BIODIESEL IN THE PACIFIC NORTHWEST

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Biodiesel in the Pacific Northwest

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Abstract

This publication presents background about biodiesel fuel and discusses its role in the Pacific Northwest (PNW), including relevant policies, usage, feedstock sources, and production. Biodiesel is an alternative to petroleum-derived diesel that is produced from fats, such as vegetable oil and used cooking oil. Potential benefits of biodiesel include reduced greenhouse gas emissions, lower dependence on foreign oil, air quality improvements, safer fuel handling and storage, and rural development opportunities. Both federal and state policies incentivize biodiesel production and use. These policies were created in response to rising oil prices and limited supply of domestic oil in the early 2000s. The PNW appeared to be a promising region for a biodiesel industry, with the ability to grow and process feedstocks and produce, transport, and consume biodiesel. Today in the PNW, biodiesel and its feedstocks are made, sold, and consumed, but significant economic barriers (e.g., low petroleum prices) and policy uncertainties have limited the expansion of the biodiesel industry. However, one of the largest US biodiesel production facilities is located in Hoquiam, Washington. Oregon is enforcing low-carbon fuel policies, and there is potential for increased regional growing and processing of biodiesel feedstocks.

Introduction

In the Pacific Northwest (PNW; herein, the states of Washington, Oregon, and Idaho), the biodiesel industry has experienced drastic changes over the past ten years. In the early 2000s, the region looked ripe with promise for expanding the production and consumption of biodiesel to create jobs, provide agricultural opportunities, and improve the sustainability of regional transportation. At present, the biodiesel industry has not achieved this anticipated level of success due to the low price of petroleum products and inconsistent policies. However, the PNW is an important player on the national scale, and each state has its strengths (Table 1). For example, Washington boasts the second largest biodiesel production facility in the nation, Oregon policies generate high percentages of on-highway biodiesel use, and Washington and Idaho grow significant quantities of canola (a biodiesel feedstock source).

In 2015, 31–50 million gallons of biodiesel were consumed in the PNW, roughly 2–3% of US biodiesel consumption (US EIA 2017a). Both biodiesel and biodiesel feedstocks are produced in the PNW. The current biodiesel production capacity is approximately 122 million gallons per year. Much of this biodiesel is exported from the region, going to California and Canada. Feedstocks sourced in the region include canola and used cooking oil. However, canola oil must also be imported from western Canada to meet biodiesel producer needs.

This publication presents background information about biodiesel fuel and discusses its role in the PNW, including relevant policies, usage, feedstock sources, and production. Due to the availability of information and scale of biodiesel production and use, Washington and Oregon are the primary focus, with Idaho included when possible.

Table 1. Biodiesel industry metrics by PNW state. Highlighted cells represent special strengths. MGY = million gallons per year.

	Washington	Oregon	Idaho
Biodiesel production capacity[1]	114 MGY	17 MGY	Low to none
Biodiesel consumed through general diesel fuel sales[2]	2.7 MGY (0.4% biodiesel)	27 MGY (5% biodiesel)	Low to none
State biodiesel purchased	1.2 MGY[3]	~5,000 gallons[4]	Low to none
Biodiesel incentives	Few currently	Multiple; effective	No known
Canola—acres harvested in 2017	54,000 acres	7,200 acres	22,300 acres

Notes: Biodiesel is blended with petrodiesel and sold as a blend in many different ratios. For example, B5 describes a biodiesel blend that is 5% biodiesel and 95% petrodiesel.
[1] In July 2020.
[2] In 2015.
[3] In 2016.
[4] Estimated from Oregon State's main fleet, Department of Administrative Services, use of 53,594 gallons of B5 (5% biodiesel blend) and 11,966 gallons of B20 (20% biodiesel blend) (personal communication—R. Wallace, Oregon Department of Energy).

Basics of Biodiesel

Biodiesel is a biofuel alternative to conventional, petroleum-derived diesel (hereafter petrodiesel). It is produced from vegetable oils, animal fats, and used cooking oils. As with other biofuels, biodiesel is often promoted as a means to lessen dependency on foreign oil, provide opportunities for rural development, and reduce greenhouse gas emissions.

Technically speaking, biodiesel consists of "mono-alkyl esters of long chain fatty acids derived from vegetable oils and animal fats" (ASTM D6751-15ce1 2015). Other forms of diesel biofuels exist, such as renewable diesel. While also made from biomass, renewable diesel has a similar chemical makeup as petrodiesel and can be piped directly through the existing petrodiesel infrastructure (AFDC 2016a). Renewable diesel is refined using hydrotreating or other processes and can be derived from additional feedstock sources, such as cellulosic biomass (AFDC 2016a). This article is limited to biodiesel because of its current prevalence, although some renewable diesel is used in the PNW (Western Washington Clean Cities Coalition 2019) and may become more common in the future (REG 2018).

Although straight vegetable oil has successfully been used as a fuel, most diesel engines suffer from engine deposits if oils and fats are used directly (Knothe 2010). This is because oils and fats have a high viscosity (the liquid is thick and slow-flowing). To lower the viscosity and create biodiesel, a process called transesterification is used in which alcohol (usually methanol) is combined with the oil or fat in the presence of a catalyst. Converting waste cooking oils to biodiesel requires additional steps to remove debris, water, and excess free fatty acids from the feedstock.

In terms of engine performance and emissions, biodiesel has advantages and disadvantages compared to petrodiesel. Generally speaking, biodiesel has superior lubricity, produces fewer overall exhaust emissions, and is safer to handle and store (Knothe 2010). Safer handling is the result of a higher flash point, which makes biodiesel less combustible as it only forms an ignitable vapor under very high temperatures (266°F compared with about 126°F for petrodiesel). Fuel efficiency is similar to that of petrodiesel. In a study comparing use of 20% biodiesel to pure petrodiesel in St. Louis buses, less than a 2% reduction in fuel economy was observed

for biodiesel, which was not a statistically significant difference (Barnitt et al. 2008). Consumer Reports (2014) found that blending 5% biodiesel with petrodiesel increased the miles per gallon (mpg) for on-highway driving (49 mpg rather than 45 mpg).

Although exhaust emissions are reduced overall, a disadvantage of biodiesel is a slight increase (≤10% compared to diesel) in one type of the exhaust emission, nitrogen oxides (US EPA 2002; Hoekman and Robbins 2012). Nitrogen oxides contribute to smog formation. Biodiesel also has lower oxidative stability (Knothe 2010), meaning the fuel degrades faster than petrodiesel when exposed to air. In addition, biodiesel thickens (i.e., gels) sooner than petrodiesel when temperatures drop into cold conditions (Knothe 2010). Cold-flow properties vary depending on the feedstock, chemical composition of the fuel, and whether the biodiesel is blended with petrodiesel. For example, 100% waste grease biodiesel should not be used when temperatures drop below 48.2°F (9°C), while a 20% soy-based biodiesel, 80% petrodiesel fuel is usable down to -2.2°F (-19°C) (Dunn 2005).

Biodiesel can be used in its pure form (B100) but is more commonly blended with petrodiesel (e.g., B5 is 5% biodiesel and 95% petrodiesel; B20 is 20% biodiesel and 80% petrodiesel). Blending biodiesel with petrodiesel can help balance the pros and cons of both sources. For example, using biodiesel reduces net greenhouse gas and other harmful emissions and improves lubricity while petrodiesel allows the fuel to be used at colder temperatures. The percentage of biodiesel in the blend will impact the fuel properties. Generally speaking, B20 represents a good compromise and is approved by many engine manufacturers.

As long as the temperature is appropriate for the blend level and the quality is ensured, biodiesel can be used in any diesel engine with little or no modification. Biodiesel is a solvent and will clear accumulated petrodiesel deposits, which means more frequent filter replacements may be necessary when initially switching to biodiesel.

High-level biodiesel blends (i.e., B50 and above) can be an appropriate fuel for knowledgeable, trained consumers. Before using high-level biodiesel blends, the National Renewable Energy Laboratory (NREL 2016) recommends consulting experienced users and suppliers, talking with the vehicle manufacturer, modifying vehicle materials (e.g., seals, gaskets) if necessary, establishing a monitoring plan, and anticipating more frequent filter changes early on. Vehicle owners may violate their engine warranty if biodiesel blends over B5 are used, but many manufacturers support up to B20. The National Biodiesel Board (NBB 2020) maintains a list of Original Equipment Manufacturers (OEM) that support B5, B20, and B100.

Impacts

Environmental

Over the life cycle of fuel production and use, biodiesel reduces net greenhouse gas emissions, which is a leading environmental benefit. Biodiesel made from canola oil is estimated to reduce greenhouse gas emissions by 66% (Kruger et al. 2015). Waste, oil-sourced biodiesel produces 86% fewer net greenhouse gas emissions (US EPA 2010). It is important to understand how land use change, including indirect land use change (caused by altered agricultural markets), is incorporated into life cycle analyses; this factor can significantly impact the estimated benefit (Chen et al. 2018).

At the current level of biodiesel usage in the PNW, the potential reductions in net greenhouse gas emissions are small. The PNW is not a major biodiesel consumer (~2% of US consumption), and most biodiesel consumed is B5. According to the Alternative Fuel Data Center (AFDC 2016b), the emission benefits of blends are approximately commensurate with the blend percentage (for example, B20 has about 20% the reduction benefit of B100). Therefore, B5 would have about 5% of the reduction benefit of pure biodiesel. If waste oil-based B100 has an 86% benefit, B5 has 5% of the 86% reduction estimate for pure waste oil biodiesel. Assuming that all the diesel sold in the PNW is B5 (as is the case in Oregon), produced from waste oil feedstock, then the reduction in greenhouse gas emissions would be roughly 4.3% compared to petrodiesel usage. In reality, the benefit is far lower because Washington and Idaho do not use B5 and most biodiesel comes from non-waste feedstocks.

Beyond reductions to greenhouse gas emissions, biodiesel presents other environmental benefits. Recycling used cooking oil prevents it from being sent to landfills. Biodiesel is readily biodegradable. Blends even enhance the biodegradability of petrodiesel through synergic effects, such that blended fuel degrades faster than can be accounted for by the added biodiesel alone (Pasqualino et al. 2006). Increased biodegradability means that fuel spills are less damaging to the environment.

Air quality is improved by replacing petrodiesel because biodiesel produces fewer exhaust emissions; however, human health impacts are uncertain. Petrodiesel exhaust is suspected to increase risk of health issues including lung cancer (Hart et al. 2006; Attfield et al. 2011; American Cancer Society 2015), and biodiesel is considered cleaner than petrodiesel (US EPA 2002; US EIA 2015b). However, nitrogen oxide emissions may be higher from biodiesel, and particulate emission-related health effects are impacted by both the quantity of particles *and* particle size (Larcombe et al. 2015). Biodiesel results in higher proportions of ultrafine particles, which are more readily inhaled (Larcombe et al. 2015). A comprehensive review conducted by the Canadian government (Health Canada 2012) concluded that current evidence suggests minimal differences in health benefits or risks with widespread use of 20% biodiesel.

Planting oilseed crops in the PNW will have local environmental impacts. These impacts will depend upon the type of feedstock, the production system, and prior land use. Positive impacts can result when biodiesel crops are used as a rotational crop. For example, some canola growers observed increased yields of subsequently grown wheat, decreased weed and disease pressure, and improved soil quality (Painter et al. 2013). On the other hand, bringing previously uncultivated land into production could have negative environmental impacts, such as the loss of wildlife habitat and water quality issues.

Economic

As of 2020, the positive economic impacts of the PNW biodiesel industry are minimal compared to what was originally predicted by policy makers in the early 2000s. Surviving producers struggle to compete with cheap petroleum and face significant policy uncertainties. Many farmers see growing oilseed crops for biodiesel as a risky investment given limited local crushing facilities and the economic challenges facing the biodiesel industry (personal communication—F. L. Young, USDA-ARS Pullman [retired]). When farmers do choose to grow oilseed, the oil crushed from the seeds is generally sold to the food industry rather than to biodiesel producers.

The decade since 2010 has seen failed biodiesel ventures in the PNW. In 2020, there were only three active facilities in the PNW. In 2008, Washington State had seven biodiesel production facilities and nine projects put on hold or cancelled (Lyons 2008). Uncertain policies, dropping petroleum prices, economic downturn, and limited feedstock supply are some of the primary causes.

The PNW is experiencing some economic benefits from the biodiesel industry, which may increase as the market matures. Biodiesel is produced and consumed. Used cooking oil is widely collected for biodiesel production, and oilseed crops are grown and crushed. Jobs are being created, with SeQuential (see Biodiesel Production section) adding 100 new employees since January 2016 (Stine 2017). REG Grays Harbor reported producing 72.3 million gallons of biodiesel in 2016 and has invested millions of dollars into the facility (Port of Grays Harbor 2017).

However, it is important to acknowledge that subsidies and other policy-generated incentives play a role in facilitating these benefits. Ultimately, economic impacts should be evaluated with an understanding of the context, objectives, scale of impacts, historical perspective, and possible alternatives. For example, other methods of reducing greenhouse gas emissions may be more cost-effective than biofuels (e.g., gas taxes), and economic feasibility may be contingent on policy intervention (Jaeger et al. 2007; Jaeger and Egelkraut 2011).

Biodiesel Policies

The Renewable Fuel Standard (RFS) program is a national-level policy created by Congress, authorized under the Energy Policy Act of 2005 and updated through the Energy Independence and Security Act of 2007 (US EPA 2016a). Each year, the RFS program sets a certain volume of renewable fuel that must replace or reduce petroleum-based fuel, with a goal of

36 billion gallons of renewable fuel in 2022. Biomass-based diesel, which includes biodiesel and renewable diesel, has set minimum volumes (2.0 billion gallons in 2017) and must reduce greenhouse gas emissions by 50% to qualify (US EPA 2016b).

A federal tax credit also encourages biodiesel, in which a one-dollar-per-gallon tax credit is provided to blenders. Recent US House and Senate bills have proposed switching to a producer credit to avoid subsidizing imported biodiesel (NBB 2017).

In addition to federal policies, Washington and Oregon have laws requiring the use of biomass-based diesel. Although a 2007 executive order in Idaho called for a policy to reduce fossil fuels and greenhouse gas emissions from state vehicles (State of Idaho Executive Order No. 2007-21), there is no mandatory requirement for the use of biodiesel.

Washington State agencies are required to use a minimum of 20% biodiesel by volume (except for Washington State Ferries [WSF], which has a lower percentage requirement—5%). Washington State Department of Enterprise Services (WS DES 2017) compiles and reports state agency biodiesel use data. Although by law at least 2% of Washington's total diesel sales by volume must be biomass-based diesel (RCW-19.112.110 2016), the mandate is not backed by a clear statement of who is responsible for meeting the mandate and for tracking compliance, making the law unenforceable. In actuality, the percent biodiesel in retail diesel fuel sold in the state is estimated at 0.4%, based on 2016 Washington State Department of Agriculture (WSDA) fuel sampling data (personal communication—M. B. Lang, WSDA).

Oregon's Renewable Fuel Standard, separate from the national RFS, mandates that all diesel sold in the state be blended with 5% biomass-based diesel (ORS 646.922 2015). Oregon also has a Clean Fuels Program, which provides a market-based approach to reduce the carbon emissions from transportation fuels. Biodiesel production, with lower net carbon emissions than petrodiesel, could play a significant role if first generation soybean biodiesel can be made more efficiently or different feedstocks such as PNW-sourced-and-produced canola or used cooking oil become more available.

Both Oregon and Washington have offered tax incentives for biodiesel production. Many of these incentives have since expired, such as the income tax credits previously available to Oregon producers and collectors of biomass for biofuel (ODOE, n.d.). B20 and higher blends derived from used cooking oil are exempt from excise tax under Oregon's Use Fuel Tax Law (ORS 319.530 2015). The modestly populated state of Oregon—4.1 million people, ranked 27th in population in the nation—is home to an entire third of the nation's B20 stations (68 of the 198 stations listed by the Alternative Fuels Data Center as of June 2017).

In Washington, sale of waste vegetable oil is tax exempt (RCW-82.08.0205 2016). Previously, Washington initiated multiple biodiesel-related policies to create a biodiesel industry. In 2006, Washington State Legislature appropriated $17 million for the Energy Freedom Loan Program to fund bioenergy projects in the state (WSDA 2006). Since 2006, many projects have failed and most tax-based incentives have expired.

Large city- and county-level governments can also affect the biodiesel industry. Portland, Oregon has its own renewable fuel standard that requires biodiesel be at least 50% sourced from used cooking oil or oil from regionally appropriate oilseed crops (e.g., canola, camelina, sunflower, safflower) (Portland City Code 16.60, effective 2007). This mandate generates demand for producers using regionally sourced feedstocks, like REG Grays Harbor and SeQuential. In 2006–2007, King County Metro Transit, which encompasses Seattle, Washington, encouraged biodiesel by using B20 for its fleet (González 2008). A contract with King County for two million gallons helped spur investment into Imperium Renewables, at a time when the company was developing its high-capacity facility in Grays Harbor (Fitzgerald 2010). However, King County suspended use of B20 in 2008 and currently will use B5 only if prices are better or equivalent to regular diesel.

Biodiesel Consumption

Nationally, the transportation sector is effectively the exclusive user of biodiesel (US EIA 2016a), although blending biodiesel with heating oil is also a potential use. In addition to on-highway diesel vehicles, diesel-powered vessels and farming equipment can use

biodiesel. Many organizations in the PNW use biodiesel (Table 2).

The PNW consumed over 30 million gallons of biodiesel in 2015, which is about 2% of US biodiesel consumption (US EIA 2017a) (Table 3). Actual consumption was likely higher, and Oregon's demand has continued to grow, with a forecast of 52.6 million gallons for 2020 (Oregon DEQ 2020). Oregon consumes nine times more biodiesel than Washington. Oregon's policies are largely responsible for this discrepancy.

Washington State agencies are the primary purchasers of biodiesel in Washington and obtained 1.2 million gallons of biodiesel in 2016 (WS DES 2017). Washington State Ferries (Figure 1) accounted for a majority of this biodiesel, consuming 67% of the State's purchase, with vessels running on an average blend level of 4.3% biodiesel. State fuel contracts require at least 51% of purchased biodiesel be sourced in-state, in terms of the fuel itself or its feedstock.

Table 2. Selected examples of current and historical public and business biodiesel consumers in the Pacific Northwest. *Links were accessed on or after June 27, 2017.*

Consumer	Description and Status	
	Current Consumers	
WA State Ferries	Currently using B5. WSF testing B10 now.	http://www.des.wa.gov/sites/default/files/public/documents/About/FormsnPublications/Reports/2016BiodieselUseReport.pdf
King County Water Taxis	2015 King County water taxis designed to run on B10.	http://kingcounty.gov/depts/transportation/news-archive/archive/2015/20150915-green-water-taxis.aspx
The Essential Baking Company *Seattle, WA*	Starting in 2007, the company uses biodiesel in their delivery vehicles. Blends go from B20–B99 depending on the temperature and comparative price of petrodiesel.	https://www.afdc.energy.gov/uploads/publication/ccn_16_2.pdf
Willamette Valley Vineyards *Turner, OR*	Using biodiesel vehicles to transport wine between tasting rooms. Employees are offered 50 gallons per month for commuting.	https://www.businessfleet.com/15639 1/winery-runs-eco-friendly-biodiesel-fleet?refresh=true
	Historical Consumers	
Royal Caribbean Cruises	In 2007, Royal Caribbean Cruises entered into a contract with Imperium Renewables for sale of 18 million gallons of biodiesel but later cancelled the contract.	http://www.seattlepi.com/business/article/Imperium-loses-biodiesel-contract-1282259.php
King County Metro Transit	Used B20 in 2006–2007 but suspended use in 2008.	https://www.seattletimes.com/seattle-news/biofuel-backlash-high-prices-pollution-worries-hit-consumers/
Eastern Washington Gateway Railroad	Biodiesel was tested for use in trains in 2008.	http://www.seattletimes.com/seattle-news/biodiesel-will-drive-eastern-wa-train-during-summerlong-test/

Table 3. Conservative estimate of biodiesel consumption in 2015 for the PNW, based on available data for known use cases. This does not include private use of B20 purchased from select gas stations (Figure 2).

Consumer	Biodiesel Use
Oregon drivers	27 million gallons (5% of the 536 million)
Washington drivers	2.7 million gallons (0.4% of 676 million—see section titled Biodiesel Policies)
State of Washington	1.1 million gallons
Total	30.8 million gallons

Source: gallons of blended diesel fuel consumed on highway came from US EIA 2015a.

Current information on biodiesel use in Idaho is not readily available, as there are no state policies requiring the use of biodiesel or the public reporting of biodiesel consumption. It is likely that some use occurs, but the amount is unknown and likely insignificant compared to the quantity consumed in Oregon and Washington.

There are 76 public fueling stations selling B20 or higher blends in the PNW (Figure 2). Most of these stations are along the Interstate-5 corridor, with a high concentration around Portland, Oregon.

Figure 1. Washington State ferry crossing from Seattle to Bainbridge Island. WSF currently uses B5 and consumes the majority of Washington State's biodiesel purchases. Photo by Noelle Hart, WSU.

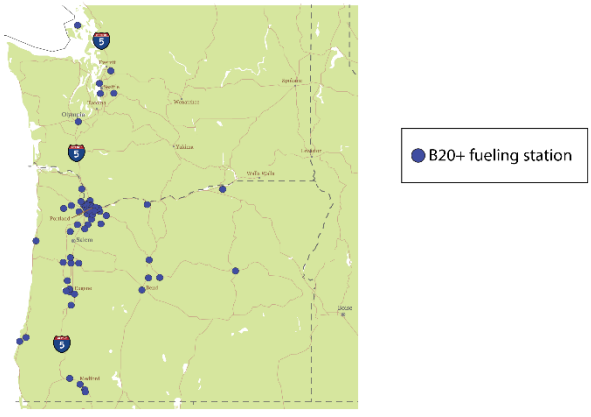

Figure 2. Public fueling stations offering B20 or higher blends in the PNW (as of 2019) are concentrated along the I-5 corridor, with numerous stations in Portland, Oregon. Visit https://www.afdc.energy.gov/locator/stations/ for the most up-to-date station listing. Figure produced by Briana Nordaker, WSU.

Biodiesel Feedstocks

Biodiesel is produced from vegetable oils (e.g., soybean oil, canola oil, corn oil), animal fats (e.g., beef tallow, chicken fat), and used cooking oils (also known as yellow grease). Microalgae, short for microscopic algae, is another potential feedstock, but commercialization is still years away. Most biodiesel in the United States is produced from soybean oil (US EIA 2020). In contrast, biodiesel production facilities in the PNW use canola oil and used cooking oil as feedstock.

Oilseed Crops

Virgin vegetable oil is a biodiesel feedstock produced from crushing oilseeds. A number of oilseed crops have been investigated in the PNW (Figure 3), including canola (*Brassica napus* L.), camelina (*Camelina sativa* L.), safflower (*Carthamus tinctorius* L.), sunflower (*Helianthus annuus* L.), flax (*Linum usitatissimum* L.), and yellow mustard (*Sinapis alba*

L.) (Jaeger and Siegel 2008; Washington Oilseed Cropping Systems, n.d.). Another possibility is soybean, the leading US oilseed feedstock for biodiesel, which is a relatively new crop for the Pacific Northwest and can be grown in areas with irrigation (Norberg et al. 2010; Shock et al. 2014). Thus far, canola has clearly proven to be the most promising feedstock for the PNW (personal communication—M. B. Lang, WSDA).

Figure 3. Washington State University Oilseed Cropping Systems Research and Extension Program (WOCS) studies a variety of oilseed crops and works directly with growers to diversify cropping systems and increase adoption of oilseed crops (http://css.wsu.edu/oilseeds/). Photos courtesy of Karen Sowers, WSU.

Canola

Canola (Figure 4) is a member of the mustard family (Brassicaceae), which includes important vegetable crops like broccoli and cabbage. Canola was bred from rapeseed species (*Brassica napus*, *Brassica rapa*, and *Brassica juncea*) for the purpose of creating an edible, nutritional oilseed crop that would thrive in Canada (hence the name: can = Canada, ola = oil) (according to the Canola Council of Canada). In the PNW, canola is grown commercially and crushed into oil. A majority of the oil is sold to the food industry, but some canola oil is processed into biodiesel (Port of Warden 2016). In addition to its direct market value, using winter canola in rotation with wheat may improve subsequent wheat yields, improve pest management, and diversify farm systems (Young et al. 2014).

In 2017, Washington ranked fourth by state acreage of canola harvested at 54,000 acres and produced 86.4 million pounds of canola, averaging 1,600 pounds per acre (USDA National Agricultural Statistics Service 2018). Canola is 40% oil, and one gallon of oil weighs eight pounds (Herkes et al. 2019), so 1,600 pounds per acre roughly translates to 80 gallons of oil per acre. Canola is grown in the eastern portion of Washington and increasingly is garnering interest as a rotational crop, given depressed wheat prices and demand from the Pacific Coast Canola crushing facility operating in Warden, WA since 2013 (Sowers 2016).

By comparison to Washington, Idaho and Oregon produced far less canola in 2017. Idaho harvested 22,300 acres and 34.6 million pounds. However, Idaho used to be the leading canola-producing state in the PNW (Figure 5) and in 2013 produced more than double its 2017 production. Oregon harvested 7,200 acres, producing 11.2 million pounds. Oregon currently restricts canola production

Figure 4. Canola in bloom (left) and ready for harvest (right). Photos courtesy of Karen Sowers, WSU.

(Oregon Department of Agriculture 2018), and canola's future beyond 2019 is unknown. In 2013, the Oregon legislature responded to the concerns of other *Brassica* growers (e.g., cabbage, kale, mustard producers) by restricting canola production to 500 acres in the Willamette Valley (Karow 2014; Perkowski 2018). The growers were concerned that their Brassica seed crops would be contaminated with canola pollen (cross-pollination) and worried about increased pest and disease pressure.

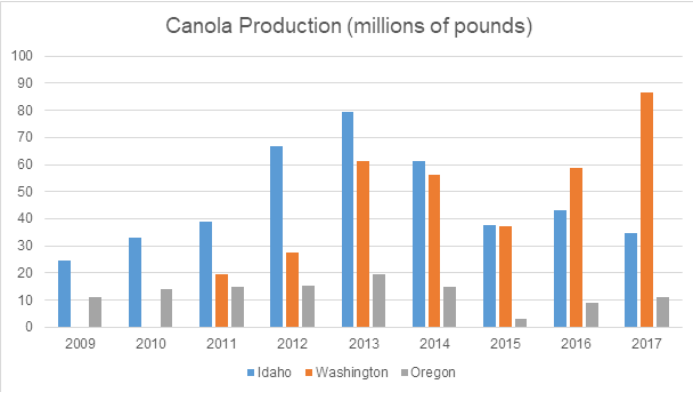

Figure 5. Canola production over time by state in the PNW. No data is available for WA in 2009 and 2010. Data source: USDA National Agricultural Statistics Service Crop Production Annual Summaries.

Camelina

Camelina, a native to Europe, is also receiving attention in the PNW. Besides a biodiesel feedstock, camelina also has a high omega-3 fatty acid content. It is another member of the mustard family (Brassicaceae) and has been grown in Idaho, Washington, and Oregon since 2005 (Jaeger and Siegel 2008). Camelina may be appropriate in the lower rainfall regions as a rotational crop (Hulbert et al. 2012). However, camelina is not living up to researchers' expectations and has largely fallen out of favor as a potential biodiesel feedstock (personal communication—F. L. Young, USDA-ARS Pullman [retired]). Compared to canola, camelina has lower average oil content, requires more energy to break open the seed, and has a higher percentage of polyunsaturates (which leads to more nitrogen oxide emissions and less oxidative stability) (National Biodiesel Education Program 2016).

Used Cooking Oil

Converting used cooking oil to biodiesel requires a more involved process than converting unused (virgin) oil because of the impurities in the oil. However, the feedstock itself is cheaper and lifecycle greenhouse gas emissions are lower because the oil is recycled. In Oregon, biodiesel is produced from used cooking oil collected in all three PNW states, as well as California and Montana (ODOE 2016), and comes from thousands of businesses, including restaurants, universities, stadiums, zoos, and food processors (SeQuential 2016a). Home cooks living near the I-5 corridor can also drop off their used oil to be recycled into biodiesel (find locations at: http://choosesq.com/drop-off-locations/).

Biodiesel Production

Washington State is the sixth highest in state biodiesel production capacity in the United States at 114 million gallons per year (MMgy) (US EIA 2020). Oregon came in 22nd at 17 MMgy. Feedstocks used by commercial biodiesel plants operating in the PNW are generally either canola oil or used cooking oil.

In the early 2000s, Washington State envisioned a biodiesel production system in which oilseeds would be grown throughout the state's dryland cropping areas, crushed at local facilities, and the oil refined into biodiesel at co-located or nearby facilities (personal communication—M. B. Lang, WSDA). The biodiesel would be used in-state, with a market driven by a state renewable fuel requirement.

While several crushing facilities were set up, grower interest in planting oilseed crops lagged. As of 2016, those early facilities were no longer in operation and the market was dominated by one large crushing facility in central Washington, whose primary market is the food oil industry. The largest of the three biodiesel plants operating in the PNW uses virgin canola oil as its feedstock, which it has had to source primarily from Canada due to low canola availability in the PNW. While the in-state market has been slow to develop in Washington, renewable fuel mandates in Oregon and other West Coast markets have buoyed the region's biodiesel production.

Coproducts

Biodiesel and crude glycerol (also known as glycerin) are the products of the transesterification process. Although pure glycerol has many uses in the food (e.g., sweetener), personal care (e.g., skin/hair

products), and pharmaceutical (e.g., cough medicine) industries, crude glycerol contains impurities that can be expensive to remove. Alternative uses for crude glycerol are being investigated, including animal feed and valued-added chemicals (Wen 2012).

Biodiesel Production Facilities

Many producers in the PNW have struggled financially due to biofuel policy changes, dropping petroleum prices, economic downturn, and limited feedstock supply. Uncertainty has plagued the industry, with investors calling for longer-term promises of incentives to reduce risk. An example of uncertainty is the months-long delay before knowing whether US Congress would pass the blenders tax credit for 2015, which did not occur until December of that year, retroactively covered all of 2015 and extended only to the end of 2016 (Kotrba 2015).

As a result of these struggles, the region has experienced rapid changes in the number of operational and planned plants since the enactment of the Energy Policy Act in 2005. In 2008, Washington alone had seven biodiesel production facilities with a combined capacity of 135 million gallons per year (MMgy), but more than nine projects were put on hold or cancelled (Lyons 2008). Financial collapse led to company turnovers and production lapses. As of mid-2020, Washington has two active biodiesel production facilities with a combined capacity of 114 MMgy, Oregon has one facility with a capacity of 17 MMgy, and Idaho has no facilities (US EIA 2020) (Figure 6). However, biodiesel production has not run at capacity; actual production in the PNW was approximately 81 million gallons in 2016.

REG Grays Harbor

Growing from a Seattle start-up, Imperium Renewables built a high-capacity plant in Hoquiam (Grays Harbor), WA and began production in 2007. It is the nation's second largest biodiesel refinery, when ranked by capacity (Biodiesel Magazine 2016). Poor market conditions and lost contracts with Carnival Cruise Lines, King County Metro, and other buyers led to financial difficulties for the company (Fitzgerald 2010). Imperium sold in 2015 to Renewable Energy Group (REG), a national biodiesel producer headquartered in Iowa.

REG Grays Harbor is the largest biorefinery in the region, with capacity over five times greater than the next largest facility in the PNW and having produced 73 million gallons of biodiesel in 2016 (Port of Grays Harbor 2017). The biorefinery uses low free fatty acid (FFA) feedstocks (in contrast to fat or grease), primarily canola oil. Most of the feedstock comes from western Canada, but Grays Harbor also receives oil from canola grown in-state. REG has expressed interest in further development of in-state canola production, as well as diversifying to include used oil and tallow (personal communication—T. Ellis, REG). The biodiesel is primarily exported out of Washington State and distributed to western Canada and the US West Coast, where biodiesel demand is high.

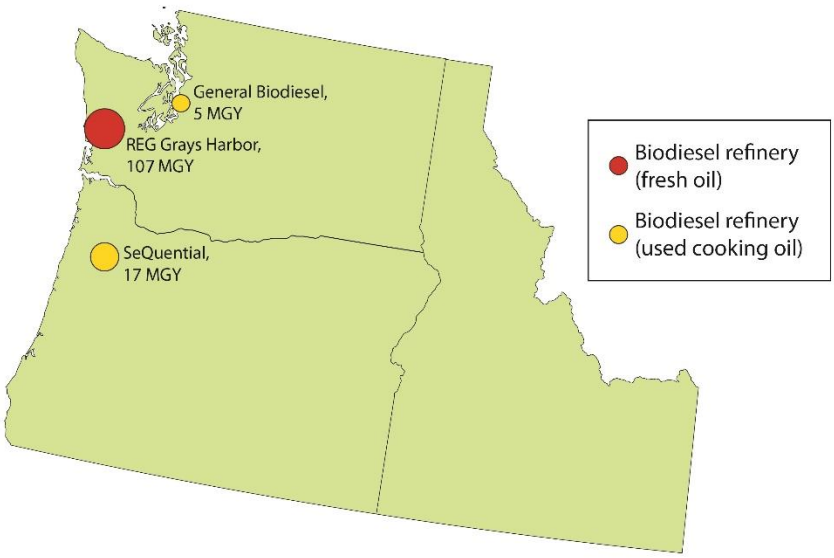

Figure 6. Biodiesel refineries and reported capacity for 2019 in the Pacific Northwest (US EIA 2019). (Individual plant capacities for2020 were not available at time of publication.) Figure produced by Briana Nordaker, WSU.

SeQuential

SeQuential (formerly Sequential Pacific Biodiesel LLC), headquartered in Portland, OR, is the longest running commercial biodiesel producer in the PNW. The company began in 2005 through a partnership between SeQuential Biofuels of Oregon and Pacific Biodiesel of Hawaii (Pacific Biodiesel 2019). The company collects used cooking oil from thousands of restaurants and businesses across the PNW, California, and Montana, including from Kettle Brand potato chips and Burgerville fast food (SeQuential 2017). The oil is made into biodiesel at SeQuential's Salem, OR facility and distributes the biodiesel in the region (SeQuential 2016b). In 2016, SeQuential produced eight-million gallons of biodiesel (Stine 2017).

General Biodiesel

General Biodiesel Northwest LLC, headquartered in Seattle, WA, has been collecting used oil and producing biodiesel on and off since its founding in 2006. Biodiesel production was active as of Spring 2018 and ramping up toward the plant's ten-million-gallon-a-year capacity (personal communication—R. Coulter, General Biodiesel). However, the production capacity reported to the EIA in January 2019 was 5 MMgy (US EIA 2019).

Future Perspectives

Efforts to establish a successful biodiesel industry in the PNW have faced significant barriers, including uncertain biofuel policies and low petroleum prices. A number of biodiesel projects failed or never came to fruition. However, the PNW is also home to the second largest biodiesel production facility in the United States.

As the biodiesel market matures or if barriers (e.g., policy uncertainties, low oil prices) are overcome, the PNW can build upon research-generated knowledge and the strengths of each state to become a significant biodiesel hub. Biofuel research is strong in the PNW, funded by state and national grants (e.g., USDA NIFA CAP) and conducted by National Laboratories, universities, and private industry partners. Washington has considerable production capacity, Oregon is implementing progressive renewable fuels policies, and Washington, Oregon, and Idaho make up over a third of the states growing canola in the United States.

In the PNW, many different strategies will likely be needed to reduce carbon emissions from the transportation sector and encourage economic growth within rural communities. This may one day include incorporating renewable diesel, such as diesel produced from poplar trees (hardwoodbiofuels.org), commercializing microalgae-based diesel, and working together with the developing bio-jet fuel industry. Despite past failures and current barriers, biodiesel's multifaceted benefits (including reduced greenhouse gas emissions, air quality improvements, and regional production opportunities) keep biodiesel in the political discourse as a potential strategy for meeting environmental and social objectives.

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