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Growing renewable fuels market continues to shape U.S. soybean demand

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INTRODUCTION

Policy frameworks to support the decarbonization of the transportation sector are driving growth in renewable fuels markets, increasing demand for U.S. soybeans as a sustainable input to production. Between 2020 and 2024, renewable diesel production in the U.S. increased sixfold. Currently, about 12% of total U.S. soybean production is used to supply this growing market with soybean oil feedstock. As the renewable fuels market continues to develop and grow, led by California, new opportunities for U.S. farmland investors are emerging.

Renewable fuels are combustible liquids derived from grain starch, oilseeds, animal fats, or other biomass, capable of powering spark ignition machinery and substituting more carbon intensive fuels such as gasoline or diesel. In the U.S., the most common renewable fuels are ethanol and biomass-based diesel (biodiesel and renewable diesel). Supporting state and federal policy and incentive programs are designed to stimulate demand for renewable fuels and support emission reductions in the transportation sector where California is currently the market and policy leader.

In this paper, we examine policies that incentivize renewable fuel production in the U.S. and focus on the recent rise in renewable diesel production, which has grown from 533 million gallons in 2020 to a projected 3.2 billion in 2024. We analyze soybean oil's use as a renewable diesel feedstock and the additional demand that has created for soybeans and the agricultural land they are grown on. Although sustainable aviation fuel (SAF) is mentioned due to recent policy developments, production is not at scale and data is limited, thus, it is excluded from the soybean oil demand analysis.

POLICIES INCENTIVIZING PRODUCTION

Several policies in the U.S. mandate or incentivize the production of renewable fuels. The Renewable Fuel Standard (RFS), enacted in 2005 and expanded and extended in 2007, precipitated a rapid increase in ethanol and biodiesel production. While renewable diesel and SAF production is also stimulated by the RFS, additional federal and state-level policies have expanded their production further. Figure 1 below outlines the main policies currently influencing the production of renewable diesel and SAF in the U.S.

The incentives created by the various policies to reduce transportation and aviation fuels' emissions are what make the fuels economically viable given they are more costly to produce than their petroleum-based counterparts. Although the economics of the refining process will vary by plant and are not publicly available, looking at the cost of crude oil versus soybean oil illustrates this point. In 2024, the average spot price of WTI crude was $75.76 per barrel, or $1.80 per gallon, assuming 42 gallons per barrel. Over the same period, the average spot price for soybean oil on the Chicago Board of Trade was $0.44 per pound, or $3.42

Figure 1. Federal and state-level policies incentivizing renewable diesel and SAF production

Policy	Level	Description	Policy Goals
Low Carbon Fuel Standard (LCFS)	State (CA, OR, WA)[i]	Specifies a carbon intensity benchmark for transportation fuel that declines over time, determining how much fuels are implicitly taxed or subsidized. Lower carbon intensity fuels generate credits in proportion to the amount their emissions are below the benchmark. Higher emissions fuels generate deficits in proportion to the amount their emissions are above the benchmark. The credit price adjusts until higher carbon fuel use reduces and lower carbon fuel use increases and credits and deficits offset each other. Like the RFS, credits can be traded so market participants can offset a deficit balance with purchased credits.	• **California:** reduce carbon intensity of transportation fuel pool by at least 30% by 2030 • **Washington:** reduce carbon intensity of transportation fuel pool by 20% below 2027 baseline by 2034 • **Oregon:** 10% reduction in average carbon intensity of transportation fuels from 2015 levels by 2025, a 20% reduction by 2030, and 37% reduction by 2035.
Inflation Reduction Act (IRA)	Federal	Includes a variety of renewable fuel incentives, including the Biodiesel and Renewable Diesel Credit, Biodiesel Mixture Credit (expiring 2024), Alternative Fuel Credit, Alternative Fuel Mixture Credit, Section 40B SAF tax credit (expiring 2024), Section 45Z Clean Fuels Production Credit (starting in 2025 and ending in 2027).	Decrease the cost of production for renewable transportation fuels and SAF and increase domestic supply
Renewable Fuel Standard (RFS)	Federal	Requires petroleum-based fuel producers to supply or blend a certain volume of renewable fuel each year. Renewable Identification numbers (RINs) are associated with each gallon of renewable fuel produced to track compliance with the volume requirement. Entities with excess RINs can trade them so those who have not met the volume requirement can purchase them and become compliant.	Volume targets of 22.3 and 3.4 billion gallons of ethanol and biomass-based diesel in 2025, respectively.
SAF Grand Challenge[ii]	Federal	A memorandum of understanding between the U.S. Departments of Energy, Transportation and Agriculture to launch a government-wide initiative to reduce the cost of SAF and reduce its lifecycle greenhouse gas emissions 50% compared to conventional jet fuel, eventually supplying enough SAF to meet 100% of aviation fuel demand by 2050.	Produce 3 billion gallons of SAF per year by 2030 and 35 billion gallons per year by 2050.

i New Mexico adopted a Clean Fuel Standard in March 2024, and rule-making is planned to develop and finalize the details.

ii Memorandum of understanding as opposed to enacted policy

Source: National Renewable Energy Laboratory; U.S. Department of Energy Alternative Fuels Data Center; United States Environmental Protection Agency

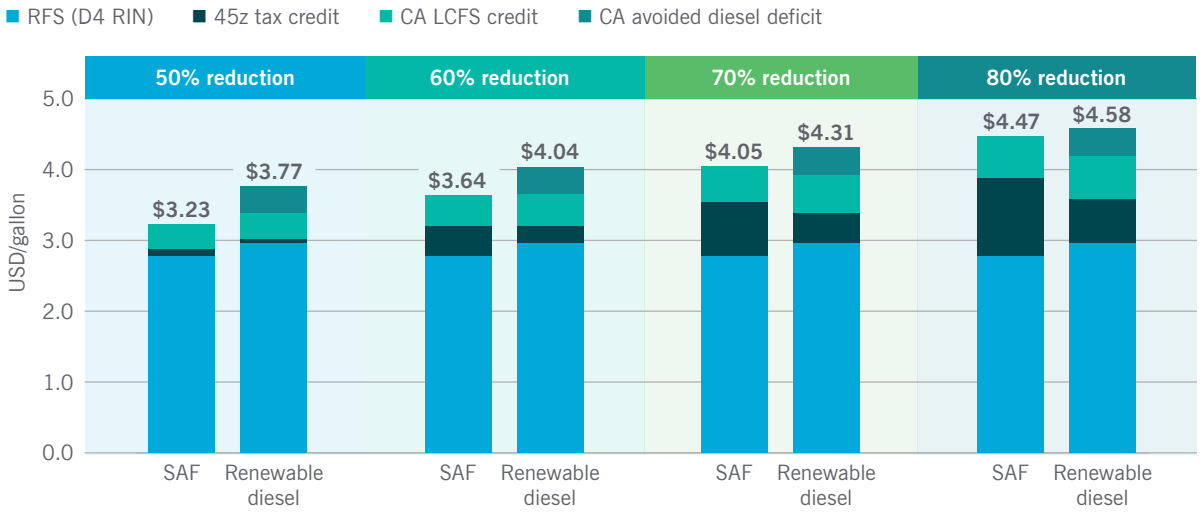
per gallon, using a conversion of 7.7 pounds of soybean oil per gallon. The nearly 90% increase in cost between crude and soybean oil clearly demonstrates why incentive programs are required to support the market.

Certain policies like LCFS differentiate incentives based on the carbon intensity of the fuel. For example, a gallon of renewable diesel produced wholly from soybean oil will have a higher carbon intensity than one from a waste or by-product like used cooking oil, thus commanding a lower credit price. Using estimated California LCFS and federal incentives expected from 2025–2027, Figure 2 demonstrates the sum of incentives for renewable diesel and SAF across a range of lifecycle greenhouse gas (GHG) emissions reductions relative to petroleum-based fuel.

As detailed in Figure 2, the incentives for renewable diesel or SAF production come in the form of tax credits, such as 45z, or tradable compliance credits derived from programs like RFS and LCFS. Tradable credits are subject to price fluctuations based on supply and demand in their respective compliance markets, so the total incentive amount will change over time. Nevertheless, RFS and LCFS either explicitly or implicitly mandate the use of renewable fuel, creating a demand floor in both the California and national market. Figure 2 shows the stack of incentives is currently higher for renewable diesel produced in California, mainly due to the extra $0.39 offered by California's Cap and Trade program which adds costs to petroleum diesel but not to petroleum jet fuel. Because renewable diesel costs roughly the same as petroleum diesel in the retail market, adding the Cap-and-Trade costs to petroleum diesel implicitly increases the value of renewable diesel.

Biofuels and other alternative fuel sources have garnered strong support over the last four years at the federal level as various policies were rolled out to decarbonize the transportation sector. The transition of presidential administrations and new Republican majority in congress following the November 2024 elections highlights the political risk associated with federal renewable fuels policy in the U.S. The new administration's trade policy could also influence the production of renewable diesel with tariffs on imported feedstocks which would impact their use in domestically refined renewable diesel and SAF. The impact would vary depending on the supply chain segment, potentially increasing demand for U.S. farm products like soybeans for oil but increasing costs for refiners.

Figure 2: Estimated federal and California state-level incentives by % emission reduction for renewable diesel and SAF production for 2025–2027



Source: National Renewable Energy Laboratory.

Although it is too early to tell what will happen to the RFS, IRA, or trade policy with the recent change of administration, it is clear that the shift at the federal level could reduce the total incentive to produce renewable diesel or SAF in the short term. Despite the short-term potential policy changes, Nuveen Natural Capital (NNC) believes the long-term demand for renewable fuels is promising, as the continuance of state-level policies like LCFS will maintain growth and over time federal policies will tend towards decarbonizing the broader economy, further increasing demand for renewable fuels.

INDUSTRY ALIGNMENT AND DEVELOPMENT OF PROCESSING CAPACITY

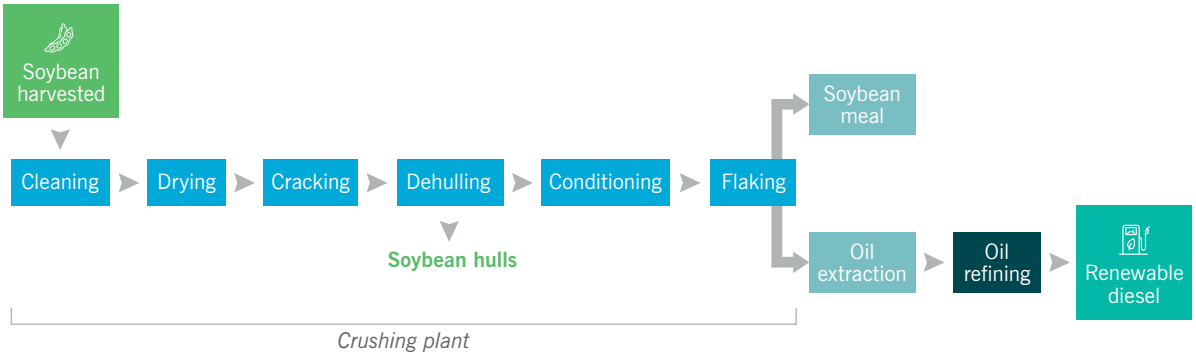
As demand for renewable diesel has grown in the U.S., demand for soybean oil as a feedstock has increased. As a result, investment in soybean crushing facilities and refineries has also increased. With the recent rise in renewable diesel consumption and investments in related infrastructure, a recurring question around biofuels has surfaced from investors and the general public: will growing demand for renewable diesel materially impact food supplies?

The question is best answered by understanding the process of soybean crushing and refining as detailed in Figure 3. Soybean hulls, meal and oil are separated during the process for an efficient use of the oilseed that results in both animal feed (hulls and meal) and oil. While soybean oil is used in foodstuffs and other industrial applications, its use in those areas has been relatively flat, increasing 2.1% from 13.9 million pounds in marketing year 2013/2014 to an estimated 14.2 million pounds in 2023/2024, according to the USDA. The more pressing question is how the extra soybean meal for animal feed will be utilized or exported, which the industry is still figuring out.

In light of the various incentives to increase the production of renewable fuels, industry participants have made significant capital investments to supply feedstock in the form of vegetable oils or refine it into renewable diesel or SAF. Two segments of the supply chain serve as indicators of this buildout: soybean crushing and refineries. Further, some crush facilities that have or are scheduled to come online are joint ventures between oilseed handlers and the refineries that need their oil to make renewable diesel. Figure 4 shows the locations and capacities of crush plants and refineries in the U.S. Most crush plants are located in the Midwest alongside intensive soybean production, while renewable diesel refineries are more dispersed and located closer to the source of demand for renewable diesel.

As a result of the buildout of soybean crush capacity, U.S. soybean crushing set a new monthly record in October 2024, processing nearly 200 million bushels and surpassing the previous

Figure 3. Soybean crushing and oil refining process for renewable diesel

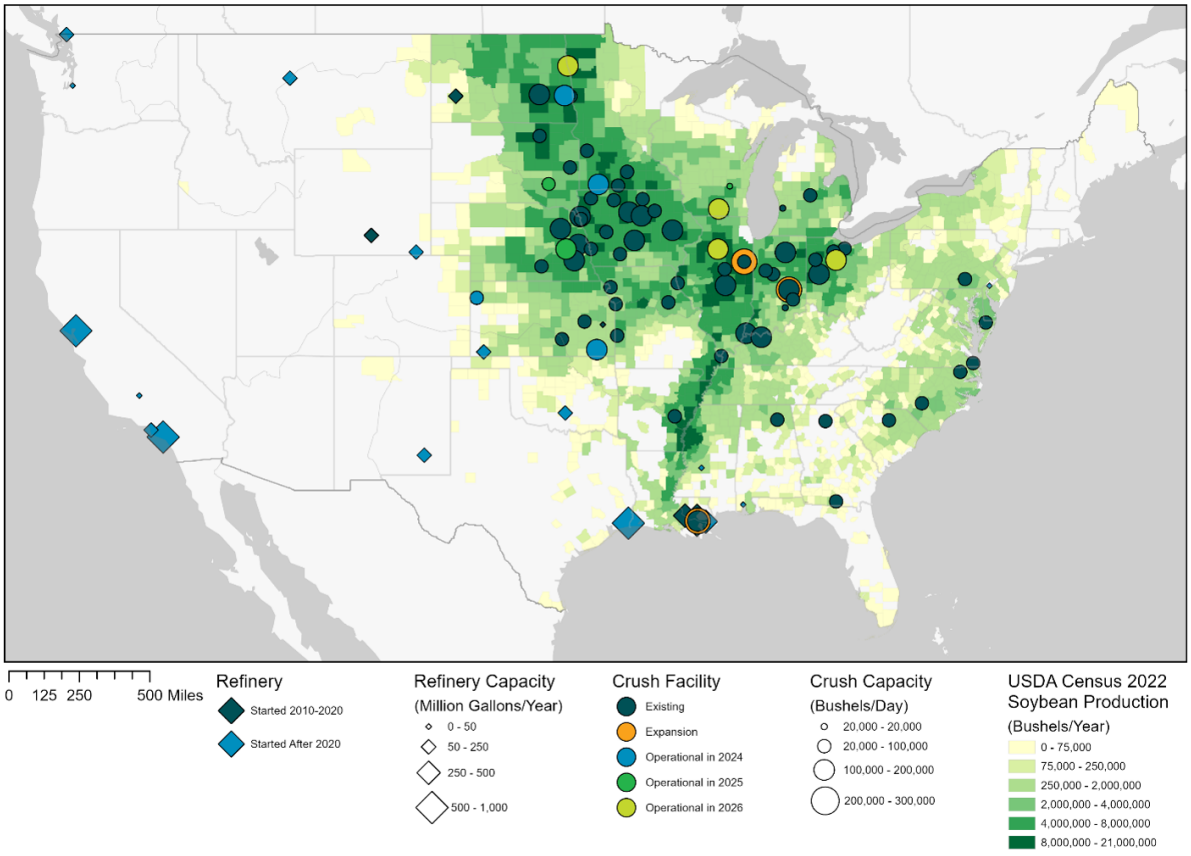


Source: NNC research.

record of 196 million bushels from March 2024, according to the National Oilseed Processors Association (NOPA). Likewise, NOPA soybean oil stocks were 1.1 billion pounds at the end of October, 27% below the five-year average for the same month due in part to the increasing use of soybean oil for renewable diesel. A report by CoBank in March 2024 pointed towards a 23% increase in crushing capacity over 2024–2026, increasing from approximately 2.25 billion bushels in 2023 to 2.75 by 2026. However, the same report details a reversion to average crush margins that has occurred in 2024, putting into question the viability of new plants that were built with a high cost of materials and labor. The extended high-rate environment may also impact any projects with debt financing.

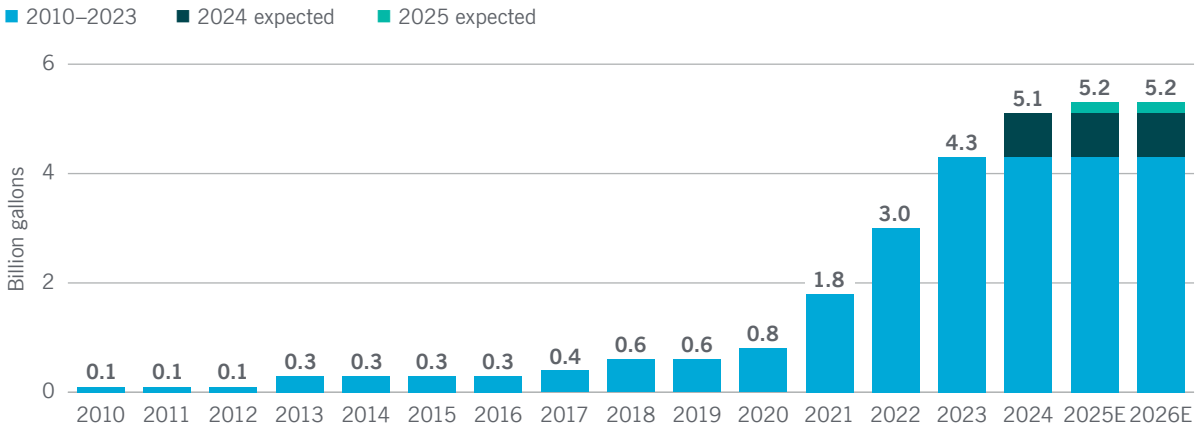
The proliferation of refinery capacity to produce renewable diesel is well documented. A previous paper published by Nuveen in 2021 estimated that capacity would reach 1.9 billion gallons per year by 2024 based on projects that had definitive start dates at the time. Due in part to the conversion of large existing refineries, the actual figure is 4.3 billion gallons as of January 1, 2024, according to the U.S. Energy Information Agency (EIA) and seen in Figure 5, representing a 14-fold increase over the past ten years. Looking ahead, there is another 0.9 billion gallons of capacity slated to come online in the next two years, underscoring the investments being made to supply renewable diesel and SAF. Still, production is expected to be approximately 3.2 billion gallons in 2024, a 1.1-billion-gallon difference between reported capacity and utilization.

Figure 4. U.S. soybean production, crush facilities and renewable diesel refineries[i]



[i] Crush facilities without publicly available capacity information are estimated.
Source: USDA; EIA; NOPA; company announcements; NNC research.

Figure 5. U.S. renewable diesel refining capacity



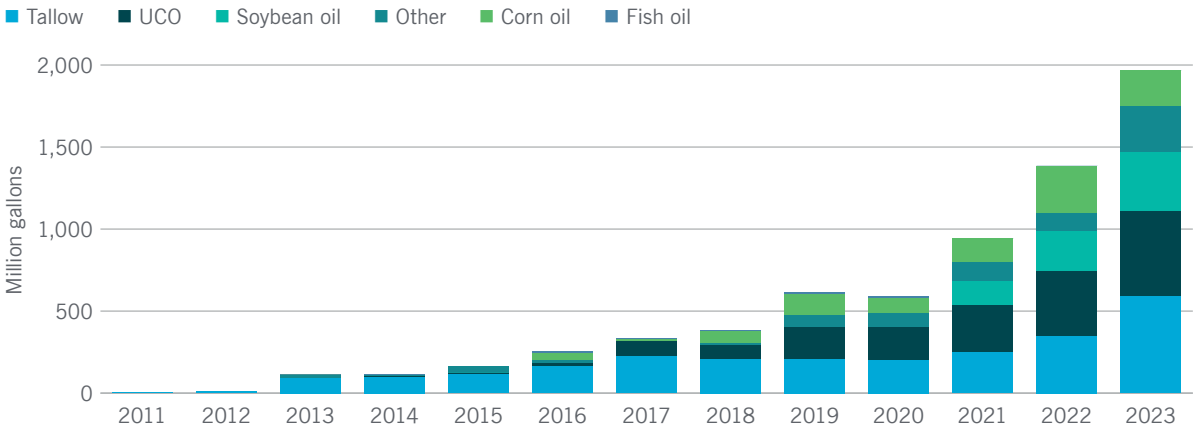
Source: EIA and industry sources per Farmdoc Daily, November 6, 2024.

SOYBEAN DEMAND FOR RENEWABLE DIESEL

In many cases, renewable diesel is produced from a mix of soybean oil and other low carbon inputs to production. Given the incentive schemes like LCFS where credit values increase based on the reduction in carbon intensity relative to petroleum-based fuels, many producers seek to use or blend feedstock with a lower carbon intensity than soybean oil, such as used cooking oil (UCO) to increase their output's value. Figure 6 demonstrates recycled or by-product feedstocks like UCO, tallow and distiller's corn oil constitute the majority of feedstock used to produce renewable diesel sold in California. Still, 365.3 million gallons of soybean oil were used in 2023 to produce that renewable diesel, or 18.6% of the feedstock mix. Furthermore, soybean oil used in the feedstock mix grew 144% from 2021 to 2023, from 149.7 million gallons in 2021 to 365.3 million gallons in 2023. In terms of total U.S. soybean oil supply, this usage grew from 4.0% of the total supply in 2021 to 9.6% in 2023.

At a national level, the EIA began reporting feedstock use for renewable diesel plants in March

Figure 6. Feedstocks used to produce renewable diesel consumed in California, 2011–2023



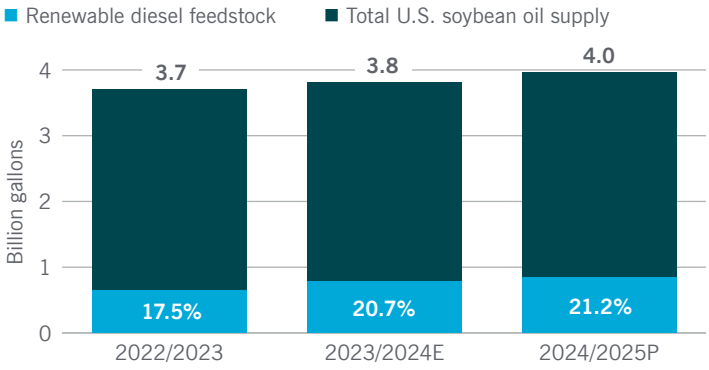
Source: California Air Resources Board.

2023, making the full 12 months' of data available for 2022 and providing monthly use thereafter in their Monthly Biofuels Capacity and Feedstocks Update. Referencing that data, and assuming 7.7 pounds of soybean oil per gallon, 0.65 billion gallons of soybean oil was used to make renewable diesel in the U.S. during the 2022/2023 soybean marketing year, which runs from September through August. Feedstock use then grew 21% to 0.79 billion gallons in 2023/2024 as refinery capacity expanded. Although use is not expected to grow as dramatically in 2024/2025, it could reach 0.84 billion gallons, assuming renewable diesel maintains its 46% share of soybean oil for biofuel use from the prior year.

Figure 7a demonstrates the use of soybean oil as renewable diesel feedstock relative to the total supply in the U.S, which includes beginning stocks, imports and production. For an industry producing less than 500 million gallons of renewable diesel and using little to no soybean oil prior to 2020, the increase in share of total supply to over 20% in five years is significant. Soybean oil imports to the U.S. have increased, moving from 39 million gallons in marketing year 2021/2022 to a projected 65 million gallons in 2024/2025. Although it is unclear if imported soybean oil was used for renewable diesel feedstock based on available data, the shift in demand that necessitated an increase in imports is clear. With the continued buildout of domestic crush capacity, the increase in soybean oil imports could be transitory with a reversion to historic levels in the medium term.

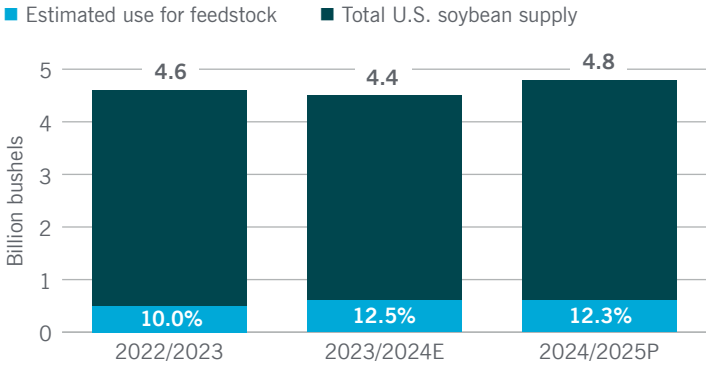
To understand what the use of soybean oil as a feedstock for renewable diesel means in terms of soybeans needed for crushing and extracting oil, a conversion of 1.42 gallons of oil per bushel is used. In 2022/2023, the amount of soybeans needed to supply 0.65 billion gallons of oil was 0.46 billion bushels, or 10% of total U.S. supply. Assuming 0.84 billion gallons are used as feedstock in 2024/2025, 0.59 billion bushels are required. Figure 7b shows the implied soybean use for soybean oil as renewable diesel feedstock over the past three years. Again, from the industry's relatively nascent state in 2020 to requiring over 12% of total U.S. supply in 2024/2025 is notable.

Figure 7a. Proportion of U.S. soybean oil supply used for renewable diesel feedstock, 2022–2025P



Source: EIA; USDA; NNC Research.

Figure 7b. Estimated use of soybeans for renewable diesel feedstock, 2022–2024F



Source: EIA; USDA; NNC Research.

Nuveen's paper on renewable diesel in 2021 estimated 725 million bushels of soybeans would be needed to supply soybean oil feedstock by 2023/2024.[1] The larger estimated use of soybeans was due to the assumption that soybean oil would supply 65% of the feedstock for 1.9 billion gallons of refining capacity estimated to be online by 2024. At the time, EIA published soybean oil use for biofuels in aggregate and did not distinguish its use between biodiesel and renewable diesel, with biodiesel making up the majority of production and soybean oil as the bulk of feedstock, and that data was used as the basis for the assumption. While both refining capacity and production of renewable diesel has exceeded the previous estimates,

soybean oil's feedstock share is roughly 25% of total production using EIA's 2024 projections, resulting in a 170-million-bushel difference compared to our previous analysis.

IMPLICATIONS FOR FARMLAND

An estimated 10.7 million acres of U.S. soybeans were required to produce the 555 million soybean bushels used to produce renewable diesel in 2023/2024 (using the average yield of 52 bushels per acre expected by USDA in 2024). This area represents 12% of the estimated 86.3 million soybean acres to be harvested in 2024 — a demand for cropland that was nonexistent prior to the buildout of refining capacity in 2021.

The expansion of crush facilities in areas of high soybean production like the Midwest will create increased competition for soybeans at a local level. This could result in higher basis – the difference between prices offered locally and the Chicago Mercantile Exchange quote – to attract supply, especially for plants located near each other or that compete with export facilities already offering higher prices. Although crop price is just one part of the profitability equation for farmers, any increase can be meaningful, especially when crop production reverts to a lower-margin environment.

An additional consideration is the stronger domestic market for soybeans created by the demand for renewable diesel. Since 2020, U.S. soybean exports have been on a downtrend, decreasing from 63.7 million metric tons to 48.2 in 2023, due in part to higher domestic demand for soybeans. The more robust domestic market helps to offset potential impacts from a second trade dispute with China, which was not the case in 2018. Although an increase in all sources of domestic and international demand presents the best pricing outcome for soybean farmers, the U.S. market is more resilient than it was prior to the renewable diesel boom. Conversely, Brazilian producers have largely filled the void created by waning U.S. exports, particularly to China, and benefitted from that additional demand. For investors in farmland, this dynamic is just one example in the case for a globally diversified portfolio.

The need to reduce the carbon intensity of feedstock for renewable fuels could have an impact on how crops like soybeans are produced. The most recent policy proposal to achieve this is the Section 45z Clean Fuels Production Credit. The tax credit requires renewable fuel producers to verify their agricultural feedstock was produced with "climate-smart" practices like cover crops and reduced tillage. While the credit would ultimately be claimed by the fuel producer, it is envisioned that a price premium would flow to farmers verifying their sustainable practices and selling their production for renewable fuel feedstock. In its current form, most farm and renewable fuels industry groups view the IRS guidance as unclear and insufficient for a large-scale transformation of production practices, but a step in the right direction. As with other policies incentivizing renewable fuels production, it will need to be reliable and create certainty for sustained investment to scale sustainable agricultural practices and lower the carbon intensity of production.

WHAT DOES THIS MEAN FOR FARMLAND INVESTORS?

A meaningful and growing component of the U.S. soybean and soybean oil market is used to produce renewable diesel. As a result of the growing demand for soybean oil, industry players have made investments in additional crush capacity to supply expanding refinery capacity with feedstock. At a local level, new or expanded soybean crushing capacity increases competition for soybeans, potentially strengthening local prices and producer economics.

While there has been significant demand growth for soybean oil for renewable diesel in the past five years, there is longer-term potential for further upside from industries that are difficult to decarbonize like aviation (SAF) and maritime shipping. Additionally, policies like Canada's Clean Fuel Regulations present additional demand on the global oilseed market. Domestically, more states could follow California, Oregon and Washington and enact LCFS, further increasing demand for oilseed feedstock. In short, these additional sources of demand have the potential to increase

the profitability of producing soybeans, in turn increasing the use value of the farmland they are grown on.

Policy risk exists, however, especially at the federal level, exemplified by recent legislation targeting feedstock use specifically. The bipartisan Farmer First Fuel Incentives Act was introduced in congress in September 2024 to restrict the 45z tax credit to fuel produced with domestic feedstock and extend it until 2034. In contrast, state-level LCFS could increase requirements for carbon intensity reduction of renewable fuels and lower the demand for agricultural feedstocks, as happened in California in November 2024. These specific policy examples are in addition to changing U.S. presidential administrations and congressional control, which has an effect on policy and its execution.

As the transportation sector and whole economies decarbonize, there are opportunities for the agricultural sector to contribute to climate solutions. The expanded production of renewable diesel and increased demand for sustainably produced soybeans is just one example of this. Solar and wind power development, bioplastics and other bio-based products, and the further expansion of renewable fuel use on top of food and fiber production will place additional demand on cropland globally. Understanding the interaction between competition for renewable energy development, renewable fuel feedstock and food and fiber production will help investors position their natural capital portfolios accordingly.

For more information, please visit our website, nuveen.com/naturalcapital.

Endnotes

Sources

1 Are U.S. low carbon fuel standards driving a structural change in oilseed demand that could support farmland returns?, Nuveen Natural Capital, October 2021

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