Biofuels are becoming a mainstay around the world.

Analysts believe competition for vegetable oils between food and fuel manufacturers will only increase since feedstock supplies like used cooking oil and tallow are fixed.

Are non-edible oilseed cover crops likely to provide the next major feedstock?

In 1912, the inventor of the diesel engine, Rudolf Diesel predicted that someday our dependence on petroleum fuels would abate as their supply diminished, creating a market for new fuels sourced from animals and vegetables. That time has arrived.

Emissions from the internal combustion engine contribute to the concentration of carbon dioxide in the atmosphere. Scientists have proven that as the amount of these gases go up they cause a greenhouse effect over the planet, raising its temperature and leading to climate change. To reverse this effect, governments around the world have agreed to reduce their carbon emissions with an eventual net-zero goal (https://unfccc.int/).

The transportation sector, in particular, has been the focus of efforts to lower emissions. More auto manufacturers are adjusting their product line to include electric vehicles, but that will not eliminate the need for cleaner burning fuels. Farm equipment and other heavy machinery are difficult to power with batteries. The same is true for airplanes, which produce a significant amount of carbon. Of the total greenhouse gas emissions produced by the United States, for example, about 3 to 4% comes from aviation (https://tinyurl.com/2p875et6).

Reducing emissions may be a global concern, but the United States confronts unique challenges compared to the rest of the world. “In Europe, they just do not drive as much,” says Bryan Yeh, president and CEO of American Biodiesel Community Fuels based in Walnut Creek, California, USA. Thus, US regulators are pushing harder on fuel refiners to incorporate lower emissions biofuels.

In December 2021, the US Environmental Protection Agency (EPA) proposed a 20% volume increase over 2020 values for its Renewable Fuel Standard program. In the months since, during the allotted comment period before the proposal takes effect, some food manufacturers testified in congressional hearings that the increase would induce market turmoil.

The outcry from food producers once again puts a spotlight on the Achilles’ heel of biofuels: the need for an exclusive, reliable feedstock. How far have producers come in their efforts to find alternatives and are they truly more environmentally friendly?

IMPORTANT DISTINCTIONS
The term “biofuel” covers a wide range of products, including fuel ethanol, biodiesel, renewable diesel, renewable heating oil, and sustainable aviation fuel (SFA).
Compared to their petroleum-based counterparts, all these fuels emit less carbon dioxide when used to produce energy, but they are chemically distinct.

Biodiesel is made through a transesterification reaction which produces glycerin and fatty acid methyl esters. Triglycerides from soybean oil, palm oil, or beef tallow form the methyl ester biodiesel when reacted with methanol in the presence of a catalyst, such as sodium methoxide.

The resulting fuel is an oxygen-containing compound with properties that do not exactly match those of petroleum diesel (https://www.biodiesel.org/). In addition, some feedstocks can form waxy coatings that plug fuel filters in cold weather. Using the right feedstocks help eliminate these problems. In some cases, triglycerides are typically preprocessed to remove any free fatty acids.

Biodiesel is currently produced to specifications set by ASTM International, a standards organization. As a result, says Yeh, “past concerns about its use with new diesel engines are no longer valid.” However, due to its oxygen content, biodiesel has higher NOₓ emissions (Table 1) than other biofuels (https://doi.org/10.1007/978-1-4419-7145-6_15).

Renewable diesel and SFA, on the other hand, does not contain oxygen. They are hydrocarbon products formed when triglyceride molecules (from feedstocks similar to those mentioned above) react with hydrogen over a metal catalyst. In 2007, the Finish company Neste was the first to produce renewable diesel (also known as Hydrotreated Vegetable Oil or HVO), and it is now the world’s largest producer. The company currently has production sites in Finland, Singapore, and The Netherlands (https://www.neste.us/). They distribute renewable diesel to various locations on the West Coast of North America, and the company says it plans to expand its headquarters in Houston, Texas, USA, to better accommodate these markets.

Table 1. A list comparing the percentage emissions reduction of biodiesel. B20 indicates a fuel with an 80/20 ratio of petroleum to biodiesel and B100 indicates pure biodiesel. Note, biodiesel causes a NOx increase.

<table>
<thead>
<tr>
<th>Emission</th>
<th>B20 (% reduction)</th>
<th>B100 (% reduction)</th>
</tr>
</thead>
<tbody>
<tr>
<td>carbon monoxide</td>
<td>12.6</td>
<td>43.2</td>
</tr>
<tr>
<td>hydrocarbons</td>
<td>11.0</td>
<td>56.3</td>
</tr>
<tr>
<td>particulates</td>
<td>18.0</td>
<td>55.4</td>
</tr>
<tr>
<td>air toxics</td>
<td>12-20</td>
<td>60-90</td>
</tr>
<tr>
<td>mutagenicity</td>
<td>20</td>
<td>80-90</td>
</tr>
<tr>
<td>nitrogen oxides</td>
<td>+1.2</td>
<td>+5.8</td>
</tr>
</tbody>
</table>

Neste did not remain the sole provider of renewable diesel for long. In the United States, companies that built refineries to process crude petroleum decades ago during the oil boom have recently repurposed their plants to produce the
fuel. According to the production capacity reported by the companies that operate these plants, US renewable diesel production will increase by an order of magnitude in just a few years, from 0.5 billion to 5 billion gallons (https://www.npr.org/transcripts/1043413986).

Although former petroleum refineries are being converted for biofuel production world-wide, economics is driving US companies to make the switch, especially on the West Coast. “California is currently the only state that has The Low Carbon Fuel Standard program that incentives the selling of these products,” says Yeh.

For nearly 20 years, California governors have legislated for the use of cleaner fuels. Most recently, the regulatory goal is to eliminate petroleum diesel emissions by 2030. According to Yeh, that will require 4 billion gallons of diesel equivalent biofuels yearly, for the state of California alone.

With increases in production mandated by the state of California and the US government, food manufacturers say they cannot buy soy and vegetable oils because supplies have gone to transportation. They testified to the US Congress that soybean oil prices more than quadrupled in the last quarter of 2021 due to increased demand by biofuel refineries (https://tinyurl.com/yckzfs8w).

Using 2020 data available from the US Energy Information Administration, Yeh calculated that soybean oil represents over 60% of biodiesel feedstock. And NPR reported that before the recent shift to biodiesel feedstock, a third of US-produced soybean oil was already dedicated to the product. Jeremy Martin, a member of the Union of Concerned Scientists, told NPR he is concerned land where higher carbon capture crops are currently grown will be turned over to soybeans to meet the escalating oil demands.

Yeh says, that is not likely for refineries selling biofuels to California, since they would be leaving money on the table. The state offers credits based on a biofuel’s feedstock since greenhouse gas emissions can worsen or improve depending on the source.

**FINDING LOW CARBON INTENSITY FEEDSTOCKS**

Theoretical calculations for indirect land-use changes, or ILUC, first appeared in a paper published in 2008, by Princeton University researchers (https://doi.org/10.1126/science.1151861). Since then, ILUC has been extensively debated. Its intention is to measure the net change in greenhouse gas emissions when natural land, like rainforests and grasslands, which sequester carbon, are cleared and converted into crop-lands for biofuels. Despite its initial controversy, ILUC impact is now incorporated into renewable fuel standards in the United States (particularly in California), the United Kingdom, and the European Union.

“In the state of California, biofuel producers earn credits proportional to the carbon intensity of the feedstock used,” says Yeh. “The carbon intensity of soybean oil is almost half of petroleum diesel, but used cooking oil is a quarter.” When the credits for carbon intensity are applied, California producers receive $0.90 more per gallon for used cooking oil feedstock (Table 2). Therefore, there should be less incentive to use soybean oil. Incidentally, the United States Department of Agriculture (USDA) agrees with Yeh, projecting that the demand for soybean oil will remain steady in 2022 (https://tinyurl.com/bdekz5hz).

Market analysts differ with this opinion based on the fact that there is a limited amount of low-carbon feedstocks. Yeh acknowledges that West Coast ports have the benefit of easier access to shipments of used cooking oil from Asian markets. In general, lower carbon feedstocks are less accessible in land-locked areas where soybean is already being grown.

Analysts also point to the recent partnership between refineries and crushers as an indicator that soybean oil will continue to be a major feedstock. In December of 2021, ADM announced a joint venture with Marathon Petroleum Corp. that will own and operate a soybean processing plant to be built in North Dakota. The plant will exclusively supply oil to the refinery for renewable diesel fuel production (https://tinyurl.com/mr4253ay). Cargill announced a similar partnership with Paseo Biofuels earlier in the year (https://tinyurl.com/yck9c8s5).

If analysts and bakers are correct about a potential unfulfilled demand for soybean oil, biofuel refineries may have to secure other feedstocks. The market is providing a prime opportunity for a new source of triglycerides.


<table>
<thead>
<tr>
<th>Carbon Intensity (gCO\textsubscript{2}emission/MJ)</th>
<th>Petroleum Diesel</th>
<th>Biodiesel Soy</th>
<th>Biodiesel UCO</th>
<th>Biodiesel Tallow</th>
<th>SAF/Renewable Diesel Tallow</th>
</tr>
</thead>
<tbody>
<tr>
<td>102</td>
<td>57.16</td>
<td>21.27</td>
<td>32.45</td>
<td>19.51</td>
<td>19.51</td>
</tr>
<tr>
<td>LCF\textsubscript{S} Credit ($/gal)</td>
<td>--</td>
<td>$0.90</td>
<td>$1.80</td>
<td>$1.52</td>
<td>$1.84</td>
</tr>
</tbody>
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**A NEW CROP OF FEEDSTOCKS**

For over a decade the USDA has supported research projects across the country aimed at identifying high-yield oilseed crops that could be used to make biofuels. According to news reports, the investment is nearly ready to pay off.

“We know so much more about cover crops than we did five or six years ago,” says Sheeja George, research proj-
George, carinata is in the process of undergoing US EPA certification, these crops are planted in the off-season when fields are typically idle which means their ILUC is neutral. According to George, carinata is in the process of undergoing US EPA certification to confirm this claim (among others) in preparation for making it eligible for sale in California.

Last May, an EPA representative told the news agency Reuters that camelina has already received approval (https://tinyurl.com/2s3r4ufz). Canadian seed developers report that popularity of the crop is growing. One producer says camelina oil tripled the company’s sales in 2020.

At the same time, carinata was catching on in South America. In 2020, an Australian agrichemical company sold carinata (brand named Nuseed) to farmers in Argentina for commercial use. In the year since, all the oil produced from Nuseed has been sold to Saipol, a biodiesel producer in Grand-Couronne, France.

And Bayer AG and Bunge have invested millions in funding to develop a gene-edited variety of covercress customized for maximum oil and meal production, along with cold weather hardiness. The start-up the companies are supporting, CoverCress, based in St. Louis, Missouri, USA, has ambitions to plant 3 million acres of the new oilseed by 2030.

When asked what stands in the way of cover crops edging into the biofuel feedstock market, George says: production. Right now, there are not enough farmers planting these oilseed crops. She says there are a few reasons why.

The first is the US government’s policy on agricultural insurance. According to George, a farmer can only claim insurance on a single crop per year. As the policy stands, farmers would have to assume the risk of planting a cover crop should it fail.

The next, possibly greater hurdle is tradition. “In the Southeast, particularly, farmers do not want to risk anything affecting their traditional crops which are cotton and peanuts,” says George. A delayed harvest from a winter cover crop could negatively impact the start of planting preparations for their primary crops. “It will take early adopters to spread, by word of mouth, that they increased their soil health and their yearly revenue by planting cash-cover crops, like carinata,” she says.

Finally, the cover crop means more work for the farmers. In the past, says George, after a fall harvest, farmers would spray down weeds and then take a break for a few months before preparing their summer crop. She says more farmers are shifting to the year-round farming necessary to maintain a cover crop, but the culture change will be slow until there is proof of a decent financial benefit for the extra effort.

Until carinata production increases, crushers may not be convinced to accommodate the crop in their facility to produce the oil needed for biofuels. Between processing an edible and non-edible oil the equipment must be thoroughly cleaned. High enough production could prompt processors to build new crush facilities and eventually establish a local supply chain.

New feedstocks cannot come too soon. In the US, emissions are back on the rise. Pandemic lockdowns in 2020 resulted in a 10% drop, but in 2021 they rebounded 6.2%. They are now just 17.4% below 2005 levels, well short of the 50% decrease the country hopes to achieve before 2030 (https://tinyurl.com/38ywxxmj).

Yeh says, although some US automakers are rethinking their engine designs, most of the car manufactures in Europe and China are making a greater commitment to electrification. Demand might not grow as fast in these regions. In the next five years current feedstock challenges are likely to peak, particularly in the Americas.

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