for utilizing a range of agricultural wastes and byproducts. In the mid-term, Oregon has substantial potential for developing cellulosic biofuels from hybrid-poplar and other short-rotation woody crops (SRWCs), wheat straw, forest thinnings and other sources. As new technologies and crops become available, Oregon's sheer diversity of agricultural production may turn out to be its biggest asset.

IMPORTED FEEDSTOCKS

The biofuels feedstocks with the highest yields grow primarily in the tropics. Oil palm, sugarcane and other tropical plants can produce much higher yields per acre than temperate plants like corn or canola. As a result of this high yield, the net energy of biofuels derived from tropical feedstocks is higher and the requirements for land are generally lower. Higher yields also mean lower prices, which makes importing feedstocks a tempting proposition. However, there are significant sustainability concerns associated with production of these feedstocks. Palm oil and tropical soybean production in particular are leading drivers of deforestation in the rain forests of Indonesia and Brazil, respectively, which together contain much of Earth's biodiversity. While there is substantial fallow land available in these countries to increase production, poor enforcement of existing regulations and unclear land tenure often result in the clearing of large tracts of virgin forest, which results in biodiversity loss and substantial greenhouse gas emissions. Other issues include poor labor conditions on plantations and the loss of land rights of indigenous groups. In addition to these important environmental and social concerns, importing feedstocks from abroad conflicts with Oregon's interest in developing a truly local biofuels industry. Thus the use of imported feedstocks should be strongly discouraged.

As part of the renewable fuel standard passed by the Oregon Legislature in 2007, the Oregon Environmental Council worked to ensure the standard cannot be triggered by biodiesel produced from imported palm oil.

If feedstocks are imported, they should come from third-party certified sustainable producers with a clear chain-of-custody. And any policy initiatives in Oregon to promote low-carbon fuels should take into account greenhouse gas impacts from imported feedstocks, particularly those caused by the clearing of forests and native habitats.

6.1 Biodiesel feedstocks in Oregon

6.1.1 Soybeans

Soybean biodiesel, and biodiesel more generally, is regarded to be relatively energy-efficient with a net energy balance of around 3.2 (as opposed to .85 for diesel).[61] While between 75-90% of current biodiesel production comes from soybeans,[62] there are a range of reasons why they are not an appropriate feedstock for Oregon. Most obviously, soybeans are not well suited for growth in the Pacific Northwest. There are also several other problems with soybeans. Soybeans only yield 20% oil, producing approximately 53 gallons of oil per acre. Because soybeans cannot be easily crushed, the oil is usually extracted using a chemical solvent (usually hexane), which has a range of negative environmental impacts, including the release of hydrocarbons.[63] The low oil yield per acre and difficulty of extraction make soybeans far from optimal as a biodiesel crop. US soybean production primarily occurs as part of a rotation with corn, and is very intensive in its use of chemical inputs.

Greenhouse gas impacts: A 1998 study by USDA and USDOE estimated that soy biodiesel provided a 78% improvement in CO_2 over fossil diesel.[64] This study looked only at CO_2 and not at other GHGs, like N_2O or methane that are produced during soybean production or refining. As a result the actual GHG benefit of soy biodiesel is most likely lower than this. Other studies that look at all GHGs suggest a low end of 40% improvement.[65] If land-use change is fully accounted for, soy biodiesel fairs even worse. In Delucchi's recently updated Lifecycle Emissions Methodology,[66] which includes estimates for emissions from converting pasture, CRP and other lands to soybean production, soy biodiesel comes in at best at 20% better than gasoline and can easily be worse, although he acknowledges a great deal of uncertainty in calculating the impact of the nitrogen inputs for soy biodiesel. This is because of the very low oil yield per acre, which will require vastly more land to produce the same amount of biodiesel than other feedstocks, with an inevitable negative impact on global warming.

6.1.2 Brassica oilseeds

The most promising conventional oilseed crops for Oregon are the high-yielding oilseeds in the Brassica genus: rapeseed, canola (low-acid rapeseed), camelina, mustard and others.[I] While soybeans are the main feedstock for biodiesel in the US, the majority of biodiesel in the world is produced from rapeseed, primarily by European producers.

Rapeseed or canola[J] produces a substantially higher oil yield than soybeans, producing about 40% oil by weight and generating over 100 gallons per acre compared to the 57 gallons per acre US average for soybeans.[66] Another important advantage is that canola oil can be produced through mechanical crushers and expellers and doesn't require solvent extraction, which allows for less toxic and more sustainable production. In Oregon, canola can be grown in rotation with wheat and other crops which have substantial biofuel potential (see below), opening possibilities for integrated facilities. An Oregon State University study of the net energy gain from Oregon canola biodiesel suggests a 69% net energy contribution.[68]

Canola does have some disadvantages, however. It cross-pollinates with other members of the Brassica genus, which has led many farmers of other Brassica crops to oppose it being planted near their farms. It has relatively high nitrogen requirements,[69] which can lead to significant chemical fertilizer inputs which in turn can have negative implications for water quality and GHG balance, and is not particularly drought-tolerant, meaning that it will require irrigation in many areas of Oregon. However, canola is currently successfully grown using agricultural practices certified by such third-party certifiers as Oregon Tilth and the Food Alliance.

[I] Many of these crops come in both winter and spring varieties, which have different yields and different possible crop rotations.

[J] Because of its lower acid content, canola meal can be used as a high-protein animal feed, making it potentially more financially attractive for Oregon farmers.

While canola has been bred commercially for years and its oil yield has been optimized, other related Brassica oilseeds' potential has not been as well developed. In particular, camelina, which has been cultivated for thousands of years in Europe, has a number of properties that may make it superior to canola as a biodiesel feedstock: it is drought-tolerant and requires fewer fertilizer and nitrogen inputs.[70]

Mustard seed is another interesting option. Yellow mustard (sinapsis alba) has been identified as a promising option for Oregon; although the seeds are only 27% oil by weight, yellow mustard may still be able to produce up to 100 gallons per acre.[71] Yellow mustard is drought-tolerant, can be grown in rotation with wheat and other crops, and the oil is not used for cooking, which helps make it more competitive as a biodiesel feedstock. The meal is high in glucosinolates, which makes it unusable as an animal feed, but which gives it properties as an organic pesticide.[72] The National Renewable Energy Laboratory and the University of Idaho have been working on developing higher glucosinolate mustard hybrids that can produce both a high-value organic pesticide, which would help reduce the water quality and environmental impacts of crop production, and a biodiesel feedstock.[73]

While further research and breeding for these crops and others is necessary, it is very likely that the best approach to oilseeds in Oregon will be to develop a range of oilseed crops optimized to different conditions and to encourage the development of biodiesel production facilities that can be flexible in terms of feedstock.

Greenhouse gas impacts: As with soybean biodiesel, the real impact of canola biodiesel depends on the details of the cropping system and the efficient use of co-products. However, there are some reasons to believe that the GHG balance of canola or rapeseed methyl ester biodiesel (RME) will be better than soybeans. The most important is the nearly double yield of biodiesel per acre from RME, which substantially reduces the environmental footprint. Unlike soybeans, canola can't be grown in the tropics, so there is less chance for a direct displacement of production to high-biodiversity areas.

However, the often higher inputs of nitrogen required for canola mean that some of this advantage is lost. A recent study even suggested that Swiss RME had a worse GHG balance than US soy biodiesel.[74] But a survey of other studies of rapeseed biodiesel produced in Europe has suggested a consensus range of 50-60% fewer GHGs than petroleum diesel although there is still substantial uncertainty about the impact of N_2O emissions.[75]

A study by Oregon State University professors suggested that canola biodiesel produced in Oregon would reduce GHG emissions by 40.5% compared to petroleum diesel. If a high-yield, low-nitrogen camelina or other crop can be developed for Oregon, it would almost certainly have a substantial GHG improvement over current canola varieties.

Oregon potential: There are only about 3,000 acres of canola being grown in Oregon and almost none of the other types of oilseeds. The best possibilities for growing canola in Oregon are in the Columbia Basin, the northeast region, the central region, and particularly the Willamette Valley. However, because specialty vegetable seed growers are worried about cross-pollination, the Oregon Department of Agriculture has instituted a ban on growing Brassica crops as feedstock for biofuels in the Willamette Valley, three central Oregon counties, a part of northeastern Oregon, and a little strip of Malheur County that borders a canola-restricted area in Idaho. Other crops, like yellow mustard, which don't cross-pollinate with Brassica crop relatives under field conditions,[76] might offer one solution to this problem.

In terms of technical potential, a 2004 OSU Extension study estimates that around 300,000 acres might be available yearly for canola in central and eastern Oregon, with another 200,000 in the Willamette Valley.[77] Assuming 100 gallons per acre, the upper limit of biodiesel production would be around 50 million gallons, although the near-term potential is likely to be half that.[78] Increases in yields and the introduction of new drought-resistant crops that could grow in arid areas like the Klamath region could increase this potential substantially. At current diesel consumption levels, Oregon needs 40 million gallons of biodiesel for a statewide B5 blend, so this could be a feasible mid-term goal for the state.

6.1.3
Waste oils and fats

The most environmentally friendly and energy-efficient possibility for biodiesel production is the use of waste vegetable oil and animal fats. Even after oil has been used for cooking or deep frying, it can be cleaned and converted into biodiesel. The biodiesel itself has properties that are similar to that produced from virgin oil feedstocks. Another source of biodiesel feedstock is animal fat and tallow from slaughter-houses and other processing facilities.

Greenhouse gas impacts: Because biodiesel from waste products displaces fossil fuels without requiring any dedicated agriculture production it provides serious advantages in GHG balance and does not have the environmental impacts associated with agricultural production. One study stated that waste vegetable oil biodiesel in Europe produced a life-cycle assessment GHG benefit of over 70% compared to petroleum diesel.[79] There are no studies of the GHG balance of biodiesel produced from animal fats. Although animal fats are essentially a waste product, methane from livestock and manure is a major source of GHGs; if this were factored in, biofuels from animal fats might result in a less favorable GHG balance.

Oregon potential: One company in Oregon, SeQuential Biofuels, already produces biodiesel from waste vegetable oil, although it plans to expand production at this plant with oilseed feedstocks. Although exact data is unavailable, SeQuential Biofuels estimates that each Oregonian is responsible for 1 gallon of waste vegetable oil a year. Based on this rough estimate there may be around 3.5 million gallons of waste vegetable oil produced in Oregon per year,[80] although how much of this it is economical to actually use is an open question.

Policy Recommendations - The Glycerin Challenge:

Biodiesel production produces 10% glycerin (or glycerol) as a byproduct. While glycerin has a range of uses in soap, cosmetics, pharmaceuticals, and other products, the huge amounts of glycerin that will be produced as biodiesel production ramps up has the potential to create a glut in current markets but is also a great opportunity. Because glycerin sales are an important component of the profitability of biodiesel production, not to mention a key component in the net energy balance, finding uses for all of the glycerin will be an important part of ensuring the long-term viability of the industry. Uses could include high value chemicals like propylene glycol, the production of biogas or other uses that are appropriate to the local circumstances. Funding research into what the most economic and environmentally beneficial use of glycerin might be in Oregon, will help both support local biodiesel producers and could also create other industries in the state.

6.2
First-Generation Ethanol Feedstocks in Oregon

6.2.1 Corn

The first ethanol plants being constructed in Oregon will use corn, mostly imported from the Midwest. Corn yields around 300-400 gallons of fuel per acre,[81] however corn is also a notoriously high-input crop, usually using large quantities of nitrogen, pesticides and water. Midwestern corn production is associated with a host of environmental problems, including eutrophication and the "dead zone" in the Gulf of Mexico, falling water tables and reduced water quality, soil erosion and other problems.

Corn products are also tightly woven into nearly every aspect of our food production system, and as the price of a bushel of corn has gone from around $2 to over $4 dollars in the last year, concerns over the impact on food prices have been raised.

Because of the energy intensity of corn production, USDOE estimates an average net energy gain of around 1.67, with .61 of that coming from the co-product credits (see the section on net energy balance [3.1] above).[82] As a result, while corn ethanol does displace petroleum, it provides relatively little reduction in overall fossil fuel use. Corn ethanol provides comparatively lower GHG benefits than other biofuels, with the Argonne National Laboratories suggesting an 18-29% improvement in GHG emissions over gasoline[83] from natural-gas fired plants. If the processing is done using coal, it can actually be no better than gasoline from a global warming perspective.[84]

Policy Recommendations - Corn Ethanol:

Considering the high environmental cost of industrial corn production, it is no surprise that corn ethanol is fairly controversial. Still, it is possible to do corn ethanol better. Improved agricultural practices and processing plant designs can substantially reduce the environmental impact of corn ethanol and improve the GHG and energy balance. Since it seems inevitable that Midwest corn will be imported into Oregon for ethanol, Oregon should devise incentives to encourage the use of these best practices. Because corn is not an appropriate ethanol feedstock for Oregon, the Oregon Environmental Council helped ensure that the state's new biofuels feedstock tax credits are not available for corn production.

6.2.2 Wheat

Oregon grows substantially more wheat than corn; in fact 2007 production of winter wheat is estimated at 40.7 million bushels from 740,000 acres. Wheat is also a viable feedstock for first-generation ethanol and can be produced in the same facilities that process corn. Ethanol yields for wheat are lower, often under 300 gallons per acre, and the net energy and GHG balances are in the same range as corn.[85]

When broader potential bioenergy systems are considered, wheat may have an important place in Oregon. This is because wheat straw is one of the most abundant cellulosic feedstocks in the state, and fully utilizing this resource could also change the environmental feasibility of first-generation wheat ethanol. For example, if wheat straw were used to produce heat and power for a first-generation ethanol plant, the GHG gas benefits could easily be doubled (a UK study suggested a 48% reduction) and the fossil energy inputs nearly eliminated.[86] These plants could then be modified to generate an increasing portion of cellulosic ethanol as well, a technique that is already being implemented in other states.[K]

Yields from corn ethanol plants have been improving dramatically, and it is certainly possible that production could be optimized for wheat to make it competitive with corn. While the large-scale use of wheat as a feedstock would clearly not be sustainable and would compete with food, some use of wheat as a bridge to more advanced technologies should not be discounted.

Oregon potential: If Oregon's entire 740,000 acres of wheat were devoted to ethanol production, it could produce over 200 million gallons per year, although this would not be feasible or advisable. Oregon has a well-deserved reputation for high-quality wheat for which millers are willing to pay premium prices.[86]

6.2.3 Sugar beets

While current US sugar policy means that producing ethanol from sugar beets is unlikely to be economically viable,[88] sugar beets and molasses are still a potential ethanol feedstock in Oregon and one that has some environmental advantages over grain ethanol. The technology is well established, as sugar beets are currently the main feedstock for ethanol in Europe. Because starch feedstocks like corn and wheat must first be converted into sugar and then fermented into ethanol, using sugar crops saves a step and a corresponding amount of energy. Yields are correspondingly higher, and West Coast sugar beet producers, including Oregon, have the highest average yield in the country. In 2004, the Far West region (California, Idaho, Oregon and Washington) had average yields per acre ranging from 28-31 tons per acre,[89] which at an average rate of 24.8 gallons per ton would produce between 694-776 gallons per acre, more than double the average yields for corn ethanol.

Considering the high value of refined sugar, another possibility for the production of ethanol would be the use of molasses, a byproduct of producing refined sugar. Sugar beet molasses is usually desugared[90] to extract maximum value and sold as animal feed, but a USDA study suggests that it may be economical to convert molasses to ethanol. Molasses ethanol has been developed as a successful industry in other countries, notably India, where high demand for sugar makes it uneconomical to convert sugarcane directly to ethanol.[91] Existing processing facilities could be converted to ethanol production, either from beet juice or molasses, which would also lower the environmental footprint.

Greenhouse gas impacts: A study of sugar beet ethanol in Switzerland stated that it produced well over a 50% improvement in life-cycle assessment of GHG emissions. Since molasses ethanol is a byproduct of sugar production and doesn't require any dedicated land, it should have even greater benefits than this.

[K] Poet™ is upgrading their corn ethanol facility in Emmetsburg, Iowa to use stover and corn cobs.

Oregon potential: Oregon produced 360,000 tons of sugar beets in 2006, which would amount to nearly 9 million gallons of ethanol. It is likely that only a small fraction of this will be economical to convert to ethanol, however.

6.2.4 Potatoes

As a high-starch plant, potatoes are suitable for ethanol production. In particular, a substantial portion of the potato crop is unsuitable for commercial use, with waste potatoes accounting for 5-20% of the crop. Potato peels and other waste products from processing potatoes are also a viable source of ethanol production. Ensuring that ethanol plants that handle other feedstocks like wheat or corn can also process potato waste may be more viable than producing dedicated potato-ethanol plants.

Greenhouse gas impacts: Using potatoes as a primary feedstock is not ideal due to their relatively low yield compared to other feedstocks. A study of GHG balance of potatoes in Switzerland suggested that they were slightly worse than US corn, although the applicability of this study to Oregon is unclear.[92] The use of waste potatoes, potato peels and other byproducts would be a likely improvement over corn and wheat ethanol.

Oregon potential: In 2005 Oregon produced over 22 million hundredweight (cwt) of potatoes[93] and should have substantial potential for potato ethanol. More research into how much waste potato feedstock is really available in Oregon and the economics of transporting it to possible plant sites needs to be done. This might be a good project for Oregon BEST, the Bio-Economy and Sustainable Technologies Research Center that is being developed in the Oregon University System.

6.2.5 Whey and other agricultural byproducts

Whey, a relatively low-value byproduct of cheese production, is another viable and environmentally sound ethanol feedstock for Oregon. Whey can be readily fermented to ethanol with little pre-processing or energy inputs. There are already several whey-to-ethanol plants in the US, although most are relatively small scale. It is not clear what yields are possible from optimized production, but interviews with whey-to-ethanol plant owners have suggested that 100 gallons of whey can produce 10 gallons of ethanol.[94]

As an easily fermentable byproduct, at least one study ranked whey ethanol as having the lowest net GHG balance and lowest overall environmental impact of any ethanol feedstock, including cellulosic ethanol.[95] While the quantities of whey ethanol that are economical to produce in Oregon are unclear, a gallon of whey ethanol is clearly more beneficial from an environmental perspective than most other types of biofuels.

These findings are probably generally applicable to a range of agricultural byproducts and waste products. Incentives to encourage farmers and entrepreneurs to fully utilize byproducts of agricultural production have the potential to reap substantial dividends in reducing GHGs and improving the environment more generally.

While production plants from these sources are likely to be relatively small-scale, this can be as much an advantage as a disadvantage, as discussed under the section on social sustainability. Smaller, locally owned plants can help improve rural incomes, while utilizing waste products that would otherwise need disposal and providing substitutes for fossil fuels.

Oregon potential: Considering the incredible diversity of agricultural products made in Oregon there are likely to be a range of other waste streams that can be viably turned into ethanol or otherwise used for energy. Non-merchantable fruit or fruit processing waste is one likely possibility.

Policy Recommendations - Whey and Other Agricultural Byproducts:

Of all types of biofuels, those derived from waste products are all-around winners. An Oregon-wide survey of agricultural waste streams, the economics of transportation and the necessary conversion technologies would be an important first step to identifying where the most promising areas for investment are. The state should also create incentives, such as tax breaks, and offer loan guarantees for smaller-scale plants that can take advantage of locally available, no-value waste products that aren't economical to transport to larger plant sites.

6.3
Second-Generation Biofuel Feedstocks in Oregon

All of the feedstocks discussed to this point for both biodiesel and ethanol have one thing in common: they are used as food or feed. While the impact of conventional biofuel production on food security worldwide is hotly debated, it is clear that the ideal solution is to use biomass that does not compete with food production, or biomass that can be produced along with food. Oregon has far more potential to produce biofuels from cellulosic sources than from first-generation feedstocks. In either case, feedstocks must be produced using sustainable practices.

A few caveats are necessary when considering cellulosic feedstocks. While most of the media attention and research have focused on producing ethanol from cellulosic feedstocks, it is not clear that will in fact be the case. Several companies, notably BP and DuPont, are working to commercialize cellulosic biobutanol, which has a much higher energy content than ethanol. Biomass gasification platforms, so-called biomass-to-liquids, can produce a range of liquid fuels, including ethanol, biobutanol, hydrogenation-derived renewable diesel and more. Producing fuels with a higher energy content or better properties than ethanol could increase the effective yield from cellulosic crops without increasing production. Considering this uncertainty, from a policy perspective it is important to develop incentives that are as neutral as possible with regard to technology. All of the estimates of ethanol yields in this section are only best estimates from existing technology.

Perhaps the greatest obstacle to the utilization of cellulosic biomass is the problem of transportation. Cellulose is bulky and heavy and difficult both to collect and transport. Unless some sort of on-site pre-processing can be done,[L] it is generally estimated that sufficient biomass needs to be within a 50-mile radius of a production facility for it to be economic. Besides limiting what biomass can be economically

[L] Producing biomass pellets is one low-tech option. A higher tech possibility would be the use of modular fast-pyrolysis units to reduce the biomass down to a dense bio-oil that could then be transported to a refinery.

used, it also suggests a relatively heavy environmental footprint for a cellulosic biofuel plant, with streams of trucks coming from surrounding areas. With agricultural residues, this would also have to happen at specific times of the year, raising concerns about air and water quality. According to one article, a million tons of corn stubble could take 67,000 semi-trailer loads, which work out to a truckload every eight minutes.[96] Still, if these issues can be overcome, Oregon has a range of possible cellulosic feedstocks that could be developed for biofuels.

6.3.1 Dedicated energy crops

Similar to the way that food crops have been developed over millennia to maximize their ability to produce high-quality food, there is growing interest in developing crops that are designed specifically for energy. The two broad categories of plants that have been the focus of these efforts are tall grasses, such switchgrass and what are known as short-rotation woody crops (SRWCs), essentially fast growing trees that can be harvested every five to six years. The advantage of dedicated energy crops is the possibility of regularly harvested, consistent feedstocks whose properties can be tailored through selective breeding to maximize their energy potential. The "Billion Ton Study," a USDA-USDOE project that determined the feasibility of a billion tons of biomass being generated yearly in the US by 2030, suggested that dedicated energy crops were essential if this level of biomass production was to be sustainably reached.[97] The study found over 1.3 billion dry tons per year of biomass potential – enough to produce biofuels to meet more than one-third of the current demand for transportation fuels in the US.

From an environmental perspective, dedicated energy crops have several distinct advantages over traditional food crops. First, all of the dedicated energy crops being considered are perennials, meaning they do not have to be replanted. This eliminates the need for tilling and allows deep networks of roots and below-ground biomass to develop, which helps rebuild fertility and sequester carbon in soils. Generally speaking, these crops require far fewer chemical inputs once established and, because they are not harvested every year, provide better habitat for wildlife.

Some promising research has examined the use of mixes of native grasses for biomass production.[98] These mixes are the closest to natural ecosystems and would likely bring the greatest environmental benefits. Ideally, these could be grown on marginal and unproductive lands. Whether enough biomass can be produced to make these economically sustainable is still an open question, however.

Hybrid poplar

Switchgrass, which is considered one of the most promising native tall-grass species for energy production, does not grow well in Oregon, although this may change as new commercial breeds are developed. Of the dedicated energy crops that are currently being talked about, hybrid poplar is already being grown on 34,000 acres in Oregon[99] and there is a growing body of research on its environmental properties.

It is important to understand that while poplars are "trees," hybrid poplar plantations and other short-rotation woody crops (SRWCs) are not "forests." They are highly managed compared to traditional plantation forests. For example, the area between the trees is often tilled for the first few years to eliminate weeds, which impacts biodiversity. And while SRWCs provide habitat for some kinds of wildlife, they are not comparable to natural forests.[100] Hybrid poplars require very little pesticide application, and herbicides are primarily used during the first few years of stand establishment.

The "hybrid poplar" trees grown in Oregon are actually a cross between Eastern cottonwood and black cottonwood and can be harvested six to eight years after planting. With current breeds about 10 tons per acre could be grown annually, which, at a conversion rate of 65-70 gallons per ton, could mean a yield of 700 gallons per acre of ethanol. Purdue University researchers have suggested that lower-lignin varieties could produce up to 1,000 gallons per acre.[101] Estimates of the net energy balance for poplar ethanol range from 84%[102] to over a 100%, although this is likely dependent on the use of the lignin byproduct for generating power.

Greenhouse gas impacts: With deeper root systems, no yearly tillage, and only minimal applications of fertilizer,[M] hybrid poplar have the potential to be carbon-negative, which means they remove more carbon from the atmosphere than they release to the atmosphere. A recent evaluation by USDA scientists found that hybrid poplar used for ethanol reduced net GHG emissions by -165% in the short term.[103] Once soil carbon levels reach equilibrium and soils are no longer absorbing carbon, hybrid poplar bioenergy systems still showed an impressive 117% improvement over gasoline. Net GHG emissions were better in both the short-term and long-term than for any other crops, including switchgrass and reed canarygrass.

These benefits would be realized when existing agricultural land is moved into hybrid poplars, but any clearing of existing forest land, including longer-rotation plantations, would release large quantities of GHGs immediately and require decades of production to break even. As a bioenergy crop, poplars are superior on all environmental criteria to any of the first-generation crops discussed above and can be grown on much of the same lands.

Oregon potential: Current hybrid poplar plantations were established primarily to supply pulp and paper mills, but companies have been shifting to longer harvest rotations to grow timber.[104] With these longer rotations and the high value of most of the biomass, current plantations might produce 23,800-51,000 bone dry tons (BDT) per year in residues that would be available for biofuel production.[105] This suggests that under the most optimistic assessment current plantations might produce around 3.5 million gallons of ethanol. It is unclear how much space in Oregon might be available for dedicated hybrid poplar breeds,

Policy Recommendations - Short-Rotation Woody Crops:

In the long-run it would make far more sense to convert wheat or corn acreage that is being used for biofuel production to hybrid poplars or other short-rotation woody crops. However, grain and food crops are generally of higher economic value. Ironically, as expanded first-generation biofuel use pushes prices for grains higher, it makes cellulosic crops even less economically attractive.[106] Providing farmers with a payment for improving the net-GHG flux of their lands within a cap and trade system would be one way to encourage short-rotation woody crops. Another possibility would be the creation of a low-carbon fuel standard, where the higher GHG reduction value of biofuels from hybrid poplar would create stronger markets for cellulosic biofuels and allow producers to pay farmers more for biomass.

[M] Typically this means that one or two applications of nitrogen of up to 50 lbs/acre (56 kg/ha) are required during the entire production cycle. (http://bioenergy.ornl.gov/misc/poplars.html) and this would likely be determined by the economics. In Eastern Oregon hybrid poplars require irrigation (usually drip irrigation), and since the plantations would need to be close to the processing plant, which will also require substantial amounts of water, this could limit their expansion.

6.3.2 Agricultural residues

While dedicated energy crops hold the greatest long-term potential for fossil fuel and GHG reductions, the short-term potential is more limited and the economics uncertain. As noted above, the use of agricultural waste products, like whey or waste vegetable oil, produces the greatest net benefits without competing for existing land. Agricultural residues, composed of the inedible parts of food crops such as corn stover and wheat straw, represent a vast potential reserve of biomass that doesn't compete with food production.

However, agricultural residues are far from being "waste" products; they are an integral part of a healthy agricultural system. Leaving residues on the field helps protect against soil erosion, maintains soil fertility and nutrients, retains soil moisture, and improves carbon sequestration.[107] As a result, only a fraction of the residues produced are actually available for use as bioenergy feedstocks. Determining a sustainable rate of residue removal is far from a straightforward exercise as it depends on the level of tilling, soil and climate type, and other variables. USDA is currently engaged in a long-term study to determine what sustainable removal rates are.

Greenhouse gas impacts: As agricultural residues don't require dedicated use of land or separate inputs, the GHG balance is expected to be more favorable than that of first-generation biofuels, but less than that of dedicated energy crops, because there is no sequestration of carbon in soils or perennial biomass. Estimates range between roughly 50-90% reduction in GHG emissions, although just as with corn or wheat ethanol, agricultural practices will be the most important factor. It is possible that excessive removal of residues may also have a negative impact on GHG balance by leading to more soil erosion and loss of carbon, and this is an area that needs greater investigation.

Because of the economies of scale and the costs of transporting residues long distances, it may make more sense to process residues at a facility that already makes grain ethanol. At least one of the cellulosic ethanol plants currently under construction in the US is actually an extension to an existing plant. Because of this, utilizing wheat residues may be more economical than utilizing grass seed residues (in the latter case the crop residues are not paired with the crop).

If residues are used in addition to grain, it makes sense to evaluate the GHG impacts of the entire rotational system, which could include biodiesel crops as well. So if you have a corn-soybean or a wheat-canola rotation, it would make more sense to analyze the net-GHG emissions from the whole cropping system and the fossil fuels displaced by both the ethanol and the biodiesel. A study by USDA researchers did exactly this, looking at the net-GHG benefits of ethanol and biodiesel produced from different rotations and tillage-types, assuming 50% removal of corn stover. Biofuels (ethanol and biodiesel) from a conventional corn-soybean rotation produced a 38% improvement in GHGs, while a no till corn-soybean-alfalfa rotation produced a 43% improvement.[108]

Considering a reasonable estimate of a 20% net-GHG benefit from natural-gas fired corn ethanol plant alone, this suggests that integrating residues into first-generation systems would result in a substantial improvement in GHG emissions, particularly if best agricultural practices are used. To confirm this for the Oregon context, it would be very useful to conduct a similar study that examines the net-GHG flux for a bioenergy cropping system that includes biofuels produced from wheat, wheat straw, and canola or other oilseeds.

One important question that needs to be answered about these systems is whether enough biomass will be available to be burned to provide energy for the plant. As the relatively efficient heat and electricity generated from burning residues is a more important source of fossil fuel displacement than the liquid fuel itself, this should ideally be prioritized over simply maximizing liquid fuel production. Since cellulosic ethanol production leaves behind a high-lignin residue, the question is whether plants can be optimized to run purely on the energy produced from the residue without needing to burn any stover or straw directly. This may in fact be feasible as the company constructing an integrated corn/corn residue cellulosic-ethanol facility in Emmetsburg, Iowa claims that they can reduce natural gas use by 83%.[109]

Oregon potential: Agricultural residues represent the largest quantity of available biomass in Oregon, up to 45% of its current potential. Most of this is residues from wheat and seed grass.

A 2000 evaluation of the potential for cellulosic ethanol in Oregon estimated over 2 million bone dry tonnes (BDT) per year of wheat residues (based on a conversion factor of 2.3 tons per acre) generated in the state. After estimating how much residue would need to be left for soil needs (approximately 40-60% depending on region), there were around 1.4 million BDT per year available for ethanol production.[110] Using the National Renewable Energy Laboratory estimate of 60 gallons per ton this would produce around 84 million gallons of ethanol.

The same study estimated that Oregon produced about 1 million BDT per year of grass seed straw, almost entirely in the Willamette Valley. About half of this is exported to Japan, and the rest is either burned or mulched into the field. If half of what is not exported could be sustainably used for ethanol production, it could produce another 15 million gallons.

6.3.3 Woody biomass

Forest thinnings, slash and residues

With over 28 million acres of forests, Oregon would seem to have a vast potential for woody biomass production. Determining how much can be sustainably harvested is a far trickier proposition, however. 31% of Oregon's forests are reserved and closed to timber production; 33% are multi-use forests that mix timber harvest with other goals, such as recreation; and 36% are primarily devoted to wood production.

Because of the high economic value of wood that can be used as timber or other products, most of what would be available for biofuel or energy production is what is called "un-merchantable material," fragments that have no easily quantifiable economic value. In addition to the slash and other unused biomass from timber operations, there is a growing need to manage forests to reduce forest fires. Years of fire suppression have left millions of acres essentially overloaded with biomass and at risk of environmentally damaging fires. Thinning and removal of biomass from these forests would improve forest health and provide a substantial supply of biomass for energy production. While there are clear environmental benefits to greater utilization of forest biomass, there are also real sustainability concerns.

Slash and Residues: Similar to agricultural residues, slash and other "unmerchantable biomass" serve a range of vital functions for forest health and ecology. Where intensive logging operations already remove more timber than is advisable to maintain forest integrity and biodiversity, creating a new incentive to remove everything that is left could have devastating consequences. Clear guidelines for the sustainable removal of biomass need to be developed and followed.

Forest thinnings: Because much of the thinning of forests will take place on multi-use and federal lands, it is especially important for environmental concerns to be answered to avoid a public backlash. In addition to the concerns raised above about what the optimal level of thinning is, the logistics of biomass removal pose serious environmental questions. The first will be the need to build roads and other infrastructure to allow the removal of tens of thousands of tons of wood from forests. None of the current studies of using forest thinnings for biomass have addressed the question of how much infrastructure would be required or the long-term impact. Road-building has a clear and documented impact on biodiversity and can have a profound effect on the character of a forest as more people are given easy access to areas that were previously inaccessible.

Policy Recommendations - Forest Certification and Greenhouse Gas Benefits:

All calculations of the net GHGs for biofuels are based on a key assumption: that the carbon released from burning the biomass is recaptured from the plant. With agricultural products and energy crops this is clearly a reasonable assumption. It is not at all clear that this will be the case for forestry. Considering the huge amount of carbon stored in forests over decades, even if clear-cutting or other practices are not used, enough carbon to outweigh the displacement of fossil fuels may be released. As biomass utilization will increase the economic pressure to use forest resources more intensely, the possibility that forest biomass use may contribute to, rather than help solve, global warming is very real.[115]

Determining the net GHG impact of biomass removal (including reduction of fire risk) is difficult. Until this area is more fully understood there is a simple policy option to provide at least some assurance. This would be to ensure that all biomass used is sourced originally from third-party-certified sustainably managed forests. The Forest Stewardship Council, a third-party certifier, already does chain-of-custody tracking of products for mill wastes, so it should be possible to identify the quantities of sustainably produced biomass that are available.

Particularly over the next ten years or so when there is likely to be at most only a few cellulosic plants constructed in Oregon, it would be perverse to provide government incentives designed to reduce global warming to products that may be contributing to it. It is strongly recommended that only biomass from third-party-certified sustainably managed forests or from federal forests that have developed scientifically sound and rigorous sustainability criteria be allowed to qualify for any state-level incentives or tax breaks. Plants intending to use woody biomass that receive funding or tax breaks from the state should also be required to use only certified biomass.

Another intrinsic problem is that once thinning of a certain area is completed, repeated thinning will not be necessary for years to come, while production facilities are fixed in place. The concern is that the economic pressure to produce more biomass from areas immediately around the plant would result in the overexploitation of forest resources and a loss of their natural character. For example, an Oregon State University study of woody biomass suggested that statewide, "1.0 million BDT (bone dry tons) per year could be available for 20 years." With hundreds of millions of dollar in initial capitol costs and a lifespan of 30-60 years,[111] the obvious question is what feedstock an ethanol plant will use after the 20 years it takes to finish thinning. Pressure to convert natural forests over to more plantation style management or even short-rotation woody crops may be intense. While it may be possible to utilize forest thinnings in a sustainable manner, these questions need to be answered before any construction begins. Particularly for any use of biomass from state and federal lands, sustainability guidelines and plans need to be developed to cover the entire projected lifetime of the plant and not just the timeline for thinning.

Greenhouse gas impacts: Based on comparisons with other cellulosic biofuels, it is likely that biofuels from sustainably extracted forest residues would have a very positive GHG balance, likely greater than those from agricultural wastes. This assumes that there is no net loss in biomass from the forest and that biomass use doesn't create incentives for deforestation, which would rapidly wipe out any gains. While thinning obviously reduces the carbon stored in the forest, implying a GHG penalty, it should reduce the possibility for catastrophic fires that release large quantities of GHGs in a short time. More research into the net impact of these different factors is needed.

Oregon potential: Oregon has nearly 3 million bone-dry tones (BDT) per year of forest residues available, although only a portion of this can probably be used sustainably and economically for biofuels.[112] Studies have estimated between 1.3 and 2.5 million BDT per year from harvest residues,[113] but even at these levels extraction would need to be carefully examined for its impact on biodiversity and forest health. Assuming a conservative million BDT per year at 66 gallons per ton, this could produce 66 million gallons of ethanol. Estimates on how much forest health thinning would be available range from .8-7.3 million BDT over 20 years.[114] While the upward levels of this range could produce around 500 million gallons of ethanol a year, the question remains what all of that biofuel production capacity would be used for after the 20 years is up. The lower end of the range, which still could be tens of millions of gallons a year, is likely more feasible.

Policy Recommendations - "Roving" biomass-to-biofuel production facilities:

Given the concern that fixed-in-place production facilities may place economic pressure to continue thinning biomass from areas immediately around the plant after it's no longer sustainable to do so, Oregon should study the feasibility of smaller-scale production facilities that could be dismantled and moved to an area where sustainable harvest could occur.

Wood residues/waste

Residues from mills are another source of woody biomass that might be available for use as bioenergy in Oregon. These have the advantage of already being at a centralized plant, rather than disbursed throughout the forest. As waste products, full utilization of these resources for energy provides clear environmental benefits by displacing fossil fuels without putting more pressure on lands.

Greenhouse gas impacts: Biofuels produced from wood wastes would be expected to have a high GHG benefit, assuming that the wood was harvested in a sustainable manner and not the result of deforestation or practices that reduce overall forest health.

Oregon potential: Oregon mills are already extremely effective at utilizing wood waste residues. For example, out of nearly seven million bone-dry tons of mill residue generated in 2002, barely ten thousand went unused. Biofuel feedstock would have to compete with existing uses for materials, which may be able to outbid them. There may be other sources of woody biomass waste that are available in small, but substantial, quantities across Oregon, including mixed waste paper, paper mill sludge, garden and park waste, and construction and demolition waste.

6.3.4 Algae

The feedstocks discussed in this paper so far are limited by the relatively large quantities of land that are required to produce them. The fact that this land has many competing uses makes this problem particularly acute, and is the greatest limitation on expanding biofuel production. The use of microalgae as a feedstock promises to get around this problem. This is because given light, water (including saltwater) and carbon dioxide, algae can reproduce it itself at an incredible rate, and certain types of algae can be composed of up to 50% oil. This oil can then be used for biodiesel production, although the algae could also be used for ethanol, biogas or burned for electricity.

The fact that algae can use saline water opens up huge areas of the country for possible production, which are also the same areas that are most limited in their ability to produce conventional feedstocks. The fact that algae requires CO_2 is also a major plus, since CO_2 captured from coal-fired power plants could be used to produce algae, which, while not permanently sequestering it, would substantially increase the amount of energy gained from the same amount of CO_2. But it is the incredible yields of oil that have been suggested for microalgae that make it such an attractive option.

Much of the basic research on using algae for biofuels came from the USDOE's Aquatic Species Program, which ran from 1978 to 1996, where they attempted to grow high-oil yielding algae in open, saltwater ponds in the desert. That program estimated that algae could produce up to 15,000 gallons per acre, hundreds of times more than any other feedstock, although they never achieved yields in this range.[116] Even at a fraction of this yield, algae biodiesel has the theoretical potential to displace a huge proportion of our fossil fuel use, with only minimal use of land that isn't suited for other types of agricultural production.

Despite its promises, the Aquatic Species Program also identified some major challenges that needed to be overcome. The open-air ponds they used would soon become dominated by local species, which crowded out the high-productivity strains they grew in the lab. Cold nights (typical in deserts and arid regions that also get the best sunlight) also drastically lowered yields.[117] This can be overcome, but developing closed-pond systems, which regulate temperature and are still cost-effective, will be a challenge. Substantial research has also gone into photo-bioreactors, essentially big cans with a light in the middle where the algae can be grown in more controlled conditions. But these have much higher capital costs and their own set of technical hurdles, including assuring that the light reaches all the algae evenly.

A number of companies are working on innovative projects to use algae for biodiesel, but at this time there are no pilot-scale plants producing biofuels from algae, unlike with cellulosic ethanol (there is also reason for skepticism as there have been allegations of fraud; at least one South African company has made outlandish claims of success).[118] That said, some interesting algae ideas include harvesting wild algae from municipal waste, using geothermal heat to keep the algae at a constant temperature,[119] and incorporating algae production into a biorefinery with an integrated feedlot.[120] Whether any of these ideas will prove to commercially viable and on what scale is not clear at this point.

Greenhouse gas impacts: While the GHG benefit would be presumably very high due to the high yields and use of waste CO_2, until a viable production process is proven the GHG reductions will be unclear.

Oregon potential: Some areas of Oregon may have enough sunlight year round, but cold nights and winters would likely prevent the use of low-cost open-air ponds. More academic research on algae would be valuable.

6.4

Matrix of Biofuel Feedstocks in Oregon

FUEL	***NET ENERGY***	***GREENHOUSE GAS BENEFIT*** (% reduction against petroleum baseline)	***YIELD*** (gallon/acre)	***NEGATIVES***	***POSITIVES***
Gasoline	.81	0%	Not applicable	Air pollution; major driver of global warming; oil spills; national, international and global security	Comparatively inexpensive; doesn't compete with food
Diesel	.83	0%	Not applicable	Air pollution; major driver of global warming; oil spills; national, international and global security	Comparatively inexpensive; doesn't compete with food
Soybean biodiesel	3.2	20-78%	53	Drives deforestation in rainforests	Reduces air pollution & GHGs
Brassica oilseeds biodiesel	Approx. 3.2	40-60%	100	Crossbreeds with other Brassicas	Higher yield then soybeans; drought-resistant varieties
Waste oils and fats biodiesel	>3.2	>70%	Not applicable	Limited availability	Doesn't require extra arable land; efficient use of wastes
Corn ethanol	1.67	0-29%	300-400	Industrial corn currently requires high inputs of fertilizer and other chemicals; food crop; coal-fired ethanol plants eliminate any GHG benefits	Large production potential nationally; technology already available
Wheat ethanol	<1.67	0-29%	< 300	Similar to corn, but more expensive	Large production potential in Oregon
Sugar beet ethanol	Not available	>50%	694-776	Currently uneconomical	High yield per acre; large production potential in Oregon
Potato ethanol	Not available	0-29%	Not applicable	Probably low yields per acre	Use of waste potatoes can benefit farmers
Whey and other agricultural byproducts ethanol/ biodiesel	Not available	50-90%	Not applicable	Limited availability	Strong reduction in GHGs; efficient use of waste

Matrix of Biofuel Feedstocks in Oregon (continued)

FUEL	***NET ENERGY***	***GREENHOUSE GAS BENEFIT*** (% reduction against petroleum baseline)	***YIELD*** (gallon/acre)	***NEGATIVES***	***POSITIVES***
Hybrid poplar cellulosic ethanol	High	0-165%	700-1000	Might drive destruction of natural forests	Perennials improve soil quality and habitat over annual crops
Agricultural residues cellulosic ethanol	High	50-90%	Varies	Can increase erosion and reduce soil fertility	Increases ethanol yield/acre without displacing food production
Forest thinnings, slash and residues cellulosic ethanol	Not available	0-165%	Varies	Can impact forest health and might drive deforestation	Can reduce forest fires; doesn't take away from food production
Algae biodiesel	Not available	N/A	Not applicable	Commercial viability is unproven; unforeseen problems	Doesn't require arable land; huge yields

7 OTHER USES FOR BIOMASS

This paper has focused essentially on the use of biomass for fuel, mainly for transportation fuel. However, there are other competing uses of biomass that offer a different set of costs and benefits than liquid fuel production

7.1 *Biogas*

Another alternative use of almost any of the feedstocks mentioned here – corn, wheat, wheat straw, potatoes and others – would be to produce biogas rather than liquid fuels. Biogas is a mixture of methane and other gases, which is produced from the decomposition of biomass in anaerobic conditions. At its simplest, this involves dumping biomass in a digester, or large pot, and waiting for it to rot. While high-efficiency biogas production is not that simple, anaerobic digestion requires fewer inputs of capital, heat or energy than either ethanol or biodiesel production. Moreover, in terms of the usable energy value, biogas production seems to produce substantially more usable energy per acre than either ethanol or biodiesel.[121] Once generated it can be purified and fed into the natural gas grid, burned for heat or electricity, or even compressed for use in compressed natural gas (CNG) vehicles.

While the focus on liquid fuels in this country has drawn attention away from producing biogas from traditional energy crops, biogas has been expanding rapidly in Europe (in Germany it is the fastest growing form of renewable energy).

Because of the lack of fossil fuel inputs into production and the high level of energy usable compared to liquid biofuels, biogas produces relatively greater GHG benefits for any feedstock than what was discussed for liquid fuels.

7.2 *Biomass Electricity*

As can be gleaned from the preceding discussions of net energy, it is more efficient to burn or gasify biomass directly to produce electricity because no costly intermediate conversion steps are needed. And, unlike cellulosic ethanol production, biomass power is an established technology that is already in use across the US. In fact, Oregon already has biomass power plants using wood wastes.[122]

Although biomass-generated electricity does not displace petroleum the way biofuels do,[N] electricity is likely to become much more important as a transportation fuel in the future. It is generally agreed that the best near-term environmental option for cars are plug-in hybrids, which can run both off electricity from the grid and use conventional liquid fuels. Using biomass energy to power electric or plug-in hybrid electric vehicles, even if gasoline was still used, may be one of the most efficient ways to reduce GHGs and fossil fuel use.

[N] The sustainability and greenhouse concerns for the sustainable harvesting of biomass are the same whether it is used for liquid fuels or for energy production.

7.3
Bio-products

While this paper does not deal with the economics of biomass, the cost of getting bulky cellulosic feedstocks to processing facilities is one of the greatest hurdles to biomass energy. Because energy feedstocks need to be cheap enough to compete with gasoline there is little margin for biofuel producers to pay more to compete with other higher-value uses for biomass as well. This is particularly true in the case of wood products, where the vast majority of mill wastes go to low-value products like fiber board, which are still more profitable than if they were sold as biomass for energy. However, there is growing interest in using biomass to create a range of chemicals, plastics and other products that are currently derived from petrochemicals.

Since about 16% of US oil consumption goes to producing these products, there is still a huge potential for displacing petroleum and reducing pollution and GHGs. In fact, many bio-refineries may be able to produce ethanol or other biofuels as well as a range of other chemicals and products. Also, because many of these co-products are valued more highly than fuel, "bio-refineries" may be able to pay for more to get biomass out of the woods and the fields than could a straight ethanol producer, for example.

Policy Recommendations - Bio-products:

While few technologies to produce chemicals, plastics and other products from biomass have been commercialized, state policy should encourage the development of these bio-based industries and not become exclusively focused on biomass energy production. For example, Oregon BEST, the Bio-Economy and Sustainable Technologies Research Center that is being developed in the Oregon University System, should research commercialization of these safer, non-toxic alternatives to petroleum-based products.

8 CONCLUSION

The first and most important way to meet our energy needs is to increase conservation and efficiency. The cheapest, most sustainable energy is the energy we never have to produce. To meet a portion of remaining energy needs, biofuels – if done right – are an important part of the equation. They can be used within our existing infrastructure to help wean us off of oil, while simultaneously improving the quality of our environment. However if done wrong, biofuels could simply compound many of our environmental problems and exchange one kind of unsustainable energy for another.

With the proper incentives and awareness of these issues, Oregon has the potential for substantial (though limited) biofuels production. An Oregon biofuels industry can support local economic development, reduce oil dependence, improve the environment, and reduce Oregon's global warming footprint.

Principles for Making Renewable Fuels Sustainable

Adhering to the following principles will help biofuels live up to their potential as green, renewable fuels.

- **Support only biofuels that reduce greenhouse gas emissions on a life cycle assessment basis:** To ensure that biofuels are in fact reducing global warming pollution, the full greenhouse gas impact of specific biofuels needs to be accurately assessed using a methodology that is updated as the science improves. To the extent possible, agricultural emissions and land use changes need to be fully accounted for. Biofuels should be required to reduce greenhouse gas emissions compared to petroleum in order to qualify for state incentives, and an incentive system that will encourage the development of increasingly more climate-friendly biofuels should be put in place.

- **Process biofuels with minimum fossil fuel inputs:** Incentives to encourage plants to use biomass, wind, solar or other renewable energy should be put in place. No state incentives should be available for biofuels plants that rely on coal to power their facility.

- **Protect air and water quality:** Careful monitoring of both tailpipe emissions and localized impacts of biorefinery operations on air and water quality will be required. State policies should be informed by the evolving understanding of these impacts.

- **Grow biofuel feedstocks using sustainable agricultural practices:** To avoid negative impacts on water and soil quality, farmers should use best agricultural practices – including minimal chemical fertilizer and pesticide inputs, buffer zones on waterways, and conservation tillage.

- **Conserve water:** The total water use for plants and irrigation should be carefully considered before sourcing feedstocks or locating biofuels production facilities. Incentives to encourage water conservation should be implemented, and research should be done to identify and develop drought-resistant feedstocks.

- **Protect biodiversity:** Biofuel and bioenergy production poses a range of threats to biodiversity if habitat is disturbed. Impacts on native species should be carefully considered as the industry develops.

- **Avoid conversion of native ecosystems:** Converting native grasslands or forests to agriculture, short-rotation woody crops, or tree plantations eliminates any greenhouse gas benefits from even advanced biofuels and does serious harm to biodiversity.

- **Support socially responsible and locally owned biofuels production:** Local communities have the greatest investment in their environment. Encouraging local input, ownership and control of biofuel production will help ensure real sustainability.

- **Provide consumer information:** Biofuel producers should be required to provide sufficient information on feedstocks and production practices to allow consumers to make an informed decision about which biofuels they purchase. Ideally, there would be a system of either voluntary or mandatory labeling that indicates the greenhouse gas balance, if not more detailed environmental and social criteria.

Policy Models

Appendix I lists the policy recommendations that have been presented in this report. The ideal policy would provide strong incentives across the board for the use of best practices during both feedstock production and biorefining. While this may seem daunting, there are already several strong models to follow.

First, there are several federal programs that outline best practices for agriculture that would go a long way towards mitigating any negative effects of biofuels, particularly the Conservation Security Program. Ideally, in order for biofuels to qualify for any state incentives or mandates, including triggering the Oregon's Renewable Fuel Standard, they should be required to be produced with at least some use of these best practices. These restrictions would fall on the producers of biofuels, who would be required to purchase feedstock only from farms that meet the requirements. One possibility would be to require the use of feedstock produced consistent with Conservation Security Program Tier I standards as an absolute minimum for tax breaks, and provide extra incentives to producers who use feedstocks produced in a way that meets the more rigorous Tier II or Tier III standards. Oregon is also home to three internationally respected third-party certification programs – Food Alliance, Oregon Tilth and Salmon-Safe – which provide recognition to farmers who adhere to a set of environmentally and socially responsible practices. Farmers growing feedstock certified by these programs should also be eligible for the same tax breaks provided for feedstock grown consistent with the Conservation Security Program.

Another strong model for addressing the sustainability of biofuels in a comprehensive manner is the Renewable Transport Fuel Obligation in the UK, which will require renewable fuels to meet minimum GHG and environmental and social sustainability requirements to qualify for the mandate (see page 18).

Another major policy innovation is California's Low-Carbon Fuel Standard (LCFS) (see page 9). While GHG emissions don't capture all of the environmental impacts, they do provide a solid proxy for a wide range of issues. The LCFS is technology neutral; it allows blenders and fuel providers to reduce GHG emissions through any means possible, including improving oil production efficiency or the use of biofuels or other technologies. The use of an opt-in system, which creates an incentive for but does not require reporting, ensures that best practices are credited without providing an unnecessary regulatory burden. By creating a high-value market for renewable fuels that provide the highest greenhouse gas improvements and associated environmental benefits, an Oregon LCFS would help focus technological innovation on sustainability and increase Oregon's already strong comparative advantage in this critical area.

As these examples show, despite the complexities of biofuels, innovative policymaking and American technological innovation can combine to get them right. Oregon, with its strong history of environmental leadership, has an opportunity to be a real leader in the development of sustainable bioenergy. Leadership on this issue today will help ensure that Oregon's vast natural heritage, as well as that of the rest of the world, will be intact for generations to come.

APPENDIX I

POLICY RECOMMENDATIONS

Greenhouse Gas Balance: Because the GHG balance of renewable fuels is the result of a complex range of factors, policy makers should address the problem in a comprehensive way. One policy solution is a Low-Carbon Fuel Standard (LCFS), such as the one currently being designed for California. A LCFS places a requirement for a gradual reduction in the greenhouse gas intensity of all fuels sold, but doesn't mandate any specific way this has to be reached. The key part of an effective LCFS is to create an incentive for all fuel producers to analyze and report what the real GHG impact of their fuels is. The University of California team advising the state on its LCFS has recommended the use of an opt-in system for reporting. Rather than require mandatory reporting from every single producer, default values will be set that assume worst-case scenarios. If producers are using better practices, they can provide that information and get more credit for GHG reductions. This ensures that best practices are credited and encouraged without providing an unnecessary regulatory burden. The LCFS should also create a market for sustainably produced feedstocks, thus encouraging best agricultural practices. Ideally, the information on overall emissions and environmental impact would also be available to consumers so that they can make informed decisions about the fuels they buy. Oregon should devise and adopt an LCFS based on these principles.

Tailpipe and Evaporative Air Emissions: It seems likely that increased use of ethanol will lead to at least some increases in NOx emissions, and therefore a possible increase in ozone levels. If biodiesel also increases NOx levels, which may not be the case, this could pose a real concern in Oregon (although US EPA testing has also indicated that the total smog-forming potential of biodiesel is 50% lower than petroleum diesel). The more difficult question may be the impact of evaporative emissions of VOCs from ethanol blends, as the more easily evaporated ethanol carries off compounds from the gasoline during storage. Because different ethanol blends may have very different air quality impacts, both as a result of burning and evaporation, the exact mix of blends used in the state will determine what the impacts are. Overall, while it seems most likely that biofuels will produce air quality benefits, considering the uncertainty in several areas, it would be advisable for the Oregon Department of Environmental Quality to assess the impacts on air quality of increased use of biofuels in the state.

Air Emissions from Biofuels Production Facilities: Biofuel plants should comply with the state's air quality rules. Any attempt to loosen restrictions on emissions from biorefineries could offset tailpipe air quality benefits.

Agricultural Impacts on Water Quality: Oregon should increase technical assistance and conservation incentives to farmers to help them minimize their impact on water quality through nutrient management planning, minimizing the use of chemical inputs, creating stream buffers, making changes to tillage and rotation, and implementing other techniques as appropriate. Specifically, Oregon should:

- Become a leader in interdisciplinary research and education in sustainable farming and energy systems by establishing a Center in the Oregon University System that would provide research on alternative, sustainable production methods, and degree programs and extension outreach on sustainable production methods.

- Increase funding for technical assistance to improve best management practices on-farm, transition to more sustainable practices (including certification), and restore watersheds and habitats on agricultural lands.

- Provide state tax credits, payments, grants, or other financial incentives for transition to certification by an independent third party, and annual incentives for best practices or certified acreage.

Water Use: Oregon should support research and development of drought-resistant biofuels crops, such as camelina, that don't require irrigation. Total long-term water requirements for the region need to be carefully considered when state agencies issue permits for new ethanol and biodiesel plants. Overall, newer designs that are more efficient at water recycling should be encouraged through tax breaks, loan guarantees or other incentives or requirements.

Biodiversity and Ecosystem Conversion: Bioenergy production needs to be done in a way that doesn't negatively impact biodiversity or rare and threatened ecosystems. In order to discourage the conversion of CRP and CREP land (and other valuable habitat) back into land used for agricultural production, biofuels produced from land that is taken out of these programs early should not qualify for state incentives. While it is likely that higher crop prices will result in some landowners not renewing their contracts after they are up, any attempts to allow an "early out" to the contracts to supply biofuels will do more harm than good. Ideally, these and other conservation programs should receive more funding to help protect ecologically valuable lands and help balance the strain put on agriculture from intensified production of biofuels. Specifically, Oregon should:

- Advocate at the federal level to ensure that early opt-outs from the CRP and CREP programs for the production of biofuel feedstocks are not allowed.

- Not allow biofuels grown on land which has taken an early opt-out from a CRP or CREP contract or other similar conservation programs to qualify for a state Low Carbon Fuel Standard or other biofuel regulatory or incentive programs.

- Provide strong incentives for farmers to protect habitat, wildlife, and water resources and make sure these incentives are competitive with the incentives provided to farmers to produce biofuel feedstocks.

Social Sustainability: To support locally owned biofuels operations where the greatest value is returned to the local farmer, Oregon could consider a system like Brazil's, which provides tax breaks to biodiesel producers who source their feedstocks from family farms rather than large agribusinesses.

Ethanol and Biodiesel Plants: State incentives to encourage the use of renewable energy and process efficiencies in new plants will pay substantial environmental dividends. Providing incentives for ethanol plants to employ biomass gasification would be a cost-effective way to reduce fossil fuels, promote real energy independence and reduce GHGs, while maximizing agricultural resources. (Financial incentives may be necessary because of the substantial up-front capital cost of biomass gasification systems.) There are a range of other process changes that can be utilized in first-generation plants to substantially improve energy efficiency, including not drying the distiller's grains. The Pacific Ethanol plant in Boardman, Oregon is already moving in this direction.

The Glycerin Challenge: Biodiesel production produces 10% glycerin (or glycerol) as a byproduct. While glycerin has a range of uses in soap, cosmetics, pharmaceuticals, and other products, the huge amounts of glycerin that will be produced as biodiesel production ramps up has the potential to create a glut in current markets but is also a great opportunity. Because glycerin sales are an important component of the profitability of biodiesel production, not to mention a key component in the net energy balance, finding uses for all of the glycerin will be an important part of ensuring the long-term viability of the industry. Uses could include high value chemicals like propylene glycol, the production of biogas or other uses that are appropriate to the local circumstances. Funding research into what the most economic and environmentally beneficial use of glycerin might be in Oregon, will help both support local biodiesel producers and could also create other industries in the state.

Corn Ethanol: Considering the high environmental cost of industrial corn production, it is no surprise that corn ethanol is fairly controversial. Still, it is possible to do corn ethanol better. Improved agricultural practices and processing plant designs can substantially reduce the environmental impact of corn ethanol and improve the GHG and energy balance. Since it seems inevitable that Midwest corn will be imported into Oregon for ethanol, Oregon should devise incentives to encourage the use of these best practices.

Whey and Other Agricultural Byproducts: Of all types of biofuels, those derived from waste products are all-around winners. An Oregon-wide survey of agricultural waste streams, the economics of transportation and the necessary conversion technologies would be an important first step to identifying where the most promising areas for investment are. The state should also create incentives, such as tax breaks, and offer loan guarantees for smaller-scale plants that can take advantage of locally available, no-value waste products that aren't economical to transport to larger plant sites.

Short-Rotation Woody Crops: In the long-run it would make far more sense to convert wheat or corn acreage that is being used for biofuel production to hybrid poplars or other short-rotation woody crops. However, grain and food crops are generally of higher economic value. Ironically, as expanded first-generation biofuel use pushes prices for grains higher, it makes cellulosic crops even less economically attractive. Providing farmers with a payment for improving the net-GHG flux of their lands within a cap and trade system would be one way to encourage short-rotation woody crops. Another possibility would be the creation of a low-carbon fuel standard, where the higher GHG reduction value of biofuels from hybrid poplar would create stronger markets for cellulosic biofuels and allow producers to pay farmers more for biomass.

Forest Certification and Greenhouse Gas Benefits: All calculations of the net GHGs for biofuels are based on a key assumption: that the carbon released from burning the biomass is recaptured from the plant. With agricultural products and energy crops this is clearly a reasonable assumption. It is not at all clear that this will be the case for forestry. Considering the huge amount of carbon stored in forests over decades, even if clear-cutting or other practices are not used, enough carbon to outweigh the displacement of fossil fuels may be released. As biomass utilization will increase the economic pressure to use forest resources more intensely, the possibility that forest biomass use may contribute to, rather than help solve, global warming is very real.

Determining the net GHG impact of biomass removal (including reduction of fire risk) is difficult. Until this area is more fully understood there is a simple policy option to provide at least some assurance. This would be to ensure that all biomass used is sourced originally from third-party-certified sustainably managed forests. The Forest Stewardship Council, a third-party certifier, already does chain-of-custody tracking of products for mill wastes, so it should be possible to identify the quantities of sustainably produced biomass that are available.

Particularly over the next ten years or so when there is likely to be at most only a few cellulosic plants constructed in Oregon, it would be perverse to provide government incentives designed to reduce global warming to products that may be contributing to it. It is strongly recommended that only biomass from third-party-certified sustainably managed forests or from federal forests that have developed scientifically sound and rigorous sustainability criteria be allowed to qualify for any state-level incentives or tax breaks. Plants intending to use woody biomass that receive funding or tax breaks from the state should also be required to use only certified biomass.

"Roving" biomass-to-biofuel production facilities: Given the concern that fixed-in-place production facilities may place economic pressure to continue thinning biomass from areas immediately around the plant after it's no longer sustainable to do so, Oregon should study the feasibility of smaller-scale production facilities that could be dismantled and moved to an area where sustainable harvest could occur.

Bio-products: While few technologies to produce chemicals, plastics and other products from biomass have been commercialized, state policy should encourage the development of these bio-based industries and not become exclusively focused on biomass energy production. For example, Oregon BEST, the Bio-Economy and Sustainable Technologies Research Center that is being developed in the Oregon University System, should research commercialization of these safer, non-toxic alternatives to petroleum-based products.

GLOSSARY

ADM	Archer Daniels Midland Company
B100	100% biodiesel
B20	a fuel blend of 20% biodiesel and 80% petroleum diesel
BDT	bone dry ton, a unit of measurement
BTU	British thermal unit, a unit of energy
CHP	combined heat and power
CO	carbon monoxide
CO2	carbon dioxide
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
DDE	dichlorodiphenyldichloroethylene, a banned pesticide
DDT	dichlorodiphenyltrichloroethane, a banned pesticide
E10	a fuel blend of 10% ethanol and 90% gasoline
E85	a fuel blend of 85% ethanol and 15% gasoline
GHG	greenhouse gas
HC	hydrocarbons
LCFS	low-carbon fuel standard
MJ	megajoule, a unit of energy
MTBE	methyl tertiary-butyl ether, a gasoline additive
NOx	a generic term for mono-nitrogen oxides (NO and NO2)
NREL	National Renewable Energy Laboratory
PCBs	polychlorinated biphenyls
PM	particulate matter
RME	rapeseed methyl ester biodiesel
SRWC	short-rotation woody crop
UK	United Kingdom
US EPA	United States Environmental Protection Agency
USDA	United States Department of Agriculture
USDOE	United States Department of Energy
VOC	volatile organic compound

ENDNOTES

1. Westcott, Paul. 2007. *Ethanol Expansion in the United States: How Will the Agricultural Sector Adjust?* USDA Economic Research Service (FDS-07D-01), p.1.
2. Epstein, Paul, and Jesse Selber, editors. 2002. *Oil: A Life Cycle Analysis of Its Health and Environmental Impacts, Executive Summary.* Harvard Medical School, The Center for Health and the Global Environment, p.1.
3. Ibid.
4. US Environmental Protection Agency. 2007. *Regulatory Impact Analysis: Renewable Fuel Standard Program*. US EPA Office of Transportation and Air Quality (EPA420-R-07-004), pp.20-21.
5. Weiss, Daniel and Nat Gryll. 2007. *Flex-Fuel Bait and Switch*. Center for American Progress. http://www.americanprogress.org/issues/2007/06/flex-fuel.html (posted June 18, 2007).
6. Worldwatch Institute. 2006. *Biofuels for Transportation: Global Potential and Implications for Sustainable Agriculture and Energy in the 21st Century*. Prepared by the Worldwatch Institute for the German Federal Ministry of Food, Agriculture and Consumer Protection in cooperation with the Agency for Technical Cooperation and the Agency of Renewable Resources.
7. National Biodiesel Board website. 2007. *U.S. Biodiesel Production Capacity.* http://www.biodiesel.org/pdf_files/fuelfactsheets/Production_Capacity.pdf (posted September 7, 2007).
8. National Biodiesel Board website. 2007. *Estimated US Biodiesel Sales.* http://nbb.org/pdf_files/fuelfactsheets/Biodiesel_Sales_Graph.pdf (accessed October 12, 2007).
9. Energy Information Administration website. 2007. *Official Statistics from the U.S. Government.* http://tonto.eia.doe.gov/dnav/pet/pet_cons_821dst_dcu_nus_a.htm (accessed October 15, 2007). In 2005, total US sales of distillate fuel oil were 63,164,569,000 gallons.
10. National Biodiesel Board website. 2005. *Energy Content.* http://www.biodiesel.org/pdf_files/fuelfactsheets/BTU_Content_Final_Oct2005.pdf (posted October 2005).
11. US Department of Energy Alternative Fuels and Advanced Vehicles Data Center website. *What is Hydrogenation-Derived Renewable Diesel?* http://www.eere.energy.gov/afdc/fuels/emerging_green_what_is.html (accessed October 14, 2007).
12. BP-DuPont website. 2007. *Biobutanol a better biofuel.* http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/downloads/B/Bio_bp_dupont_fact_sheet_jun06.pdf (posted June 2006).
13. Sheehan, John et al. 1998. *An Overview of Biodiesel and Petroleum Diesel Life Cycles.* US Department of Agriculture and US Department of Energy, p.25.
14. Punter, Gary et al. 2004. *Well-to-Wheel Evaluation for Production of Ethanol from Wheat.* A Report by the LowCVP Fuels Working Group, WTW Sub-Group, FWG-P-04-024, p.21.
15. Governor Kulongoski's Advisory Group on Global Warming. 2004. *Oregon Strategy for Greenhouse Gas Reductions*, p.82.
16. Impacts of Climate Change on the Pacific Northwest scientific meeting, June 2004. *Scientific Consensus Statement on the Likely Impacts of Climate Change on the Pacific Northwest.*
17. Physicians for Social Responsibility. 2002. *Degrees of Danger: Health Effects of Climate Change and Energy in Oregon.*
18. Zah, Rainer et al (translated by Thomas Ruddy). 2007. *Life Cycle Assessment of Energy Products: Environmental Assessment of Biofuels - Executive Summary*. Written under contract for the Federal Office of Energy, Federal Office for the Environment, and Federal Office for Agriculture (Switzerland), p.3.
19. US Environmental Protection Agency. 2007. *Regulatory Impact Analysis: Renewable Fuel Standard Program.* EPA420-R-07-004, p.223.
20. Punter, Gary et al. 2004. *Well-to-Wheel Evaluation for Production of Ethanol from Wheat.* A Report by the LowCVP Fuels Working Group, WTW Sub-Group, FWG-P-04-024, p.21.
21. Turner, Brian et al. 2007. *Creating Markets for Green Biofuels: Measuring and Improving Environmental Performance*, UC Berkeley Institute of Transportation Studies, Transportation Sustainability Research Center, Research Report UCB-ITS-TSRC-RR-2007-1, p.12.
22. West, Tristram O., and Wilfred M. Post. 2002. *Soil Organic Carbon Sequestration Rates by Tillage and Crop Rotation: A Global Data Analysis*. Soil Sciences Society. Am. J. 66:1930–1946, p.1930.
23. Ibid., p.4.
24. Murray, Brian et al, Kenneth Andrasko, and Benjamin DeAngelo, editors. 2005. *Greenhouse Gas Mitigation Potential in US Forestry and Agriculture,* US Environmental Protection Agency, p.27-28.
25. Oregon Department of Environmental Quality. 2006. *Oregon Air Quality Annual Report.* p.19.
26. American Lung Association. 2007. *Testimony of Deborah Shprentz, Consultant to the American Lung Association on EPA's Proposed Revisions to the National Ambient Air Quality Standards for Ozone 72 FR 37818*, Philadelphia, Pennsylvania, August 30, 2007.
27. Oregon Department of Environmental Quality. 2006. *Oregon Air Quality Annual Report.* p.41-43.
28. US Environmental Protection Agency. 2002. *A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions Draft Technical Report.* EPA420-P-02-001, p.5.
29. Morris, R.E. et al. 2003. *Impact of Biodiesel Fuels on Air Quality and Human Health,* Summary Report September 16, 1999–January 31, 2003. National Renewable Energy Laboratory, p.22.
30. McCormick, R.L. et al. 2006. *Effects of Biodiesel Blends on Vehicle Emissions.* National Renewable Energy Laboratory, MP-540-40554, p.iii.
31. Lacey, Steven. 2007. *Texas Biodiesel Ban Delayed.* Renewable Energy Access.com website, http://www.renewableenergyaccess.com/rea/news/story?id=47033 (posted January 8, 2007).
32. US Environmental Protection Agency. 2007. *Regulatory Impact Analysis: Renewable Fuel Standard Program*. EPA420-R-07-004, p.155

33. Allen, Paul et al. 1999. *Analysis of Air Quality Impacts if Use of Ethanol in Gasoline Public Review Draft.* California Air Resources Board, p.5.
34. US Environmental Protection Agency. 2007. *Regulatory Impact Analysis: Renewable Fuel Standard Program.* EPA420-R-07-004, p.155
35. Natural Resource Defense Council. 2006. *Unlocking the Promise of Ethanol: Promoting ethanol while protecting air quality.* Energy Facts fact sheet.
36. Jacobson, Mark Z. 2007. *Effects of Ethanol (E85) versus Gasoline Vehicles on Cancer and Mortality in the United States.* April 18 online edition of Environmental Science & Technology, 41(11), pp.4150-4157.
37. Hwang, Roland. 2007. *Natural Resources Defense Council Statement on New Study of Ethanol (E85) Impact on Air Quality,* April 26, 2007.
38. National Biodiesel Board. 1998. *Summary Results From NBB/USEPA Tier I Health and Environmental Effects Testing for Biodiesel Under the Requirements for USEPA Registration of Fuels and Fuel Additives* (40 Cfr Part 79, Sec 21 1 (B)(2) And 21 1 (E)): Final Report. p.2.
39. US Environmental Protection Agency. 1982. *Test guidelines: chemical fate--aerobic acquatic biodegradation.* Office of Toxic Substances of Pesticides and Toxic Substances, EPA 560/6-82-003.
40. Huntsinger, Teresa. 2007. *Cleaner Rivers for Oregon: Why Our Rivers Need Our Help,* Oregon Environmental Council.
41. Ongley, Edwin D. 1996. *Control of water pollution from agriculture - FAO irrigation and drainage paper.* Food and Agriculture Organization of the United Nations.
42. Malakoff, David. 1998. *Death by Suffocation in the Gulf of Mexico.* Science, Vol. 281, Issue 5374, p.190.
43. BBC News. 2007. *Gulf dead zone to be biggest ever.* http://news.bbc.co.uk/2/hi/science/nature/6904249.stm (posted July 18, 2007).
44. National Science and Technology Council Committee on Environment and Natural Resources. 2000. *Integrated Assessment of Hypoxia in the Northern Gulf of Mexico.*
45. Oregon Department of Environmental Quality. 2004. *Oregon's 2004 Water Quality Assessment,* Section 305(b) Report. ODEQ Water Quality Division, p.19.
46. Impacts of Climate Change on the Pacific Northwest scientific meeting, June 2004. *Scientific Consensus Statement on the Likely Impacts of Climate Change on the Pacific Northwest. Executive Summary.*
47. Keeney, Dennis and Mark Muller. 2006. *Water Use by Ethanol Plants: Potential Challenges.* Institute for Agriculture and Trade Policy, p.4.
48. Beeman, Perry. 2007. *Water use: Biofuel plants' thirst creates water worries.* Des Moines Register, June 3, 2007.
49. Ibid.
50. Oregon State University. 2006. *Oregon Biofuels and Biomass: Woody Biomass in Oregon – Current Uses, Barriers and Opportunities for Increased Utilization and Research Needs.* OSU Chemical Engineering Department, Institute for Natural Resources, and Oregon Wood Innovation Center.
51. Tilman, David et al. 2006. *Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass,* Science Vol. 314. No. 5805, pp.1598-1600.
52. US Fish and Wildlife Service. 2007. *Waterfowl Response to the Conservation Reserve Program and Swampbuster Provision in the Prairie Pothole Region,* 1992–2004.
53. Borst, Alan. 2006. *Bring It on Home: Local ownership of renewable energy helps 'keep it on the farm'.* US Department of Agriculture website. http://www.rurdev.usda.gov/rbs/pub/sep06/bring.htm (accessed October 16, 2007).
54. UK Department for Transport. 2006. *Project Proposal: Development of Environmental and Social Reporting Guidance on the Provenance of Biofuels Supplied Through the RTFO.* Project number PBIONL062365. http://www.dft.gov.uk/pgr/roads/environment/rtfo/secrtfoprogdocs/ecofysproposal (accessed October 16, 2007).
55. Turner, Brian et al. 2007. *Creating Markets for Green Biofuels: Measuring and Improving Environmental Performance.* UC Berkeley Institute of Transportation Studies, Report UCB-ITS-TSRC-RR-2007-1, p.38.
56. Ibid., p.38.
57. Ibid., p.40.
58. Ibid., p.38.
59. Kotrba, Ron. 2006. *Diversifying Energy Options.* Ethanol Producer Magazine, December.
60. Economic Development Department of Nevada website. *Clean Energy Companies in Nevada.* http://www.edawn.org/cleanenergy/press_kit/NV-Companies.pdf (accessed October 16, 2007), p.2.
61. US Department of Agriculture and US Department of Energy. 1998. *Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus.* National Renewable Energy Laboratory/SR-580-24089, UC Category 1503, p.33.
62. Carriquiry, Miguel, *US Biodiesel Production: Recent Developments and Prospects* Iowa Ag Review, Spring 2007, Vol. 13 No. 2, p.1. Many plants are designed to use multiple feedstocks depending on what is available at the lowest cost.
63. US Department of Agriculture and US Department of Energy. 1998. *Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus.* National Renewable Energy Laboratory/SR-580-24089, UC Category 1503, p.9.
64. Ibid., p.7.
65. Delucchi, Mark A. 2007. *Lifecycle Analysis of* CO_2*-Equivalent Greenhouse-Gas Emissions from Biofuels.* Presentation at Institute of Transportation Studies Seminar, Feb 2, 2007.
66. Delucchi, Mark A. 2003. *A Lifecycle Emissions Model (LEM): Lifecycle Emissions from Transportation Fuels, Motor Vehicles, Transportation Modes, Electricity Use, Heating and Cooking Fuels, and Materials.* Institute of Transportation Studies-Davis.
67. Chastain, Tom. 2006. *Oregon Agriculture and Potential Biodiesel Feedstocks.* Presentation at Oregon State University, Nov 20, 2006.
68. Jaeger, William K., Robin Cross, and Thorsten M. Egelkraut. 2007. *Biofuel Potential in Oregon: Background and Evaluation of Options.* Oregon State University Department of Agricultural and Resource Economics, p.iii.
69. Putnam, D.H. et al, J. Janick and J.E. Simon (editors). 1993. *Camelina: A promising low-input oilseed.* New crops, p.314-322.
70. Ibid.
71. Chastain, T.G. et al. *Biodiesel Feedstock Potential in the Willamette Valley.* Oregon State University, http://cropandsoil.oregonstate.edu/bioenergy/pdf/14.pdf (accessed October 15, 2007), p.46.
72. Ibid.

73. National Renewable Energy Laboratory. 2002. *Goals of the Mustard Project*. Presentation March 2001, http://www1.eere.energy.gov/biomass/pdfs/mustard_hybrids.pdf (accessed October 15, 2007).
74. Zah, Rainer et al (translated by Thomas Ruddy). 2007. *Life Cycle Assessment of Energy Products: Environmental Assessment of Biofuels - Executive Summary*. Written under contract for the Federal Office of Energy, Federal Office for the Environment, and Federal Office for Agriculture (Switzerland), p.IV.
75. Armstrong, A.P. et al. 2002. *Energy and Greenhouse Gas Balance of Biofuels for Europe - an update*. Prepared by the CONCAWE Ad Hoc Group on Alternative Fuels, p.9.
76. Brown, J., J.B. Davis, and A. Esser. 2005. *Pacific Northwest Condiment Yellow Mustard (Sinapis alba L.) Grower Guide 2000-2002*. National Renewable Energy Laboratory/SR-510-36307 Subcontract Report, p.1.
77. Dan O'Brien Associates. 2006. *Assessment of Biodiesel Feedstocks in Oregon*. Produced for the Portland Development Commission, p.16.
78. Chastain, Tom. 2006. *Oregon Agriculture and Potential Biodiesel Feedstocks*. Presentation at Oregon State University, Nov 20, 2006.
79. Zah, Rainer et al (translated by Thomas Ruddy). 2007. *Life Cycle Assessment of Energy Products: Environmental Assessment of Biofuels - Executive Summary*. Written under contract for the Federal Office of Energy, Federal Office for the Environment, and Federal Office for Agriculture (Switzerland), p.IV.
80. Personal communication with SeQuential Biofuels, July 2007.
81. US Department of Energy website. *Net Energy Balance for Bioethanol Production* and Use. http://www1.eere.energy.gov/biomass/net_energy_balance.html (accessed October 16, 2007).
82. Shapouri, H., J. Duffield, and A.J. Mcaloon. 2004. *The 2001 net energy balance of corn-ethanol*. Proceedings of the Conference on Agriculture as a Producer and Consumer of Energy, Arlington, VA., June 24-25, 2004, p.5.
83. Wang, Michael. 2005. *Updated Energy and Greenhouse Gas Emissions Results of Fuel Ethanol*. Presentation at The 15th International Symposium on Alcohol Fuels San Diego, CA September 26-28, 2005, Argonne National Laboratory.
84. Turner, Brian T. et al. *Creating Markets for Green Biofuels: Measuring and Improving Environmental Performance*. UC Berkeley Institute of Transportation Studies, Research Report UCB-ITS-TSRC-RR-2007-1.
85. Punter, Gary et al. 2004. *Well-to-Wheel Evaluation for Production of Ethanol from Wheat*. A Report by the LowCVP Fuels Working Group, WTW Sub-Group, FWG-P-04-024, p.22
86. Ibid.
87. Bend Weekly. 2007. *Taiwan wheat deal good news for Oregon growers*. Jun 15, 2007.
88. Shapouri, Hossein and Michael Salassi. 2006. *The Economic Feasibility of Ethanol Production from Sugar in the United States*. US Department of Agriculture.
89. Ibid., p.11.
90. US Department of Agriculture website. *Sugar and Sweeteners: Background*. Economic Research Service, http://www.ers.usda.gov/Briefing/Sugar/Background.htm (accessed October 16, 2007).
91. Gonsalves, Joseph B. 2006. *An Assessment of the Biofuels Industry in India*. United Nations Conference on Trade and Development, UNCTAD/DITC/TED/2006/6, p.5.
92. Zah, Rainer et al (translated by Thomas Ruddy). 2007. *Life Cycle Assessment of Energy Products: Environmental Assessment of Biofuels - Executive Summary*. Written under contract for the Federal Office of Energy, Federal Office for the Environment, and Federal Office for Agriculture (Switzerland), p.V.
93. National Agriculture Statistics Service website. 2006. *Oregon Potatoes*. http://www.nass.usda.gov/Statistics_by_State/Oregon/Publications/Field_Crop_Report/potatoes/05_16pt.pdf (accessed October 16, 2007).
94. Lutz, Amanda. 2006. *Turning Whey into a Renewable Fuel*. WSAW.com, http://www.wsaw.com/home/headlines/2739711.html (posted May 3, 2007).
95. Zah, Rainer et al (translated by Thomas Ruddy). 2007. *Life Cycle Assessment of Energy Products: Environmental Assessment of Biofuels - Executive Summary*. Written under contract for the Federal Office of Energy, Federal Office for the Environment, and Federal Office for Agriculture (Switzerland), p.V.
96. Hord, Bill. 2007. *The future is not now for biomass ethanol industry*. Omaha-World Herald, March 27, 2007.
97. US Department of Agriculture and US Department of Energy. 2005. *Biomass as feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*.
98. Tilman, David et al. 2006. *Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass*, Science Vol. 314. No. 5805, pp.1598-1600.
99. Oregon State University. 2006. *Oregon Biofuels and Biomass: Woody Biomass in Oregon – Current Uses, Barriers and Opportunities for Increased Utilization and Research Needs*. OSU Chemical Engineering Department, Institute for Natural Resources, and Oregon Wood Innovation Center, p.39.
100. Washington State University, Cooperative Extension. 1999. *Crop Profile for Hybrid Poplar in Oregon and Washington*.
101. Purdue University website. *Fast-growing trees could take root as future energy source*. http://www.purdue.edu/UNS/html4ever/2006/060823.Chapple.poplar.html (posted August 23, 2006).
102. Jaeger, William K., Robin Cross, and Thorsten M. Egelkraut. 2007. *Biofuel Potential in Oregon: Background and Evaluation of Options*. Oregon State University Department of Agricultural and Resource Economics, p.11.
103. Adler, Paul R., Stephen J. Del Grosso, and William J. Parton. 2007. *Life-Cycle Assessment of Net Greenhouse-Gas Flux for Bioenergy Cropping Systems, Ecological Applications*, 17(3), pp.687.
104. Oregon State University. 2006. *Oregon Biofuels and Biomass: Woody Biomass in Oregon – Current Uses, Barriers and Opportunities for Increased Utilization and Research Needs*. OSU Chemical Engineering Department, Institute for Natural Resources, and Oregon Wood Innovation Center, p.39.

105. Ibid.
106. Togkoz et al. 2007. *Emerging Biofuels: Outlook of Effects on U.S. Grain, Oilseed, and Livestock Markets. Iowa State University Center for Agricultural and Rural Development*, p.3-4.
107. Andrews, Susan S. 2006. *Crop Residue Removal for Biomass Energy Production: Effects on Soils and Recommendations.* USDA-Natural Resource Conservation Service White Paper.
108. Adler, Paul R., Stephen J. Del Grosso, and William J. Parton. 2007. *Life-Cycle Assessment of Net Greenhouse-Gas Flux for Bioenergy Cropping Systems*, Ecological Applications, 17(3), pp.687.
109. Poet Energy website. *Cellulosic ethanol*. http://www.poetenergy.com/learn/cellulosic.asp (accessed October 16, 2007).
110. Graf, Angela and Tom Koehler. 2000. *Oregon Cellulose-Ethanol Study: An Evaluation of the Potential for Ethanol Production in Oregon using Cellulose-Based Feedstocks*. Produced for the Oregon Office of Energy, p.11-12.
111. Nilles, David. 2006. *Time Testing*, Ethanol Producer Magazine, May, 2006.
112. Graf, Angela and Tom Koehler. 2000. *Oregon Cellulose-Ethanol Study: An Evaluation of the Potential for Ethanol Production in Oregon using Cellulose-Based Feedstocks.* Oregon Office of Energy, p.10.
113. Oregon State University. 2006. *Oregon Biofuels and Biomass: Woody Biomass in Oregon – Current Uses, Barriers and Opportunities for Increased Utilization and Research Needs.* OSU Chemical Engineering Department, Institute for Natural Resources, and Oregon Wood Innovation Center, p.37.
114. Ibid.
115. International Energy Agency. 2002. *Sustainable Production of Woody Biomass for Energy*, Position Paper was prepared by the Executive Committee of IEA.
116. Sheehan, John, et al. 1998. *A Look Back at the US Department of Energy's Aquatic Species Program—Biodiesel from Algae*. National Renewable Energy Laboratory, p.iii.
117. Ibid., part I, p.18.
118. Biopact website. 2007. *South African algae biofuels company breaks down*. http://biopact.com/2007/06/south-african-algae-biofuels-company.html (posted June 15, 2007).
119. Renewable Energy Access website. 2007. *Biodiesel from Algae, Powered by Geothermal*. http://www.renewableenergyaccess.com/rea/news/story?id=48504 (posted May 15, 2007).
120. XL Renewables website. 2007. *Algae – XL Future Feedstock*. http://www.xldairygroup.com/biodetail.cfm?ContentKey=494 (accessed October 16, 2007).
121. Holliday, Lucy. 2005. *Rye-Grass as an Energy Crop Using Biogas Technology*. UK Department for Business Enterprise and Regulatory Reform, Executive Summary, p.2.
122. Biomass One website. http://www.biomassone.com (accessed October 16, 2007).

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