



Agenda Item B1

Fuels Assessment Discussion Paper

For Low Carbon Fuel Advisory Committee Input

April 2010

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Purpose

This document contains a description of some of the alternative fuels that are likely to be used to comply with an Oregon low carbon fuel standard. The purpose of this fuels assessment is to provide background on alternative fuel production, use, and commercialization status which will assist the advisory committee with giving DEQ input on feasible volumes of alternative fuels produced, available, or used between now and 2022. DEQ welcomes additional data or information which will assist with this effort. The goal of the April 15, 2010 low carbon fuel advisory committee meeting is to bound high and low possible amounts of alternative fuels used, so DEQ will be asking the advisory committee for low, medium and high (but feasible) estimates for alternative fuels use in Oregon in 2022.

In giving input on the estimates, it should be considered that alternative fuel use would increase under a low carbon fuel standard above amounts required by existing regulations or predicted by historic increases. There are several pieces of information that can inform our fuel estimates. For example, estimates could be based on:

- Regulations applicable to an alternative transportation fuel or alternative-fueled vehicle, such as the federal Renewable Fuel Standard 2 requirement for biofuels or the Oregon low emission vehicle rule (which will increase the number of electric vehicles on the road);
- Historic increases in alternative fuel use; or
- Evaluating alternative fuel use trends in other countries, states, or areas that use large volumes of an alternative fuel or vehicles can help us identify feasible adoption rates for both light-duty passenger vehicles¹ and medium/heavy-duty vehicle applications. It will be important to examine the context that helped produce the large volume of use of an alternative fuel;
- Predictions of future use;
- Studies and expert evaluation; and
- Compliance scenario methodologies for LCFS used by Washington, East Coast/Mid-Atlantic States, and California.

The estimates of feasible volumes of alternative fuel used in Oregon between now and 2022 will be used to develop compliance scenarios, which will in turn be used in the low carbon fuel standard economic analysis.

¹ Light-duty vehicles include passenger cars and light trucks, including minivans, sport utility vehicles (SUVs) and trucks with gross vehicle weight less than 8,500 pounds.

Advisory Committee Questions

This document is intended to begin the process of generating input from the advisory committee members on the following questions. At the April 15, 2010 meeting, experts on transportation uses of natural gas and electricity, as well as biofuel production, will present information and be available for advisory committee questions. DEQ has made a preliminary estimate of low, moderate and high use for some alternative fuels between now and 2022. DEQ expects to revise these after input from the low carbon fuel advisory committee.

General question: Have we missed any fuels or production processes you think will be used to produce substantial volumes of fuels by 2022? If so, please email [Sue Langston](mailto:Sue.Langston@deq.or.gov) with the name of the fuel and production process, a short description of the production process, and the number and location of pilot/demonstration/commercial plants, either in the US or the world. Please note that a fuel does NOT need to be included in this assessment to be included in the Oregon low carbon fuel standard program.

Ethanol questions:

- How many **flex fuel vehicles** (vehicles that can use either gasoline or ethanol blends up to 85%) are likely to be on the road, given current trends? Please consider low, medium, and high estimates that will be feasible from now through 2022. *(For DEQ's preliminary low and high estimates of flex fuel vehicle use, please see section on Starch- and Sugar-Based Ethanol beginning on page 12)*
- When is commercial production of **cellulosic ethanol** production likely to start? What is the range of volume that will be available, given feedstocks in Oregon and the Pacific Northwest? Please consider low, medium, and high estimates that will be feasible from now through 2022. *(For DEQ's preliminary low and high estimates of cellulosic ethanol availability, please see the section on Cellulosic Ethanol beginning on page 21)*

Diesel questions:

- What are likely **volumes of biodiesel (FAME)** that can be made available, given feedstocks in Oregon and the Pacific Northwest? Please consider low, medium, and high estimates that will be feasible from now through 2022. *(For DEQ's preliminary low and high estimates of biodiesel availability, please see the section on Biodiesel (FAME) beginning on page 29)*
- How much **5% biodiesel (B5), 10% biodiesel (B10), 20% biodiesel (B20), 99% biodiesel (B99), and 100% biodiesel (B100)**, will be used in the future, given current trends? Please consider low, medium, and high estimates that will be feasible from now through 2022 for light-duty passenger car use and medium- and heavy-duty applications. *(For DEQ's preliminary low and high estimates of higher biodiesel blend use, please see the section on Biodiesel (FAME) beginning on page 29)*

- What is a reasonable estimate of when **renewable diesel (hydrogenation-derived)** will be fully commercialized and available in OR? What are likely volumes of renewable diesel that can be made available, given feedstocks in Oregon and the Pacific Northwest? Please consider low, medium, and high estimates that will be feasible from now through 2022. *(For DEQ's preliminary low and high estimates of renewable diesel availability, please see the section on Renewable Diesel beginning on page 35)*
- What is a reasonable estimate of when **Fisher-Tropsch diesel** will be fully commercialized and available in OR? What are likely volumes of Fisher-Tropsch diesel that can be made available, given feedstocks in Oregon and the Pacific Northwest? Are there any other synthetic fuel production processes that we should consider? Please consider low, medium, and high estimates that will be feasible from now through 2022. *(For DEQ's preliminary low and high estimates of Fisher-Tropsch diesel availability, please see the section beginning on page 39)*

Electricity questions:

- How many **electric vehicles** (full-battery) are likely to be on the road in 2022? What penetration rate is feasible in Oregon? Please consider low, medium, and high estimates that will be feasible from now through 2022. *(For DEQ's preliminary low and high estimates of electric vehicle use, please see the section on Electricity beginning on page 44)*
- How many **plug-in hybrid electric vehicles** (vehicles that run on either gasoline or electricity) are likely to be on the road in 2022? What penetration rate is feasible in Oregon? Please consider low, medium, and high estimates that will be feasible from now through 2022. *(For DEQ's preliminary low and high estimates of plug in hybrid electric vehicle use, please see the section on Electricity beginning on page 44)*

Compressed Natural Gas questions:

- What volume of **compressed natural gas** will be used in the future, given the current status of fueling infrastructure and trends in use? Please consider low, medium, and high estimates that will be feasible from now through 2022 for both heavy-duty and light-duty applications. *(For DEQ's preliminary low and high estimates of CNG use, please see the section on CNG beginning on page 51)*
- What are the prospects for residential and public CNG refueling?

Other fuels questions:

- Will **biogas, hydrogen, or liquefied natural gas (LNG)** be used in significant volumes in the future?
- What about **butanol or biobutanol**?
- Are there any other alternative fuels we should consider in large volumes for the compliance scenarios? For example, fuels made from algae.

Fuels Covered

There are many types of fuels that could be used to comply with an Oregon low carbon fuel standard. This document provides background on some of the various fuels which could potentially be supplied to Oregon so that the advisory committee can have adequate background to give input. DEQ would like to acknowledge Oregon Department of Energy's substantial contribution toward writing many of these fuel assessments. This fuels assessment covers the following fuels and feedstocks:

Ethanol

1. Starch- and Sugar-Based Ethanol
2. Cellulosic Ethanol

Diesel

3. Biodiesel (FAME)
4. Renewable Diesel (Hydrogenation-Derived)
5. Fisher-Tropsch and Other Synthetic Fuels (such as synthetic diesel, cellulosic diesel, or synthetic gasoline)

Electricity

6. Electricity

Natural Gas

7. Biogas
8. Compressed Natural Gas (CNG)
9. Liquefied Natural Gas (LNG)

Other

10. Biobutanol/Butanol
11. Hydrogen
12. Algae

Contents of Each Fuel's Assessment

- **Feedstock and Production Process.** For each of these fuels listed above, we give a brief description of the feedstock which can be used to make the fuel, and of the production process or processes. We also list additional materials produced during the manufacturing of a fuel. These "co-products" can displace the need for other materials to be manufactured and thereby have a significant effect on a fuel's carbon intensity.
- **Commercialization Status of Fuel and Vehicles.** Next, we describe the commercialization status of the fuel. This includes information on whether the fuel is

still in the early development stages and essentially has only been produced in a laboratory, whether it is in the initial stages of commercialization (for example, it has been produced at a pilot or demonstration scale), or whether it is fully commercialized and developed to the point at which its production and sale becomes economically feasible.

- **Production.** For each fuel, we also discuss statistics on production. We look at the current production or capacity for production in Oregon, whether there is potential for more production in Oregon based on the feedstock available, and then discuss production volumes or capacity in the rest of the United States or the world, if applicable.
- **Use of Fuel for Transportation Purposes.** Next, the fuel assessments contain (if information is available) a discussion of the current use of the fuel in Oregon, focusing on the volume used, the number of vehicles using the fuel, the existing infrastructure for the fuel, and any barriers to expansion or special issues.
- **Summary of Known Trends.** This section covers available data on trends in the use of the fuel for transportation, the production of the fuel (if relevant), and the use, availability or production of alternative-fueled vehicles. Where available, information is provided that is specific to trends in Oregon or the United States. For some fuels, data was not collected until recently. For example, the U.S. Energy Information Administration did not start collecting data on CNG used as a transportation fuel until 2004. For most fuel, information is not yet available for 2008 or 2009, although there are some exceptions.
- **Preliminary Estimates of 2022 Use.** This section contains estimates of future use, based on the trends in Oregon, the United States, or the world. Based on historic trends in fuel or vehicle use, regulatory requirements, studies, adoption rates in other areas, expert opinions, and methodologies used by others, DEQ has proposed a draft, preliminary estimate for low, moderate and high use in 2022 for some of the alternative fuels. The purpose is to solicit advisory committee input, data, discussion and feedback. **DEQ intends to revise the estimates of alternative fuel and vehicle use after input and data have been obtained from the low carbon fuel advisory committee.**
- **References and Further Reading.** Lastly, each fuel assessment contains references to the data, studies or reports from which the fuel assessment is developed. There are references and links for further reading at the end of each fuel assessment, should you want more information. If you are reviewing an electronic copy of this document and you are online, you can click on any reference to be taken to the original source.

Summary of Fuels Assessment Discussion Paper

Several of the fuels we assessed are not likely to be commercialized prior to 2022. California categorized these as “Long-Term – Technologies Projected after 2020².” The fuels assessment contains brief descriptions of these. Some fuels, such as hydrogen, are not likely to be used in Oregon in significant volumes due to infrastructure issues. Based on information available to date, DEQ does not anticipate using the following fuels in our compliance scenarios for Oregon:

- Liquefied Natural Gas
- Hydrogen
- Biofuels from algae

If you have information that indicates that a fuel listed above (or other fuels not included in this fuels assessment) will be used in Oregon or commercialized and produced in substantial volumes by the year 2022, please share that information with [Sue Langston](#), and include the name of the fuel and production process, a short description of the production process, the number and location of pilot/demonstration/commercial plants, and any information helpful to evaluating the potential for use in 2020.

The following three tables summarize the information found in the assessments for each fuel, such as commercialization status, production, and use of the fuels which are likely to be commercially produced and available within the low carbon fuel standard timeline. For more details, please refer to each fuel assessment.

Table 1 summarizes commercialization status and production information for alternative fuels.

Table 2 summarizes proposed low, moderate and high estimates of alternative fuels use in 2022. **These are for discussion purposes only.** DEQ intends to revise these after input from the low carbon fuel advisory committee.

Table 3 summarizes proposed low, moderate and high estimates of alternative fueled vehicles in 2022. **These are for discussion purposes only.** DEQ intends to revise these after input from the low carbon fuel advisory committee.

² California Air Resources Board (CARB) Proposed Regulation to Implement the Low Carbon Fuel Standard, Volume II: Appendices. Appendix B: Supporting Documentation For The Technology Assessment
http://www.arb.ca.gov/fuels/lcfs/030409lcfs_isor_vol2.pdf

Table 1: Summary Table for Alternative Fuels. Details and references for each fuel and information cited are found in the fuel assessments. For fuel used only in alternative-fueled vehicles (flex fuel vehicles which use E85, electricity, CNG, LNG and hydrogen) please see “Table 3: Summary Table for Alternative Fueled Vehicles in Oregon in 2022” on page 9.

Fuel	Commercialization of fuel			Production of Fuel			Planned Facilities
	Number of Commercial Plants in US	Number of Commercial Plants in World	Number of Pilot or Demonstration Plants in US	Oregon Production Capacity (Million gal per year)	U.S. Production Capacity (Million gal per year)	World Production (Million gal per year)	Planned Oregon production (Million gal per year)
Starch- and Sugar-Based Ethanol	189 (2 in Oregon)	Unknown	Not Applicable.	41.4 (in 2010)	11,930 (in 2009)	17,335 (in 2008)	Unknown
Cellulosic Ethanol	0 currently	0 currently	26 pilot, demo, or commercial plants under construction	0 currently	Small*	Small*	2 pilots 25-50 commercial
Biodiesel (FAME)	173 (6 in Oregon)	Unknown	Not Applicable.	7	2,690	Unknown	1 (0.27 capacity)
Renewable Diesel (Hydrogenation-Derived)	0 currently 2 under construction 2 planned (in 2009)	2	Unknown	0 currently	0 currently planned: 385 (in 2009)	130 planned: 930 (in 2009)	0 (1 planned in WA)
Fisher-Tropsch	0 currently	4	At least 2	0 currently	Small*	3659 (capacity: 2009)	0
Biogas	Unknown	Unknown	Unknown	(34 facilities)	Unknown	Unknown	
Biobutanol	0 currently	0 currently	At least 4	0 currently	1**	1.01**	1 pilot
Algae	0 currently	0 currently	Unknown	0 currently	0 currently	Unknown	0 currently

* Some demonstration and pilot projects are currently producing and selling fuel.

** Only some of this is used for transportation purposes

Table 2: Summary table for projected alternative fuel use in Oregon in 2022. Details and references for each fuel and information cited are found in the fuel assessments.

Fuel	Trends	Low estimate of 2022 use and rationale	Moderate estimate of 2022 use and rationale	High estimate of 2022 use and rationale
Starch- and Sugar-Based Ethanol (waste)	Production fully commercialized.	1.5 million gallons Based on current OR capacity.	There is potential for a pilot/demonstration scale plant.	There is potential for a commercial plant to be built, depending on feedstocks.
Starch- and Sugar-Based Ethanol (crops)	Production fully commercialized.	40 million gallons Based on current OR plants in operation.	40 million gallons Based on current OR plants in operation	145.5 million gallons Based on current existing OR plants
Cellulosic Ethanol (consider waste vs. crops)	Commercial facilities are under construction. Production not commercialized. Many pilot/ demonstration projects.	58 million gallons Based on RFS2 EPA estimates. (Primary Control Case)	189 million gallons Based on RFS2 EPA estimates. (High Ethanol Control Case)	244 million gallons Based on EPA Table 1.8-14: Projected Cellulosic Ethanol Volumes by State. Urban waste: 44 million. Forest: 200 million gallons.
Biodiesel (FAME) (consider waste vs. crops)	Production fully commercialized.	Based on OR's future 5% renewable fuel standard, 26.5 million gallons	Moderate and high estimates of biodiesel availability in Oregon could be based on trends in biodiesel production, volume or feedstocks available regionally, federal RFS2 required volumes, or future predictions of use.	
Renewable Diesel (Hydrogenation-Derived)	Production fully commercialized.	Zero It is possible no renewable diesel will be available in Oregon.	25 – 100 million gallons Based on proposed project and potential for project to supply some fuel to Oregon.	100-500 million gallons Based potential for commercial production by a WA refiner.
Fisher-Tropsch from coal or gas	Production fully commercialized.	Zero Based on little incentive from RFS2 or LCFS.	Zero Based on little incentive from RFS2 or LCFS.	Zero Based on little incentive from RFS2 or LCFS.
Fisher-Tropsch or other synthetic diesel from biomass or waste	Production process under development.	77 million gallons Based on RFS2 EPA estimates (Primary Control Case).	110 million gallons Based on RFS2 EPA. (Low Ethanol Case)	150-300 million gallons Based on commercialization status, commercial scale facilities could be built.
Biogas	Production fully commercialized.	Zero Based on historic and current use.	1/2 of remaining unused biogas potential in Oregon.	3/4 of remaining unused biogas potential in Oregon.
Biobutanol or butanol	Production not commercialized. No commercial facilities under construction.	Zero Based on commercialization status.	10 to 25 million gallons Based on the proposed biobutanol plant in Oregon.	25 to 75 million gallons There is potential for commercial production to be built and producing by 2022.
Algae	Production not commercialized. Few pilot projects, many issues.	Zero Based on commercialization status.	Zero Based on commercialization status.	Zero Based on commercialization status.

Table Sources:

US EPA. Renewable Fuel Standard Program (RFS2) Final Regulatory Impact Analysis. 2/2010. <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>
 Primary Control Case: page 71. High Ethanol Case: page79. Low Ethanol Case: page 78. Table 1.8-14: Projected Cellulosic Ethanol Volumes by State: page 277

Table 3: Summary Table for Alternative Fueled Vehicles in Oregon in 2022. Details for each fuel and information cited are found in the fuel assessments. The low, moderate, and high estimates are for discussion purposes only. DEQ intends to revise these based on low carbon fuel advisory committee input or any additional data provided.

Vehicles	Low estimate – 2022	Moderate estimate - 2022	High estimate – 2022
<p>Flex fuel vehicles (use gasoline with blends up to 85% ethanol)</p> <p>Oregon stats:</p> <ul style="list-style-type: none"> • 9 public fueling stations • 100,000 flex fuel vehicles (2009) <p>Commercialization status: <u>Light-duty (passenger):</u> 31 new models offered in 2008. Fully commercialized and becoming more available.</p>	<p>Estimates for number of flex fuel vehicles, E85 consumption, and access to E85 fueling stations could be based on:</p> <p>Historic use, EIA predictions, the rate of change in other areas with high ethanol use, on future predictions, or on the “Low Ethanol Control Case” from RFS2.³</p>	<p>The rate of change in other areas with high ethanol use, on future predictions, or on the “Primary Control Case” from RFS2.³</p>	<p>The rate of change in other areas with high ethanol use, on future predictions, or on the “High Ethanol Control Case” from RFS2.³</p>
<p>Electric vehicles</p> <p>Oregon stats:</p> <ul style="list-style-type: none"> • Aprox. 30 public fueling stations • 1636 vehicles (2007) <p>Commercialization status: <u>Light-duty (passenger):</u> Electric vehicles are on the verge of wide commercialization. 9 full-function electric vehicles or plug-in hybrid electric vehicles are due to be launched by 2011 (in addition to low-speed and neighborhood vehicles). <u>Medium/heavy- duty:</u> Four heavy-duty plug-in vehicles are currently available with two more coming to market in 2010. For some applications, such as forklifts, there are many models available.</p>	<p>Based on Oregon’s Low Emission Vehicle rules, a minimum of approximately 12,000 full battery electric vehicles and 17,000 plug-in-hybrid electric vehicles must be placed in Oregon in by 2022.⁴</p>	<p>Moderate and high estimates could be based on future electric vehicle predictions from consultants, government or auto manufacturers.</p>	

³ US EPA. Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis. Pages 71, 78 and 79. <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

⁴ Dave Nordberg, ODEQ. Minimum Number Electric Vehicles Required in Oregon by ZEV Rules, 4/5/2010.

Vehicles	Low estimate – 2022	Moderate estimate – 2022	High estimate – 2022
<p>Compressed Natural Gas (CNG)</p> <p>Oregon stats:</p> <ul style="list-style-type: none"> • 2 public fueling stations • 9-10 other fueling stations • 1500 vehicles (2007) <p>Commercialization status: <u>Light-duty:</u> 1 new model available in 2008. Commercialized, but becoming less available.</p> <p><u>Medium/ heavy-duty:</u> commercialized and available for applications such as buses, step vans and trucks.</p>	<p>A low estimate could be based on the historic rate of increase for CNG use in Oregon or the US, or on future predictions. Most of the increase would likely be in the medium-duty vehicle range.</p>	<p>Moderate and high estimates could be based on several different sources of information, such as future electric vehicle predictions from consultants, natural gas associations, government or natural gas vehicle manufacturers.</p>	
<p>Liquefied Natural Gas (LNG)</p> <p>Oregon stats:</p> <ul style="list-style-type: none"> • No vehicles • No fueling stations <p>Commercialization status: <u>Light-duty:</u> not commercialized <u>Medium/ heavy-duty:</u> commercialized and available for applications such as refuse haulers, local delivery, and transit buses.</p>	<p>Zero Based on the historic use and lack of fueling infrastructure, DEQ proposes not to include any LNG in the compliance scenarios for the low carbon fuel standard.</p>		
<p>Hydrogen</p> <p>Oregon stats:</p> <ul style="list-style-type: none"> • No vehicles • No fueling stations <p>Commercialization status: Not commercialized</p>	<p>Zero Based on the historic use, commercialization status, and lack of fueling infrastructure, DEQ proposes not to include any LNG in the compliance scenarios for the low carbon fuel standard.</p>		

Starch- and Sugar-Based Ethanol

Feedstock and production process

Feedstock. According to the US Department of Energy: “The vast majority of today's ethanol is derived from starch- and sugar-based feedstocks. The sugars in these feedstocks are relatively easy to extract and ferment using widely available biochemical conversion technologies, making large-scale ethanol production affordable. Starch-based feedstocks include plants such as corn, wheat, and milo. The starches in these plants are chains of sugars that can be broken down into simple sugars before fermentation. Sugar-based feedstocks, such as sugar cane, sorghum and sugar beets, contain simple sugars that can be extracted and fermented readily. Corn is used for more than 90 percent of current U.S. ethanol production. Brazil, the world's second-largest ethanol producer behind the United States, uses sugar cane as a feedstock.⁵

Starch- and sugar- based ethanol can also be made from waste starch and sugar products such as food processor and agricultural wastes or food store spoilage.

Production process. Corn ethanol is produced using either a dry-mill or wet-mill process. The difference between the two processes is the initial treatment of the biomass. Wet-mill facilities were common in the industry's early days, but now dry-mill facilities account for more than 80 percent of industry capacity. Dry-mill plants are typically smaller than wet-mill plants and use less energy per gallon of ethanol produced.⁶

- **Corn ethanol by dry-mill process:** First the corn is ground into a powdered meal, which is then mixed with water and enzymes to convert the starch into fermentable sugars. Yeast is added to ferment the sugars into ethanol. After distillation to separate the alcohol from the remaining water and solids, a denaturant such as gasoline is added to make the alcohol unfit for human consumption.
- **Corn ethanol by wet-mill process:** The corn grain is first soaked in hot water to separate the protein and starch. The product is then coarsely ground, and the germ is separated to be processed into corn oil. Next, the remaining slurry, which contains gluten, starch, and fiber, is finely ground and separated so the fiber can be blended into animal feed and the starch/gluten mixture can be further processed. The starch is then dried to make corn starch or

⁵ US Department of Energy (US DOE) website. http://www.afdc.energy.gov/afdc/ethanol/feedstocks_starch_sugar.html

⁶ US DOE website. http://www.afdc.energy.gov/afdc/ethanol/production_starch_sugar.html

	<p>processed to produce sugars, corn syrup, and beverage sweeteners. The sugars are then fermented to produce ethanol.⁷</p> <ul style="list-style-type: none"> • Ethanol from waste starches and sugars: Waste products from food processors may arrive at the plant in mainly solid form (for example, fruit “seconds” that are unsuitable for sale), or may already contain a substantial amount of water (for example, wastewater from processing potatoes). If needed, the solids are ground, and then in the case of starchy wastes, enzymes are added to convert the starch into fermentable sugars. Appropriate strains of yeast are added to ferment the sugars into ethanol, and the ethanol is separated by distillation and a denaturant is added to prevent human consumption.
<p>Co-products</p>	<p>Dry-mill process: The two main co-products associated with the dry-mill production of ethanol are distillers grain and carbon dioxide. Distillers grain (wet or dry solids and liquids remaining after distillation), is generally recombined for sale as high-protein animal feed. Some facilities also incorporate dryers to remove the moisture from the wet distillers grains and to extend its shelf life. This dried co-product is called dried distillers grain with solubles. The CO₂ co-product is commonly captured and marketed to the food processing industry for use in carbonated beverages or the production of dry ice.⁸</p> <p>Wet-mill process: The main products of the wet-mill process are corn sweeteners such as high fructose corn syrup; however they also produce corn ethanol, corn oil, animal feed, and cornstarch.⁹</p> <p>Waste starches and sugars: There is potential for co-products from this production process, however not much work has been done in this area.</p>
<p>Commercialization status</p> <ul style="list-style-type: none"> • Fuel • Vehicles 	<p>Fuel. The production of ethanol from starch and sugar crops (such as corn and sugarcane) is fully commercialized. Production of ethanol from waste starches and sugars is in an early stage of commercialization, with some wastes (such as potato processing wastewater and waste berries) already converted into ethanol on a small commercial scale. More work is needed to perfect production processes for other waste starches and sugars.</p> <p>Vehicles.</p> <p>Gasoline vehicles. Existing gasoline vehicles can use a blend containing</p>

⁷ US DOE, Alternative Fuels & Advanced Vehicles Data Center.

http://www.afdc.energy.gov/afdc/ethanol/production_starch_sugar.html

⁸ US DOE, Alt Fuels & Advanced Vehicles Data Ctr. http://www.afdc.energy.gov/afdc/ethanol/production_starch_sugar.html

⁹ US DOE, Alt Fuels & Advanced Vehicles Data Ctr. http://www.afdc.energy.gov/afdc/ethanol/production_starch_sugar.html

	<p>up to 10 percent ethanol. They are fully commercialized.</p> <p>Flex fuel vehicles. Flex fuel vehicles can be filled with either gasoline or a gasoline blend of 85 percent ethanol (E85). Flex fuel vehicles can use blends from all gasoline to an 85 percent ethanol/ 15 percent gasoline blend. Flex fuel vehicles are becoming increasingly available, and GM and Ford have said that by 2012, half of the vehicles they offer for sale will be flex fuel vehicles.¹⁰</p>
<p>Current production in Oregon</p>	<p>Oregon ethanol production capacity is presently at 149.5 million gallons per year, however only 41.5 million gallons per year are operational.</p> <p>Cascade Grain Products, LLC Plant location: Clatskanie, Oregon Status: Currently not operational, Auction scheduled for December 2009 under Chapter 7 Capacity: 108 million Gal/yr Process: Dry-mill, natural gas, DDGS Feedstock: Corn</p> <p>Pacific Ethanol, Inc Plant location: Boardman, Oregon Status: Operational Capacity: 40 million Gal/yr Process: Dry-mill, natural gas, WDGS Feedstock: Corn</p> <p>Summit Natural Energy Plant location: Cornelius, Oregon Status: Operational Capacity: 1.5 million Gal/yr Process: Biochemical Feedstock: Agricultural waste</p>
<p>Potential production in Oregon</p>	<p>Oregon has very limited ability to grow corn. However, given Oregon’s location along rail transport lines from the Midwest to Pacific ports, Oregon could potentially produce large quantities of ethanol using Midwestern corn.</p> <p>Oregon does have additional ability to produce ethanol from waste starches and sugars, particularly from food processing. However, knowledge of the amount of potentially available feedstock is sparse, and there are two categories of difficulties to overcome: intermittent availability of potential feedstocks, tied to seasonal harvests; and finding suitable yeasts and</p>

¹⁰ For links to the GM and Ford commitments for flex fuel vehicles, please visit: http://www.afdc.energy.gov/afdc/vehicles/flexible_fuel_availability.html

	<p>enzymes for each specific feedstock to optimize fermentation. See the Oregon Biomass Assessment report prepared for the April 15, 2010 Advisory Committee meeting for information on Oregon’s potential for producing biomass. http://www.deq.state.or.us/aq/committees/advcomLowCarbonFuel.htm)</p>
<p>Out-of-state production</p>	<p>In Idaho, 65 million gallons per year is currently operational.</p> <p>Pacific Ethanol, Inc Plant location: Burly, Idaho Status: Operational (restarted production in December 2009 after coming out of Chapter 11) Capacity: 60 million Gal/yr Process: Dry-mill, natural gas, WDGS Feedstock: Corn</p> <p>Idaho Ethanol Processing, LLC Plant location: Caldwell, Idaho Status: Operational Capacity: 5 million Gal/yr Process: Biochemical, natural gas Feedstock: Food processing and agricultural waste According to the Renewable Fuels Association (RFA)¹¹ as of October 2009 the U.S. has an ethanol production capacity of 13,131.4 million gallons per year of which 11,930.4 million gallons per year is operational. Another 1,432 million gallons per year capacity is under construction or expansion. The world in 2008 produced approximately 17,335 million gallons of ethanol.¹²</p> <p>Several small facilities produce ethanol from waste sugars and starches such as potato processing waste and brewery waste.¹³</p>
<p>Current use in Oregon</p> <ul style="list-style-type: none"> • Volume • Number of vehicles 	<p>Volume. Over 150 million gallons of ethanol is used annually in Oregon.¹⁴ A 10 percent ethanol blend is required by the Oregon renewable fuel standard, with some exceptions.¹⁵</p> <p>Number of vehicles. Any gasoline vehicle can use up to 10 percent</p>

¹¹ Renewable Fuels Association website. <http://www.ethanolrfa.org/industry/statistics/>

¹² Renewable Fuels Association website. <http://www.ethanolrfa.org/industry/statistics/#E>

¹³ US EPA. Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis. Page 130.
<http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

¹⁴ Rick Wallace, ODOE, personal communication

¹⁵ Oregon Department of Agriculture (ODA) website. http://www.oregon.gov/ODA/MSD/renewable_fuel_standard.shtml

<ul style="list-style-type: none"> • Existing fueling infrastructure • Barriers to expansion • Special issues 	<p>ethanol. Flex fuel vehicles can use up to 85 percent ethanol (E85). There are over 100,000 flex fuel vehicles in Oregon.¹⁶ In the US in 2007, E85 accounted for an estimated 54 million gallons of gasoline equivalent.¹⁷</p> <p>Existing fueling infrastructure. Over 99 percent of the gasoline dispensers in Oregon dispense a 10 percent ethanol blend. At present there are nine stations that offer E85.¹⁸</p> <p>Barriers to expansion. The main barriers to expanded use of ethanol in Oregon are the small market share of flex fuel vehicles and the small number of E85 fueling stations.</p> <p>The use of ethanol in blends above E10 has been seriously restricted by the failure of pumps handling higher concentrations to gain Underwriter’s Laboratory¹⁹ approval (a product safety certification company). Recently, Underwriter’s Laboratory approved a pump for up to 25% blends of ethanol²⁰. It is possible that this barrier to the use of E85 will be overcome in the future, allowing E85 to be more widely available.</p> <p>Special issues. Ethanol produced from waste starches and sugars qualifies as an “advanced biofuel” under the federal RFS2, potentially giving producers a commercial boost.</p>
<p>Summary of known trends:</p> <ul style="list-style-type: none"> • Volume produced • Volume used • Number of vehicles 	<p>Trends in Ethanol</p> <p>Volume produced</p> <p>Trend #1: Ethanol produced from starch and sugars is an example of how quickly a new fuel can go from very low production to large production volumes. Ethanol production in the United States has increased from 954 million gallons of gasoline equivalent in 1998 to 6,230 million gallons of gasoline equivalent in 2008.²¹</p> <p>Trend #2: The same decade has seen three ethanol plants open (and one close) in Oregon.</p> <p>Volume used</p> <p>It is unknown how much E85 is used in Oregon.</p> <p>Number of flex fuel vehicles. (Flex fuel vehicles are cars or trucks</p>

¹⁶ Rick Wallace, Oregon Department of Energy (ODOE), personal communication 2/2010

¹⁷ US DOE, Alt Fuels & Advanced Vehicles Data Ctr. <http://www.afdc.energy.gov/afdc/data/fuels.html>

¹⁸ US DOE, Alt Fuels & Advanced Vehicles Data Ctr. <http://www.afdc.energy.gov/afdc/data/infrastructure.html>

¹⁹ Underwriters Laboratory website. <http://www.ul.com/global/eng/pages/?noredirect>

²⁰ Ethanol Producer Magazine. Fuel dispenser UL approved for E25. March 2010.

<http://www.ul.com/global/eng/pages/?noredirect>

²¹ US DOE, Alt Fuels & Advanced Vehicles Data Ctr. <http://www.afdc.energy.gov/afdc/data/fuels.html>

	<p>capable of using gasoline or ethanol blends up to 85%)</p> <p>Trend #3: In the U.S., consumption of ethanol in flex fuel vehicles has increased approximately 23% per year from 2000 to 2007 (from 1.2 million gallons of gasoline equivalent to over 54 million gallons of gasoline equivalent).²²</p> <p>Trend #4: Options for light-duty passenger E85 vehicles increased exponentially during the last decade. In 2008, 31 new types of flex fuel vehicles were offered for sale.²³</p> <p>Trend #5: Use of medium- and heavy-duty E85 flex fuel vehicles was negligible until 2006, when EIA reported 117,003 medium-duty flex fuel vehicles.²⁴</p> <p>Trend #6: The Environmental Protection Agency has received a petition to increase the ethanol blendwall to 15%. The US Department of Energy has been conducting testing related to this issue, and is scheduled to complete a study that will provide critical data in June 2010.²⁵</p>
<p>Preliminary Estimates of 2022 Use:</p> <ul style="list-style-type: none"> • Future use • Low • Moderate • High 	<p>Future estimates of flex fuel vehicles and E85 use</p> <p><i>Ethanol used in flex fuel vehicles (E85)</i></p> <p>Forecast #1: Several auto manufacturers have said that by 2012, half of the vehicles they offer for sale will be flex fuel vehicles.²⁶ New cars are increasingly being designed to run on E85, which could increase the fuel efficiency of flex fuel vehicles. The Energy Information Administration predicts that the fuel economy of flex fuel vehicles will improve dramatically in the next five years, so that by 2015, many flex fuel vehicles will achieve virtually the same MPG as similar gasoline vehicles.²⁷</p> <p><i>Volume of E85 used in flex fuel vehicles</i></p> <p>Forecast #2: The Energy Information Administration predicts an increase in E85 use compared to historic trends, all of it in light-duty cars and</p>

²² US DOE, Alt Fuels & Advanced Vehicles Data Ctr. <http://www.afdc.energy.gov/afdc/data/fuels.html>

²³ US DOE, Alt Fuels & Advanced Vehicles Data Ctr. <http://www.afdc.energy.gov/afdc/data/vehicles.html>

²⁴ US DOE, Alt Fuels & Advanced Vehicles Data Ctr. <http://www.afdc.energy.gov/afdc/data/vehicles.html>

²⁵ US EPA Letter to Growth Energy. Nov, 2009.

http://www.growthenergy.org/static/docs/2009/11/letter_EPAtoGrowthEnergy.pdf

²⁶ For links to the GM and Ford commitments for flex fuel vehicles, please visit:

http://www.afdc.energy.gov/afdc/vehicles/flexible_fuel_availability.html

²⁷ US Energy Information Administration (US EIA). *Annual Energy Outlook 2010*. Supplemental Tables. Table 46.

<http://www.eia.doe.gov/oiaf/aeo/supplement/>

trucks. The EIA estimates that E85 use will increase beginning in 2016; and that by 2022, use of E85 will reach 625.2 trillion btu nationwide.²⁸

Number of flex fuel vehicles

Forecast #3: The volumes of biofuels required by the federal Renewable Fuel Standard 2 are likely to necessitate increased E85 infrastructure and E85 use.²⁹ EPA calculated the costs associated with needed infrastructure, and also predicted that sales of light-duty flex fuel vehicles could range from 2.6 to 13.7 million nationwide³⁰, while EIA only predicted sales of 1.5 million.³¹

Forecast #4: A low carbon fuel standard in Oregon could potentially spur more E85 use in flex fuel vehicles than would have happened otherwise. Trends in other countries or states that use large volumes of flex fuel vehicles could help us identify feasible adoption rates for both light-duty/passenger and medium/heavy-duty applications.

Ethanol blendwall

Forecast #5: The current blendwall (the maximum amount of ethanol that can be blended into conventional gasoline) for ethanol in conventional gasoline engines is 10%. Washington State is considering using a 15% ethanol blendwall based on the federal Renewable Fuel Standard 2 in developing their low carbon fuel standard compliance scenarios.³²

Forecast #6: The volumes of biofuels required by the federal Renewable Fuel Standard 2 might necessitate more than 10% ethanol blended into gasoline.³³

Low estimate (proposed for discussion)

A low estimate for number of flex fuel vehicles, E85 consumption, and access to E85 fueling stations could be based on historic use, Energy Information Administration predictions, or on the “Low Ethanol Control Case” from the federal Renewable Fuel Standard 2.³⁴

²⁸ US EIA *Annual Energy Outlook 2010*. Supplemental Tables. Table 45 and 46.

<http://www.eia.doe.gov/oiaf/aeo/supplement/>

²⁹ US EPA. RFS2 Regulatory Impact Analysis. page 244 <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

³⁰ US EPA. RFS2 Regulatory Impact Analysis. <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

³¹ US EIA. *Annual Energy Outlook 2010*. Supplemental Tables. Table 57. <http://www.eia.doe.gov/oiaf/aeo/supplement/>

³² Washington Department of Ecology low carbon fuel standard website. Presentation March 25, 2010.

<http://www.ecy.wa.gov/climatechange/fuelstandards.htm>.

³³ US EPA. RFS2 Regulatory Impact Analysis. Page 292. <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

³⁴ US EPA. RFS2 Regulatory Impact Analysis. Page 78. <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

	<p>Moderate estimate (proposed for discussion)</p> <p>A moderate estimate for number of flex fuel vehicles, E85 consumption, and access to E85 fueling stations could be based on Energy Information Administration predictions, on the rate of change in other states or countries that have focused on using biofuels, on consultant reports, or on the “Primary Control Case” from the federal Renewable Fuel Standard 2.³⁵</p> <p>High (but feasible) estimate</p> <p>A high (but feasible) estimate for number of flex fuel vehicles, E85 consumption, and access to E85 fueling stations could be based on Energy Information Administration predictions, on the rate of change in other states or countries that have focused on using biofuels, on consultant reports, or on the “High Ethanol Control Case” from the federal Renewable Fuel Standard 2.³⁶</p>
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Further reading:

U.S. EPA. E85 and Flex Fuel Vehicles: Technical Highlights. Oct 2009.
<http://www.epa.gov/otaq/renewablefuels/420f09065.htm>

U.S. Department of Energy. Conversion of gasoline to flex fuel.
http://www.afdc.energy.gov/afdc/technology_bulletin_0807.html

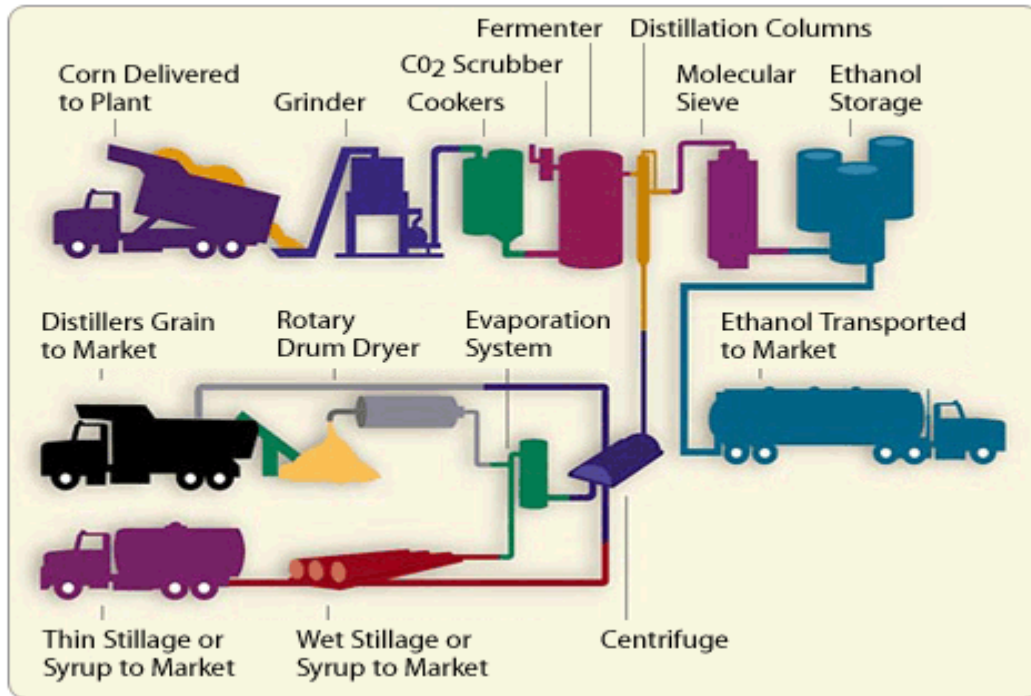
U.S. Department of Energy. Data, Analysis, and Trends.
<http://www.afdc.energy.gov/afdc/data/vehicles.html>

Environmental Protection Agency. Renewable Fuel Standard Program. Final Regulatory Impact Analysis. <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

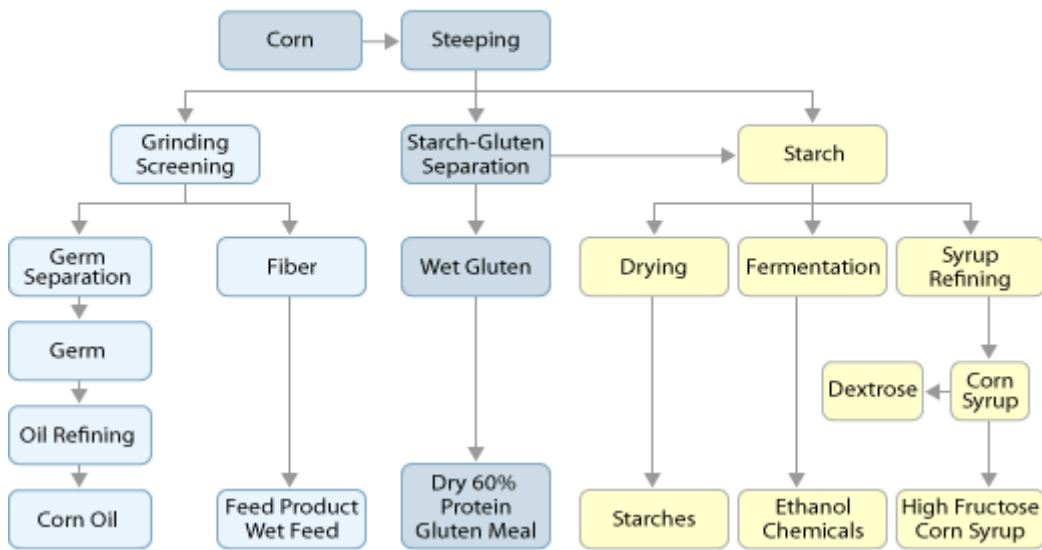
³⁵ US EPA. RFS2 Regulatory Impact Analysis. Page 71. <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

³⁶ US EPA. RFS2 Regulatory Impact Analysis. Page 79. <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

Figure 1: Processes for Producing Sugar- and Starch-Based Ethanol
Dry Mill Ethanol Process



Wet Mill Ethanol Process



Source: Renewable Fuels Association³⁷

³⁷ US DOE. Alt Fuels & Adv Vehicles Data Ctr. http://www.afdc.energy.gov/afdc/ethanol/production_starch_sugar.html

Cellulosic Ethanol

Feedstock and production process	<p>Feedstock. Cellulose is the main component of plant cell walls and is the most common organic compound on earth. Cellulosic ethanol is chemically identical to starch-based ethanol but instead derived from "biomass," a term encompassing everything from waste materials like corn stover and cobs, mill waste and paper pulp, to fast-growing plants like switchgrass and poplar.³⁸</p> <p>Cellulose is a polymer of glucose, a simple sugar that is easily consumed by yeast to produce ethanol. Polymers are large molecules made up of simpler molecules bound together much like links in a chain. Plants use cellulose as a strengthening material, much like a skeleton, which allows them to stand upright and grow toward the sun, withstand environmental stresses, and block pests. Because of this strengthening, it is difficult to break cellulose down into its simple sugar components, requiring additional processing compared to starch-based ethanol.³⁹</p> <p>Production process. There are many processes at various stages of research and development for producing cellulosic ethanol. The two main categories of processes are biochemical conversion and thermochemical conversion. Companies use either one or the other of these processes, or some combination of the two. Figure 1 at the end of this fuel assessment contains diagrams for each category. For more information, consult the U.S. Department of Energy Biomass Program website at: http://www1.eere.energy.gov/biomass/abcs_biofuels.html#prod.</p> <ul style="list-style-type: none">• Biochemical Conversion: Because cellulosic feedstocks are more difficult to break down into fermentable sugars than starch- and sugar-based feedstocks, the cellulosic biochemical conversion process requires additional steps (see diagram in Figure 1). Two key steps are biomass pretreatment and cellulose hydrolysis. During pretreatment, the hemicellulose part of the biomass is broken down into simple sugars and removed for fermentation. During cellulose hydrolysis, the cellulosic portion of the biomass is broken down into the simple sugar glucose.⁴⁰• Thermochemical Conversion: Ethanol can also be produced
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³⁸ Report of the Alternative Fuel Infrastructure Working Group. Dec. 2009. www.ci.corvallis.or.us/council/mail-archive/mayor/docAt9X61rHTt.doc

³⁹ Purdue University Extension. Cellulosic Ethanol- Biofuel Beyond Corn. ID-335. <http://www.ces.purdue.edu/extmedia/ID/ID-335.pdf>

⁴⁰ US DOE. Alt Fuels & Advanced Vehicles Data Ctr. http://www.afdc.energy.gov/afdc/ethanol/production_cellulosic.html

	<p>using thermochemical processes. In this approach, heat and chemicals are used to break biomass into syngas (a mixture of carbon monoxide and hydrogen) and reassemble it into products such as ethanol.</p>
<p>Co-products</p>	<p>In many instances, the biomass to produce cellulosic ethanol is itself a co- or by-product of agricultural or industrial processes. Several of the technologies that are currently under development produce interesting co- or by-products, which can significantly improve the economics of biorefineries.⁴¹</p> <ul style="list-style-type: none"> • Lignin is a non-fermentable residue that is the natural binding component in plants, which can be employed to power the operation. Eventually, lignin may be used in commercial applications such as plastics. • Ash left over from burning lignin can be used as a soil amendment. • Protein from the leaves and stems of the feedstock plants can be used in animal feed. Agricultural residues contain four to six percent protein while crops like switchgrass and alfalfa contain 10 percent and 15 to 20 percent, respectively.⁴²
<p>Commercialization status</p> <ul style="list-style-type: none"> • Fuel • Vehicles 	<p>Fuel. Cellulosic ethanol has not yet been produced commercially. However, several commercial cellulosic ethanol production plants are under construction, and intensive research and development is rapidly advancing the state of cellulosic ethanol technology.⁴³ Several pilot and demonstration plants are now operating.</p> <p>Vehicles. Gasoline vehicles which can use a blend containing 10 percent ethanol are fully commercialized, as are flex fuel vehicles which use gasoline, 85% ethanol, or a mix of the two. (See Starch- and Sugar-Based Ethanol section on page 16 for details on flex fuel vehicle use)</p>
<p>Current production in Oregon</p>	<p>No cellulosic ethanol plants are currently operational in Oregon. However, several companies are in various stages of planning and construction for demonstration and pilot facilities.</p> <p>ZeaChem Plant location: Boardman, Oregon Status: Construction has begun on a 250,000 Gal/yr pilot plant, completion planned end of 2010 Product: Acetic acid, which can be converted to ethanol Process: Biochemical and thermochemical Feedstock: Woody biomass (poplar)</p>

⁴¹ US DOE. Alt Fuels & Advanced Vehicles Data Ctr. http://www.afdc.energy.gov/afdc/ethanol/production_cellulosic.html

⁴² Why Cellulosic Ethanol? Cellulosic Ethanol Producers. <http://www.whyinvestinenergy.com/why-cellulosic-ethanol.php>

⁴³ Economics Improve for First Commercial Cellulosic Ethanol Plants. New York Times. Feb. 2010. <http://www.nytimes.com/cwire/2010/02/16/16climatewire-economics-improve-for-first-commercial-cellu-93478.html>

	<p>Future plans: Construction of a 25 to 50 million Gal/yr commercial plant to begin in 2010, estimated completion 2012 to 2013 Awarded \$25 million grant from U.S. DOE</p> <p>Pacific Ethanol Plant Location: Boardman, Oregon Status: Planned 2.7 million Gal/yr cellulosic ethanol plant in addition to existing corn ethanol plant, completion date unspecified Process: Biochemical Feedstocks: Woody biomass (poplar) and wheat straw Awarded \$24 million grant from U.S. DOE</p> <p>Diesel Brewing Plant location: Salem, Oregon Status: Demonstration facility (Phase I start-up date: December 2009) Product: Cellulosic bio-butanol and ethanol Process: Gasification, synthesis gas cleanup and catalytic conversion Feedstocks: Dairy manure and woody biomass Future plans: Semi-commercial plant, Eastern Oregon</p> <p>Trillium Fiber Fuels Facility location: Corvallis Oregon Status: R&D, developing isomerization process-small batch Process: Biochemical Feedstocks: Grass and wheat straw and softwoods Awarded \$750,000 from U.S. DOE to develop cellulosic technology</p>
<p>Potential production in Oregon</p>	<p>Oregon is rich in biomass potential. Feedstocks from forest residues, mill residues, agricultural residues, urban wood wastes and dedicated energy crops are all areas of potential for cellulosic ethanol production. See Biomass Assessment for more details. See the Oregon Biomass Assessment report prepared for the April 15, 2010 Advisory Committee meeting for information on Oregon’s potential for producing biomass for cellulosic biofuels. (http://www.deq.state.or.us/aq/committees/advcomLowCarbonFuel.htm)</p> <p>Diesel Brewing Plant location: Boardman, Oregon Status: Demonstration unit (Phase II), 10-ton/day. Start-up date planned for October 2010. Product: Cellulosic bio-butanol and ethanol Process: Gasification, synthesis gas cleanup and catalytic conversion Feedstocks: Dairy manure and woody biomass Future plans: Commercial Scale, at least 100 dry tons/day, Boardman, Oregon (October 2012)⁴⁴</p>

⁴⁴ Diesel Brewing website. <http://www.dieselbrewing.com/projects.htm>

<p>Out-of-state production</p>	<p>The U.S. Department of Agriculture and the U.S. Department of Energy have found that at least 1 billion tons of cellulose could be sustainably collected and processed in the U.S. each year. This resource represents an equivalent of 67 billion gallons of ethanol, replacing 30 percent of gasoline consumption in the United States.⁴⁵</p> <p>Currently there are no large-scale commercial cellulosic ethanol plants operating in the United States; however, several pilot and semi-commercial plants are operating in the United States⁴⁶ and around the world.⁴⁷ POET Ethanol and AE Biofuels have plants using corn cobs and stover as feedstocks, while KL Energy Corporation and Range Fuels are using woody biomass. Coskata uses a process that can process several different feedstocks, ranging from agricultural waste to garbage. The ability to produce cellulosic ethanol using many feedstocks and several different technologies is proven, but these technologies need to be scaled up and commercialized and costs need to come down in order to be competitive in the transportation fuels market.</p> <p>Some companies are reporting significant progress in reducing production costs. For example, over the first year of operations at its pilot scale ethanol plant in South Dakota, POET Ethanol reduced their production costs from \$4.13 per gallon to \$2.35, and intends to reduce costs to below \$2.00 per gallon by the time their commercial plant comes on-line.⁴⁸</p>
<p>Current use in Oregon</p> <ul style="list-style-type: none"> • Volume • Number of vehicles • Existing fueling infrastructure • Barriers to 	<p>Volume. Over 150 million gallons of ethanol is used in Oregon. It is difficult to say how much of this is cellulosic because no one is tracking this information. Although cellulosic ethanol is not produced at a commercial scale, several plants produce and market cellulosic ethanol from pilot and demonstration-sized plants.⁴⁹</p> <p>Number of vehicles. Cellulosic ethanol is chemically indistinguishable from starch-based ethanol. Any gasoline vehicle can use blends up to 10 percent ethanol or E10. Flex fuel vehicles can use blends from E0 to E85 (85</p>

⁴⁵ US Department of Agriculture (USDA) and US DOE. April 2005. Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply. http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf

⁴⁶ US DOE. Integrated Biorefinery Project Locations (for refineries producing ethanol, diesel, or other products from biomass that have received a grant award). Refineries are categorized as in the research and development, pilot, demonstration, or commercial stage. http://www1.eere.energy.gov/biomass/integrated_biorefineries.html

⁴⁷ Renewable Fuels Association. U.S. Advanced and Cellulosic Ethanol Projects Under Development and Construction. Updated 2/25/10. <http://www.ethanolrfa.org/resource/cellulosic/documents/CurrentAdvancedCelluloseBiofuelsProjects2-25-10.pdf>

⁴⁸ POET Energy website. 2009. On first anniversary of pilot plant start-up, POET announces cost reductions in cellulosic ethanol. <http://www.poetenergy.com/news/showRelease.asp?id=181>

⁴⁹ Iogen website. <http://www.ioegen.ca/>

<p>expansion</p> <ul style="list-style-type: none"> • Special issues 	<p>percent ethanol/15 percent gasoline). There are over 100,000 of these vehicles in Oregon.⁵⁰ Please see the section on Sugar- and Starch-Based Ethanol on page 16 for a discussion of flex fuel vehicle use and trends.</p> <p>Existing fueling infrastructure. Over 99 percent of the gasoline dispensers in Oregon dispense a 10 percent ethanol blend. At present there are nine stations that offer E85.</p> <p>Barriers to expansion. There are no barriers to using cellulosic ethanol once it is produced, as it is indistinguishable from starch-based ethanol already in use. The barriers lie in producing cellulosic ethanol at industrial scale at competitive prices, and obtaining financing.</p> <p>Special Issues. The Environmental Protection Agency, under the Renewable Fuel Standard Program, will require that renewable fuel be blended into petroleum from 9 billion gallons in 2008 to 36 billion gallons by 2022.⁵¹ There are several different categories of required renewable fuel. In 2022, the following will be required in the United States:</p> <ul style="list-style-type: none"> • 16 billion gallons of cellulosic biofuels (which could be ethanol or diesel) • 4 billion gallons of unspecified “advanced” fuel, which will need to have a carbon intensity of 50% less than petroleum fuels. These could be cellulosic ethanol, biomass-based diesel, or some other fuel. <p>The federal program is a volumetric program which means the fuel distributors could sell high blends in one region and zero or low blends in another region and still meet the programs requirement. The program is primarily designed to significantly increase the volume of renewable fuel that is blended into gasoline. EPA recognizes that the required volumes could be met with a wide variety of fuel choices, and has developed a projected set of reasonable fuel volumes based on their best estimate of likely fuels that would come to market. They have projected a primary control case, and then two sensitivity control cases (high and low cellulosic ethanol).</p> <p>See the Appendix A on page 77 for more information on the federal Renewable Fuel Standard 2.</p>
<p>Summary of known trends:</p> <ul style="list-style-type: none"> • Volume produced • Volume used 	<p>Trends in Cellulosic Ethanol as a transportation fuel</p> <p>Volume produced</p> <ol style="list-style-type: none"> 1. Production in Oregon: One cellulosic ethanol demonstration plant is planned, while another will begin construction soon. There are plans for a

⁵⁰ Rick Wallace, Oregon Department of Energy, personal communication 2/2010

⁵¹EPA Proposes New Regulations for the National Renewable Fuel Standard Program for 2010 and Beyond.

<http://www.epa.gov/oms/renewablefuels/420f09023.htm#3>

<ul style="list-style-type: none"> • Number of vehicles 	<p>commercial facility with a capacity of 25-50 million gallons per year.</p> <ol style="list-style-type: none"> 2. Production in the US. There are approximately 26 pilot, demonstration, and planned commercial cellulosic ethanol plants in the United States.⁵² 3. Due to the federal Renewable Fuel Standard 2, higher volumes of lower carbon biofuels will be required. <p>Volume used and number of E85 vehicles. For trends in ethanol and E85 (15% gasoline and 85% ethanol) use, please refer to the Ethanol from Starch- and Sugar-Based Ethanol section of this Fuels Assessment on page 16.</p>
<p>Preliminary Estimates of 2022 Use:</p> <ul style="list-style-type: none"> • Future use • Low • Moderate • High 	<p>Future use estimates for cellulosic ethanol</p> <p>A low carbon fuel standard in Oregon could potentially spur cellulosic ethanol production with lower carbon emissions than would have occurred under the federal Renewable Fuel Standard 2. In addition, some of the fuel that will be used to meet RFS2 will be exempt from the low carbon fuel standard, such as heating oil, propane, and jet fuel.</p> <p>Low estimate (proposed for discussion)</p> <p>EPA’s Primary Control Case (for the Renewable Fuel Standard Program) predicts there will be an estimated 4.92 billion gallons of cellulosic ethanol in 2022. Based on Oregon’s consumption of gasoline and diesel compared to that of the entire United States, Oregon’s share of this is 58 million gallons.⁵³</p> <p>Moderate (proposed for discussion)</p> <p>EPA’s High Ethanol Control Case predicts there will be an estimated 16 billion gallons of cellulosic ethanol in 2022. Based on Oregon’s consumption of gasoline and diesel compared to that of the entire United States, Oregon’s share of this is 189 million gallons.⁵⁴</p> <p>High (but feasible) estimate (proposed for discussion)</p> <p>EPA conducted an analysis of available cellulosic feedstock in each state. Based on their analysis, 44 million gallons of cellulosic ethanol could be produced from urban waste and 200 million gallons from</p>

⁵² Renewable Fuels Association website. <http://www.ethanolrfa.org/resource/cellulosic/>

⁵³ US EPA. RFS2 Regulatory Impact Analysis. page 71. <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

⁵⁴ US EPA. RFS2 Regulatory Impact Analysis. page 79. <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

	forest sources, for a total of 244 million gallons of gasoline equivalent. ⁵⁵ It is possible that more cellulosic ethanol from outside the state would also be available.
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Further reading:

US Department of Energy Biomass Program website:

http://www1.eere.energy.gov/biomass/abcs_biofuels.html#prod

Renewable Fuels Association. U.S. Advanced and Cellulosic Ethanol Projects Under Development and Construction. Updated 2/25/10.

<http://www.ethanolrfa.org/resource/cellulosic/documents/CurrentAdvancedCelluloseBiofuelsProjects2-25-10.pdf>

US Environmental Protection Agency. EPA Proposes New Regulations for the National Renewable Fuel Standard Program for 2010 and Beyond. <http://www.epa.gov/oms/renewablefuels/420f09023.htm#3>

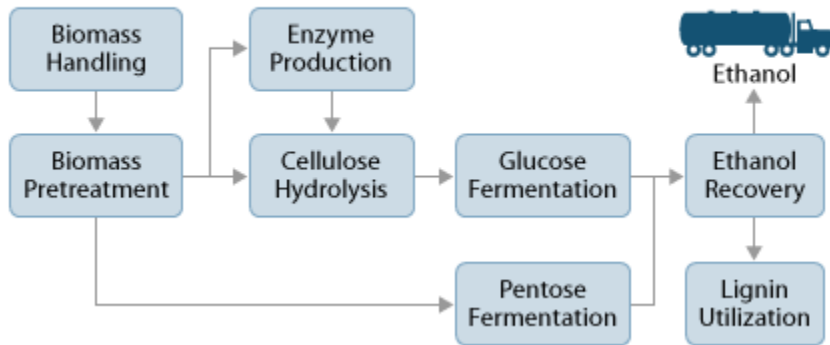
Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis. EPA-420-R-10-006. 2/2010. <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

⁵⁵US EPA. RFS2 Regulatory Impact Analysis. page 227. <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

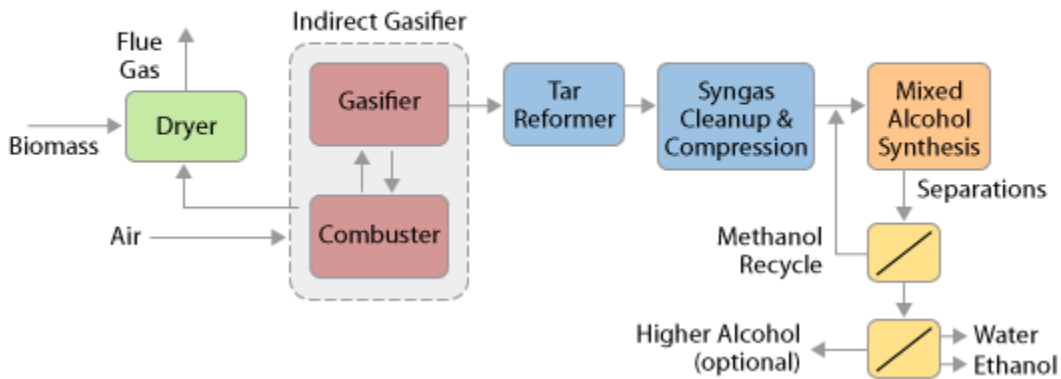
Figure 1: Processes for Producing Cellulosic Ethanol

Source: U.S. Department of Energy Biomass Program website at http://www1.eere.energy.gov/biomass/abcs_biofuels.html#prod.

Schematic of a Biochemical Cellulosic Ethanol Production Process



Schematic of a Thermochemical Cellulosic Ethanol Production Process



Biodiesel (FAME⁵⁶) process

<p>Feedstock and production process</p>	<p>Feedstock.</p> <p>Biodiesel is a natural and renewable domestic fuel alternative for diesel engines made from vegetable oils and animal fats. The most common feedstocks for biodiesel are new or used vegetable oils made from crops such as soybean, camelina, rapeseed, canola, palm, cottonseed, sunflower and peanut. Biodiesel can also be made from recycled cooking grease. Most biodiesel made in Oregon is made from waste vegetable oil. In the United States, most biodiesel is produced from soybean oil.⁵⁷</p> <p>Production process.</p> <p>According to the U.S. Department of Energy, fats and oils are chemically reacted with an alcohol to produce chemical compounds known as fatty acid methyl esters (FAME). Biodiesel is the name given to these esters when they are intended for use as fuel.</p> <p>Biodiesel can be produced using a variety of esterification technologies. The oils and fats are filtered and preprocessed to remove water and contaminants. If free fatty acids are present, they can be removed or transformed into biodiesel using special pretreatment technologies. The pretreated oils and fats are then mixed with an alcohol (usually methanol) and a catalyst (usually sodium hydroxide). The oil molecules (triglycerides) are broken apart and reformed into methyl esters and glycerin, which are then separated from each other and purified.⁵⁸</p> <p>Biodiesel must meet rigorous ASTM D6751-07b specifications.</p>
<p>Co-products</p>	<p>Glycerin (used in pharmaceuticals and cosmetics, among other markets) is a co-product.</p>
<p>Commercialization status</p> <ul style="list-style-type: none"> • Fuel • Vehicles 	<p>Fuel. Biodiesel produced through the FAME process is fully commercialized, and has an annual production capacity of 2.69 billion gallons per year in the United States.⁵⁹</p> <p>Vehicles. Biodiesel can be used in unmodified diesel engines with current fueling infrastructure. Performance, storage requirements, and</p>

⁵⁶ "FAME" stands for Fatty Acid Methyl Esters.

⁵⁷ Oregon State University Extension website. <http://www.extension.org/faq/42257>

⁵⁸ US DOE. Alt Fuels & Advanced Vehicles Data Ctr.. <http://www.afdc.energy.gov/afdc/fuels/biodiesel.html>

⁵⁹ National Biodiesel Board. US Biodiesel Production Capacity. June 2009. http://www.biodiesel.org/pdf_files/fuelfactsheets/Production_Capacity.pdf

	<p>maintenance are similar for biodiesel blends and petroleum diesel.</p> <p>Biodiesel has a formal technical definition that is recognized by ASTM International (known formerly as the American Society for Testing and Materials), the organization responsible for providing industry standards. B100 or 100 percent biodiesel must meet ASTM D 6751. Biodiesel blends B6 to B20 must meet ASTM D7467-08 and blends B5 and below must meet the diesel ASTM standard D975.</p> <p>Like conventional diesel, biodiesel will cloud and gel at very cold temperatures, but blends like B20 are slightly more sensitive than #2 diesel in this respect.</p>
<p>Current production in Oregon</p>	<p><u>Completed Projects</u>⁶⁰</p> <p>There are six biodiesel production facilities in Oregon with a total capacity of just over 7 million gallons per year. The majority of the feedstock is waste vegetable oil but some of these plants will process virgin canola, camelina or other seed oils.</p> <p>Sequential Pacific. Salem Oregon, Operating 5.3 million Gal/yr capacity, Feedstocks; waste vegetable oil, canola & camelina</p> <p>Beaver Biodiesel. Albany Oregon, Operating 500,000 Gal/yr capacity, Feedstocks; waste vegetable oil</p> <p>Evergreen Fuels. Klamath Falls Oregon, Operating 400,000 Gal/yr capacity, Feedstocks; Canola, camelina & waste vegetable oil</p> <p>Portland Biodiesel. Portland Oregon, Idle 1 million Gal/yr capacity, Feedstocks; waste vegetable oil</p> <p>K & S Madison Farm. Echo Oregon, Operating 20,000 Gal/yr capacity, Feedstocks; Canola Oil</p> <p>Lookout Mountain. Prineville Oregon, Seasonal 20,000 Gal/yr capacity, Feedstocks; waste vegetable oil</p> <p><u>Developing Projects</u></p> <p>Willamette Biodiesel. Rickreal Oregon 270,000 Gal/yr capacity, Feedstocks; Seed oils Received a grant of \$127,323 from USDA. Estimated opening late 2010</p>

⁶⁰ Rick Wallace, Oregon Department of Energy, personal communication.

<p>Potential production in Oregon</p>	<p>Enough virgin soy oil, recycled restaurant grease, and other feedstocks are readily available in the United States to provide feedstock for about 1.7 billion gallons of biodiesel per year (under policies designed to encourage biodiesel use). This represents roughly 5% of on-road diesel used in the United States.⁶¹</p>
<p>Out-of-state production</p>	<p><u>Regional Biodiesel</u></p> <p>The region outside of our state boasts of biodiesel production capacity well over 140 million gallons per year. Much of this production capacity is currently idle or running under capacity.</p> <p>According to the National Biodiesel Board⁶²:</p> <p style="padding-left: 40px;">“There are presently 173 companies that have invested millions of dollars into the development of biodiesel manufacturing plants and are actively marketing biodiesel. The annual production capacity from these plants is 2.69 billion gallons per year. It is important to note that production capacity differs from the actual number of gallons sold. Twenty-nine companies have reported that their plants are currently under construction and are scheduled to be completed within the next 12-18 months. One plant is expanding their existing operation. Their combined capacity, if realized, would result in another 427.8 million gallons per year of biodiesel production.”</p> <p>Note: Annual Production Capacity only refers to the reported maximum production capacity of the facility. Therefore, it does not represent how many gallons of biodiesel were actually produced at each plant. In fact, due to current economic conditions, the capacity utilization at many of these facilities is extremely low.</p>
<p>Current use in Oregon</p> <ul style="list-style-type: none"> • Volume • Number of vehicles • Existing fueling infrastructure • Barriers to 	<p>Volume. There are six biodiesel production facilities in Oregon with a total capacity of just over 7 million gallons per year.</p> <p>Use of higher blends of biodiesel, such as B10, B20, B99 or B100 is not tracked.</p> <p>Number of vehicles. A Renewable Fuel Standard is a program that increases the volume of renewable fuels to be blended into petroleum fuels. Due to the Oregon renewable fuel standard, all vehicles and equipment,</p>

⁶¹ National Renewable Energy Laboratory. Biomass Oil Analysis: Research Needs and Recommendations. <http://www1.eere.energy.gov/biomass/pdfs/34796.pdf>

⁶² National Biodiesel Board. US Biodiesel Production Capacity. June 2009. http://www.biodiesel.org/pdf_files/fuelfactsheets/Production_Capacity.pdf

<p>expansion</p> <ul style="list-style-type: none"> • Special issues 	<p>with the exception of marine engines and locomotives, use at least a 2% blend of biodiesel, as of October 1st, 2009⁶³. Use from the Oregon renewable fuel standard is estimated to be 10.5 million gallons per year.⁶⁴ In the Portland area, all vehicles and equipment use a 5% blend of biodiesel.⁶⁵</p> <p>Existing fueling infrastructure.</p> <p>Biodiesel is distributed from the point of production via truck, train, or barge. Pipeline distribution of biodiesel, which would be the most economical option, is still in the experimental phase. However, Kinder Morgan transports a B2 blend of biodiesel (2 percent biodiesel, 98 percent petroleum diesel) in their Portland to Eugene pipeline. Biodiesel produced in Oregon is typically transported by truck. Biodiesel produced out of state, typically soy based biodiesel from the Mid-West is transported by train to Portland terminals and distribution centers. Biodiesel is blended into petroleum diesel at terminals and then transported to smaller distributors and retailers. Higher blends from B10 to B99 of biodiesel are also available in the state. According to the National Biodiesel Board, currently there are 25 distributors and 43 retailers offering high blends of biodiesel in the state of Oregon. Sales of biodiesel in Oregon are hard to determine as the sales are recorded as diesel sales regardless of blend level.</p> <p>Special issues. Under the federal Renewable Fuel Standard 2 program (See Appendix A on page 77 for details), EPA will require 1 billion gallons of biodiesel and 4 billion gallons of “other advanced biofuels” with a carbon intensity at least 50% less than gasoline or diesel. EPA recognizes that the required volumes could be met with a wide variety of fuel choices, and has developed a projected set of reasonable fuel volumes based on their best estimate of likely fuels that would come to market. They have projected a primary control case, and then two sensitivity control cases (high and low cellulosic ethanol).</p>
<p>Summary of known trends:</p> <ul style="list-style-type: none"> • Volume used • Volume produced • Number of 	<p>Trend: volume used.</p> <p>Trend #1: Biodiesel consumption has increased from an estimated 6.8 million gallons of gasoline equivalent in 2000 to 372 million gallons of gasoline equivalent in 2007.⁶⁶</p> <p>Trend #2: Increased required blends. When Oregon’s biodiesel</p>

⁶³ ODA website. ODA Measurement Standards Division. Biofuel renewable fuel standard. http://www.oregon.gov/ODA/MSD/renewable_fuel_standard.shtml

⁶⁴ Rick Wallace, Oregon Department of Energy. Presentation. <http://www.deq.state.or.us/qa/committees/docs/GHGFuelSupplyDistribution.pdf>

⁶⁵ City of Portland website. Biofuels. <http://www.portlandonline.com/bps/index.cfm?c=42843>

⁶⁶ US EIA. Annual Energy Review 2008. Table 10.5. <http://www.eia.doe.gov/emeu/aer/renew.html>

<p>vehicles</p>	<p>capacity reaches 15 million gallons, all diesel sold in Oregon must contain at least 5% biodiesel. The required volume in Oregon would be approximately 26.5 million gallons annually. It is possible that some of this could be met through other biomass-based diesel.⁶⁷</p> <p>There is also potential that in between now and 2022, the City of Portland could increase the required blend within the City of Portland from 5% to 10%.</p> <p>Trend: volume produced.</p> <p>Trend #3: As illustrated by the graph below U.S. production of biodiesel has increased from 9 million gallons in 2001 to over 680 million gallons in 2008.⁶⁸</p> <div data-bbox="506 684 1349 1394" data-label="Figure"> <table border="1"> <caption>Gallons of Biodiesel Produced in the United States, 2001-2008</caption> <thead> <tr> <th>Year</th> <th>Production (Million Gallons)</th> </tr> </thead> <tbody> <tr><td>2001</td><td>9</td></tr> <tr><td>2002</td><td>10</td></tr> <tr><td>2003</td><td>15</td></tr> <tr><td>2004</td><td>25</td></tr> <tr><td>2005</td><td>90</td></tr> <tr><td>2006</td><td>250</td></tr> <tr><td>2007</td><td>490</td></tr> <tr><td>2008</td><td>680</td></tr> </tbody> </table> </div>	Year	Production (Million Gallons)	2001	9	2002	10	2003	15	2004	25	2005	90	2006	250	2007	490	2008	680
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<p>Preliminary Estimates of 2022 Use:</p> <ul style="list-style-type: none"> • Future use • Low • Moderate • High 	<p>Future use estimates for biodiesel</p> <p>A low carbon fuel standard in Oregon could potentially spur more biodiesel production than would have happened otherwise.</p> <p>Low estimate (proposed for discussion)</p> <p>Based on Oregon’s statutes related to biodiesel blends described in Trend #2, 26.5 million gallons would be approximately the amount required by the Oregon renewable fuel standard in 2022. This would</p>																		

⁶⁷ ODA. Oregon Renewable Fuel Standard. http://www.oregon.gov/ODA/energy.shtml#Renewable_fuel_standards

⁶⁸ US EIA. Annual Energy Review 2008. Table 10.4. <http://www.eia.doe.gov/emeu/aer/renew.html>

	<p>be a reasonable estimate to bracket the low range of Oregon’s biodiesel production in 2022, although it does not include potential increases due to City of Portland regulations. In addition, some of this required volume could be met through use of other type of biomass-based diesel.</p> <p>Moderate and High estimates</p> <p>Moderate and high estimates of biodiesel availability in Oregon could be based on many different factors, such as:</p> <ul style="list-style-type: none">• Trends in biodiesel production• Volume available regionally• Available feedstocks• Predictions of future use• Federal Renewable Fuel Standard 2 required volumes for biomass-based diesel
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Further Reading:

US Department of Energy. Alternative and Advanced Fuels. Biodiesel.
<http://www.afdc.energy.gov/afdc/fuels/biodiesel.html>

Renewable Diesel

(Hydrogenation-Derived Renewable Diesel)

<p>Feedstock and production process</p>	<p>Feedstock. Hydrogenation-derived renewable diesel (renewable diesel) is produced from a wide variety of feedstocks, including tallow, poultry fat, trap grease, waste vegetable oil, algal oil, soybean oil, and canola oil. Soybean oil is the most common vegetable oil feedstock for renewable diesel produced in the United States.</p> <p>Production process. Renewable diesel is produced in a conventional petroleum refinery from fats or vegetable oils in a process also known as Fatty Acids to Hydrocarbon Hydrotreatment. Diesel produced in this process is called “renewable diesel” to differentiate it from biodiesel, which is a product of the transesterification of animal fats and vegetable oils. Renewable diesel and biodiesel use similar feedstocks but have different processing methods and create chemically different products. Gasoline can be produced using a similar refining process, but this is in an earlier stage of development.</p>
<p>Co-products</p>	<p>None.</p>
<p>Commercialization status</p> <ul style="list-style-type: none"> • Fuel • Vehicles 	<p>Fuel. Renewable diesel is fully commercialized in several areas of the world. In the United States, it is in a transitional stage from pilot and demonstration plants to full-scale commercial production, and not currently widely available. It is likely to become fully commercialized in the near future. A number of producers have commercial trials underway. Blends of up to 100 percent can be used without any modification to existing infrastructure, however cold weather testing beyond a two percent blend has not yet been done.⁶⁹</p> <p>Vehicles. Renewable diesel has an identical chemical structure with petroleum-based diesel since it is free of ester compounds. The refined oil can be used alone or combined with petroleum, to replace or complement diesel fuel. Renewable diesel can be used in existing conventional diesel vehicles⁷⁰</p>
<p>Current production in Oregon</p>	<p>Not currently produced in Oregon.</p>
<p>Potential Production in</p>	<p>Oregon does not have an oil refinery. It is unlikely that a refinery will be established in Oregon. However, renewable diesel is compatible with the</p>

⁶⁹ Final Report: Alberta Renewable Diesel Demonstration. February 2009. <http://www.renewablediesel.ca/pdf/ARDD%20Final%20Report.pdf>

⁷⁰ Final Report: Alberta Renewable Diesel Demonstration. February 2009. <http://www.renewablediesel.ca/pdf/ARDD%20Final%20Report.pdf>

Oregon	existing fuel distribution and storage infrastructure and could be refined in Washington and distributed to Oregon as is - no modifications would be required.
Out-of-state production	<p>A number of manufacturers around the world have developed renewable diesel refining processes, and are now either producing commercial volumes of renewable diesel or constructing commercial facilities. Following are brief descriptions of some of the projects.</p> <p>ConocoPhillips (United States, Ireland) ConocoPhillips is producing approximately 40,000 gallons per day of renewable diesel at its Whitegate refinery in Cork, Ireland.⁷¹ The primary renewable feedstock is soybean oil, but other vegetable oils and animal fats and oils could be used as well.⁷² The renewable diesel is being produced using existing refinery equipment and is blended and transported with petroleum-based diesel.</p> <p>Neste Oil (Finland) Neste Oil is producing renewable diesel using its NExBTL process from two plants in Finland with a combined capacity of 116 million gallons a year. Two more plants are under construction, one in Singapore and one in the Netherlands, and will come online in 2010 and 2011 respectively, with a combined capacity of 545 million gallons per year.⁷³</p> <p>UOP-Eni (United States, Italy) The first "Ecofining" facility developed by UOP and Italian oil and gas company Eni is scheduled to come online in 2010, processing 273,000 gallons per day of vegetable oils.⁷⁴ The U.S. Department of Energy has supported UOP's Renewable Energy and Chemicals unit in developing renewable diesel production technologies.⁷⁵</p> <p>Syntroleum (United States) Syntroleum formed a joint venture with Tyson Foods to produce renewable diesel and jet fuel using its biofining process. Production from its first plant is expected to be 75 million gallons per year beginning in 2010.⁷⁶</p>

⁷¹ ConocoPhillips. http://www.conocophillips.com/ENot_applicable.bout/company_reports/spirit_mag/Pages/whitegate_story.aspx.

⁷² Biodiesel Magazine. March 2007. "ConocoPhillips begins production of renewable diesel." http://www.biodieselmagazine.com/article.jsp?article_id=1481

⁷³ Neste Annual Report for 2009. <http://www.nesteoil.com/>

⁷⁴ UOP website. <http://www.uop.com/renewables/10010.html>

⁷⁵ US DOE. http://www.afdc.energy.gov/afdc/fuels/emerging_green_production.html

⁷⁶ Syntroleum website. http://www.syntroleum.com/proj_rba_biofining.aspx

	<p>Darling International and Valero Energy (Louisiana) A joint venture between Darling International and Valero Energy will produce 135 million gallons per year of renewable diesel mainly from waste grease and fats.⁷⁷</p> <p>Tesoro (Washington State) Tesoro signed an agreement with AltAir Fuels in December, 2009 to provide renewable jet fuel and diesel to airlines and airport equipment.⁷⁸</p> <p>Petrobras (Brazil) Brazilian oil company Petrobras developed the H-BIO process, which produces renewable diesel using hydrotreating units in existing oil refineries. Petrobras is planning to use the H-BIO process in three of its refineries by 2007 and two more by 2008, with a total vegetable oil consumption of more than 294,000 gallons per day or approximately 100 million gallons per year.⁷⁹</p>
<p>Current use in Oregon</p> <ul style="list-style-type: none"> • Volume • Number of vehicles • Existing fueling infrastructure • Barriers to expansion • Special issues 	<p>Volume. None known at this time.</p> <p>Number of vehicles. Renewable diesel can be used in existing conventional diesel vehicles.⁸⁰</p> <p>Existing fueling infrastructure. Renewable diesel can use the existing pipelines, stations and road transport systems for conventional diesel. In addition to the fuel infrastructure, renewable diesel benefits from being able to use the current refinery infrastructure as well.</p> <p>Barriers to expansion. Oregon’s lack of oil refining capacity makes the state dependent upon the decisions of refiners outside the state.</p> <p>Special issues. Renewable Diesel is a highly stable diesel fuel with a higher cetane number (diesel’s combustion quality) than biodiesel and conventional petrodiesel, suggesting improved vehicle performance and fuel economy. Additionally, its ultra-low sulfur content will reduce emissions.</p>
<p>Summary of known trends:</p> <ul style="list-style-type: none"> • Volume produced 	<p>Trends in renewable diesel as a transportation fuel</p> <p>Volume produced</p>

⁷⁷ Darling International Inc. Announces Renewable Diesel Project With Valero Energy Corporation. <http://www.darlingii.com/pdf/Press%20Release%20re%20Green%20Diesel%20Project%20Valero-Final.pdf>

⁷⁸ Press Release: Airlines Sign Landmark MOU for Camelina-based Renewable jet fuel and green diesel. http://www.altairfuels.com/AltAir_PressRelease_dec09.pdf.

⁷⁹ US DOE. Alt Fuels & Adv Vehicles Data Ctr. http://www.afdc.energy.gov/afdc/fuels/emerging_green_production.html

⁸⁰ Alberta, Canada. Final Report: Alberta Renewable Diesel Demonstration. February 2009. <http://www.renewablediesel.ca/pdf/ARDD%20Final%20Report.pdf>

	<p>Currently, the three commercial renewable diesel plants in the world have approximately 130 million gallon a year combined capacity. The three additional plants under construction have a combined capacity of 620 million gallons per year, and are expected to be producing in 2010-2011.</p> <p>Tesoro has proposed a project at an Anacortes refinery to produce renewable diesel and renewable jet fuel.</p> <p>(Please see the section on Biodiesel (FAME) for trends in biodiesel production and use on page 29)</p>
<p>Preliminary Estimates of 2022 Use:</p> <ul style="list-style-type: none"> • Future use • Low • Moderate • High 	<p>Future use estimates</p> <p>A low carbon fuel standard in Oregon could potentially spur more renewable diesel use for transportation than would have happened otherwise. Trends in other countries or states that use large volumes of renewable diesel could help us identify feasible adoption rates for both passenger and medium/heavy-duty applications.</p> <p>Low estimate (proposed for discussion)</p> <p>It is possible that no renewable diesel will be available in Oregon by 2022.</p> <p>Moderate estimate (proposed for discussion)</p> <p>Because there is a project proposed at a Washington refinery, it is possible that portion of the planned amount of renewable diesel will be supplied to Oregon by 2022, for example, 25 to 100 million gallons.</p> <p>High (but feasible) estimate (proposed for discussion)</p> <p>One or more of the Washington refineries supplying diesel to Oregon could produce renewable diesel and supply it to Oregon by 2022. A commercial volume might be 150-500 million gallons.</p>

Fischer-Tropsch and Other Synthetic Fuels

Fuels produced from the Fischer-Tropsch process are also known as synthetic diesel, synthetic gasoline, and (when made from biomass) cellulosic diesel. Other technologies can also produce synthetic fuel.

Feedstock and production process	<p>There are many technologies and production processes that could produce synthetic diesel or even potentially synthetic gasoline. It is outside the scope of this document to cover all of the potential technologies under development. EPA, in their <i>Regulatory Impact Analysis for the Renewable Fuel Standard Program</i> discusses a variety of biofuels production processes.⁸¹ For a list of developing technologies and fuels produced, please see Appendix B of this document on page 79.</p> <p>Feedstock. Fischer-Tropsch (Fischer-Tropsch) diesel is produced by converting gaseous hydrocarbons called synthesis gas (or “syngas” - a mixture of carbon monoxide and hydrogen produced from biomass or fossil fuels, such as natural gas and gasified coal) into liquid diesel. Additionally some technologies can produce fuel from plastic, tires, and other waste.⁸²</p> <p>Production process.⁸³ In 1923, Franz Fischer and Hans Tropsch, scientists at Kaiser Wilhelm Institute, first studied conversion of coal-derived syngas into useful compounds (diesel is one of many chemicals and fuels that can be derived from syngas), using what was to become known as Fischer-Tropsch synthesis. Key to the process are catalysts: substances that facilitate a chemical reaction but are not consumed by the reaction. A schematic of the overall process can be shown in three steps, with each step taking place in the presence of a specific catalyst:</p> <ol style="list-style-type: none">1. Syngas formation (Coal or Natural gas or Biomass) + Oxygen → Syngas2. Fischer-Tropsch Reaction Syngas → New Hydrocarbon + Water3. Refining New Hydrocarbon → Fuels, Chemicals, etc. <p>The benefit of the process lies in converting a relatively inflexible energy</p>
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⁸¹ US EPA. RFS2 Regulatory Impact Analysis. Section 1.4, page 91-128.

<http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

⁸² Synthetic Diesel Fuel Production Facility.

http://www.shipconstructor.com/index.php?option=com_content&view=article&id=203&Itemid=150&lang=en

⁸³ US DOE. The Fischer-Tropsch Process. http://www.afdc.energy.gov/afdc/fuels/emerging_diesel_process.html

	<p>source (such as coal, natural gas or biomass) into a variety of products that meet specific needs. There are Fischer-Tropsch technologies that can convert coal-to-liquid (CTL), gas-to-liquid (GTL), and bio-to-liquid (BTL). The latter would mean a less carbon-intensive alternative that could use either agricultural feedstocks or waste biomass materials.</p> <p>Flash pyrolysis converts biomass into diesel through pyrolysis and hydrotreatment.⁸⁴</p>
Co-products	None
Commercialization Status <ul style="list-style-type: none"> • Fuel • Vehicles 	<p>Fuel. While the Fischer-Tropsch process is a well-proven technology, it requires a large capital investment in equipment followed by high operation and maintenance costs. However, as petroleum prices increase, making synfuels from coal, natural gas, and biomass become more economically competitive. Along with advanced energy companies focusing exclusively on alternative fuels, many oil companies also have dedicated synthetic fuel development programs in place. The production of fuel from biomass through Fischer-Tropsch is not yet fully commercialized. One company has been producing fuel from biomass through flash pyrolysis since 1989.</p> <p>Vehicles. One major benefit of Fischer-Tropsch and other synthetic diesel is their compatibility with currently existing vehicle technologies and fuel distribution systems. Biomass-derived gasoline and diesel could be transported through existing pipelines, dispensed at existing fueling stations, and used to fuel today's gasoline- and diesel-powered vehicles on their own or as a blendstock.</p>
Current Production in Oregon	Not currently produced in Oregon.
Potential Production in Oregon	See the Oregon Biomass Assessment report prepared for the April 15, 2010 Advisory Committee meeting for information on Oregon's potential for producing biomass. (http://www.deq.state.or.us/aq/committees/advcomLowCarbonFuel.htm)
Out-of-state Production	Fischer-Tropsch production was commercialized in Germany in 1936 to take advantage of coal-rich reserves and accounted for an estimated 9% of German war production of fuels and 25% of the automobile fuel during World War II.

⁸⁴ CARB. Staff Report, Initial Statement of Reasons. Appendix B, Chapter III: Technical Assessment of Proposed Regulation to Implement the Low Carbon Fuel Standard, Vol. 1. March 5, 2009.

	<p>To enhance energy independence in the face of apartheid-related economic isolation embargoes, Sasol in South Africa satisfied most of its diesel demand with natural gas- and coal-derived Fischer-Tropsch diesel for decades and is still using the fuel in significant quantities.</p> <p>One of the largest implementations of Fischer-Tropsch technology is in Bintulu, Malaysia. This Shell facility converts natural gas into low-sulfur diesel fuels and food-grade wax. The scale is 12,000 barrel/day.</p> <p>In the United States, Fischer-Tropsch diesel has been used in demonstration projects. In Pennsylvania, Waste Management and Processors Inc. was funded by the state to implement Fischer-Tropsch technology licensed from Shell and Sasol to convert so-called waste coal (leftovers from the mining process) into low-sulfur diesel fuel.</p> <p>Many oil companies such as Shell Oil, Chevron (Texaco), and ExxonMobil have been conducting research and have built pilot plants or smaller commercial plants. In conjunction with several private sector organizations, National Energy Technology Laboratory built and operated a pilot plant in LaPorte, Texas, focusing on the development of slurry-phase reactor technology.^{85,86}</p> <p>Rentech anticipates completing its 640 barrels-per day commercial facility in Rialto, California by 2012.⁸⁷</p> <p>Ensyn Corp's commercial plant in Ottawa, Canada has been producing fuel from residual wood through flash pyrolysis since 1989.⁸⁸</p>
<p>Current Use in Oregon</p> <ul style="list-style-type: none"> • Volume • Number of vehicles • Existing fueling infrastructure • Barriers to expansion • Special issues 	<p>Volume. Not applicable.</p> <p>Number of vehicles. Not applicable.</p> <p>Existing fueling infrastructure. Fischer-Tropsch fuels can use the existing pipelines, stations and road transport systems as a conventional diesel and gasoline or as a blendstock with diesel or gasoline.</p> <p>Barriers to expansion. Developing a commercial scale production process.</p> <p>Special issues. Under the federal Renewable Fuel Standard 2 program (See Appendix A on page 77 for details), EPA will require 16 billion gallons of cellulosic biofuels with a carbon intensity at least 60%</p>

⁸⁵ US DOE Factsheet. Fischer-Tropsch Fuels. <http://www.netl.doe.gov/publications/factsheets/rd/R&D089.pdf>

⁸⁶ US DOE. Gas to Liquids Production. http://www.afdc.energy.gov/afdc/fuels/emerging_gas_liquids_production.html

⁸⁷ Rentech website. Rialto Project. <http://www.rentechinc.com/rialto.php>

⁸⁸ CARB. Staff Report, Initial Statement of Reasons. Appendix B, Chapter III: Technical Assessment of Proposed Regulation to Implement the Low Carbon Fuel Standard, Vol. 1. March 5, 2009.

	<p>less than gasoline or diesel, and 1 billion gallons of biodiesel and 4 billion gallons of “other advanced biofuels” with a carbon intensity at least 50% less than that of gasoline or diesel. Diesel produced from biomass through the Fischer-Tropsch process could fit into any of these categories. EPA recognizes that the required volumes could be met with a wide variety of fuel choices, and has developed a projected set of reasonable fuel volumes based on their best estimate of likely fuels that would come to market. They have projected a primary control case, and two sensitivity control cases (high and low cellulosic ethanol).</p>
<p>Summary of known trends:</p> <ul style="list-style-type: none"> • Volume produced • Volume used • Number of vehicles 	<p>Trend: volume used. None in Oregon.</p> <p>Trend: volume produced. None in Oregon.</p> <p>Trend: number of vehicles. Not applicable.</p>
<p>Preliminary Estimates of 2022 Use:</p> <ul style="list-style-type: none"> • Future use • Low • Moderate • High 	<p>Future use estimates</p> <p>Due to the federal Renewable Fuel Standard 2, higher volumes of lower carbon biofuels will be required.</p> <p>A low carbon fuel standard in Oregon could potentially spur Fisher-Tropsch and other synthetic diesel fuel production. Trends in other countries or states produce Fisher-Tropsch and other synthetic diesel fuels could help us identify feasible future production.</p> <p>Low estimate (proposed for discussion)</p> <p>EPA’s Primary Control Case (for the Renewable Fuel Standard Program) predicts there will be an estimated 6.52 billion gallons of cellulosic diesel in 2022. Based on Oregon’s consumption of gasoline and diesel compared to the United States, Oregon’s share of this is 77 million gallons.⁸⁹</p> <p>Moderate Estimate (proposed for discussion)</p> <p>EPA’s Low Ethanol Case (for the Renewable Fuel Standard Program) predicts there will be an estimated 9.26 billion gallons of cellulosic diesel in 2022. Based on Oregon’s consumption of gasoline and diesel compared to the United States, Oregon’s share of this is 110 million gallons.⁹⁰</p>

⁸⁹ US EPA. RFS2 Regulatory Impact Analysis. page 71. <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

⁹⁰ US EPA. RFS2 Regulatory Impact Analysis. page78. <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

	High (but feasible) estimate (proposed for discussion)
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Based on the commercialization status of Fischer-Tropsch and other synthetic diesel fuels, it is possible that commercial scale facilities (**150-300 million gallons**) could be built and producing fuel by 2022.

Further Reading:

GreenCar.com: <http://www.greencar.com/articles/5-things-need-fischer-tropsch-process.php>

U.S Dept. of Energy: http://www.afdc.energy.gov/afdc/fuels/emerging_diesel.html

U.S. Dept. of Energy, Office of Fossil Energy, National Energy Technology Laboratory:
<http://www.netl.doe.gov/publications/factsheets/rd/R&D089.pdf>

Electricity

<p>Feedstock and production process</p>	<p>Feedstock. Electricity production uses a diverse spectrum of primarily domestic based energy sources. The common sources for electricity used in Oregon are hydropower, coal, natural gas, nuclear, wind, biomass, geothermal and solar. Technologies for the production of electricity from other sources, such as wave energy, are being researched but are not yet commercialized.</p> <p>Production process. Electricity is a form of energy converted from other sources of energy listed above. It is most commonly produced using a source of heat to create steam to drive turbines connected to electromagnetic generators. It is also produced by driving turbines mechanically as occurs in hydroelectric and wind power projects. Less commonly, electricity can be generated directly from solar energy using photovoltaic cells.</p>
<p>Co-products</p>	<p>Not Applicable.</p>
<p>Commercialization status</p> <ul style="list-style-type: none"> • Fuel • Vehicles 	<p>Fuel. Technology for many sources of electrical production (e.g. coal and hydropower) are fully established while others (e.g., wind, solar, geothermal etc.) continue to be developed. The electrical grid used to distribute this energy is fully established throughout the country.</p> <p>Unlike many proposed alternative fuels, electricity already has a large network delivery system in place. The power sector is constructed to be able to meet peak demand. However, throughout a 24 hour day, the grid can supply significantly more energy than is currently required.⁹¹ This spare capacity could be used in the transportation sector.</p> <p>Additional infrastructure could be needed to supply electricity for transportation, such as public charging stations, increased investments in grid reliability, and smart grid technology.</p> <p>Vehicles. Electric vehicles come in several different forms. The two major categories are pure electric vehicles and plug-in hybrid electric vehicles. In the case of plug-in hybrid electric vehicles, the vehicle will incorporate both an electric motor and an internal combustion engine, which runs on petroleum fuel.</p>

⁹¹ Pacific Northwest National Laboratory. Impacts Assessment of Plug-in Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids. Part1: Technical Analysis. PNNL-SA-53700.

http://energytech.pnl.gov/publications/pdf/PHEV_Feasibility_Analysis_Part1.pdf

	<p>Electric vehicles have been around for over a hundred years but have not become mainstream due to range and speed limitations. New battery technology is changing the range and speed of electric vehicles. These new technologies are currently expensive, but with mass production, costs could come down.</p> <p>Light-duty (passenger) electric vehicles are on the verge of wide commercialization. Nine full-function electric vehicles or plug-in vehicles are due to be launched by 2011 (in addition to low-speed and neighborhood vehicles).</p> <p>Four heavy-duty plug-in vehicles are currently available with two more coming to market in 2010. For some applications, such as forklifts, there are many models available.</p>
<p>Current production in Oregon</p>	<p>Production/Providers. Three investor-owned utilities, three energy service suppliers, and 36 consumer-owned utilities supply electricity in Oregon. The five main providers of electricity in Oregon are the investor owned utilities Portland General Electric (PGE) and Pacific Power (a PacificCorp company), the city of Eugene, the electricity services supplier Sempra Energy Solutions, and the Central Lincoln People’s Utility District. The two main sources of electricity in Oregon are hydropower and coal, but natural gas is playing an increasing role.</p> <p>Oregon’s electricity resource mix for 2007 (the most recent year available) was 43.2 percent hydro, 37.8 percent coal, 14.1 percent natural gas, 3.2 percent nuclear, 1.5 percent wind and geothermal, and 0.3 percent biomass.</p>
<p>Potential production in Oregon</p>	<p>Potential production. Oregon has seen growth in renewable electricity production in the last several years. To ensure continued growth in clean energy, the legislature passed the Oregon Renewable Energy Act of 2007. The state of Oregon established a renewable portfolio standard for electric utilities and retail electricity suppliers, which requires that all utilities and electricity service suppliers serving Oregon include a percentage of electricity generated from qualifying renewable energy sources in their source mix. The percentage of qualifying electricity that must be included varies over time, with all utilities and electricity service suppliers obligated to include some renewably generated electricity in their portfolio by the year 2025.⁹²</p> <p>Oregon has potential for future electricity generation from low carbon sources such as wind, geothermal, biomass and solar. Many of the scenarios for implementing these technologies include natural gas facilities to provide backup power generation.</p>

⁹² ODOE. A Renewable Portfolio Standard for Oregon. http://www.oregon.gov/ENERGY/RENEW/RPS_home.shtml

<p>Out-of-state production</p>	<p>Out-of-state Production. Oregon is connected to a large regional grid network that can transport electricity in and out of the state. Electricity comes from many sources out-of-state such as coal, hydro, nuclear, and renewable and natural gas.</p>
<p>Current use in Oregon</p> <ul style="list-style-type: none"> • Volume • Number of vehicles • Existing fueling infrastructure • Barriers to expansion • Special issues 	<p>Volume. There are no reliable figures on current volume of electricity used for transportation purposes. Due to the small number of electric vehicles currently in use, the volume of electricity they consume is insignificant compared to the volume used for non-transportation purposes.</p> <p>Number of vehicles. Over 40,000 electric vehicles and plug-in hybrid electric vehicles are currently used in the United States and just over 400 are registered with the DMV in Oregon.⁹³ This number does not include non-road equipment and vehicles. The EIA estimates that in 2007, there were 1,636 electric vehicles in use in Oregon.⁹⁴ Many of these are used in fleet applications, from maintenance to checking parking meters; these electric vehicles are mostly limited to 25 mph speed and 20-mile range. A growing number of electric vehicles are coming to market are of a new generation of freeway-speed electric vehicles that will be available to the mass consumer market in 2010. Electric vehicles have also been introduced at the high end of the market with the introduction of the Tesla Roadster. Battery technology has improved dramatically and full-function electric vehicles are poised for rapid expansion into Oregon. Many auto manufacturers will be introducing electric vehicles and plug-in hybrid electric vehicles beginning in late 2010. Virtually every major auto manufacturer in the world, along with numerous smaller companies, is developing electric vehicles or plug-in hybrid electric vehicles.</p> <p>Existing fueling infrastructure. Most electric vehicles can be charged from a standard U.S. 120 volt outlet. However, recharge times at this voltage are fairly long. For some electric vehicles, it could take 8 to 14 hours to charge the car from empty to full.⁹⁵ The technology exists for charging much more quickly at 220 volts (2-6 hours) and 480 volts (under 1 hour). These are called “level 2” and “level 3” charging stations, respectively. Currently there are just over 30 public electric vehicle-charging stations in Oregon with new ones added on an almost monthly basis. It is expected that “level 2” charging will be the norm for charging full battery electric vehicles.</p> <p>On August 5, 2009, Electric Transportation Engineering Corporation (eTec), a subsidiary of ECotality, Inc., was selected by the U.S.</p>

⁹³ Rick Wallace, Oregon Department of Energy, personal communication.

⁹⁴ US EIA. Table V10. http://www.eia.doe.gov/cneaf/alternate/page/atftables/attf_v10.html.

⁹⁵ New York Times Online. August 3, 2009. “Nissan Unveils Leaf, an Electric Car” <http://wheels.blogs.nytimes.com/2009/08/03/nissan-unveils-leaf-electric-car/>

Department of Energy as the project manager for a program to accelerate the development and production of various electric drive vehicle systems to substantially reduce petroleum consumption. The grant is valued at approximately \$99.8 million to undertake the largest deployment of electric vehicles and charging infrastructure in U.S. history.⁹⁶

The project takes advantage of the early availability of the Nissan LEAF, a zero-emission light-duty passenger electric vehicle, to develop, implement and study techniques for optimizing the effectiveness of charging infrastructure that will support widespread electric vehicle deployment. The project will install electric vehicle charging infrastructure and deploy Nissan battery electric vehicles in strategic markets in five states: Arizona, California, Oregon, Tennessee, and Washington.

The Oregon effort will monitor just under one thousand vehicles and the infrastructure to recharge them at their home as well as over 1,250 public level 2 and 50 fast charging station (level 3) charging stations. The project will install and monitor the infrastructure in Portland, Salem, Corvallis and Eugene.

It is expected that additional charging infrastructure will be installed, due to current state and federal incentives that can pay for up to 85 percent of the costs.

In terms of grid capacity available for charging electric vehicles, a 2007 study from the U.S. Department of Energy's Pacific Northwest National Lab looked at the regional percentage of the passenger car light-duty fleet which could be replaced with plug-in hybrid electric vehicles supplied with energy from the existing power system without additional investments in generation, transmission and distribution. To estimate the unused generation capability that would be available for plug-in hybrid electric vehicles, they looked at the total capacity minus the hourly generation that is committed to meeting load demand. The study did not include hydroelectric, nuclear or renewable plants in its estimates. The unused generation was further curtailed by accounting for scheduled maintenance; other planned outages and by precluding the use of peaking plants designed for short run-time operations. The study concluded that although the Pacific Northwest had less unused power than other regions

⁹⁶ Oregon Department of Transportation (ODOT) website. Innovative Partnerships Program.
http://www.oregon.gov/ODOT/HWY/OIPP/inn_ev-charging.shtml

	<p>of the United States, there is unused power that could power between 1.6 and 2.8 million plug-in hybrid electric vehicles in Oregon.⁹⁷</p> <p>Barriers to expansion.</p> <p>Product barriers. Battery costs are the most significant product-related barrier. Although nearly every automaker has announced plans to make electric vehicles, the battery industry does not currently have sufficient production capability to achieve economies of scale. A tremendous amount of research and development investment will be going into battery technology in the next few years and will likely parallel what has happened to computer memory in the last decade, with each successive generation becoming smaller, lighter, less expensive and able to hold more energy. Until then, early adopters will be paying a significant premium over comparable internal combustion vehicles.</p> <p>In addition, there are currently few vehicle choices, especially for moderately priced vehicles and for large capacity vehicles like trucks, minivans, buses and SUVs.</p> <p>Distribution Barriers. Utilities must be able to handle the potential increase in total demand, daily peak loads and other challenges. While electric vehicles are inherently simpler than internal combustion vehicles, there are currently very few auto mechanics and technicians trained to work on them.</p> <p>Infrastructure Barriers. Electric vehicle owners currently face challenges in finding convenient public charging stations. A reliable infrastructure for charging is an absolute necessity to encourage growth and acceptance. Public investment might be necessary to help build sufficient public charging infrastructure due to the low cost of electricity. Fast charging can be expensive to install. The Society of Automotive Engineers is still developing standards for some charging technologies.</p>
<p>Summary of known trends:</p> <ul style="list-style-type: none"> • Volume used • Number of vehicles 	<p>Trends in Electricity as a transportation fuel</p> <p>Volume used</p> <p>Trend #1: In Oregon, current use of electricity in vehicles and equipment is approximately 1,636 electric vehicles.⁹⁸</p> <p>Trend #2: In the United States, consumption of electricity as a</p>

⁹⁷ Pacific Northwest National Laboratory. Impacts Assessment of Plug-in Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids. Part1: Technical Analysis. PNNL-SA-53700.

http://energytech.pnl.gov/publications/pdf/PHEV_Feasibility_Analysis_Part1.pdf

⁹⁸ US EIA. Table V10. Estimated Number of Electric Vehicles in Use by User Group and State, 2007.

<http://www.eia.doe.gov/cneaf/alternate/page/atftables/atft v10.html>.

	<p>transportation fuel has increased 1.2 million gallons of gasoline equivalent in 1998 to 5 million gallons of gasoline equivalent in 2007.⁹⁹</p> <p>Number of vehicles</p> <p>Trend #3: In the United States, the number of electric vehicles in use increased substantially. In 2007, there were over 12 times as many electric vehicles on the road as there were in 1997.¹⁰⁰</p> <p>Trend #4: Oregon Zero Emission Vehicle rules will increase the minimum number of electric or plug in hybrid electric vehicles sold in Oregon. Vehicle rules, a minimum of approximately 12,000 full battery electric vehicles and 17,000 plug-in-hybrid electric vehicles must be placed in Oregon in by 2022.¹⁰¹</p>
<p>Preliminary Estimates of 2022 Use:</p> <ul style="list-style-type: none"> • Future use • Low • Moderate • High 	<p>Future use estimates</p> <p>Forecast #1: It is difficult to base predictions of future use of electricity on past use of electricity as a transportation fuel because the technology has changed and will continue to change. In the past, available electric vehicles were limited in speed and range. New electric vehicles are freeway ready, have longer ranges, and consequently use more electricity and have more potential for use as a transportation fuel.</p> <p>Forecast #2: The U.S. Energy Information Administration predicts that electricity used as a transportation fuel will increase for light duty vehicles, particularly for plug-in gasoline hybrids. They predicted a decline in full-battery electric vehicles. Their estimate of future use is only slightly higher than the historic rate of electric vehicles use (15% average per year). Based on this information, electricity use in light-duty transportation would be 5.54 trillion Btus in 2022.¹⁰²</p> <p>Forecast #3: It is likely that plug-in hybrid electric vehicles will be more popular than pure electric vehicles due to range anxiety and battery cost.</p> <p>Forecast #4: A low carbon fuel standard in Oregon could potentially spur more electricity use for transportation than would have happened otherwise. Trends in other countries or states that use large volumes of electricity could help us identify feasible adoption rates for both passenger and medium/heavy-duty applications.</p>

⁹⁹ US DOE. Alt Fuels& Advanced Vehicles Data Ctr. <http://www.afdc.energy.gov/afdc/data/fuels.html>

¹⁰⁰ US DOE. Alt Fuels& Advanced Vehicles Data Ctr. <http://www.afdc.energy.gov/afdc/data/vehicles.html>

¹⁰¹ Dave Nordberg, ODEQ. Minimum Number Electric Vehicles Required in Oregon by ZEV Rules, 4/5/2010.

¹⁰² US EIA. *Annual Energy Outlook 2010*. Supplemental Tables. Table 46. <http://www.eia.doe.gov/oiaf/aeo/supplement/>

	<p>Low estimate (proposed for discussion)</p> <p>Based on Oregon’s Low Emission Vehicle rules, a minimum of approximately 12,000 full battery electric vehicles and 17,000 plug-in-hybrid electric vehicles must be placed in Oregon in by 2022.¹⁰³</p> <p>Moderate and High estimates (proposed for discussion)</p> <p>Moderate and high estimates could be based on future electric vehicle predictions from academics, governments, consultants, or auto manufacturers.</p>
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Further reading:

University of Berkeley, CA. Electric Vehicles in the United States: A New Model with Forecasts to 2030. Center for Entrepreneurship & Technology (CET) Technical Brief. Number: 2009.1.v.2.0
http://cet.berkeley.edu/dl/CET_Technical%20Brief_EconomicModel2030_f.pdf

Electrification Coalition: Electrification Roadmap.
<http://www.electrificationcoalition.org/electrification-roadmap.php>

Pike Research: Electric Vehicles: 10 Predictions for 2010.
<http://www.pikeresearch.com/research/electric-vehicles-10-predictions-for-2010>

Green Car Institute. The Current and Future Market for Electric Vehicles.
<http://greencars.org/pdf/gcimarketing.pdf>

McKinsey & Company. The Current and Future Market for Electric Vehicles.
http://www.mckinsey.com/client-service/ccsi/pdf/roads_toward_low_carbon_future.pdf

International Energy Agency. Technology Roadmap. Electric and plug-in hybrid electric vehicles.
http://www.iea.org/papers/2009/EV_PHEV_Roadmap.pdf

Worldwide Nanotechnology Electric Vehicle (EV) Market Shares Strategies, and Forecasts, 2009 to 2015. <http://wintergreenresearch.com/reports/ElectricVehicles.htm>

¹⁰³ Dave Nordberg, ODEQ. Minimum Number Electric Vehicles Required in Oregon by ZEV Rules, 4/5/2010.

Compressed Natural Gas (CNG) - Fossil Sources

<p>Feedstock and production process</p>	<p>Feedstock. Natural gas consists of a mixture of hydrocarbons, predominantly methane (CH₄). Most natural gas is extracted from gas and oil wells via drilling, and then processed to remove impurities and bring it to pipeline quality specifications. Smaller amounts are derived from sources such as synthetic gas, coal-derived gas, and landfill gas and other biogas resources. (Biogas as a source of CNG and LNG is addressed in a separate fuel assessment on page 61.)</p> <p>Production process. To produce compressed natural gas, natural gas must first be upgraded to pipeline quality by removing impurities such as water, sulfur, carbon dioxide, oils and other condensates, and natural gas liquids. After it is upgraded, natural gas can be compressed to approximately 3,600 pounds per square inch for use as a transportation fuel</p>
<p>Co-products</p>	<p>Not applicable.</p>
<p>Commercialization status</p> <ul style="list-style-type: none"> • Fuel • Vehicles 	<p>Fuel. Production and distribution of natural gas is a mature industry in the United States. Oregon is tied into a vast natural gas pipeline distribution system in North America. Natural gas accounts for approximately one quarter of the energy used in the United States. Of this, the bulk of natural gas goes to residential, commercial, industrial, and electric power production. Only about one tenth of one percent is currently compressed and used as a transportation fuel.¹⁰⁴</p> <p>Vehicles. Natural gas vehicle technology is fully commercialized for both light and heavy-duty applications, and compressed natural gas vehicles are widely available in most regions of the world. However, the vehicles are more widespread in other parts of the world than in the United States. Europe, Latin America, and the Middle East have experienced strong growth in compressed natural gas use in the transportation sector. Recently, several large United States companies, such as, AT&T, UPS and PG&E have committed to incorporating thousands of natural gas vehicles into their fleets. According to the Natural Gas Vehicle Institute¹⁰⁵, there are over 50 manufacturers of CNG vehicles and over 150 models worldwide, with 8.4 million CNG vehicles on the road worldwide and roughly 130,000</p>

¹⁰⁴ US EIA. 2008. Natural Gas Consumption by End Use, OR.

http://tonto.eia.doe.gov/dnav/ng/ng_cons_sum_dcu_SOR_a.htm

¹⁰⁵ Natural Gas Vehicle Institute. <http://www.ngvi.com/index.html>

	<p>in the United States.</p> <p>There are numerous options for medium-duty transportation uses such as transit buses, school buses, step-vans, and trucks.¹⁰⁶ However, there are few natural gas light-duty passenger cars and trucks available in the United States. Some existing vehicles can be converted to run on CNG.</p> <p>Cost is one of the chief factors driving the use of compressed natural gas as a transportation fuel. According to Natural Gas Vehicles of America, natural gas has been 25-42 percent cheaper than diesel over the last 14 years and on average costs more than one-third less than conventional gasoline at the pump. Additionally, CNG costs to the end user are less volatile than gasoline or diesel due to regulation of natural gas prices by the Oregon Public Utilities Commission. The economic advantage of CNG over gasoline has been steadily increasing as new technology to extract natural gas has created vast new recoverable reserves in the United States. If gasoline prices increase, CNG could experience an increase in use.</p>
<p>Current production in Oregon</p>	<p>Oregon’s natural gas is supplied by three providers: Avista, Cascade Natural Gas and NW Natural. The vast majority is imported, and arrives in gaseous form via pipeline. Some natural gas is liquefied and stored for re-gasification and use during peak heating months.</p> <p>In 2007, Oregon had 18 wells producing 409 million cubic feet of natural gas annually. Total natural gas delivered to Oregon was 242,393 million cubic feet according to the Energy Information Agency¹⁰⁷. Hence, gas produced in Oregon in 2007 was only two tenths of a percent of the gas used in Oregon.</p>
<p>Potential production in Oregon</p>	<p>Oregon does not have substantial natural gas reserves, although more Oregon production is possible.</p>
<p>Out-of-state production</p>	<p>Most natural gas consumed in the United States is domestically produced, with significant imports from Canada. New drilling technologies have unlocked new natural gas reserves from several sources such as shale, deep natural gas, coalbed methane and tight natural gas. The nation’s reserves have surged by 35 percent recently, accounting for the largest increases in history. While we import approximately 57 percent of our oil¹⁰⁸, 98 percent of natural gas used in the United States comes from North America, and by</p>

¹⁰⁶ US DOE. Alt Fuels & Advanced Vehicles Data Ctr. <http://www.afdc.energy.gov/afdc/vehicles/search/heavy>

¹⁰⁷ US EIA. Natural Gas Gross Withdrawals and Production. http://tonto.eia.doe.gov/dnav/ng/ng_prod_sum_dcu_sor_a.htm.

¹⁰⁸ US EIA. Feb. 2010. How Dependent are we on Foreign Oil? http://tonto.eia.doe.gov/energy_in_brief/foreign_oil_dependence.cfm.

	<p>2030, it is estimated that 98 percent will come from United States reserves alone.¹⁰⁹ A recent study¹¹⁰ concluded that the United States has 118 years worth of natural gas resources at current production levels. Additionally, in 13 of the past 14 years, the amount of new natural gas discovered in the United States has exceeded the amount that has been extracted.</p>
<p>Current use</p> <ul style="list-style-type: none"> • Volume • Number of vehicles • Existing fueling infrastructure • Barriers to expansion • Special issues 	<p>Volume. In Oregon, the trend is for increased use of CNG as a transportation fuel. From 2004 to 2008, use of natural gas as a transportation fuel doubled from 96 million cubic feet to 190 million cubic feet.¹¹¹</p> <p>Number of vehicles. There are 400 registered highway CNG vehicles in Oregon. According to the Energy Information Administration, in 2007 there were 1,500 CNG vehicles and equipment in Oregon¹¹². Currently the state of Oregon motor pool has the largest fleet of CNG vehicles with approximately 160 vehicles.</p> <p>Existing fueling infrastructure. Oregon currently has CNG refueling infrastructure at several locations along the I5 corridor. However, most of this infrastructure is inaccessible to the general public.</p> <ul style="list-style-type: none"> • Medford: Jackson county and Rogue Valley Transit District currently have CNG compressors, but hope to build a new regional fueling station in White City using modern fast fill technology. Jackson County and Rogue Valley Transit District pumps in Medford provide the only publicly accessible CNG in Oregon. Recently the City of Medford received a grant to purchase a CNG powered street sweeper. The local natural gas provider, Avista, also has a CNG powered fleet with refueling capabilities but is unable to allow public refueling due to Public Utility Commission rules. • Springfield: Fueling stations at the former state of Oregon motor pool facility in Springfield is still operational and currently being rented by the University of Oregon. • Salem: Salem has two compressor stations: <ul style="list-style-type: none"> ○ Oregon Department of Administrative Services Motor Pool.

¹⁰⁹ US EIA. http://www.eia.doe.gov/oil_gas/natural_gas/info_glance/natural_gas.html

¹¹⁰ North American Natural Gas Supply Assessment. 2008. By Navigant Consulting prepared for the American Clean Skies Foundation. <http://www.cleanskies.org/pdf/navigant-natural-gas-supply-0708.pdf>.

¹¹¹ US EIA. Data from 2007. Natural Gas Consumption by End Use, Annual, for Oregon. http://tonto.eia.doe.gov/dnav/ng/ng_cons_sum_dcunusm.htm.

¹¹² US EIA. Data from 2007. Alternatives to Traditional Transportation Fuels. Estimated Number of Compressed Natural Gas (CNG) Vehicles in Use by User Group and State http://www.eia.doe.gov/cneaf/alternate/page/atftables/atft_v9.html

The legislature passed a bill (HB 3676) during the last session that sunsets in 2014 and allows the sale, distribution and dispensing of compressed natural gas to private entities.

- Salem Keizer Transit District facility. On some occasions, the transit facility has allowed fueling stops by outside customers, but generally does not offer public refueling.
- **Portland area:** The closed Portland area state motor pool site is operating as a cardlock. The Port of Portland has a compressor to refuel buses and other equipment but does not offer public refueling. NW Natural has some refueling capabilities but they are not suitable for public access and they have the same limitation as Avista in offering public refueling. A public refueling facility in Hillsboro recently closed due to economic reasons.

Barriers to expansion. For light-duty passenger car applications, CNG refueling infrastructure is the barrier to market adoption vehicles. A metropolitan network of compressors and dispensers with card lock public access are required to give consumers options for refueling CNG vehicles. Investors are reluctant to pursue these opportunities without guaranteed markets developing. Consumers are reluctant to pursue home refueling appliances due to initial cost and lack of locations to refill their vehicles away from home.

For medium and heavy-duty applications, capital expense for a large fleet CNG system (including compression, storage and card lock dispensers) is in the range of \$500,000 - \$1 million, depending on the amount of fuel needed at any given time. Such a system would displace from 0.5 to 1 million gallons of diesel annually. The highest cost-to-benefit ratio is seen in large fleets that return to base, such as buses, waste haulers, taxicabs, distributors, delivery vehicles and some corporate fleets. These captive fleets are the key and basis to deployment of CNG infrastructure.

Special issues: paving the way for Fuel Cell Vehicles.

Natural gas vehicle and infrastructure development could facilitate the transition to fuel cell technology. As gaseous fuels, natural gas and hydrogen share issues related to fuel storage, fueling infrastructure, station siting and public acceptability. Vehicles fueled with hydrogen-natural gas blends could be an intermediate step toward a hydrogen-based transportation network.

<p>Summary of known trends:</p> <ul style="list-style-type: none"> • Volume used • Number of vehicles 	<p>Volume used</p> <p>Trend# 1: In Oregon, use of compressed natural gas as a transportation fuel increased over 200% from 2004 to 2008.¹¹³</p> <p>Trend# 2: In the United States, consumption of compressed natural gas as a transportation fuel increased 169% in the decade from 1997 to 2007. During that same timeframe, use of CNG increased an average of 11% per year.¹¹⁴</p> <p>Number of vehicles</p> <p>Trend# 3: In the United States, the number of CNG vehicles in use increased approximately 5% per year from 1997 to 2007.¹¹⁵</p> <p>Trend# 4: Worldwide, there are over 7 times more CNG vehicles on the road in 2008 than in 2007.¹¹⁶</p>
<p>Preliminary Estimates of 2022 Use:</p> <ul style="list-style-type: none"> • Future use • Low • Moderate • High 	<p>Future use estimates</p> <p>Forecast #1: The Energy Information Administration¹¹⁷ predicts that CNG use in light-duty passenger vehicles will decline slightly. They also predict that by 2020:</p> <ol style="list-style-type: none"> Transit bus use of CNG will nearly triple School bus use of CNG will double Medium-duty truck use of CNG will more than double Heavy-duty truck use of CNG will be nine times higher than in 2007 <p>Forecast #2: A low carbon fuel standard in Oregon could potentially spur more CNG use for transportation than would have happened otherwise. Trends in other countries or states that use large volumes of CNG could help us identify feasible adoption rates for both passenger and medium/heavy-duty applications.</p> <p>Low estimate (proposed for discussion)</p> <p>A low estimate could be based on the historic rate of increase for CNG use in Oregon or the US, or on future predictions. Most of the increase would</p>

¹¹³ US EIA. Data from 2004-2008. Data were not available for previous years. Natural Gas Consumption by End Use, Annual, for Oregon. http://tonto.eia.doe.gov/dnav/ng/ng_cons_sum_dcu_nus_m.htm.

¹¹⁴ US DOE. Alt Fuels & Advanced Vehicles Data Ctr. <http://www.afdc.energy.gov/afdc/data/fuels.html>

¹¹⁵ US DOE. Alt Fuels & Advanced Vehicles Data Ctr. <http://www.afdc.energy.gov/afdc/data/vehicles.html>

¹¹⁶ International Association for Natural Gas Vehicles website. Vehicle Statistics. <http://iangv.org/tools-resources/statistics.html>

¹¹⁷ US EIA. *Annual Energy Outlook 2010*. Supplemental Tables. Table 46. <http://www.eia.doe.gov/oiaf/aeo/supplement/>

	<p>likely be in the medium-duty vehicle range.</p> <p>Moderate and High estimates (proposed for discussion)</p> <p>Moderate and high estimates could be based on several different sources of information, such as future electric vehicle predictions from consultants, natural gas associations, government or natural gas vehicle manufacturers. Please see “Further reading” section below.</p>
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Further reading:

California Energy Commission. Compressed Natural Gas (Cng) As A Transportation Fuel. http://www.consumerenergycenter.org/transportation/Not_applicable.fvs/cng.html

Natural Gas Vehicles for America:

- Fact Sheet: Potential Contribution of NGVs to Displacing 35 Billion Gallons of Non-Petroleum Fuels by 2017. <http://www.ngvamerica.org/pdfs/PotentialNGVs.pdf>
- The Great Discontinuity: Why Historical Studies Are Not a Useful Guide in Making Current and Future Heavy-Duty Vehicle Purchase Decisions. <http://www.ngvamerica.org/pdfs/marketplace/MP.Analyses.Discon.pdf>
- The Case For Natural Gas: The Most Abundant, Clean And Cost-Efficient American Fuel. An Issue Brief. <http://www.ngvamerica.org/pdfs/NGVAIssueBrief022309.pdf>

Natural Gas End Use: A Vision for Today and the Future. September 22, 2009 <http://www.gasfoundation.org/ResearchStudies/FullstudyEnduse.pdf>

Liquefied Natural Gas (LNG) - Fossil Sources

<p>Feedstock and production process</p>	<p>Feedstock. Natural gas consists of a mixture of hydrocarbons, predominantly methane (CH₄). Most natural gas is extracted from gas and oil wells via drilling, and then processed to remove impurities and bring it to pipeline quality specifications. Much smaller amounts are derived from sources such as synthetic gas, landfill gas and other biogas resources, and coal-derived gas. (Biogas as a source of CNG and LNG is addressed in a separate fuel assessment on page 61.)</p> <p>Production process. To produce liquefied natural gas, or LNG, natural gas is purified and condensed into liquid by cooling to -260°F (-162°C). Because it must be kept at such cold temperatures, LNG is stored in double-wall, vacuum-insulated pressure vessels.</p> <p>It is important to distinguish between LNG as a bulk commercial product, and LNG for use as a transportation fuel. The LNG that is ultimately used in a vehicle may or may not have been liquefied at a previous stage in its distribution. The three main distribution chain scenarios are:</p> <ul style="list-style-type: none"> • Extraction site (North America) → Pipeline → LNG fueling station • Extraction site (overseas) → Liquefaction (overseas) → Tanker → Re-gasification (U.S.) → Pipeline → LNG fueling station • Extraction site (overseas) → Liquefaction (overseas) → Tanker → Tank truck → LNG fueling station <p>This paper addresses LNG used in vehicles and equipment as a transportation fuel.</p>
<p>Co-products</p>	<p>Not applicable.</p>
<p>Commercialization status</p> <ul style="list-style-type: none"> • Fuel • Vehicles 	<p>Fuel. Production and distribution of natural gas is a mature industry in the U.S., and Oregon is tied into a vast natural gas pipeline distribution system in North America. Natural gas liquefaction technology is fully commercialized, although the use of LNG vehicle fueling stations is not widespread on the west coast outside of a few locations, including the Southern California.</p>

	<p>Vehicles. LNG vehicle technology is fully commercialized for heavy-duty applications such as refuse haulers, local delivery and transit buses,¹¹⁸ and LNG vehicles are widely available for purchase in most regions of the world. LNG vehicles are typically original equipment manufacturer modified for this fuel use. There are no light-duty passenger LNG vehicles available in the US.</p>
<p>Current production in Oregon</p>	<p>LNG is not commercially transported or sold in Oregon at this time. Currently the only use of LNG in Oregon is by natural gas providers in order to reduce its storage volume until it is needed during peak heating months.</p> <p>(See CNG Fuels Assessment for information about Oregon’s current natural gas production on page 51.)</p>
<p>Potential production in Oregon</p>	<p>(See CNG Fuels Assessment for information about Oregon’s potential natural gas production on page 51.)</p>
<p>Out-of-state production</p>	<p>Currently, most natural gas arrives in Oregon in gaseous form via pipeline. (See CNG Fuels Assessment for information about out-of-state natural gas supplies.) Transportation use as LNG from the gas that arrives via pipeline would require liquefaction.</p> <p>The U.S. currently imports a small portion of its natural gas supplies as LNG, mainly from Africa and the Middle East. In the future, LNG could arrive in Oregon by sea on specialized tankers with insulated walls. It would then be transported in a liquefied form, or re-gasified, transported over land by pipeline, and re-liquefied at a fueling station.</p>
<p>Current use</p> <ul style="list-style-type: none"> • Volume • Number of vehicles • Existing fueling infrastructure • Barriers to expansion • Special issues 	<p>Volume. LNG is not currently used as a transportation fuel in Oregon.</p> <p>Number of vehicles. None in Oregon.</p> <p>Existing fueling infrastructure. None in Oregon.</p> <p>Barriers to expansion. LNG refueling infrastructure is the barrier to market adoption of LNG vehicles. A fueling station costs approximately \$1 million dollars.¹¹⁹ Manufacturers build vehicles and could provide fueling infrastructure if there were a demand in our market. Fleets might consider the fuel if the infrastructure was available locally.</p>
<p>Summary of</p>	<p>Trends in Liquefied Natural Gas as a transportation</p>

¹¹⁸ US DOE. Alt Fuels & Advanced Vehicles Data Ctr. <http://www.afdc.energy.gov/afdc/vehicles/search/heavy>

¹¹⁹ California Energy Commission: Liquefied Natural Gas (LNG) as a Transportation Fuel <http://www.consumerenergycenter.org/transportation/afvs/lng.html>

<p>known trends:</p> <ul style="list-style-type: none"> • Volume used • Number of vehicles 	<p>fuel</p> <p>Volume used</p> <p>Trend #1: In the United States, consumption of liquefied natural gas as a transportation fuel has increased 648% in the decade from 1997 to 2007.¹²⁰</p> <p>Number of vehicles</p> <p>Trend #2: In the United States, the number of LNG vehicles in use increased approximately 350% from 1997 to 2007.¹²¹</p>
<p>Preliminary Estimates of 2022 Use:</p> <ul style="list-style-type: none"> • Future use • Low • High 	<p>Future use</p> <p>Forecast #1: If Oregon followed U.S. trends, LNG could play an integral role in future transportation fuel use.</p> <p>Forecast #2: Other countries and areas of the U.S. are investing in LNG infrastructure and vehicles.¹²²</p> <p>Forecast #3: If there were either government or private investment in LNG infrastructure, LNG could become an important contributor to transportation in Oregon.</p> <p>Forecast #4: A low carbon fuel standard in Oregon could potentially spur more LNG use for transportation than would have happened otherwise. Trends in other countries or states that use large volumes of LNG could help us identify feasible adoption rates for medium- and heavy-duty applications.</p> <p>Low estimate (proposed for discussion)</p> <p>It is possible, due to lack of infrastructure and historic use, that no LNG will be used for transportation purposes in Oregon.</p> <p>High (but feasible) estimate (proposed for discussion)</p> <p>Based on the historic use and lack of fueling infrastructure, DEQ proposes not to include any LNG in the compliance scenarios for the low carbon fuel standard.</p> <p>In the event that LNG is used in Oregon for transportation, LNG would</p>

¹²⁰ US DOE. Alt Fuels & Advanced Vehicles Data Ctr. <http://www.afdc.energy.gov/afdc/data/fuels.html>

¹²¹ US DOE. Alt Fuels & Advanced Vehicles Data Ctr. <http://www.afdc.energy.gov/afdc/data/vehicles.html>

¹²² NGV Global News. Aug. 2009. USDOE Allocates \$300M for Alternative Fuel Projects. <http://www.ngvglobal.com/us-department-of-energy-allocates-300m-for-alternative-fuel-projects-0826>

	be assigned a carbon intensity and could participate in the low carbon fuel standard as any other fuel would. In addition, the rules will address LNG, as we have discussed in past advisory committee meetings.
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Further reading:

Environmental Protection Agency

http://www.afdc.energy.gov/afdc/pdfs/epa_lng.pdf

California Energy Commission: LNG Frequently Asked Questions.

<http://www.energy.ca.gov/lng/faq.html>

California Energy Commission: Liquefied Natural Gas (LNG) as a Transportation Fuel

http://www.consumerenergycenter.org/transportation/Not_applicable.fvs/lng.html

Biogas (Biomethane)

<p>Feedstock and production process</p>	<p>Feedstock. Biogas (also referred to as biomethane) is produced from the biological breakdown of biodegradable organic materials (anaerobic digestion), resulting in a mixture of methane, carbon dioxide, and trace amounts of other gases. Biogas captured from landfills is referred to as landfill gas (raw landfill gas is about 50% methane), while digester gas (from 55% to 80% methane) refers to the production of biogas from wastewater treatment plants (sewage), and livestock manure, food waste, industrial waste, and other sources. Biogas is either flared off (burned) resulting in no capture of energy, combusted for electricity generation or heating, or refined into pipeline-quality gas. Biogas can be compressed and used as a transportation fuel in CNG vehicles, or used as a liquefied gas, or converted to hydrogen.</p> <p>Production process. Digester gas is produced from a biochemical process where several types of bacteria break down biomass in several steps. In step one, the bacteria break down the carbohydrates, proteins, and fats in biomass into acids, alcohol, CO₂, hydrogen, ammonia and sulfides, a process called hydrolysis, or liquefaction. Step two utilizes acid forming bacteria that further metabolize the products of hydrolysis into acetic acid, hydrogen, and CO₂. In the final step, methane forming bacteria convert these products into biogas, which contains methane, CO₂, Sulfur compounds, PM, and water. As the methane is dilute and contains contaminants, the biogas must be pretreated, conditioned, and compressed to approximately 3600 psi or liquefied to LNG before use as a fuel. The production of liquefied natural gas (LNG) from landfill gas requires additional steps including purification and cryogenic systems.</p>
<p>Co-products</p>	<p>By-products from anaerobic digestion can include fertilizers.</p>
<p>Commercialization status</p> <ul style="list-style-type: none"> • Fuel • Vehicles 	<p>Fuel. As active landfills must control landfill gas as environmental and health safety precaution, landfill gas collection systems using a network of wells, headers, and blowers to collect and route the gas to flaring or treatment are well established. The conversion of landfill gas to CNG is well established, and the Los Angeles County Sanitation District has successfully converted landfill gas to CNG since 1994 at its Clean Fuels facility. Several plants throughout the world, including one in California, upgrade biogas and inject it into natural gas pipelines. The conversion of landfill gas to LNG is much less prevalent, but facilities do exist. A plant in Rosenberg, TX produces 8,500 gallons per day, and there are two commercial scale demonstration projects in California.</p> <p>Anaerobic digestion technology to produce biogas is well developed worldwide. The biogas generated is mainly used to generate electricity, as</p>

	<p>well as to power onsite engines converted to run on biogas. In general, is not well utilized beyond the production facilities.</p> <p>Vehicles. Biogas, once treated and compressed or liquefied, can be used in the same vehicles that use fossil CNG or LNG. (See fuel assessments for CNG and LNG for details). Compressed natural gas vehicle technology is fully commercialized for both light and heavy-duty applications, and natural gas vehicles are widely available for purchase in most regions of the world. (See compressed natural gas fuel assessment on page 51 for details.) Liquefied natural gas vehicle technology is fully commercialized for heavy-duty applications. (See liquefied natural gas fuel assessment on page 57 for details.)</p>
<p>Current production in Oregon</p>	<p>Landfill gas¹²³:</p> <ul style="list-style-type: none"> • Four projects with a combined capacity of 18.4 megawatts capture landfill gas and use it to produce electricity: Short Mountain, Coffin Butte, Dry Creek, and Columbia Ridge landfills. • The Findley Butte landfill in Boardman captures biogas for co-generation of electricity, and has a capacity of 3.2 megawatts. • St. Johns landfill pipes captured landfill gas to a nearby industrial facility. • There are three facilities in development at Riverbend, Arlington, and Hillsboro landfills <p>Wastewater treatment plants: Anaerobic digesters are part of the sewage treatment process at 28 large wastewater treatment plants in Oregon. The digester gas produced at these facilities in 2004 had an energy value of about 0.8 trillion Btu.¹²⁴</p> <p>Twenty-eight wastewater treatment plants in Oregon use digester gas on site as boiler fuel to produce heat for the anaerobic digestion process and for space heating. The digester gas produced at these facilities in 2004 had an energy value of about 0.8 trillion Btu. Nine wastewater treatment plants use digester gas as fuel to generate electricity. These include Tri-City Service District, Clackamas County Service District, Clean Water Services, City of Portland, City of Gresham, City of Salem, City of Medford, and Eugene Public Works. These plants generated about 26 million kilowatt-hours in 2004.¹²⁵</p> <p>Agricultural waste: Several facilities produce biogas from agricultural</p>

¹²³ US EPA website. Landfill Methane Outreach Program Energy Projects and Candidate Landfills. <http://www.epa.gov/lmop/projects-candidates/index.html>

¹²⁴ ODOE website: <http://egov.oregon.gov/ENERGY/RENEW/Biomass/use.shtml#Biogas>

¹²⁵ ODOE website. <http://www.oregon.gov/ENERGY/RENEW/Biomass/use.shtml>

	<p>waste. These include Cal-Gon Dairy, Port of Tillamook, and Stahlbush Island Farms.</p> <p>There are also several biogas production facilities in development, such as Rickreall Dairy, Ferrera Farms, Lochmead Dairy, Three Mile Farms, and Neils Jenson Farms.</p>
<p>Potential production in Oregon</p>	<p>Many facilities in Oregon produce biogas, however it's production for use as a transportation fuel is limited. The following describes current Oregon production of biogas from all sources for all uses.</p> <p>Landfill Gas: EPA considers a landfill to be a good candidate for generating biogas when it has at least one million tons of waste and is still operational or has been closed for five years or less. Most landfills that fit this description already use biogas, although not for transportation purposes. There are three candidate landfills in Oregon.¹²⁶ These are the Knott landfill in Bend, Northern Wasco County landfill in The Dalles, and Roseburg landfill in Roseburg. Other landfills in Oregon might also be appropriate for a landfill gas project depending on the conditions at the site.</p> <p>Wastewater treatment plants: The Department of Energy estimates that, overall, as much as 36 percent of the biogas produced at Oregon's wastewater treatment facilities is unused. This surplus biogas is a potential source of transportation fuel. In 2004, the unused gas had an energy value of approximately 0.3 trillion Btu.¹²⁷</p> <p>Agricultural waste: EPA indicates that the potential for a positive financial return from producing biogas from livestock manure appears to be best at dairy operations with more than 500 cows and swine operations with more than 2,000 head.¹²⁸ In 2003, 111 dairies in the state were licensed for herds of 500 or more cows. Based on the cumulative number of cows on-site at these dairies, the Department of Energy estimates that approximately 3,400 million cubic feet of biogas is potentially available annually through anaerobic digestion technology. This amount of biogas would have an energy value of about 1.7 trillion Btu, which could produce up to 13 average megawatts of electricity.¹²⁹</p>
<p>Out-of-state production</p>	<p>Landfill gas: According to the Energy Information Administration, production of landfill gas in the United States has increased from 2006 to 2007 from 150 to 173 trillion BTUs.¹³⁰ Several studies indicate that there is a</p>

¹²⁶ US EPA. Energy Projects and Candidate Landfills. <http://www.epa.gov/lmop/projects-candidates/index.html>

¹²⁷ ODOE. Oregon's Biomass Energy Resources: <http://oregon.gov/ENERGY/RENEW/Biomass/resource.shtml>

¹²⁸ US EPA website. http://www.epa.gov/agstar/pdf/biogas%20recovery%20systems_screenres.pdf

¹²⁹ ODOE. Oregon's Biomass Energy Resources: <http://oregon.gov/ENERGY/RENEW/Biomass/resource.shtml>

¹³⁰ US EIA. Data from 2006 and 2007. Table 1.7 Waste Energy Consumption by Type of Waste and Energy Use Sector. http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/table1_11.pdf

	<p>large potential for production of biogas throughout the United States. Natural Gas Vehicles for America cites a 1998 study estimating that the biogas potential from landfills, animal waste, and sewage is equivalent to 6% of U.S. natural gas consumption or 10 billion gasoline gallon equivalents of transportation fuel (about 7% of year 2006 U.S. gasoline consumption).¹³¹</p> <p>Wastewater treatment plants: According to the EPA, there remains a great deal of potential for biogas production and use from wastewater treatment plants throughout the United States.¹³²</p> <p>Agricultural waste: In 2009, there were 140 anaerobic digester systems operating at commercial livestock farms the United States. These projects generate approximately 378,500 MWh annually through electricity production, boiler projects and pipeline injection.¹³³</p>
<p>Current use in Oregon</p> <ul style="list-style-type: none"> • Volume • Number of vehicles • Existing fueling infrastructure • Barriers to expansion 	<p>Volume. It is unknown how much biogas is used as a transportation fuel in Oregon, but the volume is not large relative to other fuels.</p> <p>Number of vehicles. Unknown.</p> <p>Existing fueling infrastructure. Unknown.</p> <p>Barriers to expansion. The volume of available feedstock and geography of pipeline supply and fleet fueling limit the potential for expansion of the use of biogas as a transportation fuel.</p>
<p>Summary of known trends:</p> <ul style="list-style-type: none"> • Volume produced • Volume used • Number of vehicles 	<p>Trends in Biogas as a transportation fuel</p> <p>Volume produced. Although this is not related directly to transportation use of biogas, in the United States, production of biogas produced from landfills increased over 15% percent from 2006 to 2007.</p> <p>Volume used. In a limited number of locations and countries, biogas has proven a useful transportation fuel and contributes substantially to the transportation mix in that area or country.¹³⁴</p> <p>Number of vehicles. Unknown.</p>

¹³¹ The American Biogas Alliance. Fact Sheet: Sequestering Greenhouse Gases from Landfills, Animal Waste, Sewage, and Other Sources Via Biomethane Production. . <http://www.ngvc.org/pdfs/BiomethaneFactSheet.pdf>

¹³² US EPA. Combined Heat and Power Partnership: <http://www.epa.gov/CHP/markets/wastewater.html>

¹³³ US EPA. Guide to Anaerobic Digesters. Agstar. <http://www.epa.gov/agstar/operational.html>

¹³⁴ Fachtagung 2003 O. Jönsson, M. Persson. Swedish Gas Centre, http://www.fvee.de/fileadmin/publikationen/Workshopbaende/ws2003-2/ws2003-2_02_04.pdf

Preliminary Estimates of 2022 Use:

- **Future use**
- **Low**
- **Moderate**
- **High**

Future estimates

Forecast #1: As markets develop for low carbon fuels biogas could be used for transport due to its favorable low carbon emissions.

Forecast #2: Biogas can play a role in future transportation in Oregon, but not a large one due to feedstock restraints. However, due to its exceptionally low carbon intensity, a small amount of biogas fuel could generate credits.

Forecast #3: A low carbon fuel standard in Oregon could potentially spur more biogas production and use for transportation than would have happened otherwise. Trends in other countries or states that use large volumes of biogas for transportation could help us identify feasible production and use rates for both passenger and medium/heavy-duty applications.

Low estimate (proposed for discussion)

Zero. Based on very low current use of biogas for transportation in Oregon, DEQ proposes that no increased biogas use in Oregon would bracket the lower range of inputs for the LCFS compliance scenarios.

Moderate estimate (proposed for discussion)

1/2 of remaining unused biogas potential. DEQ proposes the high estimate for biogas used as a transportation fuel is based on 1/2 of the unused Oregon potential. DEQ proposes to calculate unused biogas potential based on:

- Landfills currently operating or closed less than 5 years with 1 million tons of waste that do not capture and use landfill gas.
- Dairy operations of 500 head or greater with no anaerobic digester
- Unused wastewater treatment plants

High (but feasible) (proposed for discussion)

3/4 of remaining unused biogas potential. DEQ proposes the high estimate for biogas used as a transportation fuel is based on 3/4 of the unused Oregon potential.

Further reading:

Butanol or Bio-Butanol

<p>Feedstock and production</p>	<p>Feedstock. Biobutanol is butanol (a 4-carbon alcohol known as butyl alcohol) produced from biomass feedstocks. Currently, butanol's primary use is as an industrial solvent in products such as lacquers and enamels. Like ethanol, biobutanol is an alcohol that can be produced through processing of domestically grown crops, such as corn, wheat, sugar beets, sorghum, and cassava.¹³⁵ Biobutanol can also be produced from a mixture of wood wastes, agricultural residues and manure.</p> <p>Production. Historically, biobutanol was manufactured from corn and molasses in a fermentation process know as an ABE (acetone, butanol, ethanol) fermentation. Biobutanol made from fermentation processes are more expensive than from petrochemical production processes. Currently, butanol is produced almost entirely from petroleum.¹³⁶ Commercial biobutanol production has several limitations, including low values for final product concentration and degradation stemming from the toxicity of butanol to microbial organisms.¹³⁷ Researchers are also working on developing more efficient production processes with greater output.^{138, 139}</p> <p>Biobutanol can also be produced from processes that gasify wood wastes, agricultural residues and manure into a singes.¹⁴⁰ This gasification process converts biomass into a synthesis gas that is cleaned, fed into a catalytic reactor and purified to generate biobutanol, ethanol and methanol.¹⁴¹</p>
<p>Co-products</p>	<p>The conventional microbial producer of (bio)butanol from agricultural feedstocks generates three products: acetone, butanol and ethanol, via ABE</p>

¹³⁵ US DOE, What is Biobutanol? http://www.afdc.energy.gov/afdc/fuels/emerging_biobutanol_what_is.html

¹³⁶ US DOE, What is Biobutanol? http://www.afdc.energy.gov/afdc/fuels/emerging_biobutanol_what_is.html

¹³⁷ Green Car Congress website. 31st Symposium on Biotechnology for Fuels and Chemicals; Some New Approaches for Producing Butanol. 4 May 2009. <http://www.greencarcongress.com/2009/05/31st-symposium-20090504.html#more>

¹³⁸ Green Car Congress website. Researchers Develop New Bacterial Strain with Higher Butanol Tolerance; Potential to Double the Output of Biobutanol from Conventional Bacterial Fermentation. 20 August 2009. <http://www.greencarcongress.com/2009/08/yang-20090820.html#more>

¹³⁹ Richard Van Noorden Biobutanol enters battle of the alcohols 02 January 2008. S Atsumi, T Hanai and J C Liao, *Nature*, 2008, 451, 86 (DOI:10.1038/nature06450). <http://www.rsc.org/chemistryworld/Issues/2008/February/BiobutanolEntersBattleAlcohols.asp>

¹⁴⁰ Green Car Congress website. Diesel Brewing to Manufacture Cellulosic Biobutanol from Biomass and Manure With Thermochemical Process. 21 April 20. <http://www.greencarcongress.com/2009/04/diesel-brewing-20090421.html#more>

¹⁴¹ Anna Austin. Brewing Biobutanol in Salem. Biodeisel Magazine. July 2009.. http://www.biodieselmagazine.com/article.jsp?article_id=3537&q=&page=all

	fermentation. Electricity can also be generated from the production method. ¹⁴²
Commercialization status <ul style="list-style-type: none"> • Fuel • Vehicles 	<p>Fuel. The production of butanol is fully commercialized. The production of biobutanol is not fully commercialized at this time. California Air Resources Board staff indicate they do not think the fuel will be fully commercialized until sometime after 2020.¹⁴³ The fuel is still in the research and development phase, however, several pilot plants have been planned.¹⁴⁴</p> <p>Gevo, Inc. retrofitted an existing demonstration scale ethanol plant to produce biobutanol in 2009. Successful production of biobutanol at the 1 million gallon per year pilot plant demonstrates the viability of this technology for retrofitting existing ethanol plants to make biobutanol.¹⁴⁵</p> <p>Vehicles. According to the U.S. DOE Alternative Fuels and Advanced Vehicles Data Center, biobutanol is compatible with the current gasoline distribution infrastructure and would not require new or modified pipelines, blending facilities, storage tanks or retail station pumps to produce and distribute.¹⁴⁶</p> <p>Under U.S. Environmental Protection Agency regulations, biobutanol can be blended as an oxygenate with gasoline in concentrations up to 11.5 percent by volume. Biobutanol can also improve the blending of ethanol with gasoline.¹⁴⁷ Results showed that butanol mixed with diesel can reduce emissions of criteria pollutants.¹⁴⁸</p>
Current production in Oregon	<p>Oregon-based Diesel Brewing has launched an initiative to manufacture cellulosic biobutanol from biomass and dairy farm manure.</p> <p>Diesel Brewing is beginning with a demonstration facility to be built in Salem, Oregon by the end of 2009, which will process one ton per day of biomass.¹⁴⁹ The company plans to construct a 10-ton unit with a start-up date</p>

¹⁴² Anna Austin. Brewing Biobutanol in Salem. Biodeisel Magazine. July 2009.

http://www.biodieselmagazine.com/article.jsp?article_id=3537&q=&page=all

¹⁴³ CARB. Staff Report, Initial Statement of Reasons. Appendix B, March 5, 2009.

¹⁴⁴ Richard Van Noorden. Biobutanol enters battle of the alcohols. January 2008. S Atsumi, T Hanai and J C Liao, *Nature*, 2008, 451, 86 (DOI:10.1038/nature06450)

<http://www.rsc.org/chemistryworld/Issues/2008/February/BiobutanolEntersBattleAlcohols.asp>

¹⁴⁵ Gevo Biobutanol Retrofit Plant Starts Up; Gevo Launches Development Company to Retrofit Ethanol Plants. Sept. 30, 2009. <http://www.greencarcongress.com/biobutanol/index.html>

¹⁴⁶ Biodiesel Magazine website. Brewing Biodiesel in Salem.

http://www.biodieselmagazine.com/article.jsp?article_id=3537&q=&page=all

¹⁴⁷ US DOE. Alt Fuels & Advanced Vehicles Data Ctr.

http://www.afdc.energy.gov/afdc/fuels/emerging_biobutanol_benefits.html

¹⁴⁸ Diesel Brewing to Manufacture Cellulosic Biobutanol from Biomass and Manure With Thermochemical Process.

<http://www.greencarcongress.com/2009/04/diesel-brewing-20090421.html#more>

¹⁴⁹ Diesel Brewing to Help Oregon Achieve Energy Independence *Company will Convert Renewable Biomass and Manure into Transportation Fuels*. April 20, 2009.

	of October 2010 in Boardman, Oregon to demonstrate production yields, fuel ratios, and gas cleanup procedures, and will allow the company to further fine tune and balance the processes. Diesel Brewing plans to build a commercial-scale plant of at least 100 dry tons-a-day, again in Boardman, with a projected start-up of October 2012. ¹⁵⁰ The company anticipates building more refineries across Oregon after successful completion of the pilot and demonstration phases. ¹⁵¹
Potential production in Oregon	See the Oregon Biomass Assessment report prepared for the April 15, 2010 Advisory Committee meeting for information on Oregon’s potential for producing biomass. (http://www.deq.state.or.us/aq/committees/advcomLowCarbonFuel.htm)
Out-of-state production	Currently, biobutanol is not produced on a commercial scale. ¹⁵²
Current use in Oregon <ul style="list-style-type: none"> • Volume • Number of vehicles • Existing fueling infrastructure • Barriers to expansion • Special issues 	<p>Volume. None.</p> <p>Number of vehicles. Not applicable.</p> <p>Existing fueling infrastructure. The infrastructure needed for widespread commercial availability of biobutanol, such as processing plants and pipelines for transport, are already available and being used for fossil fuels and gas.</p> <p>Barriers to expansion. Problems associated with using agricultural feedstocks as fuel could affect the viability of biobutanol from such sources.</p> <p>To date, biobutanol has been relatively expensive to produce. Production of butanol from corn and other biomass has been stymied by the lack of technology to make it economically viable. The problem has been historically low yields and low concentrations of biobutanol compared to those of bioethanol.¹⁵³ Until now, the technology and economics did not exist to pursue butanol over ethanol as a viable alternative to gasoline.¹⁵⁴</p>
Summary of known trends:	Trend: volume used. None in Oregon.

http://www.businesswire.com/portal/site/home/permalink/?ndmViewId=news_view&newsId=20090420005173&newsLang=en

¹⁵⁰ Diesel Brewing to Help Oregon Achieve Energy Independence. *Company will Convert Renewable Biomass and Manure into Transportation Fuels.* Apr. 20, 2009.

http://www.businesswire.com/portal/site/home/permalink/?ndmViewId=news_view&newsId=20090420005173&newsLang=en

¹⁵¹ Brewing Biobutanol in Salem. *Biodeisel Magazine.* Jul. 2009.

http://www.biodieselmagazine.com/article.jsp?article_id=3537&q=&page=all

¹⁵² Biobutanol: Friend or Foe? *Ethanol Producer Magazine.* http://www.ethanolproducer.com/article.jsp?article_id=6337

¹⁵³ ButylFuel, LLC. <http://www.butanol.com/>

¹⁵⁴ ButylFuel, LLC. <http://www.butanol.com/>

<ul style="list-style-type: none"> • Volume produced • Volume used • Number of vehicles 	<p>Trend: volume produced. None in Oregon.</p> <p>Trend: number of vehicles. Not applicable.</p>
<p>Preliminary Estimates of 2022 Use:</p> <ul style="list-style-type: none"> • Future use • Low • High 	<p>Future use. A low carbon fuel standard in Oregon could potentially spur biobutanol fuel production. Trends in other countries or states produce biobutanol could help us identify feasible future production.</p> <p>Low estimate (proposed for discussion)</p> <p>It is possible, due to lack of infrastructure and historic use, that no biobutanol will be used for transportation purposes in Oregon. In the event that biobutanol is used in Oregon for transportation, a carbon intensity for biobutanol would be calculated and the fuel would be treated as any other biofuel under the low carbon fuel standard.</p> <p>Moderate estimate (proposed for discussion)</p> <p>Based on the proposed biobutanol demonstration plant in Oregon, it is feasible a larger facility could be built in Oregon, and that 10 to 25 million gallons will be available in 2022.</p> <p>High (but feasible) estimate (proposed for discussion)</p> <p>Based on the size of one or two commercial plants, it is feasible that 25 to 75 million gallons will be available in 2022.</p>

Hydrogen Fuels

Feedstock and production process

Feedstock. A hydrogen vehicle is an alternative fuel vehicle that uses hydrogen as its onboard fuel for motive power. The power plants of such vehicles convert the chemical energy of hydrogen to mechanical energy either by burning hydrogen in an internal combustion engine, or by reacting hydrogen with oxygen in a fuel cell to run electric motors. Widespread use of hydrogen for fueling transportation is a key element of a proposed hydrogen economy.

The ability to create hydrogen fuel from a variety of resources and its clean-burning properties make it a desirable alternative fuel. However, it can be produced from a wide range of sources (such as wind, solar, or nuclear) that are intermittent, too diffuse or too cumbersome to directly propel vehicles. Integrated wind-to-hydrogen plants, using electrolysis of water, are exploring technologies to deliver costs low enough, and quantities great enough, to compete with traditional energy sources.

Pure hydrogen and hydrogen mixed with natural gas (hythane) have been used effectively to power automobiles with internal combustion engines.

Production process. The predominant method for producing hydrogen gas is steam reforming of natural gas. Methanol, coal or biomass can also be used to make hydrogen. The U.S. Department of Energy¹⁵⁵ and other market developers see hydrogen infrastructure based on natural gas steam reformation at the service station, opposed to vehicles powered by hydrogen reformed onboard the vehicle.

A hydrogen internal combustion engine vehicle is a type of hydrogen vehicle using an internal combustion engine. Hydrogen internal combustion engine vehicles are different from hydrogen fuel cell vehicles; the engine is simply a modified version of the traditional gasoline-powered internal combustion engine.

Hydrogen also has potential as fuel for fuel cell vehicles. Hydrogen and oxygen fed into a proton exchange membrane fuel cell "stack" produce enough electricity to power an electric automobile, without producing any harmful emissions from the vehicle.

Many companies are working to develop technologies that might efficiently exploit the potential of hydrogen energy for mobile uses. The attraction of using hydrogen as an energy currency is that hydrogen prepared without

¹⁵⁵ US DOE Hydrogen Program. <http://www.hydrogen.energy.gov/>

	using fossil fuel inputs has no carbon dioxide emissions.
Co-products	None
Commercialization Status <ul style="list-style-type: none"> • Fuel • Vehicles 	<p>Fuel. Although fueling stations exist in many states and other countries, researchers continue to work on increase efficiency and yield in hydrogen production processes and storage.¹⁵⁶</p> <p>Vehicles. Hydrogen vehicles are not fully commercialized</p> <ul style="list-style-type: none"> • Hydrogen internal combustion engine vehicles are not yet commercialized.¹⁵⁷ • Hydrogen fuel cell vehicles are not yet commercialized. In 2009, seven automakers committed to commercializing hydrogen vehicles by 2015.^{158,159}
Current Production in Oregon	Hydrogen fuel is not available commercially in Oregon.
Potential Production in Oregon	Production prospects in Oregon are highly dependent upon significant infrastructure investments and market demand for the hydrogen fuel.
Out-of-state Production	The California Hydrogen Highway is an initiative by the California Governor to implement a series of hydrogen refueling stations along that state. As of July 2007 California had 179 fuel cell vehicles and twenty-five stations were in operation. However, there have already been three hydrogen-fueling stations decommissioned. ¹⁶⁰
Current Use in Oregon <ul style="list-style-type: none"> • Volume • Number of vehicles • Existing fueling 	<p>Volume. None.</p> <p>Number of vehicles. None in Oregon.</p> <p>Existing fueling infrastructure. None in Oregon.¹⁶¹</p>

¹⁵⁶ US DOE http://www.hydrogen.energy.gov/pdfs/2009_htac_annual_report.pdf

¹⁵⁷ CARB. Staff Report, Initial Statement of Reasons. Appendix B, Chapter III: Technical Assessment of Proposed Regulation to Implement the Low Carbon Fuel Standard, Vol. 1. March 5, 2009.

¹⁵⁸ US DOE. 2009 ANNUAL REPORT of The Hydrogen and Fuel Cell Technical Advisory Committee: http://www.hydrogen.energy.gov/pdfs/2009_htac_annual_report.pdf

¹⁵⁹ GM website. GM's Fuel Cell System Shrinks in Size, Weight, Cost http://media.gm.com/content/media/us/en/news/news_detail.html/content/Pages/news/us/en/2010/Mar/0316_fuelcell

¹⁶⁰ California Fuel Cell Partnership. <http://www.cafcp.org>

¹⁶¹ Alt. Fuel Prices website. <http://www.altfuelprices.com/>

<p>infrastructure</p> <ul style="list-style-type: none"> • Barriers to expansion • Special issues 	<p>Barriers to expansion.¹⁶²</p> <ul style="list-style-type: none"> • Current fuel cell car costs \$400,000 - \$1, 000,000 (million). Most hydrogen cars are only available in demonstration models. The estimated number of hydrogen-powered cars in the United States was 200 as of October 2009, mostly in California • Not enough room onboard for hydrogen fuel to give the driving range consumers want • Hydrogen fuel is 2x to 3x the price of gasoline • Need fueling infrastructure • Hydrogen could have a difficult time competing with other advancing technologies • Ford Motor Company has dropped its plans to develop hydrogen cars, stating that "The next major step in Ford's plan is to increase over time the volume of electrified vehicles".¹⁶³
<p>Summary of known trends:</p> <ul style="list-style-type: none"> • Volume produced • Volume used • Number of vehicles 	<p>Trend: volume used. From 2003 to 2007, hydrogen use in the United States increased from 2,000 to 66,000 gallons of gasoline equivalent, an average increase of 55% per year.¹⁶⁴</p> <p>Other countries and states see great promise in hydrogen, and are investing in vehicles and fueling infrastructure.^{165,166}</p> <p>Trend: volume produced. In the U.S. and worldwide, the number of fueling stations continues to grow.¹⁶⁷</p> <p>Trend: number of vehicles. The number of hydrogen vehicles in use has increased from 9 in 2003 to 223 in 2007.¹⁶⁸</p>
<p>Preliminary Estimates of 2022 Use:</p>	<p>Future use estimates</p> <p>Forecast #1: Several states in the US, as well as other countries, see great</p>

¹⁶² Joseph J. Romm PhD. The hype about hydrogen: fact and fiction in the race to save the climate.

¹⁶³ The Wall Street Journal.

http://online.wsj.com/public/resources/documents/Ford_Motor_Company_Business_Plan122008.pdf

¹⁶⁴ US DOE. Alternative Fuels and Advanced Vehicles Data Center. <http://www.afdc.energy.gov/afdc/data/fuels.html>

¹⁶⁵ Callaghan Jerram and Anissa Dehamna. Fuel Cell Today 2009 Hydrogen Infrastructure Survey Lisa June 2009.

<http://www.fuelcelltoday.com/media/pdf/surveys/2009-Infrastructure-Survey-Free.pdf>

¹⁶⁶ California Hydrogen Highway Network Hydrogen Infrastructure.

http://www.hydrogenhighway.ca.gov/facts/ca_infrastructure.pdf

¹⁶⁷ US DOE: http://www.hydrogen.energy.gov/pdfs/2009_htac_annual_report.pdf

¹⁶⁸ US DOE. Alternative Fuels and Advanced Vehicles Data Center. <http://www.afdc.energy.gov/afdc/data/fuels.html>

<ul style="list-style-type: none"> • Future use • Low • High 	<p>promise in hydrogen, and have been investing in vehicles and fueling stations.</p> <p>Forecast #2: The Energy Information Administration predicts that starting in 2016, the U.S. will start to see a dramatic increase in the use of hydrogen, from 0.8 to 11.4 million gallons of gasoline equivalent. They predict all of this will be in light-duty vehicles use.¹⁶⁹</p> <p>Low estimate (proposed for discussion)</p> <p>Zero. Based on the commercialization status of fuels and vehicles, and the lack of infrastructure in Oregon, DEQ concludes that it is possible no hydrogen will be used in Oregon by 2022.</p> <p>High (but feasible) estimate (proposed for discussion)</p> <p>Zero. Based on the historic use and lack of fueling infrastructure, DEQ proposes not to include any hydrogen in the compliance scenarios for the low carbon fuel standard.</p> <p>In the event that hydrogen is used in Oregon for transportation, hydrogen would be assigned a carbon intensity and could participate in the low carbon fuel standard as any other fuel would. In addition, the rules will address hydrogen, as we have discussed in past advisory committee meetings.</p>
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Further reading:

US Department of Energy: http://www.hydrogen.energy.gov/pdfs/2009_htac_annual_report.pdf

US Department of Energy Hydrogen website: <http://www.hydrogen.energy.gov/>

California Fuel Cell Partnership website: <http://www.cafcp.org/home>

¹⁶⁹ US EIA. *Annual Energy Outlook 2010*. Supplemental Table 46. <http://www.eia.doe.gov/oiaf/aeo/supplement/>

Biofuels from Algae

<p>Feedstock and production</p>	<p>Feedstock. Typically, oils from microalgae are the feedstock for biodiesel production.¹⁷⁰</p> <p>Production. Algae uses energy from sunlight to produce simple sugars, converts them into oils or complex carbohydrates and stores both substances in its cells. Potential fuels from algae include biodiesel, ethanol, Fischer Tropsch rules, hydrogen, alkanes, and methane.¹⁷¹</p> <p>While years of research have gone into studying the use of microalgae as a source for producing hydrogen, no commercial-scale process has been demonstrated to date.¹⁷² Several companies are currently conducting pilot projects to further research the production of biofuels from algae.¹⁷³</p> <p>Current research and development efforts in the United States have largely focused on microalgae as a source of oils. Several species produce high oil yields that greatly outweigh yields from conventional crops. The oil from algae could be refined into gasoline range hydrocarbons. Existing process equipment may be able to be used for this purpose.¹⁷⁴</p>
<p>Co-products</p>	<p>Cultivation of algae in conjunction of wastewater treatment (with CO₂ addition from combustion emissions) has the potential of fixing CO₂, removing soluble nitrogen and phosphorous in the wastewater, and producing O₂, in addition to generating biomass for biofuel feedstock. Biomass by-products from the oil extraction process may also have potential uses in cattle feed, cosmetics, vitamins and pigments.¹⁷⁵</p>

¹⁷⁰ CARB. Staff Report, Initial Statement of Reasons. Appendix B, Chapter III: Technical Assessment of Proposed Regulation to Implement the Low Carbon Fuel Standard, Vol. 1. March 5, 2009.

¹⁷¹ CARB. Staff Report, Initial Statement of Reasons. Appendix B, Chapter III: Technical Assessment of Proposed Regulation to Implement the Low Carbon Fuel Standard, Vol. 1. March 5, 2009.

¹⁷² John R Benemann (2008). Microalgae Biofuels: A Brief Introduction. As referenced (40) in Appendix B, Chapter III: Technical Assessment of Proposed Regulation to Implement the Low Carbon Fuel Standard, Vol. 1. March 5, 2009. California Air Resources Board, Staff Report, Initial Statement of Reasons.

¹⁷³ CARB. Staff Report, Initial Statement of Reasons. Appendix B, Chapter III: Technical Assessment of Proposed Regulation to Implement the Low Carbon Fuel Standard, Vol. 1. March 5, 2009.

¹⁷⁴ Alexander E Farrell, Danial Sperling, and et al. (2007. A Low-Carbon Fuel Standard for California Part 1: Technical Analysis) As referenced (5) in Appendix B, Chapter III: Technical Assessment of Proposed Regulation to Implement the Low Carbon Fuel Standard, Vol. 1. March 5, 2009. CARB Staff Report, Initial Statement of Reasons.

¹⁷⁵ CARB. Staff Report, Initial Statement of Reasons. Appendix B, Chapter III: Technical Assessment of Proposed Regulation to Implement the Low Carbon Fuel Standard, Vol. 1. March 5, 2009.

	Methane production from the digestion of the algal residues is another possible co-product. ¹⁷⁶
Commercialization status <ul style="list-style-type: none"> • Fuel • Vehicles 	<p>Fuel. Producing biofuels from algae is not commercialized. There are very few pilot or demonstration scale facilities in the United States. Technology to mass-produce algae and extract its oils could be five to ten years in the future. Research continues in this regard, and the technology is anticipated to be commercially viable sometime after 2020.¹⁷⁷</p> <p>Vehicles. A San Diego, CA company claims to have made a renewable fuel using modified algae that meets fuel quality standards for use as an alternative to gasoline. However, this technology is still under development and is not expected to be commercially viable before 2011.¹⁷⁸</p>
Current production in Oregon	<p>Oregon State University researchers are working to find an efficient method of processing algae to produce biodiesel fuel and ethanol. Two small experimental photobioreactors to grow microscopic algae in a closed system have been built at OSU's Sustainable Technologies Laboratory in Corvallis.¹⁷⁹</p> <p>WW Moss has proposed a 100-acre algal biofuels facility for the Port of Umatilla. The company said it would produce biodiesel, omega-3 fatty acids for the nutraceutical market and animal protein supplements.¹⁸⁰</p>
Potential production in Oregon	Unknown at this time.
Out-of-state production	Unknown at this time.
Current use in Oregon <ul style="list-style-type: none"> • Volume • Number of vehicles 	<p>Volume. There is no production of biofuels from algae in Oregon.</p> <p>Number of vehicles. Not applicable.</p>

¹⁷⁶ Anders S Carlsson, et al. 2007. Micro- and Macro-Algae: Utility for Industrial Applications. Outputs from the EPOBIO Project. As referenced (37) in Appendix B, Chapter III: Technical Assessment of Proposed Regulation to Implement the Low Carbon Fuel Standard, Vol. 1. Mar. 5, 2009. CARB Staff Report, Initial Statement of Reasons.

¹⁷⁷ CARB. Staff Report, Initial Statement of Reasons. Appendix B, Chapter III: Technical Assessment of Proposed Regulation to Implement the Low Carbon Fuel Standard, Vol. 1. Mar. 5, 2009.

¹⁷⁸ Green Car Congress. 2008. "Sapphire Energy Introduces Algae-Derived Bio-Gasoline." As referenced (42) in Appendix B, Chapter III: Technical Assessment of Proposed Regulation to Implement the Low Carbon Fuel Standard, Vol. 1. March 5, 2009. California Air Resources Board, Staff Report, Initial Statement of Reasons.

<http://www.greencarcongress.com/2008/05/sapphire-energy.html>

¹⁷⁹ High Plains/Midwest Ag Journal. Mar. 2008. Oregon State works to turn algae into biodiesel.

<http://www.hpi.com/archives/2008/apr08/apr7/OregonStateWorkstoturnalgae.cfm?title=Oregon%20State%20works%20to%20turn%20algae%20into%20biodiesel>

¹⁸⁰ Biofuels Digest. Oct. 2009. WW Moss proposes 100-acre algae farm in Oregon.

<http://www.biofuelsdigest.com/blog2/2009/10/30/ww-moss-proposes-100-acre-algae-farm-in-oregon/>

<ul style="list-style-type: none"> • Existing fueling infrastructure • Barriers to expansion 	<p>Existing fueling infrastructure. Not applicable.</p> <p>Barriers to expansion. Not commercialized, and it is in the research and development phase.</p>
<p>Summary of known trends:</p> <ul style="list-style-type: none"> • Volume produced • Volume used • Number of vehicles 	<p>Trend: volume used. None in Oregon.</p> <p>Trend: volume produced. None in Oregon.</p> <p>Trend: number of vehicles. Not applicable.</p>
<p>Preliminary Estimates of 2022 Use:</p> <ul style="list-style-type: none"> • Low • High 	<p>Low estimate (proposed for discussion)</p> <p>Zero. Based on the commercialization status and California Air Resources Board’s assessment of the potential for biofuels from algae, it is possible that no biofuels produced from algae will be produced before 2022.</p> <p>High (but feasible) estimate (proposed for discussion)</p> <p>Zero. Based on the commercialization status and California Air Resources Board’s assessment of the potential for biofuels from algae, DEQ proposes not to include any biofuels from algae in the compliance scenarios for the low carbon fuel standard.</p> <p>In the event that biofuels from algae are used in Oregon for transportation, they would be assigned a carbon intensity and could participate in the low carbon fuel standard as any other biofuel would.</p>

Further Reading:

Appendix A. Federal Renewable Fuel Standard 2 (RFS2)

The Environmental Protection Agency, under the Energy Independence and Security Act, will require that renewable fuel be blended into petroleum from 9 billion gallons in 2008 to 36 billion gallons by 2022.¹⁸¹ This is known as the federal Renewable Fuel Standard 2, or RFS2 for short. The federal program is a volumetric program which means the fuel distributors could sell high blends in one region and zero or low blends in another region and still meet the programs requirement. The program is primarily designed to significantly increase the volume of renewable fuel that is blended into gasoline.

There are several different categories of required renewable fuel.

In 2022, the following will be required in the United States:

- **16 billion gallons of cellulosic biofuels.** To qualify, a cellulosic biofuel would need to have a carbon intensity at least 60% less than the carbon intensity of conventional fuel (as determined by EPA). The following are considered cellulosic biofuels:
 - Cellulosic ethanol
 - Synthetic gasoline, synthetic diesel fuel or heating oil
 - Synthetic jet fuel, propane and biogas
 - Cellulosic diesel, such as Fischer-Tropsch diesel produced from biomass or other lignocellulosic to diesel production process
- **1 billion gallons of biomass-based diesel.** To qualify, a biomass-based diesel would need to have a carbon intensity at least 50% less than the carbon intensity of conventional fuel (as determined by EPA). The following are considered biomass-based diesel:
 - Biodiesel (FAME)
 - Non-Co-processed Renewable Diesel (renewable diesel that has not been co-processed with a petroleum feedstock)
 - Cellulosic diesel
- **4 billion gallons of unspecified “Other advanced biofuel.”** To qualify, an advanced biofuel would need to have a carbon intensity at least 50% less than the carbon intensity of conventional fuel (as determined by EPA). This could be anything listed above, plus butanol, biogas, Brazilian sugarcane ethanol, or any other type of fuel that meets the EPA requirements.

¹⁸¹US EPA. EPA Proposes New Regulations for the National Renewable Fuel Standard Program for 2010 and Beyond. <http://www.epa.gov/oms/renewablefuels/420f09023.htm#3>

Oregon's proportional share of these fuels

In 2007, Oregon consumption of gasoline and diesel represented approximately 1.18% of the total gasoline and diesel consumption in the United States.¹⁸²

Oregon proportional share of these required federal Renewable Fuel Standard 2 fuels in 2022:

- Cellulosic biofuels: 188 million gallons
- Biomass-based diesel: 11.8 million gallons
- Other advanced: 46 million gallons

EPA, as outlined in Chapter 1.2 the Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis¹⁸³, covers the following information:

Chapter 1: Renewable Fuel Production and Consumption

This chapter describes the various feedstocks and renewable fuel types that could potentially be used to meet the renewable fuel volumes required by EISA. The availability and challenges of harvesting, storing, and transporting these feedstocks are discussed, as well as the different renewable fuel production technologies, industry plans, and potential growth projections for future facilities. A discussion of renewable fuel distribution and consumption is included.

EPA recognizes that the required volumes could be met with a wide variety of fuel choices, and has developed a projected set of reasonable fuel volumes based on their best estimate of likely fuels that would come to market. They have projected a primary control case, and then two sensitivity control cases (high and low cellulosic ethanol).

¹⁸² US EIA. Sales of Distillate Fuel Oil by End Use. http://tonto.eia.doe.gov/dnav/pet/pet_cons_821dst_dcu_nus_a.htm, and Product Supplied http://tonto.eia.doe.gov/dnav/pet/PET_CONS_PSUP_DC_NUS_MBBL_A.htm

¹⁸³ US EPA. RFS2. Final Regulatory Impact Analysis. <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

Appendix B. List of Biofuel Categories, the Fuels Produced and the Companies Pursuing the Technologies

Table Source: EPA’s Renewable Fuel Standard Program (RFS2) Final Regulatory Impact Analysis. Table 1.4-1, page 115.¹⁸⁴

List of Biofuel Categories, the Fuels Produced and the Companies Pursuing the Technologies

Technology Category	Fuels Produced	Companies
Biochemical from Corn Grain	Ethanol	ICM, Delta T, Broin
Biochemical Cellulosic Ethanol	Ethanol	Abengoa, AE Fuels, Cornell Univ., Citrus Energy, DuPont/Danisco, Florida Crystals, Novenzymes, Poet, Western Biomass, ICM, Alltech/Ecofin, IOGEN, Qteros, and Raven Biofuels, BPI, New Age Energy, Universal, Fiberright, KL Energy.
Thermochemical/Catalytic conversion of Cellulose	Ethanol	Range Fuels, Pearson Technologies, Fulcrum Bioenergy, Enerkem, and Gulf Coast Energy.
Thermochemical/Biochemical conversion of Cellulose	Ethanol	Coskata and INEOS Bio.
Strong Acid Hydrolysis of Cellulose/Biochemical	Ethanol	Blue Fire, Arkenol, Pencor, Pangen, Auburn Univ., Agresti.
Dilute Acid, Steam Explosion of Cellulose/Biochemical	Ethanol	Verenum, BP, Central Minnesota Ethanol Coop.
Consolidated Bioprocessing (one step hydrolysis and fermentation) of Cellulose/Biochemical	Ethanol	Mascoma
Biochemical conversion of Cellulose via carboxylic acid	Ethanol, Gasoline, Jet Fuel, Diesel Fuel	Terrabon, Swift Fuels, Zeachem
Thermochemical/Fischer Tropsch	Diesel Fuel and Naphtha	Choren, Flambeau River Biofuels, Baard, Clearfuels, Gulf Coast Energy, Rentech, TRI.
Thermochemical/Fischer Tropsch	DME	Chemrec, New Page.
Catalytic Depolymerization of Cellulose	Diesel, Jet Fuel or Naphtha	Cello Energy
Biochemical conversion of Cellulose	Diesel, Jet Fuel or Naphtha	Bell Bioenergy
Catalytic Reforming of Sugars	Gasoline	Virent

¹⁸⁴ US EPA. RFS2. Regulatory Impact Analysis. Page 115. <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>

Biochemical conversion of Sugars	Diesel, Jet Fuel or Gasoline	Amyris, Gevo, LS9.
Biochemical of Sugars – converted corn ethanol plants	Isobutanol	Gevo/ICM.
Pyrolysis of Cellulose	Diesel, Jet Fuel, or Gasoline,	Envergent (UOP/Ensyn), Dynamotive, Petrobras, Univ. of Mass, KIOR.
Hydrotreating of Plant Oils	Renewable Diesel Fuel	UOP, Neste, Eni, Conoco-Phillips, Dynamic Fuels (Syntroleum/Tyson).
Fatty Acid Methyl Ester (FAME)	Biodiesel	Many
Free Fatty Acid to Biodiesel	Biodiesel	Endicott
Production of Algae Oils via Photobioreactor or open pond	Algae Oil (Biodiesel or Renewable Diesel Fuel)	Solazyme, Algenol, Aurora Biofuels, Petrosun, Sapphire Energy, Livefuels, Solix, HR Biopetroleum (Cellana), XL Renewables, Petroalgae, Synthetic Genomics, GreenFuel.