Agenda Item B2: Oregon Biomass Assessment: Potential for fuel production from Oregon feedstocks

State of Oregon
Department of
Environmental
Quality

The purpose of this biomass assessment is to summarize available studies and information on the quantity of biomass feedstocks that may be available annually in Oregon for production of advanced biofuels. Links to each of these studies can be found in the Appendix on page 13.

The main question this document will address is does Oregon currently have available biomass feedstock, or the potential to produce such feedstock, for advanced biofuels? The document describes:

Summary

Oregon has limited ability to produce feedstock for corn ethanol and soy biodiesel, but could have much more feedstock available for production of cellulosic ethanol, cellulosic diesel, and fuel from waste such as yellow grease. Oregon also has the ability to produce feedstocks for biodiesel and renewable diesel, and to produce biogas, but to a lesser extent. (See section 2 starting on page 6 for a discussion of each fuel type and its associated forms of biomass.)

Based upon estimates from biomass inventory and assessment studies conducted during the past decade, a range of 424 to 524 million gallons of gasoline equivalent of biofuel and other alternative transportation fuel a year could be produced from Oregon biomass. This represents approximately 20% to 24.6% of Oregon's consumption of gasoline and diesel (2.172 billion gallons as of 2008). Both low and high projections are provided because many of the studies estimated a range of available biomass for forest and agricultural residue, as well as urban wood waste, dependent on price for collection and transport of the materials. Because these sources are dispersed, more of the available material can be collected if a higher price is paid. See the Appendix on page 13 for more information and links to each of the studies.

If only waste sources of biomass were used, and no crops, 182 to 282 million gallons of gasoline equivalent biofuels and compressed natural gas could be made from biomass waste in Oregon. This

represents approximately 8% to 13% of Oregon's current consumption of gasoline and diesel. The variance in the analysis is due to a range of prices that could be paid for waste material utilized.

Several energy production facilities are also looking at using biomass. Also note that the studies to date have not covered several of Oregon's potential sources of biomass. In addition to several sources of biomass for cellulosic fuel, very few of the feedstocks for producing biodiesel have been quantified. In addition to biomass, some fuel production technologies are under development that would produce fuel from waste such as tires or plastic. This study does not cover those feedstocks.

The variance in the low and high estimates for the first three categories in **Table 1** below (forest residue, agricultural residue and urban wood waste) comes from analysis of the cost to collect and transport the material. At lower prices, less material can be collected, while at higher prices, more of the material can be collected. See the Appendix (page 13) or the studies for more details.

Table 1: Potential range of low carbon fuel production from available Oregon biomass

Source	**Potential fuel volume produced** (Millions of gallons of gasoline equivalent/yr)
Fuel from Waste	
1. Forest residue	58 to 132 *(dependent on price paid)*
2. Agricultural residue (corn and wheat only)	13 to 32 *(dependent on price paid)*
3. Urban wood waste	11 to 19 *(dependent on price paid)*
4. Unused mill residues	1
5. Orchard and vineyard prunings	6
6. Grass straw residue	33
7. Greenwaste	18
8. Mixed Waste Paper	41
9. Biogas	0[1]
Total Fuel from Waste	**182 to 282**
Fuel from Crops	
Expiring Conservation Reserve Program planted to a dedicated energy crop	239
Existing crops	13
Total Fuel from Crops	**242**
Total	**424 to 524**

[1] The amount of fuel produced from biogas is 0.023 million gallons of gasoline equivalent per year.

This summary relies on several existing sources of information, summarized in Appendix A (page 13). There are several sources of potential biomass feedstock from waste that are not included in this estimate, because no recent studies have quantified volumes available.

Figure 1: Lower estimates of biomass availability compared with gasoline and diesel use in Oregon

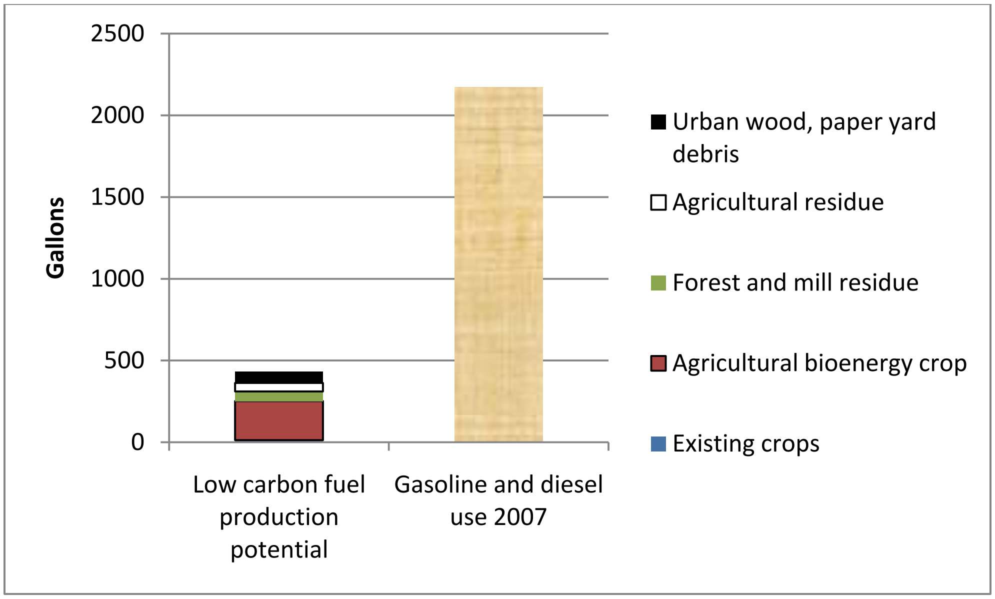
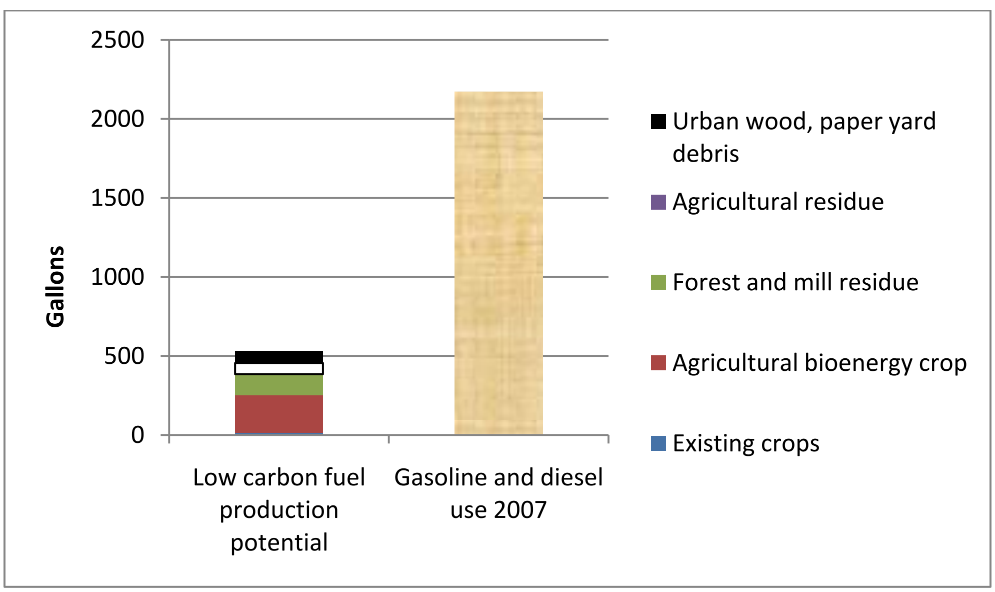


Figure 2: Higher estimates of biomass availability and alternative fuel production compared with gasoline and diesel use in Oregon



There is ongoing biomass work occurring in Oregon. As a result of these efforts, more and better information will be available in the future. Efforts include:

- Oregon Department of Agriculture, Oregon Department of Energy and Oregon Department of Forestry are collaborating on this issue.
- A forthcoming study will address the potential for bioenergy production from grass straw in Lane County.
- Oregon State University is working on quantifying available agricultural residue.
- Washington State University's Climate Friendly Farming Program is also investigating agricultural residue potential.

1. Types of biomass potentially available in Oregon

Oregon defines biomass as any organic matter, including woody biomass, agricultural crops, wood wastes and residues, plants, aquatic plants, grasses, residues, fibers, animal wastes, municipal wastes and other waste materials.

The following describes sources of different types of biomass:

A. Wood

There are several types of woody biomass.

1. **Forest-derived biomass:** This category includes several types of biomass, such as thinning of timberland with high fire hazard, logging residue (the tree tops, limbs and cull material leftover from commercial logging activity), and thinning of timberland for commercial harvest preparation or other purposes.

2. **Urban wood waste:** This category includes wood discarded from individual houses, commercial businesses and construction and demolition sites, such as lumber, pallets, crates, wood furniture, tree and brush pruning's, limbs, trunks and stumps.

3. **Hybrid poplar plantations:** Whole trees can be used as a source of biomass, or when hybrid poplars are harvested for other purposes, such as pulp chips, the leftover bark, leaves and stumps can be used for fuel.

4. **Mill waste/residue:** During the milling process, waste such as bark, chunks, slabs, shavings and sawdust are produced.

B. Municipal Solid Waste

This category can include several different sources of biomass, including food waste, waste paper, yellow grease, brown grease, food processing waste and cardboard.

C. Biogas

Biological degradation of organic material such as wastewater, manure and organic material in landfills produces biogas, which can be upgraded and used as a transportation fuel in the form of compressed natural gas or liquefied natural gas, or used to produce electricity. There are three main sources of biogas:

1. **Wastewater Treatment:** Several wastewater treatment plants are producing biogas, through anaerobic digestion, however it is rarely used for a transportation fuel in Oregon.

2. **Organic Waste Digesters:** Manure from livestock on Oregon farms is a resource for the production of biogas through anaerobic digestion technology. Other organic wastes, such as agricultural and food-processing wastes, also could be used as digester feedstock.

3. **Landfills:** Anaerobic digestion of organic materials in landfills produces landfill gas, which can be captured and used.

D. Agricultural Sources

1. **Agricultural Residue:** There are several sources of agricultural residue. Agricultural crop residues are residues left on a field after the harvest of a crop. The harvest of grass seed and field crops such as corn and wheat generates a residue of straw, stalks and stubble. In addition, orchard pruning and processing of various agricultural crops such as mint and fruits and vegetables produces residues.

2. **Existing biofuels crops:** Some crops that can be used for fuel production are already grown in Oregon in limited quantities. The limited quantities could, however be used for fuel production. Crops that are produced in Oregon suitable for fuel production include:
   a. Corn
   b. Canola
   c. Camelina
   d. Hybrid poplar
   e. Sugar beets

3. **Potential biofuels crops:** Several biofuels crops could be grown in Oregon, in addition to the list above. Washington State's low carbon fuel standard program has identified five potential biofuels crops, which can be grown in the Pacific Northwest (Pont, 2009). The amount of biomass that can be produced from these crops is influenced by the areas of Oregon where they can be grown, whether they would be grown as perennial or rotational crops, and the market for the product. These crops include:

   - **Hybrid poplars.** Hybrid poplar is a perennial crop that is successfully grown in western Oregon and irrigated regions of eastern Oregon.

   - **Switchgrass and miscanthus.** Researchers are currently developing varieties of these perennial grasses, which can be grown on irrigated cropland in the Columbia Basin.

   - **Brassica juncea.** Brassica juncea includes several varieties of yellow and brown mustards that are grown for oil, as a condiment, and for greens.

- **Camelina.** Camelina is an oilseed crop that can tolerate a range of growing conditions. It requires relatively low inputs and also has relatively low yields compared to some other oilseed crops. Sales of oilseed meal for livestock feed are usually an important contributor to the economic viability of oilseed crops, but currently only limited levels of camelina are allowed to be blended into livestock feed. More data are necessary before camelina can be fed at higher levels and to other types of livestock.

Several agricultural producers and researchers in the Willamette Valley and Malheur County are also trying soybeans as an alternative crop for irrigated agricultural land. Cold tolerance issues have prevented growers from successfully raising soybean crops in the past, but researchers in the public and private sector have helped develop some cold-tolerant varieties.

There are also sources of biomass that have not been fully quantified for Oregon. Washington completed a biomass inventory (Frear, 2005) that covered 45 potential sources of biomass in Washington. Potential sources for which quantities have not been evaluated in Oregon include things such barley straw, mint slug, horse manure, culled fruits and vegetables, yellow grease (restaurant grease), brown grease (sewer and pipe grease that are trapped and collected), food processing waste, and cheese whey.

2. Type of fuel that can be produced from each biomass source

A variety of conversion technologies can be used to produce fuel or energy from biomass. A number of these technologies are currently used in Oregon to provide space and process heat, generate electricity, or produce liquid and solid fuels.

The Oregon Department of Energy recently conducted a survey of bioenergy producers and found that biomass feedstocks are being utilized throughout the state.

- Over 3 million tons of woody biomass was used in 2007 to produce steam and electricity.
- Anaerobic digesters and landfill gas capture systems were installed at over 30 locations in the state.
- Over 1 million tons of residual wood waste and chips are used to produce wood pellets and briquettes
- Used oil and waste grease is being collected and processed into biodiesel by at least three firms.

Oregon entrepreneurs, researchers, and companies are also experimenting with other conversion technologies. For example, there are currently efforts underway to develop, test, and commercialize pyrolysis, torrefaction, and gasification of woody biomass and agricultural wastes.

The feedstocks listed in Section 1 can produce several different types of fuel.

Ethanol can be made from:

- Starches such as corn, sugarcane, sugar beets or sorghum
- Cellulose such as poplar or willow, switchgrass, miscanthus

- Agricultural waste such as corn stover, or wheat, grass or barley straw
- Wood waste such as logging residue, mill residue, land clearing or forest thinning
- Municipal solid waste such as yard debris, paper waste, or food waste

Biodistillates such as renewable, synthetic or biodiesel can be made from:

- Oils such as soybeans, palm oil, canola, brassica, or camelina
- Municipal solid waste such as yellow grease

CNG and LNG can be made from:

- Food packaging waste such as culled fruits and vegetables, fruit pomace, cheese whey, animal waste
- Biowaste such as animal manure, brown grease, biosolids, landfill gas

Many of the above can also produce electricity or hydrogen. In addition, several technologies are under development to produce cellulosic diesel from biomass.

3. Issues related to using biomass for transportation fuel production

Highest and best use

The discussion of highest and best use for biomass feedstock is an active debate within many of the different resource areas. Recent federal programs, such as the Biomass Crop Assistance Program, have brought this debate to the fore and have provided more urgency for policy makers. While there is certain to be much debate on this topic in coming years, one thing is clear – this is a topic policy must take into consideration.

Much of the biomass that is considered a waste product, like sawdust or other mill residues, are low in price and are often the easiest biomass feedstock to access. As such, this waste stream has historically been utilized to a high degree in the production of other products (composite materials, particle/fiber board, animal bedding) or used to provide fuel for energy production (typically at a boiler to provide heat and power for the mill).

Ultimately, the markets for these feedstocks will determine how and where they are used. Some of the currently available biomass could be used in future waste-to-energy projects. It is useful, however, to consider that Oregon is poised to make investments in facilities that will increase the utilization of available biomass.

Sustainability

There are sustainability issues with using biomass for fuel production. Several of the studies cited considered sustainability and forest health, such as soil productivity, water quality, and wildlife habitat.

According to Oregon Department of Energy:

> "Leaving some dead wood in the forest is good for forest ecosystems. Standing snags and dead wood on the forest floor provide habitat for wildlife. Woody debris on the ground deters erosion and, by its decomposition, helps maintain soil fertility and tilth. Although dead trees and woody debris play an important role in forest ecosystems, excessive accumulation of forest biomass becomes a threat to the health of live trees by making the forest susceptible to disease, insect infestations and high-intensity forest fires.
>
> Reduced timber harvest activity and suppression of forest fires have caused an unnatural surplus of dead wood in many Oregon forests. Selective thinning in these areas could remove the excess biomass that poses a risk to sustainable forests." (ODOE, 2010)

There are also concerns related to agricultural soil health and biomass removal. The primary consideration in agriculture is maintaining the productivity of the soil where crops are grown. After harvest, crop residue has a vital role to play in controlling erosion from wind and water, deterring runoff, maintaining or improving soil productivity, and maintaining nutrient levels. A percentage of crop residue left on the field helps maintain soil carbon and nutrients and improves soil tilth and porosity. For these reasons, only a percentage of agricultural residue is available as a biomass energy resource.

Carbon Intensity

Fuel generated from waste, such as forest residue, municipal solid waste, or agricultural residue will in general have lower carbon intensity than a fuel produced from a crop. This is because it is waste material, and the lifecycle analysis therefore does not include the production of the material, just the transport of the waste, conversion into fuel, distribution and use. For example, California Air Resources Board (CARB, 2009) found that the lifecycle greenhouse gas emissions for compressed natural gas from fossil sources are much higher than those for landfill gas (biomethane). Similarly, the lifecycle greenhouse gas emissions from biodiesel produced from soybeans is higher than biodiesel produced from used cooking oil.

Availability of biomass is dependent on price

Some biomass sources are dispersed over a wide area, such as agricultural or forest residue. Collection of biomass, particularly from sources that are widespread, can be costly compared to other sources that are already gathered in one location, such as mill residue. Estimates of forest-derived biomass found in the following studies often vary depending on the estimated cost of collection. Most of the studies looked at a range of costs per dry ton delivered or roadside ton delivered, and gave estimates of biomass produced based on collection costs. Some of the studies did not look at this factor, and this is noted in the summaries found in the Appendix on page 13. Some sources indicate that it may be difficult for fuel producers to ensure a steady supply of biomass from some sources of waste, for example, wastes associated with seasonal harvests. Wastes and residues might be used in conjunction with a cropped biomass supply, or with wastes or residues from a non-seasonal source. Or, a fuel producer might develop a steady, reliable source of waste or residue

4. Summary of conclusions from biomass studies in Oregon

None of the biomass studies in Oregon quantified all sources of biomass. Most focused on a limited number of biomass sources. Each study also used different assumptions, and some studies covered only a sub-region of the state. In general, most of the studies considered factors such as the amount of wheat straw or corn stover that would need to be left in the field for soil health, and the amount of forest residue needed to be left in the forest for forest health and wildlife habitat. Most of the studies estimated a total volume of biomass produced, and then subtracted out the amount that would need to be left in the forest or field for soil health, wildlife habitat, etc. They also generally subtracted out the biomass used for other purposes. For example, approximately 98 percent of mill residues are used for other purposes, so the numbers cited below are the unused amount. It is noted in the Appendix if this is the case for each study, and if a study took sustainability into consideration.

For each study referenced below, there is a link to the study itself so that if you can read further about the assumptions, methodology, sources of data, and the results. Each study is also summarized in the Appendix beginning on page 13.

Range of Potential Fuel Production from Available Biomass in Oregon (based on most recent study available for biomass source)

Each of the studies referenced in Tables 1 and 2 is summarized in the Appendix beginning on page 13. Also, please note that this summary of available biomass sources is not comprehensive, and that there are several potential sources of biomass in Oregon not included in these tables because they have not yet been inventoried.

The variance in the low and high estimates for the first three categories (forest residue, agricultural residue and urban wood waste) comes from analysis of the price to collect the material. At lower prices, less material can be collected, while at higher prices, more of the material can be collected. See the Appendix or the studies for more details.

Table 2: Potential Ethanol Production from Biomass Waste

Biomass	**Estimate of Quantity Available** (Annual bone dry tons)	**Conversion factor** (gal/dry ton)	**Ethanol production potential** (Million gal/yr)	**Millions of gallons of gasoline equivalent/yr**
1. Forest residue	924,418[2] to 2,100,369[2]	90.4[3]	84 to 190	58 to 132
2. Agricultural residue (corn and wheat only)	194,272[2] to 481,825[2]	95[4]	18 to 46	13 to 32
3. Urban wood waste	182,532[5] to 304,220[5]	90.4	17 to 28	11 to 19
4. Unused mill residues	16,320[6]	90.4	1	1
5. Orchard and Vineyard Prunings	94,564[2]	95	9	6
6. Grass straw residue	500,000[7]	95	48	33
7. Greenwaste	278,750[7]	90.4	25	18
8. Mixed Waste Paper	652,536[7]	90.4	59	41
Total	**2,843,392 to 4,428,584**		**261 to 405**	**182 to 282**

[2] Skog et al 2008
[3] Ethanol yield assumption is GREET value for forest residue gasification
[4] Ethanol yield assumption is GREET value for corn stover
[5] Walsh, 2000
[6] Wright, 2009
[7] Graf and Koehler 2000

Table 3: Potential Biogas Production from Biomass Waste (ODOE, 2010)

Biomass	**Estimate of Quantity Available** (million cubic feet)	**Millions of Gallons of Gasoline Equivalent**
Wastewater Treatment	600	0.001
Manure	3,400	0.008
Landfills	4,600	0.011
Total	**9,600**	0.023

5. Existing biofuels crops

Some existing Oregon crops could potentially be used for fuel production. Please note that currently, these crops have other uses.

Corn: Oregon's corn for grain production in 2009 was 6,880,000 bushels (USDA, 2010). If this crop were used for fuel production, the yield would be 18,713,600 gallons per year of ethanol.[8] This is 13 million gallons of gasoline equivalent.

Canola: In 2009, 11,220,000 lbs (5610 tons) of canola was produced in Oregon (USDA, 2010). This would yield 10 million 0.53 million gallons of biodiesel, which is 0.54 million gallons of gasoline equivalent produced from Oregon's current crop of canola.[9]

Other: According to USDA, Oregon also produces small amounts of sugarbeets (395,000 thousand tons in 2009) and sunflower oil (323,255 tons in 2007) (USDA, 2010). Because the amounts are so small, they are not included in the biomass totals.

6. Potential Biofuels Crops

Agriculture in Oregon is a robust industry that accounts for over 10% of the state's sales and employs over 10% of Oregon jobs. The survival of both rural and urban communities depend on agriculture. (Farm Bureau, retrieved 2010). In 2007, approximately 3 million acres, or almost 5% of Oregon was dedicated to harvested cropland. (USDA, retrieved 2010)

[8] Ethanol yield assumptions are based on GREET dry mill assumption of 2.72 gal/bushel

[9] Canola yield assumptions are based on GREET soybean biodiesel assumption of 0.96 lb biodiesel/lb oil

Several biofuels crops could be grown in Oregon on existing agricultural cropland, which are not currently grown in large quantities, such as switchgrass, miscanthus, brassica juncea, sorghum, and camelina. In addition, there could be increased production of crops that are already grown in Oregon. These include corn, canola, camelina, hybrid poplar, and sugar beets. Estimating the amount of biofuels that could be produced by 2022 on existing croplands for biofuels production is outside the scope of this discussion paper.

Another potential source of cropland is retiring Conservation Reserve Program acres. Conservation Reserve Program is a farm program that retires acres from production for a certain amount of time in order to address soil, water, and related natural resource concerns on their lands. Over the next 10 years, many Conservation Reserve Program contracts may expire (depends somewhat on the 2012 Farm Bill). Some farmers may choose to re-enroll their land, but some may choose to return land to agricultural production, and program acreage limitations may prevent others from re-enrolling their land. There is potential for fuel production from some of these expired Conservation Reserve Program lands, however, some of these acres might not be returned to production or will be used to cultivate other crops. There are concerns with bringing this land into production because much of it is highly erodible or otherwise environmentally sensitive. The calculation of Conservation Reserve Program acres expiring from 2010 until 2019 is intended to intended to illustrate the upper limit of fuel volume which could be produced if these expiring acres were used to produce biomass crops for fuel.

There are erosion, wildlife habitat, soil quality, and other concerns that would need to be taken into account if these acres were actually used for crops to produce fuel. In addition, cultivating expiring Conservation Reserve Program acres would have direct land use change impacts, but there is good potential for growing crops on some of this land. By 2019, over 540,000 acres of Conservation Reserve Program contracts are likely to expire in Oregon. (USDA Farm Services Agency, 2010)

In a presentation to the Washington State Department of Ecology, Pont (Pont, 2009) concluded that planting acreage for fuel production to Miscanthus would yield the highest production of biofuel per acre. Consequently, planting retired Conservation Reserve Program acres to Miscanthus could yield 363 million gallons of ethanol, which is equal to 239 million gallons of gasoline equivalent per year. This same acreage, if planted to camelina or brassica juncea, could yield 22 million gallons of biodiesel.

Appendix: Summary of Biomass Studies in Oregon

A. Biomass Energy and Biofuels from Oregon's Forests. Prepared for Oregon Forest Resources Institute.

Authors: (Bowyer, Jim. 2006)

Available from: http://www.oregonforests.org/assets/uploads//Biomass_Full_Report.pdf

Please note that this study only covers 20 counties in Oregon. This study did not look statewide at biomass. Bowyer *et al.* (2006) looked at forest biomass available in 20 eastern and southern counties. This study did not estimate forest biomass in the Willamette valley.

This study excluded from consideration areas with low fire risk, over 30% slope, less merchantable timber, and roadless areas. It also estimates availability based on treatment options tailored to forest conditions.

Page 1-77 through 1-103 of this report contains a review of existing studies of biomass supply from fuel treatment thinning, logging residue, and other forest and woodland resources in Oregon.

Type of biomass	What is included	Estimated Biomass Available (annual bone dry tons)	Notes
Fuel treatment thinning- Eastern and Southern Oregon	Logging residues from forest restoration or timber stand improvement work – i.e. harvesting conducted primarily to reduce fire hazard or improve stand health	1,000,000 - 2,000,000	Public and private forestland with high fire risk (not including Western Oregon forests or any wilderness, parks, roadless areas, etc.). Over 20 years. Cost would be $59 per dry ton delivered. See page 2-3.
Primary mill residue: Unused	Bark, coarse residues (chunk and slab) and fine residues (shavings and sawdust)	9,912	Does not include mill residue currently used for other purposes

B. Oregon cellulose ethanol study: an evaluation of the potential for ethanol production in Oregon using cellulose based feedstocks. Prepared for Oregon Office of Energy.

Authors: Graf, A., and T. Koehler. 2000. (Graf and Koehler 2000)

Available at: http://www.oregon.gov/ENERGY/RENEW/Biomass/study.shtml

Type of biomass	What is included	Estimated Biomass Available (annual bone dry tons)	Notes
Wheat straw	Wheat straw available after soil conditioning	1,497,346	See page 12
Grass straw	Grass straw burned or chopped	500,000	See page 12
Greenwaste		278,750	See page 10
Mixed Waste Paper		652,536	See page 10
Wood and lumber		326,688	See page 10
Paper mill sludge		183,960	See page 10
Forest residues		2,940,000	See page 10
Agricultural residues		1,018,842	See page 10

C. Strategic Development of Bioenergy in the Western States: Biomass Resource Assessment and Supply Analysis for the WGA Region. 2008, Western Govenors' Association

Authors: Skog, K.; Rummer, R.; Barbour, J.; Nelson, R. (Skog *et al.* 2008)

Available at: http://www.fpl.fs.fed.us/documnts/pdf2008/fpl_2008_gordon001.pdf

The study covered forest biomass and agricultural residues such as wheat straw, corn stover and orchard prunings. This study considers sustainability in its estimates of available biomass. Skog *et al.* (2008) excluded forest types where the treatments contradicted the ecological objectives. See report for more information (link). Also, when estimating logging residue, Skog used allowable removal fractions to recognize the need to maintain nutrients and habitat on site. Lastly, when estimating agricultural residue (corn stover and wheat straw) Skog estimated available amount remaining after accounting for portion of residues needed to maintain soil health.

Type of biomass	**What is included**	**Low estimate** (annual bone dry tons)	**High estimate** (annual bone dry tons)	**Notes**
Forest Biomass	• Thinning of high fire hazard timberland • Logging residue • Treatment of Pinyon Juniper woodland • General thinning of private timberland • Precommercial thinning on National forest land in western OR • Unused mill residue	924,418	2,100,369	Availability varies depending on price paid for residues ($10/dry ton delivered to $100/dry ton delivered) with a low supply and a high supply case. Assumed biomass volumes would be harvested over 22-30 years. Base case and high case cover a range of uncertainty about the supply from sources.
Corn stover		2,899	8,458	Availability varies depending on the price paid for residues ($40/dry ton to $50/dry ton)

Winter wheat straw		185,274	453,012	Availability varies depending on the price paid for residues ($30/dry ton to $50/dry ton)
Spring wheat straw		6,099	20,355	Availability varies depending on the price paid for residues ($35/dry ton to $50/dry ton)
Orchard and vineyard pruning	Trimmings, dead wood, etc.	94,564	94,564	This portion of the study did not look at availability based on price.

D. Biomass feedstock availability in the United States: 1999 state level analysis. Oak Ridge National Lab., Oak Ridge, TN. (Updated January, 2000).

Authors: Walsh, M.E., R.L. Perlack, A.T. Turhollow, D. de la Torre Ugarte, D.A. Becker, R.L. Graham, S.E. Slinsky, and D.E. Ray. 1999. (Walsh *et al.* 1999)

Available at: http://bioenergy.ornl.gov/resourcedata/index.html.

For forest residues, Walsh *et al.* (2000) estimated the total quantity of non-merchantable biomass residue available after a commercial harvest, then revise the inventory downward to reflect quantities that can actually be recovered based on road access, retrieval efficiencies, etc.

For agricultural residues, Walsh *et al.* (2000) estimated the total quantities of residues produced, then subtracted out the amount that must be left to maintain organic content and prevent erosion.

Type of biomass	What is included	Estimated Biomass Available (annual bone dry tons)	Notes
Forest residues (slash – tree tops, limbs, non-merchantable logs from timber harvest conducted primarily to produce merchantable timber)	Logging residues, rough rotten and salvable dead wood. Does NOT include: excess saplings and small pole trees	1,299,000 to 2,515,900	Availability varies depending on price paid for residues ($30/dry ton delivered to $50/dry ton delivered)
Mill residues (currently used at above 98%)	Bark, coarse residues (chunk and slab) and fine residues (shavings and sawdust)	10,000 to 6,834,000	Availability varies depending on price paid for residues ($20/dry ton delivered to $50/dry ton delivered) The high number assumes mill waste would be pulled from other uses.

Agricultural residue	Stalks of corn stover and wheat straw	155,855 to 155,855	Total quantity of residue produced minus the quantity that must be left to maintain soil quality (organic matter and erosion). $40/dry ton
Urban wood wastes	Yard trimmings, site clearing wastes. Pallets, wood packaging, other miscellaneous commercial and household wood wastes, demolition and construction wastes	182,532 to 304,220	Availability varies depending on price paid for residues ($20/dry ton delivered to $30/dry ton delivered)

E. Biomass Energy Data Book: Edition 2. Prepared for the Office of the Biomass Program Energy Efficiency and Renewable Energy by Oak Ridge National Laboratory.

Authors: Wright, L., B Boundy, P. Badger, B Perlack and S. Davis. 2009. (Wright, 2009)

Available at: http://cta.ornl.gov/bedb/download.shtml

Type of biomass	What is included	Estimated Biomass Available (annual bone dry tons)	Notes
Unused Primary Mill Residue Production and Use	Bark, coarse residues (chunk and slab) and fine residues (shavings and sawdust)	16,320	This represents the unused .02 % of the 7,577,270 dry tons of mill residue produced in 2007 in Oregon.

F. Oregon Department of Energy Website

Oregon Dept. of Energy. http://www.oregon.gov/ENERGY/RENEW/Biomass/resource.shtml

Type of biomass	What is included	Estimated Biomass Available	Notes
Wastewater Treatment	Unused biogas from wastewater treatment facilities.	600 million cubic feet of biogas is potentially available annually through anaerobic digestion technology	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 energy source.
Manure	This includes manure from the 111 dairies with 500 or more cows.	3,400 million cubic feet of biogas is potentially available annually through anaerobic digestion technology	
Landfills	Based on EPA estimates of landfill gas available at candidate landfills.	4,600 million cubic feet of landfill gas is potentially available on an annual basis.	The US Environmental Protection Agency's Landfill Methane Outreach Program has identified five landfills in Oregon as "candidate" landfills for production of electricity from landfill gas. The EPA selected these candidate landfills based on national data sources rather than on-site evaluation. More detailed assessment would be needed to determine the economic feasibility of developing a power generating facility at any of the state's landfills.

Literature Cited

Bowyer, Jim. 2006. Biomass Energy and Biofuels from Oregon's Forests. Prepared for Oregon Forest Resources Institute. (Bowyer, 2006)

California Air Resources Board (CARB). Retrieved March, 2010. Low Carbon Fuel Standard Program. Lifecycle Analysis. http://www.arb.ca.gov/fuels/lcfs/lcfs.htm

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