Economics of Biofuels

Does biodiesel make cents?

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Introduction

There is a green energy revolution happening worldwide. In the United States, the Biden Administration rejoined the Paris Agreement and set a plan to reach "net zero emissions economy-wide by no later than 2050" (FACT SHEET). The government has reintroduced renewable energy benefits to incentivize investment in renewable energy. Biofuel has a lot of potential in the transportation sector because it is just as efficient as gas and diesel as a fuel, but biofuel is much cleaner. The cetane number for biodiesel is higher than diesel, indicating that biodiesel has better ignition properties and engine efficiency (Dunford).

While biodiesel is more environmentally friendly and has a higher cetane number, oil refineries are more profitable. Oil and gas remain the main energy sources in the U.S., therefore, production of diesel is still much higher than biodiesel. To fully understand current trends, it is crucial to first know the differences between biodiesel and ethanol outlooks. From current trends, biodiesel looks the most promising. There are some tradeoffs in the production of biodiesel based on the feedstock's chemical composition. Producers must often balance optimal combustion characteristics and performance in cold weather. To encourage firms to enter the biofuel market, the government has utilized incentives and tax cuts dating back to the early 1900's. These incentives are needed to push investment in biofuels. To explore how much more economically efficient diesel is than biodiesel, this paper calculates the net present value of a refinery and a biodiesel plant started in 2011 and in 2021.

An Overview of Biofuels

There are two main biofuels used in transportation: biodiesel and ethanol. Biodiesel is liquid fuel that comes from renewed and biological raw materials such as used cooking, animal fat, vegetable oil, and algae. It differs from diesel and gasoline since these fuels are non-renewable, and "emit pollutants in the form of oxides of nitrogen, oxides of sulphur, carbon dioxide, carbon monoxide, lead, hydrocarbons, etc. during their production and use" (Sharma, et. all). Biodiesel emits significantly less pollutants than its non-renewable counterpart diesel. Ethanol is similar to biodiesel in that it can be a renewable and clean source of energy. The difference lies in the type of vehicles these fuels are used for. Biodiesel is a substitute for distillate fuels like diesel, kerosene, and jet fuel, and can be blended with diesel. Distillate fuels can be used for larger transportation units, like semi-trucks, trains, jets, and planes. Ethanol is made from biomass, specifically starch and sugar, and is blended with gasoline (AFDC). Gasoline is used for smaller vehicles like cars. And because of recent technological advances in electric power and the push to electrify the car fleet, biofuel producers have chosen to focus on biodiesel. Furthermore, the U.S. government is pushing for electric cars to have a bigger share in the market through incentives. President Biden plans to sign an executive order “that sets an ambitious new target to make half of all new vehicles sold in 2030 zero-emissions vehicles” (FACT SHEET). As the country focuses on reducing emissions, the demand for gasoline will decrease dramatically over the next decade as electric cars will be utilized to replace traditional cars. Consequently, the gasoline market is expected to shrink, and since ethanol is mixed with gasoline, its market will shrink as well. Researchers have not discovered a way to electrify larger vehicles that rely on diesel fuel, such as planes and semi-trucks. These vehicles require much more fuel, and current electric batteries cannot produce nearly enough power. Fuel companies are looking to biodiesel to “clean up” diesel. For the reasons discussed above, biodiesel currently has more potential than ethanol as a biofuel. This white paper will model trends in the biodiesel market.

The Chemical Composition of Biodiesel

The raw material for biodiesel production is extremely important because feedstock costs represent approximately 80% of the total production costs. Nearly all vegetable oils and animal fat can be used as feedstock to make biodiesel. The main feedstocks for biodiesel are canola oil, soybean oil, and palm oil (Elgharbawy).

Recycled material can also be a feedstock, such as used cooking oil. The use of non-edible oils and animal fats for biodiesel production has grown in popularity due to the concern of using food materials for fuel. Algae, on the other hand, is not a main feedstock but is important to mention because it does not require agricultural land to grow, and its productivity is estimated to be very high. The chemical name for biodiesel is fatty acid methyl esters or FAME. FAME is the “leading biofuel for diesel engines, because they have very similar fuel properties to fossil fuel and can be used without any changes to the engine” (Soetaert). Additionally, the process technology for biodiesel is relatively easy. These two factors combined make the biodiesel market quick to enter.

Composition and Properties of Diesel and Biodiesel

Property	Units	Diesel Fuel	Biodiesel
Composition	--	(C_{10}-C_{21})	FAME (C_{12}-C_{22})
Oxygen Content	%	0	11
Hydrogen Content		13	12
Density @15 °C	g/cm^3	0.85	0.86-0.90
Kinematic Viscosity @40 °C	C.st	2.5	1.9-6
Flash Point	C	60-80	100-170
Sulphur Content	ppm	10	500
Calorific Value	MJ/kg	45	37.3
Cetane Number	--	40-55	48-65

The feedstocks for biodiesel all have similar chemical composition. They are made up of triglycerides and different chain lengths of individual fatty acids (Soetaert). The major feedstocks have a fatty chain length of 16 and 18 carbons and can be saturated or unsaturated fats. The main components in traditional diesel fuel are chained hydrocarbons with around 16 carbons. The feedstocks of biodiesel differ from each other in the amount of unsaturated fatty acids. However, there is a tradeoff between having more saturated or unsaturated fatty acids in the methyl esters. "The best combustion characteristics as well as oxidation stability come from saturated fatty acids; however, cold temperature behavior is worse due to the high melting point of these fatty acids" (Soetaert). On the flip side, biodiesel with more unsaturated fatty acids perform better in colder temperatures but have less oxidation stability making them harder to store.

Top Biodiesel Feedstocks

Edible Oils – Used mainly for direct human consumption as food intake.	**Non-Edible Oils – not valid for food, not healthy or hygienic. Used mainly in industrial applications such as biofuel, soap, detergent, etc.**
Palm Oil – Abut 70 – 90% utilized in food industries while rest used in industrial applications. 1.25 liters produces 1 liter of biodiesel.	Jatropha Oil – Extracted from Jatropha seeds. Cultivated in elevated temperature weather with sewage water. Main resource of biodiesel in Asia and Africa. 30-35wt% can be converted to biodiesel. Also used in other applications such as soap, cosmetics, and lubricants.

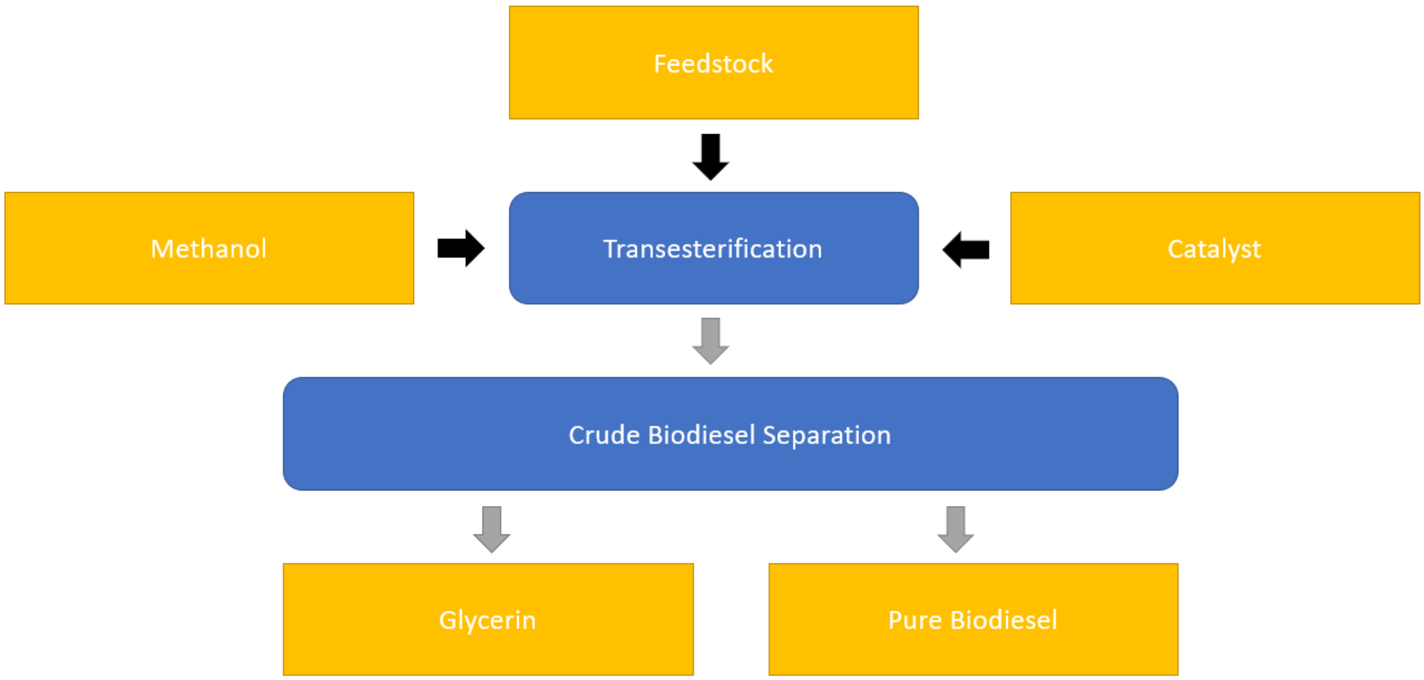
Soybean Oil – Vital edible oil due to health advantages. Mainly produced in US, Brazil, and East Asia. 1.3 liters produces 1 liter of biodiesel.	Used Cooking Oil (UCO) – characterized by low price, availability, ease of assemblage from homes, restaurants, and renewability. Contains high amounts of free fatty acids (FFAs). FFAs are undesirable because they hinder the transesterification reaction and decrease biodiesel yield.
Canola Oil (Rapeseed) – Rap or Canola is a flower that is planted mainly in Europe and Canada. Used as animal food. 1.1 liters produces 1 liter of biodiesel.	Animal Fat and Tallow – highly viscous, solid at room temperature and have poor vaporization characteristics because contains more saturated fatty acids. Tallow is rendered form of beef or mutton fat and made up of triglycerides. Cheap raw material.

Source: A Review on Biodiesel Feedstocks and Production Technologies

Producers must balance out these characteristics and usually blend different types of feedstocks. For example, coconut oil and palm kernel oil have fatty chains of 12 to 14 carbons, thus the FAME from these oils have lower boiling points and can ignite with less effort.

FAME is produced using two methods: transesterification using triacylglycerol or esterification using fatty acids.

Biodiesel Production Process in Simplest Form



Source: AIA Global

Transesterification, or an alcoholysis reaction, uses alcohol to react with the triglycerides to create glycerol and the desired FAME. The products are separated using methanolysis. Esterification is a similar method, but it uses an excess amount of alcohol. A catalyst must be used in either method to yield more FAME without compromising the mild reaction conditions. Catalysts can be alkaline or basic compounds, acids, enzymes and more.

Intersection with Government Policy: A Brief History

The energy market and government have always been intertwined; with energy affecting public policy and vice versa. Government policy has utilized biofuels in times of energy uncertainty or crisis. The Harvard Kennedy School of Government states that “biofuels have become big policy and big business”, so an administration can blanketly support biofuels and employ whichever rationale that will gain public favor (Lawrence). Some of these rationales include producing clean energy, decreasing reliance on foreign oil, and equalizing energy markets. As early as 1907, “Congress passed legislation meant to spur the development of a domestic transportation biofuels industry” (Lawrence). The reasoning for developing biofuels was to foster competition with Standard Oil, who was determined an “illegal” monopoly by the Supreme Court. During WWII, biofuel was used as a main fuel source after petroleum supply lines were disrupted5. At this time, the production of biofuel was much more expensive than petroleum, so after supply lines were restored, biofuel was put in the backburner.

Modern interest in biofuel in the 1970’s led to the creation of biodiesel. The 1973 oil crisis scared countries into investing in alternate forms of energy, as they suffered from shortages of petroleum. In the United States, the Clean Air Act of 1990 was passed to combat smog, reduce air pollution, and restore visibility in major cities. These goals were accomplished by establishing emission standards and deadlines to achieve these feats (Clean Air Act).

Later, the Bush administration passed the Energy Policy Act of 2005 that mandated petroleum to be blended with biofuel (ethanol and biodiesel) in higher ratios. A part of this act was the Renewable Fuel Standards (RFS) Act which expanded the renewable energy sector and aimed to reduce greenhouse gasses. Under this act, the plan was to produce more renewable fuel each year, up to 36 billion gallons annually by 2022 (EPA). The Energy Policy Act was revised in 2007, providing standards for biofuel. It mainly required "ethanol production and use to emit 20 percent less greenhouse gases than gasoline, and advanced biofuels (made from agricultural waste or crops like switch grass) to release 50 percent less" (Lawrence).

Another concern with oil circulating around this time was reliance on Middle East oil. The idea of "peak oil" was circulating, and the United States wanted to reduce "economic vulnerability due to dependence on foreign oil" (Lawrence). The Harvard Kennedy School of Government argues that the EPA of 2005 was not effective in solving either of these problems. A tariff on imported oil would have made domestic oil relatively cheaper, thus bringing demand back home. Carbon taxes or clean energy incentives would be a better method to effectively reduce emissions (Lawrence). The EPA of 2005 did not place limits on non-renewable energy, it simply added biofuels to the mix. According to Harvard, a more effective policy would be to "implement a pigouvian tax or a cap and trade program to raise the cost of emitting carbon" (Lawrence).

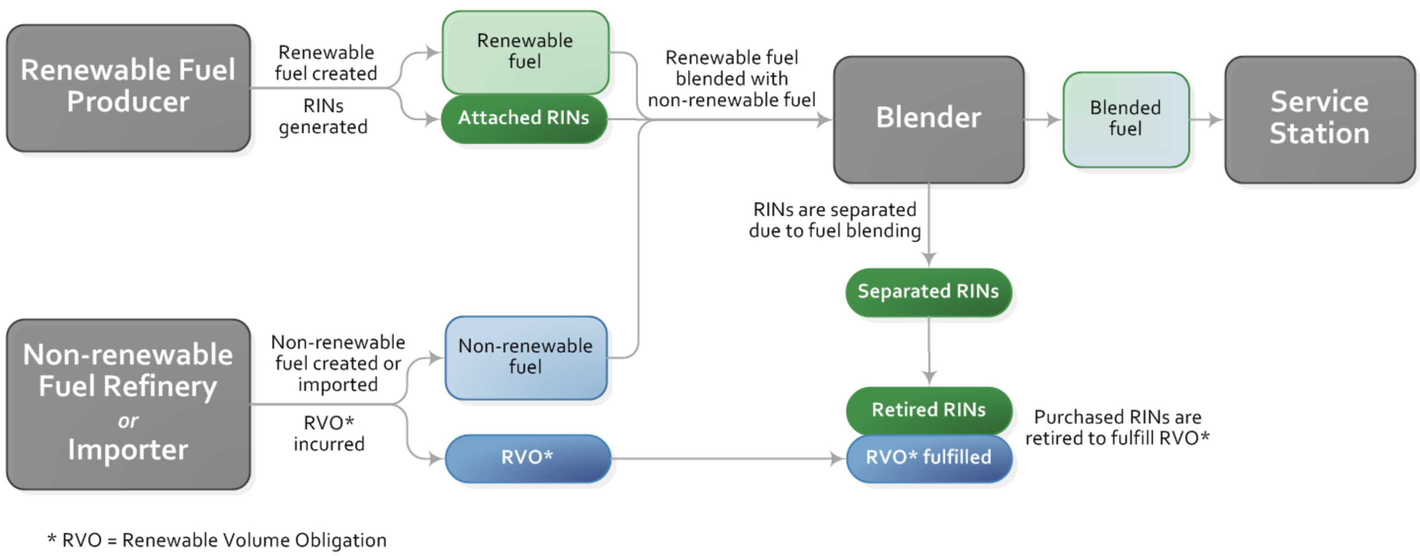
The Biodiesel Tax Credit, active 2005 to 2013, enacted a $1.00 per gallon tax credit for those who produce biodiesel or renewable diesel up to established standards. "The tax credit supports higher levels of biodiesel and renewable diesel consumption by offsetting the higher cost of these fuels relative to petroleum-based diesel fuel" (Hanson). The U.S. Energy Information Administration finds that when the tax credit is active "domestic production and foreign imports of biodiesel increased significantly relative to the preceding years" (Hanson). The Biodiesel tax credit was renewed in 2019 until 2022. It was forecasted in 2018 that, "EIA expects that the tax credit will contribute to increased levels of both domestic production and net imports of biomass-based diesel through 2021," with domestic production increasing from 119,000 b/d in 2019 to 135,000 b/d in 2020 and 158,000 b/d in 2021" (Hanson).

The RFS program has been a boon to the Midwest corn belt, but refining companies opposed it because it cut into their petroleum-based market share, and because the blending requirements cost the refining industry hundreds of $ millions. We'll cover this more in depth in the next section. The RFS program has become a political battle between the farmer and the refiner.

What is a RIN?

The US Environmental Protection Agency (EPA) administers the RFS program and tracks compliance through the Renewable Identification Number (RIN) system. Renewable Identification Numbers or RINs are credits used for compliance and are considered the "currency" of the RFS program. RINs are unique numbers assigned to batches of biofuels used to track compliance. Each gallon of renewable fuel is assigned an equivalence value to determine how many gallon-RINs can be generated for the gallon of renewable fuel. Ethanol has an equivalence value of 1.0 while biodiesel has an equivalence value of 1.5. When biofuels are manufactured, RINs are created. Market participants then can trade RINs, and obligated parties obtain and ultimately retire the RINs for compliance to fulfil the RVO (Renewable Volume Obligation). For a general idea of the lifecycle of a RIN, see diagram below.

Lifecycle of a Renewable Identification Number (RIN)



Source: EPA

What are Renewable Volume Obligations (RVOs)? Each year, the Environmental Protection Agency (EPA) is tasked with drafting a proposal to establish the minimum amount of renewable fuel, expressed as a percentage, that should be blended into transportation fuels. The volumes required of each obligated party are based on a percentage of its petroleum product sales. As previously mentioned, obligated parties can meet their RVOs by either selling required biofuels volumes or purchasing RINs from parties that exceed their requirements (US Department of Energy).

Flaws in the RFS Program

Since the launch of the RFS program, mandates have been contentious for US refiners. One root driver of the RFS was national energy supply security, but since the inception of the RFS in the

2005 the US has transformed to become a crude exporter and the largest oil producer in the world.

Top 10 largest oil producers and share of total oil production (2020)

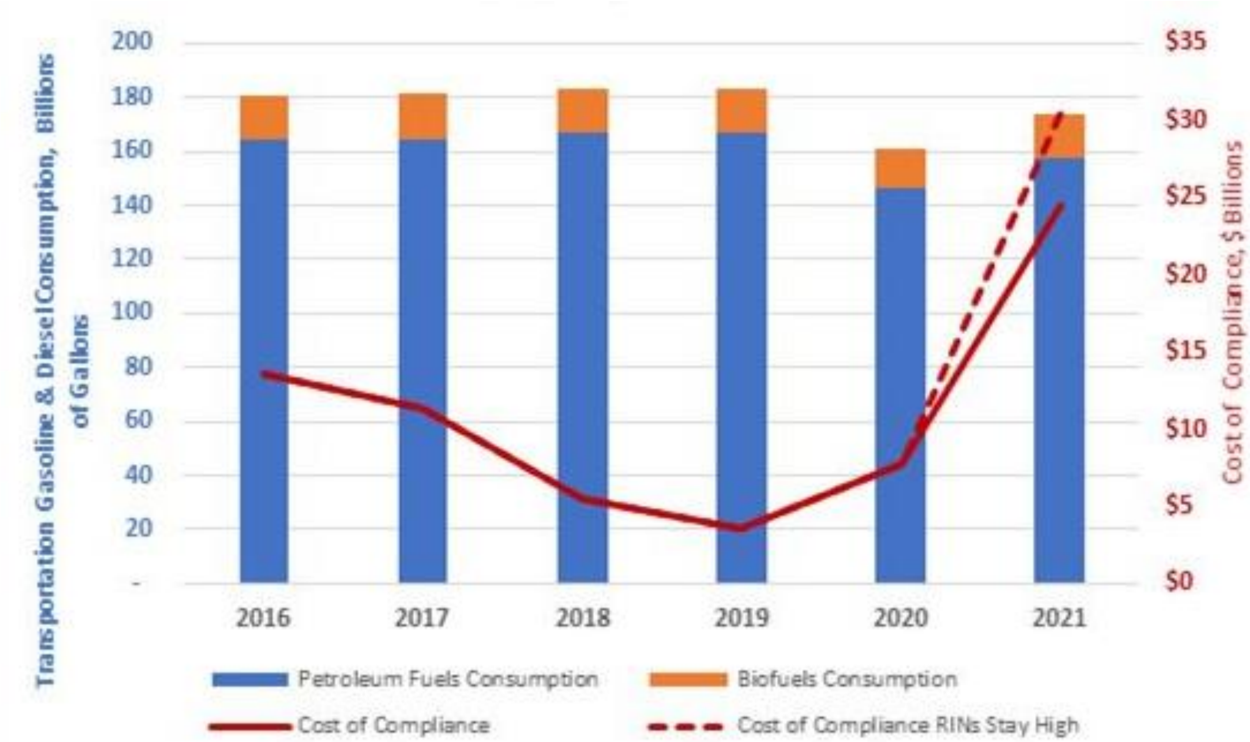
Country	Million barrels per day	Share of world total
United States	18.61	20%
Saudi Arabia	10.81	12%
Russia	10.50	11%
Canada	5.23	6%
China	4.86	5%
Iraq	4.16	4%
United Arab Emirates	3.78	4%
Brazil	3.77	4%
Iran	3.01	3%
Kuwait	2.75	3%
Total top 10	67.49	72%
World total	93.86	

Source: EIA

The concerns with energy security have been neutralized, but the high price of compliance for US refiners continues to be an issue. By design, RVOs rise annually based on the assumption that fuel demand will continue to rise. If a refiner cannot meet its EPA-assigned annual blend target, they must buy RINs on the open market. When annual biofuel mandates are attainable, purchasing RINs on the open market is not a concert; however, when RFS mandates exceed the limits of the blend wall, refineries must purchase RINs that are limited in the market as a result of increased RIN demand.

What is this so called "blend wall"? Conventional biofuels have a specified target volume for each year in the mandates. However, increased use of ethanol has been limited by what the industry calls the "blend wall," the limit of no more than 10% ethanol by volume that older gasoline engines can use in their fuel. As consumption of transportation fuel has slowed, due in part to more fuel-efficient vehicles prior to the 2020 pandemic, the blend wall has limited the growth of biofuel consumption. This reduces production which in turn reduces the number of RINs in the market available to purchase. The pandemic lockdowns in 2020 had a disastrous impact on transportation fuel demand. Earnings for oil and gas companies, specifically refiners, were in negative territory until Q2 2021. Because of demand destruction, the price of RINs rose over 500% in 2020, even as realized margins were near zero. As a result, US refiners continue to press for an overhaul of the RFS program and mandates.

Historical RFS Compliance Cost



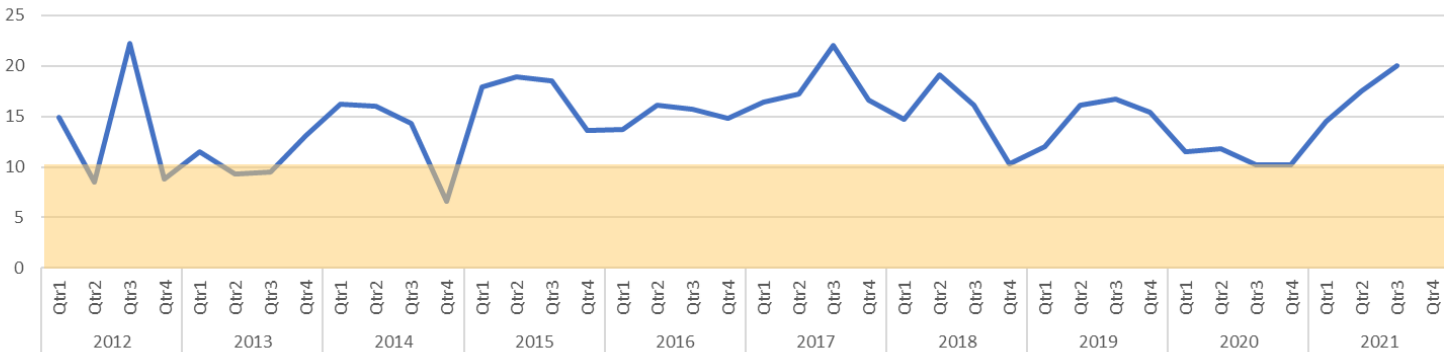
Source: AFPM

According to the American Fuels and Petrochemicals Manufacturers (AFPM), "the RFS is more expensive in 2021 than at any other point in the program's 15-year history." Refiners in 2021 have faced ethanol credits (D6 RINS) nearly 19x higher than in January 2020 and record high biomass-based diesel credits (D4 RINS). The total cost in 2021 could be as high as $30 billion in, more than twice the amount in 2016. By comparison, the refining sector spends $16 billion on workforce pay and benefits, according to AFPM.

The 3:2:1 crack spread approximates the product yield at a typical U.S. refinery. For every three barrels of crude oil processed, two barrels of gasoline and one barrel of distillate fuel are produced. Crack spreads are good indicators for short term profit margins of oil refineries in the U.S. because it compares the cost of crude (major cost for a refinery) to the wholesale price of the outputs. The crack spreads do not account for any other variable costs or fixed costs (i.e. RIN costs). As shown in the chart below, the average 3:2:1 crack spread during Q2 2021 was over $17/bbl, indicating profitability. Quarterly earnings for Q2 2021 in the Refining segment for

Phillips 66 resulted in a loss of $729 million. Realized margins were lower as the benefit of the improved market crack spreads was offset by higher RIN costs.

USGC 3:2:1 Crack Spread (BPD)



Source: EIA

According to Reuters, Monroe Energy, a subsidiary of Delta Airlines, has increased its biofuel liabilities to a company record of $547 million by end of Q3 2021. PBF Energy has amassed a $1.3 billion credit liability from slowing or halting purchases per its Q3 filing. CVR Energy has a $442 million credit liability per its Q3 filing. President of the American Fuel & Petrochemical Manufacturers, Chet Thompson, said that "this whole situation is proof of how the RFS program is…The program is making it more expensive to produce gasoline and diesel in the United States."

Price volatility has been another issue in the RIN market due to the delay by the EPA in setting the 2021 blending mandates. As of writing the EPA has proposed mandates for 2020-2022. "On December 7, 2021, EPA proposed a package of actions setting biofuel volumes for the Renewable Fuel Standard (RFS) program for years 2020, 2021, and 2022, and introducing regulatory changes intended to enhance the program's objectives" (EPA).

Proposed Mandates for 2020-2022

Biofuel Type	2020	2021	2022
Cellulosic Biofuel	0.51	0.62	0.77
Biomass-Based Diesel	2.43**	2.43**	2.76
Advanced Biofuel	4.63	5.20	5.77
Total Renewable Fuel	17.13	18.52	20.77
Supplemental Standard	n/a	n/a	0.25

Source: EPA

The announcement is considered a win for the biofuels industry and farmers, but a huge blow to oil refineries. The EPA is also proposing to deny petitions that would exempt small refineries from blending biofuels into fuel mixes as obligated by the RFS.

A study focusing on the RFS program and effects by Iowa State University's Center for Agricultural and Rural Development concluded that the mandates have provided price support for both corn and soybeans. The policy has boosted the value of the US agriculture sector by the $ billions according to the study, while it did little for the petroleum industry (dtnpf.com).

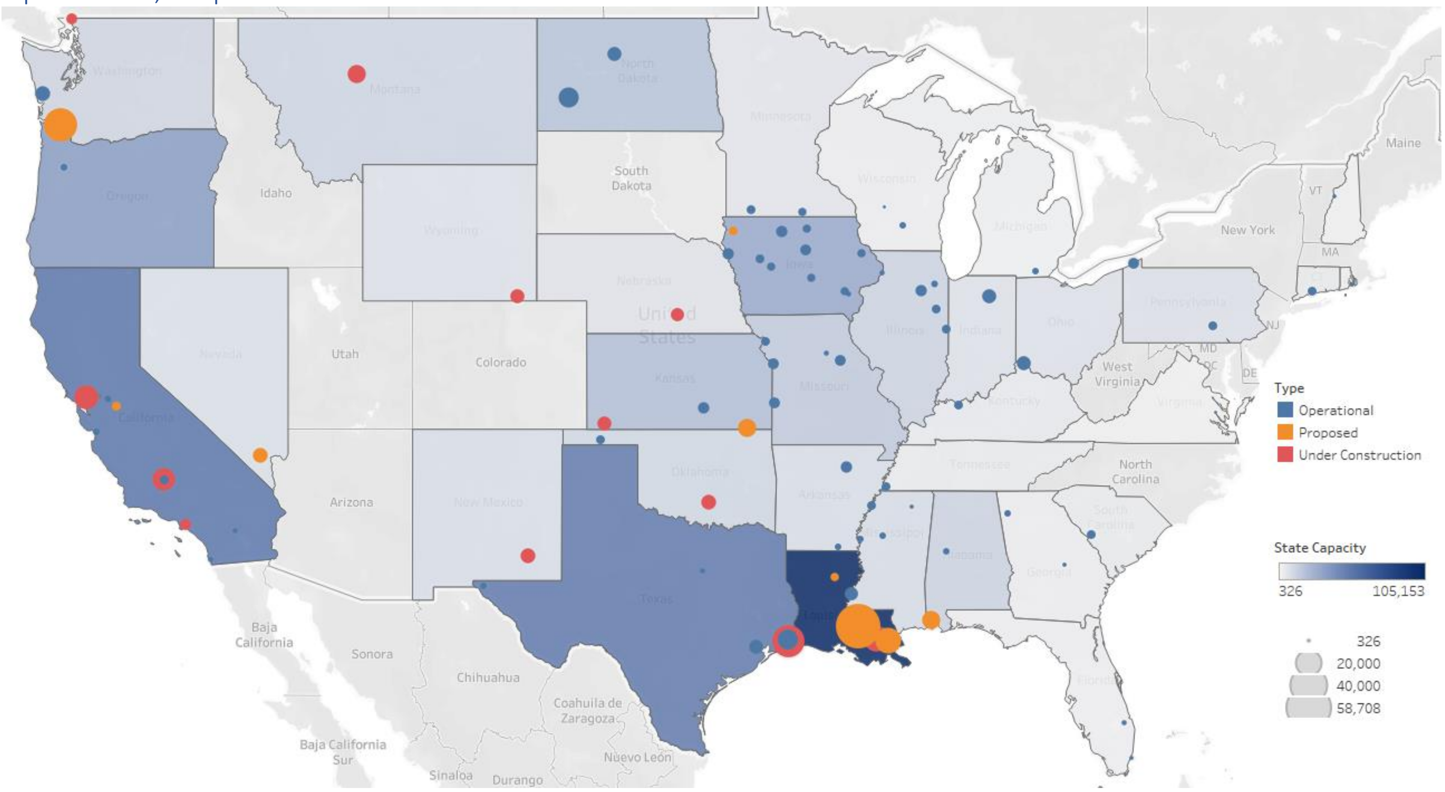
And finally, there is RIN fraud. Unfortunately, when the RIN price is relatively high so is the incentive to "game the system". The EPA has identified producers generating invalid biodiesel RINs in the past, approximately 15 since 2013 as published on the EPA website.

US Biodiesel Supply

According to the IEA's Renewables 2021 report, renewable diesel and biojet account for 78% of biofuel supply growth driven by the RFS and blender's tax credit, as well as the low-carbon fuel standard in California. We discus California's LCFS more in depth in a later section. Shown on the map below are biodiesel plants that are currently operational, under construction, and proposed.

All US Biodiesel Plants (BPD)

Operational, Proposed and Under Construction.



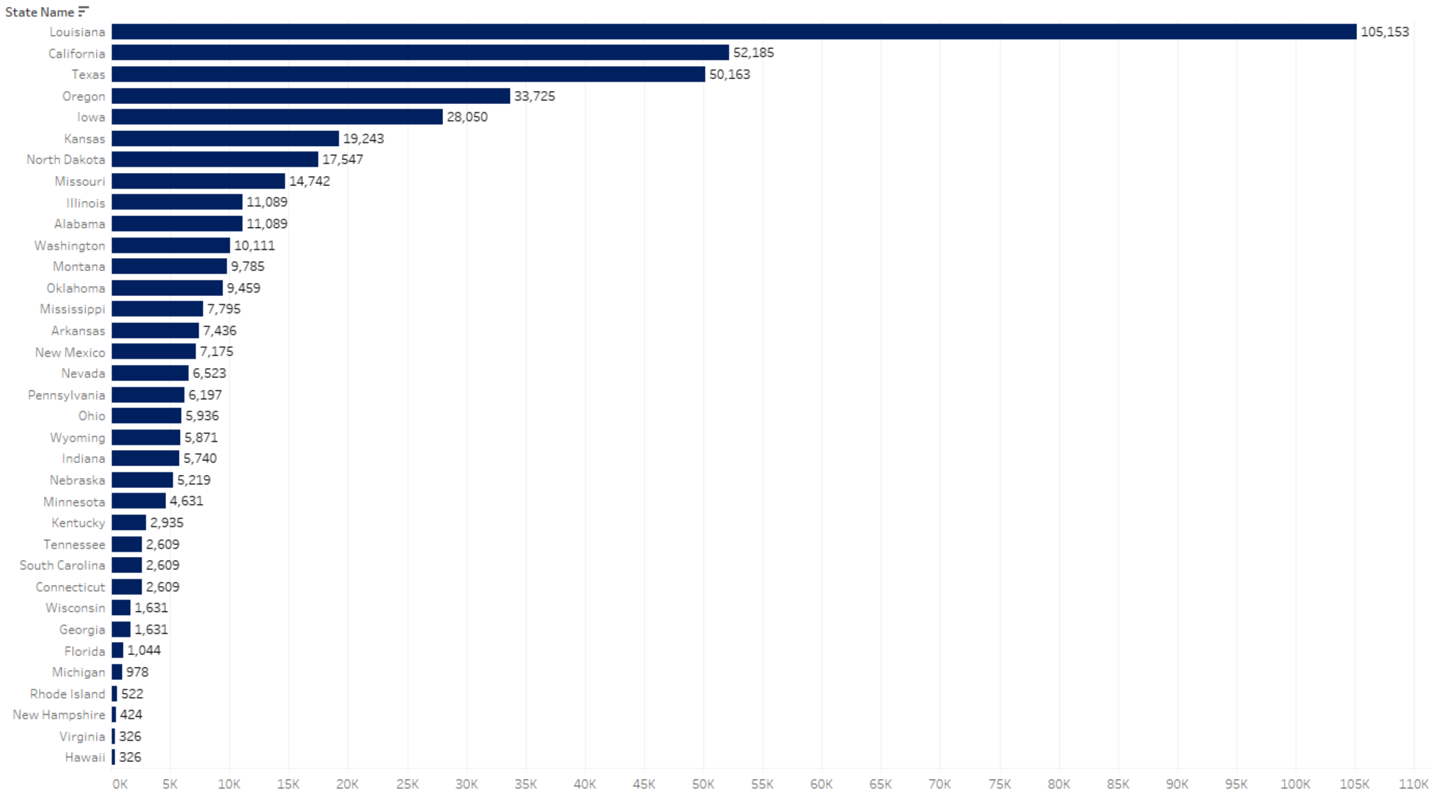
Source: Biodiesel Magazine and AIA Global

The RFS program was first introduced under President George W. Bush and later revised and expanded in 2007. The state of Iowa has benefited mightily from the mandate, producing more corn and soybeans. Both corn and soybean production play a crucial role in America's first-generation biofuels capacity growth. Since the revised standard went into effect, biofuels production in the United States has doubled. Conventional biorefineries in the Midwest currently account for just under half of global biofuels production capacity today.

US Operational Biodiesel Plants

Of all US biodiesel plants that are operational, Iowa leads with 25.7 thousand bpd followed by Texas with 19.5 thousand bpd, and North Dakota with 17.6 thousand bpd.

Top US States with Biodiesel Production Operational (BPD)



Source: Biodiesel Magazine and AIA Global

The largest operating plant in the US is the Marathon Petroleum biodiesel plant in Dickenson, North Dakota with a capacity of 12 thousand bpd. This plant is a converted petroleum refinery into a renewable diesel facility and produces both renewable diesel and naphtha. The Dickenson plant began producing renewable diesel in late 2020 and reached full production capacity in 2021. Feedstock for the Dickenson plant includes corn oil and soybean oil. In 2020 Marathon Petroleum acquired a vegetable oil and animal fat pre-treating and storage facility in Beatrice, Nebraska to supply feedstock to its refinery. California is the primary market for the renewable diesel facility (nsenergybusiness.com).

The second largest plant is the RBF Port Neches plant in Port Neches, Texas with a capacity of 11.7 thousand bpd. The plant consists of two parallel process units for pretreatment and transesterification. Main feedstocks include soybean and canola oil, but the plant has processed other feedstock including corn oil, used cooking oil, and corn oil. These are the only two plants currently operating with a capacity over 10 thousand bpd. The Port Neches plant was the largest biodiesel refinery in the US for over a decade until the conversion of the Marathon Dickenson refinery.

Top US Biodiesel Plants Operational (BPD)

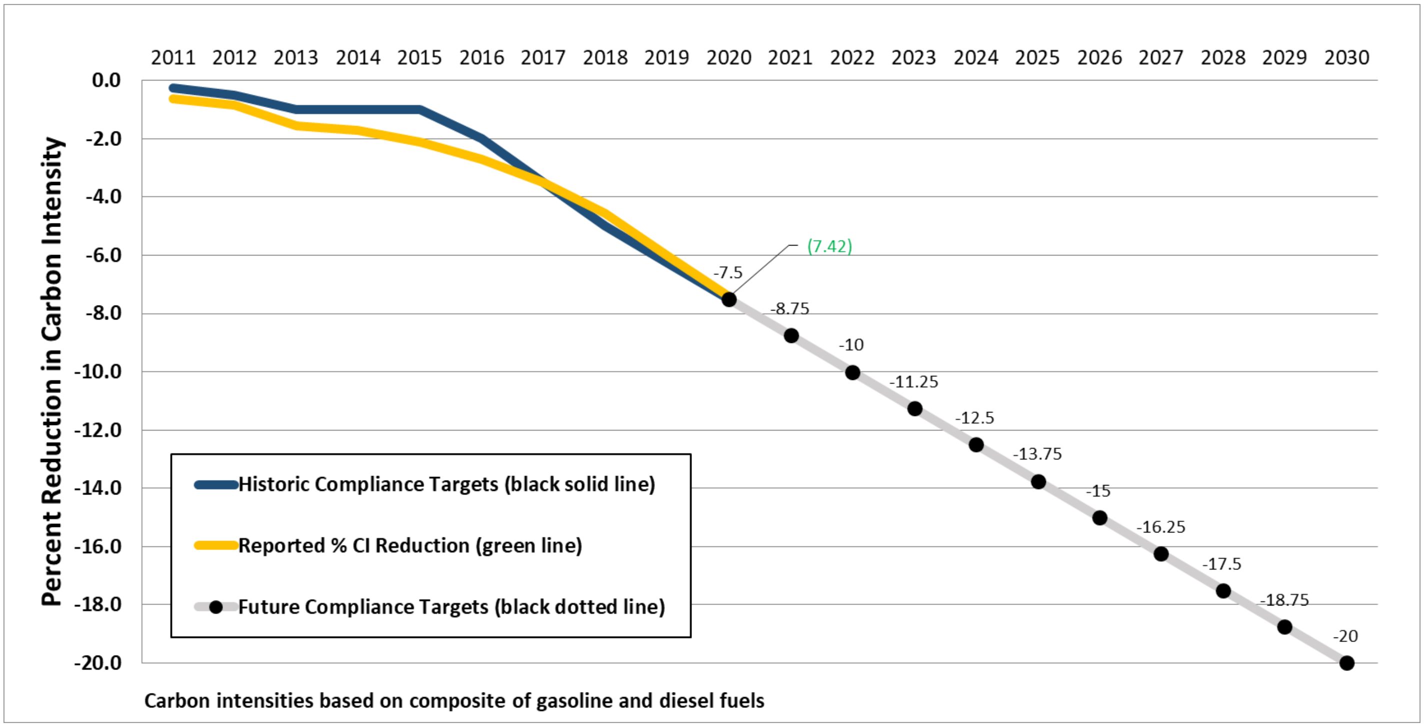
Rank	Plant Name	City	State	BPD
1	Marathon Petroleum - Dickinson Refinery *Rewable Diesel	Dickinson	ND	12,003
2	RBF Port Neches, LLC	Port Neches	TX	11,742
3	REG Grays Harbor LLC	Hoquiam	WA	6,523
4	Cincinnati Renewable Fuels (Marathon)	Cincinnati	OH	5,936
5	World Energy - Houston	Galena Park	TX	5,871
6	Louis Dreyfus Agricultural Industries LLC	Claypool	IN	5,740
7	Archer Daniels Midland Co. - Velva	Velva	ND	5,545
8	World Energy - Natchez	Natchez	MS	4,697
9	REG Seneca LLC	Seneca	IL	3,914
	Cargill - Wichita	Wichita	KS	3,914
	Ag Processing Inc. - Sergeant Bluff	Sergeant Bluff	IA	3,914
	Ag Processing Inc. - Algona	Algona	IA	3,914

Source: Biodiesel Magazine and AIA Global

California's Low Carbon Fuel Standard

In 2009 the California Air Resources Board (CARB) approved the Low Carbon Fuel Standard (LCFS) and began implementation on January 1, 2011. The LCFS was designed to encourage the use of cleaner low-carbon transportation fuels, and production of these fuels, as well as reduce greenhouse gas (GHG) emissions, and reduce the petroleum dependence in the transportation sector. The LCFS standards are expressed in carbon intensity (CI) of gasoline and diesel fuel, and their respective substitutes. (arb.ca.gov)

2011-2020 Performance of the Low Carbon Fuel Standard (%)

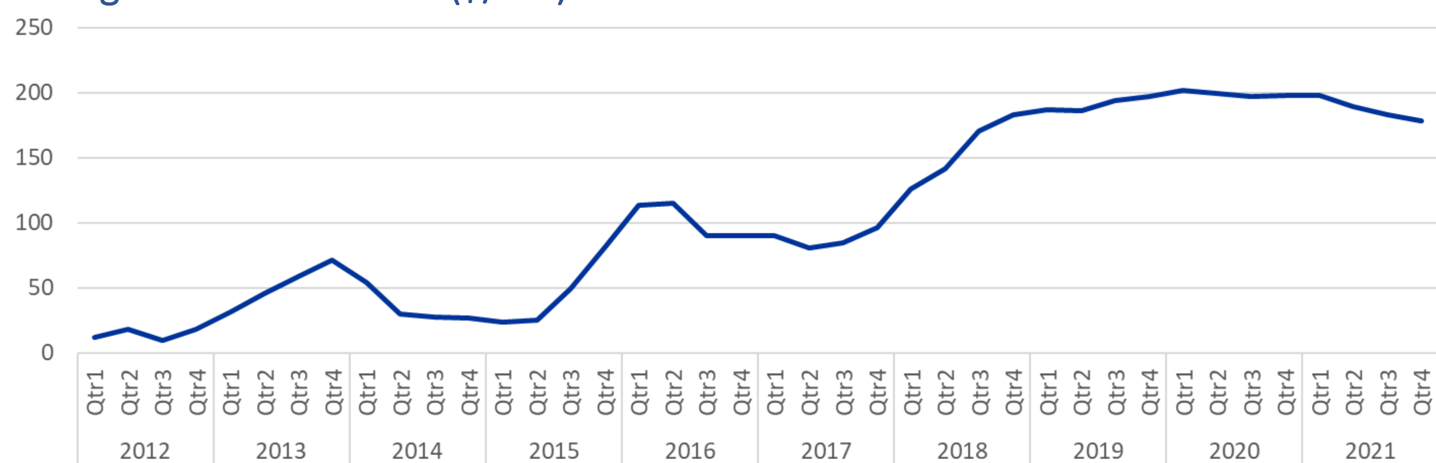


Source: CARB

The carbon intensity scores assessed for fuels used in California are compared to a declining CI benchmark for each year. Low carbon fuels below the benchmark generate credits while fuels above the benchmark generate deficits, which are both denominated in metric tons of GHG emissions. (arb.ca.gov)

As shown above, the LCFS credit generation met 7.42% of the 7.5% target reduction. The LCFS target is to achieve a 20% reduction by 2030. (arb.ca.gov)

Average LCFS Credit Price ($/MT)

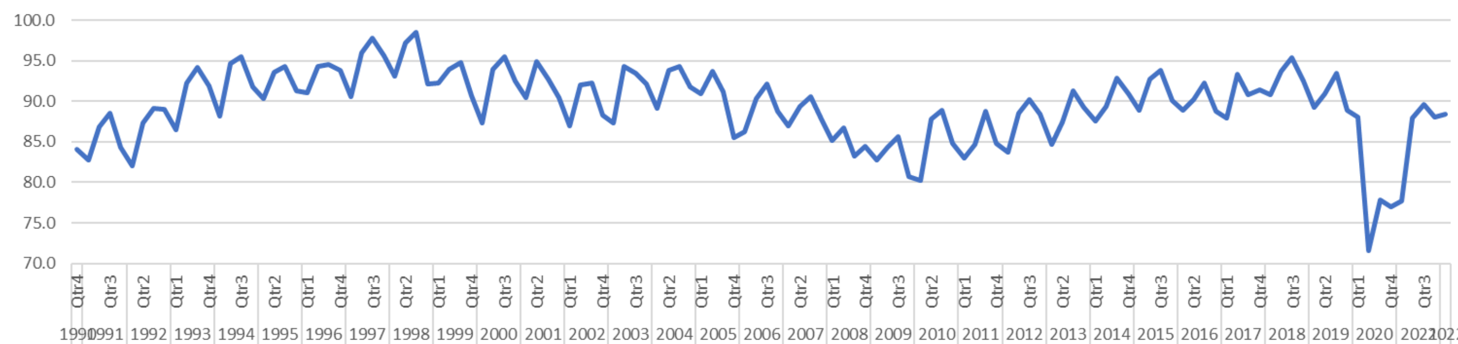


Source: CARB

To comply with the LCFS, refiners, importers of motor gasoline and diesel, and wholesalers of motor transportation fuel in California are required to either produce low carbon fuels or purchase credits to demonstrate compliance. The LCFS created one of the largest carbon markets in the transportation sector, but since 2018 LCFS credit prices have hovered around the $200/mt level. This is a cost to refiners in California that other refiners in the U.S. aren't paying.

As a result of the collapse in demand from Covid-19 lockdowns and restrictions, refineries lowered utilization rates to the lowest on record while some ceased production altogether.

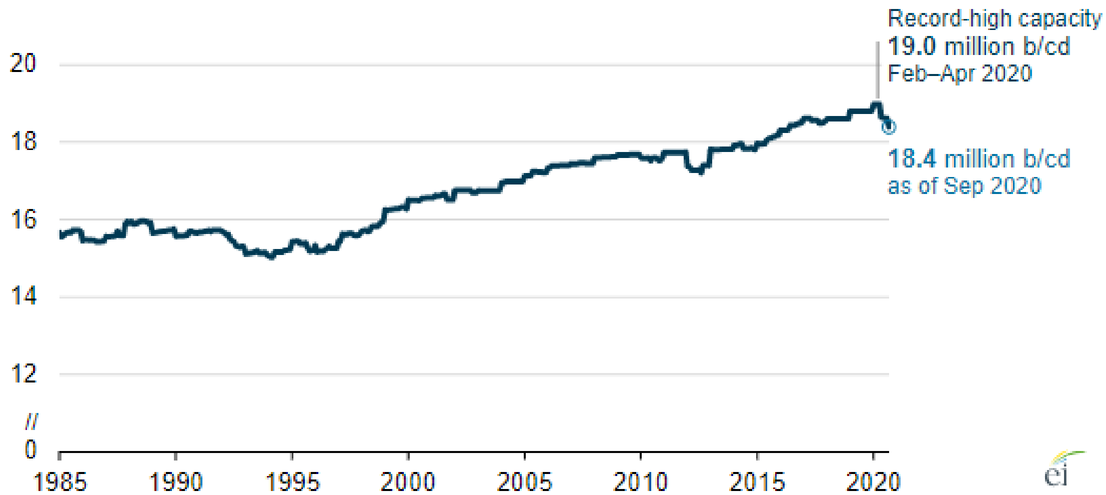
Average US Refinery Utilization Rates (%)



Source: EIA

Two large refiners in California, Marathon Petroleum in Martinez and Phillips 66 in Rodeo announced plans to cease production of fuels using crude oil in 2020 and in 2023, respectively. With low utilization rates and the closure of the Marathon Martinez refinery, credits under the LCFS traded lower in 2021 due to the drop transportation fuel production. With the refinery closures in 2020, refining capacity in the US dropped 4.5%. At the beginning of 2021 there were 129 refineries operating in the US, down from 135 at the beginning of 2020.

US petroleum refining capacity falls to its lowest level since May 2016 (BPD)



Source: EIA

Other closures around the US include:

- Philadelphia Energy Solutions refinery in Philadelphia, Pennsylvania: 335,000 bpd
- Shell refinery in Convent, Louisiana: 211,146 bpd
- Tesoro (Marathon) refinery in Martinez, California: 161,000 bpd
- HollyFrontier refinery in Cheyenne, Wyoming: 48,000 bpd
- Western Refining refinery in Gallup, New Mexico: 27,000 bpd
- The Dakota Prairie refinery in Dickinson, North Dakota: 19,000 bpd
- Phillips 66 refinery in Alliance, Louisiana: 255,000 bpd (2021)
- Phillips 66 refinery in Rodeo, California: 120,000 bpd (2023)

US Biodiesel Projects

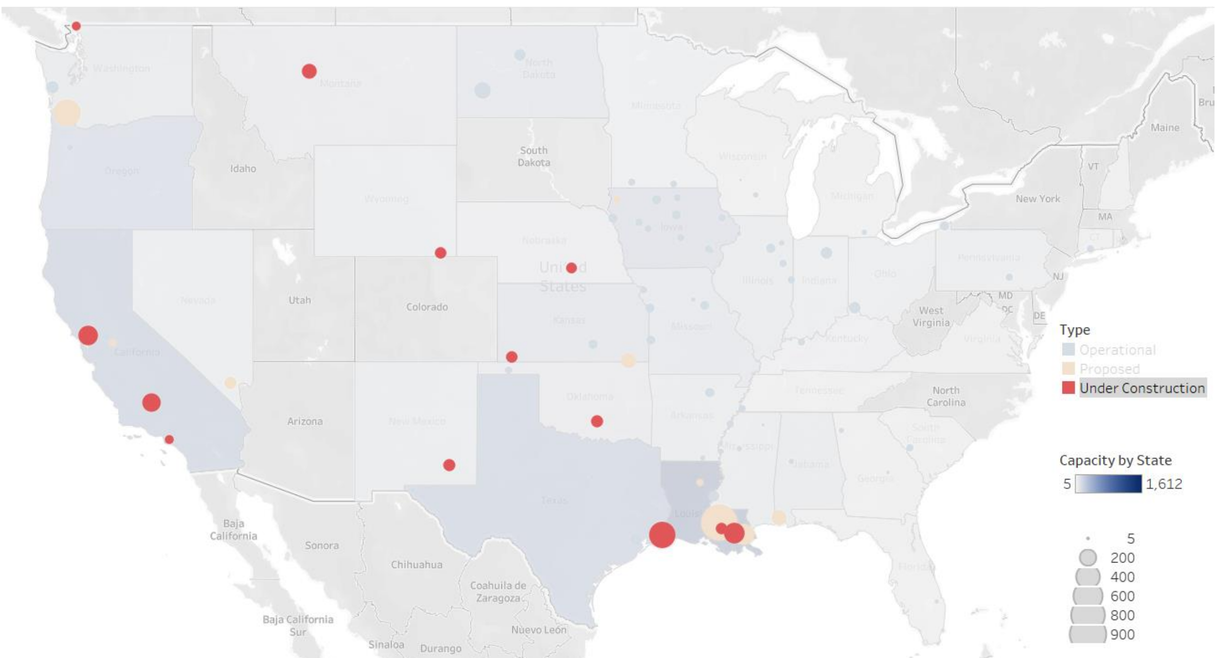
The US EPA has projected that refiners, importers and other obligated parties will rely on renewable diesel and biodiesel to meet a 21 billion ethanol equivalent USG renewable fuel blending requirement for 2022. A $1 per gallon federal blending tax credit coupled with proposed federal RFS mandates for 2022 add support for additional biodiesel production.

In California, renewable diesel production has increased since the launch of the state's Low Carbon Fuel Standard (LCFS) in 2011. Transportation fuel distributors supplying low-carbon fuels including renewable diesel and biodiesel receive credits that offset deficits incurred by conventional, higher-carbon fuel in California per CARB's LCFS. California has been lucrative for renewables given the compliance incentives. (Argus Media)

The credits generated by renewable diesel producers have some of the lowest carbon intensities of any of the LCFS-approved liquid fuel pathways. The average carbon intensity of renewable diesel, measured in grams of carbon dioxide equivalent per megajoule (gCO2e/MJ), has been about 30 gCO2e/MJ since spring 2016. Much of this low carbon intensity fuel is made from used cooking oil feedstock. Compared with other liquid transportation fuels, renewable diesel's carbon intensity is approximately 20 gCO2e/MJ lower than ethanol and about equal to the average carbon intensity of biodiesel. Ultra-low sulfur diesel, which accounts for most of the diesel supplied in California, has a carbon intensity of 102 gCO2e/MJ. Under the LCFS program, renewable diesel generates a large number of credits relative to other fuels because it has some of the largest lifecycle greenhouse gas reductions compared with other fuels. (EIA)

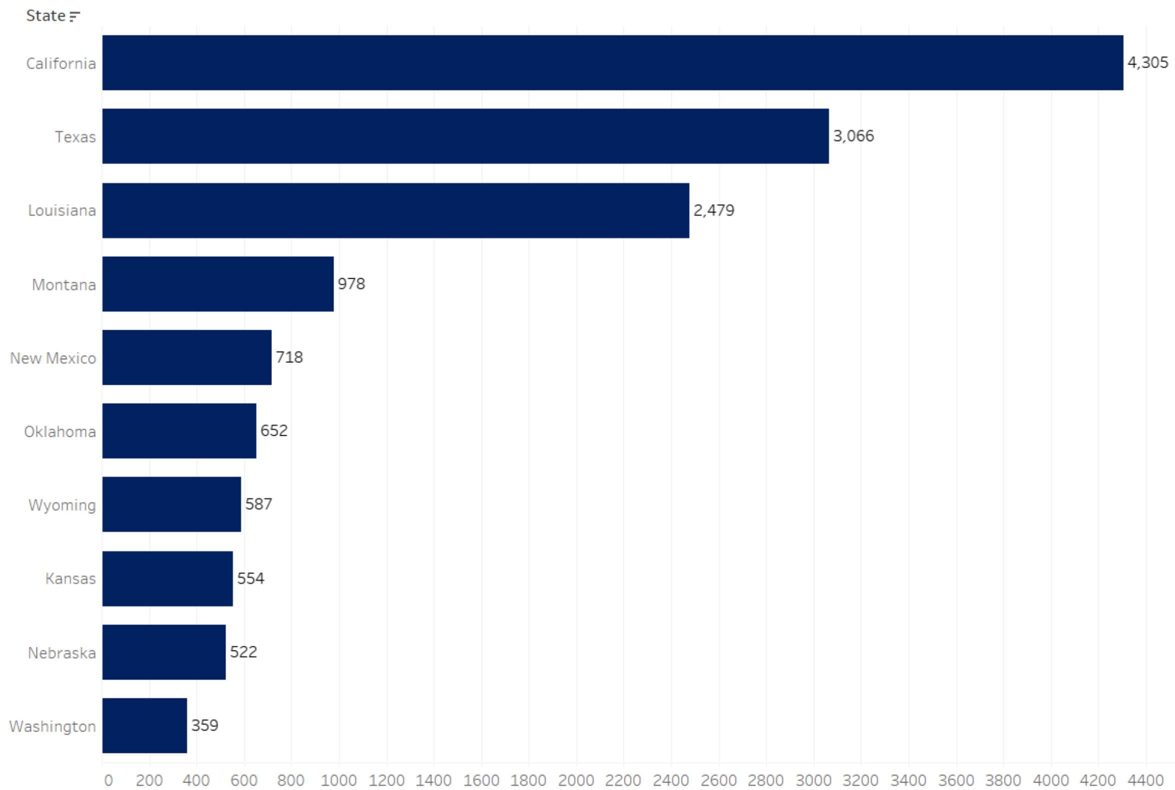
As shown in the map and bar chart below, the state leads in new facilities under construction.

Biodiesel Plants under Construction (BPD)



Source: Biodiesel Magazine

Leading US States with Biodiesel Plants under Construction (BPD)



Source: Biodiesel Magazine

Top 10 US Biodiesel Plants Under Construction

Rank	Parent	City	State	
1	Diamond Green Diesel (Valero)	Port Arthur	TX	30,659
2	Diamond Green Diesel (Valero)	Norco	LA	18,917
3	Marathon	Martinez	CA	16,960
4	Bakersfield Renewable Fuels (GCEH) *Rewable Diesel	Bakersfield	CA	15,003
5	Montana Renewables (Calumet) *Rewable Diesel	Great Falls	MT	9,785
6	Phillips 66	Rodeo	CA	7,828
7	HollyFrontier	Artesia	NM	7,175
8	CVR Energy	Wynnewood	OK	6,523
9	HollyFrontier	Cheyenne	WY	5,871
	REG	Geismar	LA	5,871

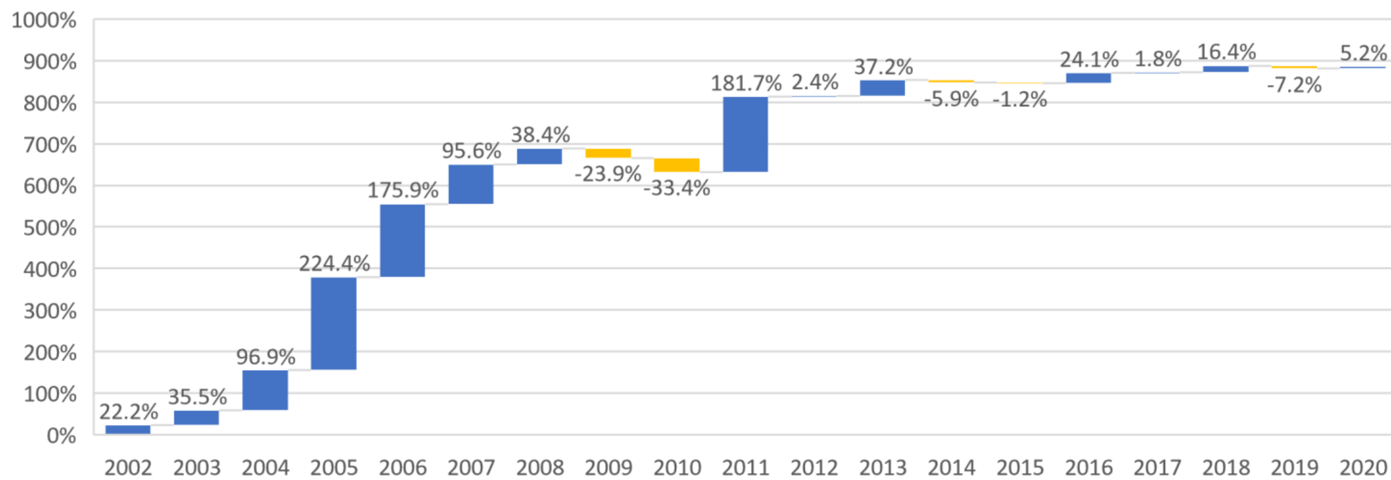
Source: Biodiesel Magazine

Investing in a New Biodiesel Plant

Does it make cents?

The early 2000s saw rapid growth in the biodiesel sector. These sharp increases correspond with periods of biofuel friendly government policy like the Energy Policy Act of 2005 and 2007. For example, 2005 saw a sector production increase of over 200%, shown in the chart below. To explore the economic efficiency of biodiesel versus diesel, this paper will calculate the NPV for each fuel over a 10-year period using different discount rates. Marginal revenue and average production capacity are used to calculate cash flows in our NPV model.

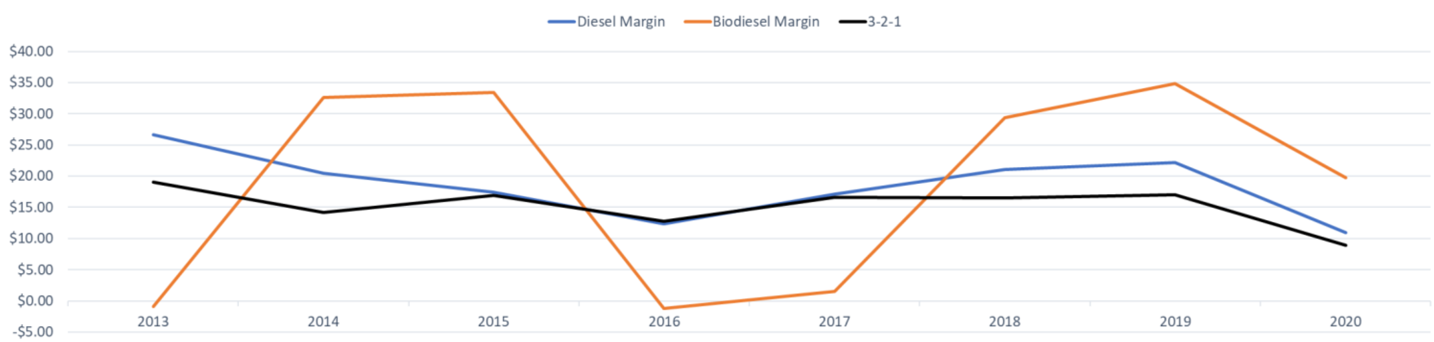
US Biodiesel Production (% Change YOY)



Source: EIA

The line chart below shows profit margin indicators for a diesel only, biodiesel, and an average oil refinery (shown by line 3-2-1) from 2006 to 2020. These margins only account for the cost of feedstock or crude, and do not include transportation costs or tax breaks.

Diesel vs Biodiesel Margin Indicators ($/bbl)



Source: EIA and AFDC

The Diesel Margin represents profit margins for a refinery that uses an entire barrel of crude to make diesel. This is a theoretical margin because in reality a refinery will produce a batch of products. The 3-2-1 method uses 3 barrels of crude to make 2 barrels of gasoline and one barrel of diesel. The latter method is much more common at refineries. Recently, all four profit margins have been relatively close to each other, with biodiesel dipping down because of rising soybean oil costs. As more competition entered the biofuel market, demand for soybean oil skyrocketed. Supply could not keep up with demand, so the prices for soybean oil rose. Economists from Wall Street Journal expect this trend to continue into 2022 (Macrotrends). However, this margin calculation does not include government incentives. Considering recent government policy, the profit margins for biodiesel are higher. Incentives were not included in any margin calculations because the tax breaks awarded to oil companies for gasoline and diesel are very difficult to track per gallon.

Investment for an average biofuel plant was estimated to be about $149 million. Harvard University estimates equipment to be about $67 million and other investment costs to be approximately $81 million (Lawrence). The average cost to start up a refinery is $5-15 billion, averaged to be $10 billion for this calculation (O'Chunks).

The last component of this formula is the discount rate. The net present value for energy projects should be calculated using a discount rate of 3%, 7%, and 10% according to Harvard University and Energy Education. For comparison purposes, the NPV was first calculated for a biofuel plant and oil refinery started in 2011 and running until 2021. The NPV was then divided by the initial investment. See the table below for the results of the NPV to investment ratios.

NPV to Investment Ratio For a Project Started in 2011 – 2021

Discount Rate	3%	7%	10%
Biodiesel NPV (2011-2021)	(1.20)	(1.96)	(2.53)
Diesel NPV (2011-2021)	30.79	24.35	20.72

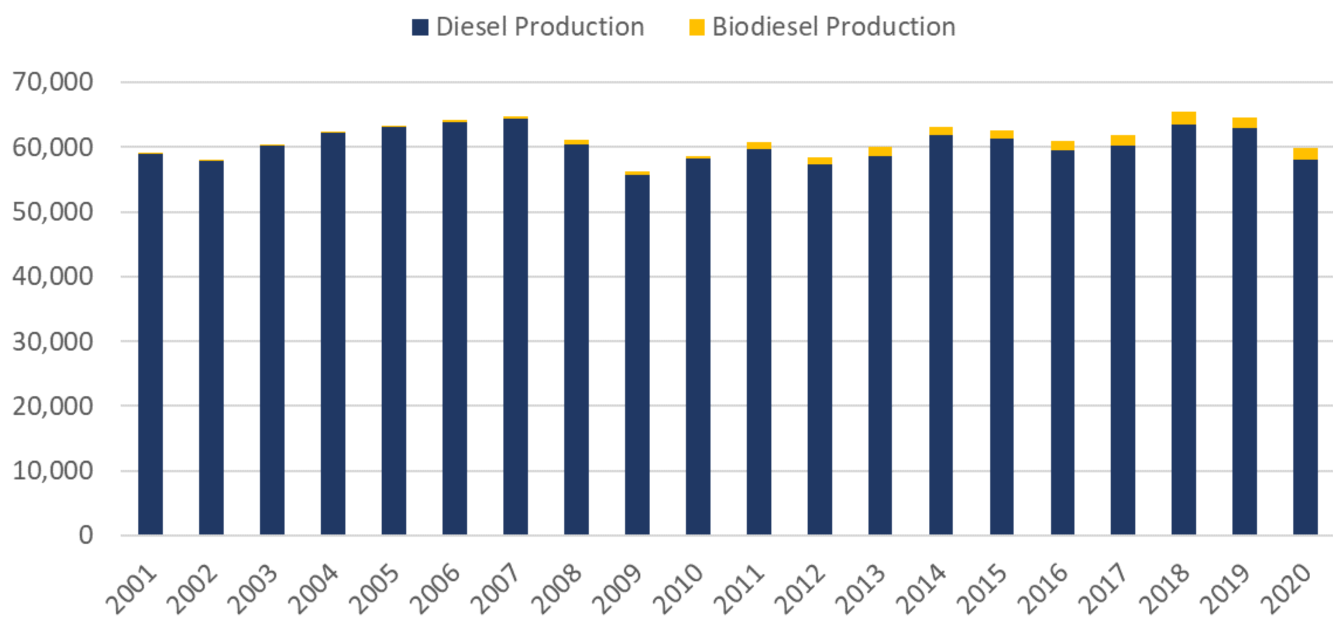
For the next calculation, future cash flows were estimated using an average of the known cash flows. This NPV starts at 2021 and goes until 2031 using the same investment amount and discount rates. The NPV to initial investment ratio for a refinery producing diesel decreases significantly but is still profitable. Whereas a biodiesel plant is unprofitable and seems to make no sense or "cents" without the benefits of the tax incentives and credits from various programs.

NPV to Investment Ratio For a Project Started in 2021 – 2031

Discount Rate	3%	7%	10%
Biodiesel NPV (2021-2031)	(17.31)	(16.14)	(15.33)
Diesel NPV (2021-2031)	1.29	0.84	0.59

Diesel from petroleum is obviously the most efficient fuel. Profit margins for biodiesel are much more volatile due to the sensitivity of prices for soybeans. Another aspect to keep in mind is economies of scale. Refineries have much more production capacity. Regardless, the share of biodiesel production is growing given government regulations. In 2020, the share of biodiesel in diesel production was about 3%, compared to in 2001 it was about 0.014%.

Share of Biodiesel Production (Millions of Gallons)



Source: EIA

Impact of Government Regulations

Now it makes cents!

President Biden's infrastructure and climate plan promotes clean energy. The infrastructure plan "would supercharge an already booming clean-power sector" (Goldfuss & Brill). According to Christy Goldfuss from the Washington Post, these tax credits supplemented by “improvements in existing regulations would cut toxic air pollutants like sulfur dioxide and nitrous oxide up to 84% and 62% in just five years.” Biden’s climate plan also plans to extend clean energy tax credits, including the Biodiesel Tax Credit, for the next 10 years. Under the U.S. Department of Agriculture’s Higher Blends Infrastructure Incentive Program (HBIIP), entities who invest in infrastructure to dispense “ethanol blends greater than 10% or biodiesel blends greater than 5%” are eligible for grants. This program was renewed August 19th and plans to invest $26 million into the biofuels industry (USDA). From the Alternative Fuels Data Center, successful HBIIP candidates may receive up to 50% of their total costs covered or $3 million if they are a new entity, and existing producers may apply for up to 25% of related project costs or $1,250,000 (ADFC). These benefits will make biofuel production cheaper for companies relative to petroleum.

Major oil and gas companies have followed suit and began investing in clean energy, as government incentives make investing in clean energy more profitable. For example, ExxonMobil has been researching algae biofuel, and “says it is on pace to make algae biofuel commercially viable by the end of the decade” (Matthews). Exxon’s interest in algae is due to a few reasons. Algae is “one of the most abundant organisms on earth” and absorbs carbon dioxide. It also does not take agricultural space to grow, so it will not be competing for land with food. Exxon plans to use this algae biodiesel to fuel jets and planes. Valero manufactures renewable diesel, which has a slightly different chemical structure than true biodiesel. Their Diamond Diesel is made of food waste, like inedible animal fats and used cooking oil. They take advantage of existing infrastructure, such as pipelines originally used for petroleum (Diamond Green Diesel). Additionally, Royal Dutch Shell has announced a new biofuel facility. They will manufacture “sustainable aviation fuel (SAF) and renewable diesel made from waste.” Phillips 66 is also investing in renewable diesel at their Rodeo refinery. Phillips 66 expects to be up and running by 2024 and expect to sell 1 billion gallons annually (Voegele). In summary, there is plenty of new production capacity for clean energy including biodiesel, and the market is expected to expand in the next few years.

Conclusion

There is major growth happening in the biofuel sector. This expansion is mostly through biodiesel. The share of ethanol and gasoline in the transportation market is decreasing, as electric power takes over smaller vehicles. Although diesel is more economically efficient, biodiesel is environmentally friendly. Considering worsening climate change, environmental impact has become a main concern for energy.

Many local and state governments already use biodiesel blends in school and transit buses, garbage trucks, snowplows, mail trucks, and military vehicles, but the biggest opportunity is the use of biodiesel and renewable biodiesel in aviation. In December 2021, a United Airlines flight from Chicago to Washington completed its trip with one of its two engines on the 737 Max using fuel made from used cooking oil and rendered waste fat from beef, pork, and chicken. United has announced a goal to eliminate greenhouse gas emissions by 2050, but in reaching that goal it will take huge government investments in the form of tax breaks and/or grants as well as technological advances in aviation, according to academics.

Without tax incentives, biofuel production is not economical. The models in this paper showed that the NPV for a refinery for two different time periods return profit values in the $ Billions, whereas the NPV for a biodiesel plant returned a negative value. These numbers highlight the need for government incentives in the biofuel industry. Aggressive government policies push oil and gas firms into the biofuel industry when they otherwise would have invested in petroleum assets. A monumental transfer to renewable energy is needed to slow the effects of climate change, and energy policy has made that shift possible.

The refining industry is currently penalized with higher costs from programs aimed at blending more biofuels and reducing GHG emissions. Under the EPA's RFS program, CARB's LCFS in California, and tax incentives, future biofuel production in the form of biodiesel will likely come from traditional petroleum refiners rather than agricultural companies. It makes sense and cents from a petroleum refiner's standpoint to invest in new capacity in the form of biofuels given these incentives.

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