Researchers seek to expand supplies of clean aviation fuels by producing more from agricultural sources

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Professor David Chiaramonti is looking down at the ground to help resolve a problem up in the sky: airplanes' emissions of carbon dioxide

(CO_2) and other pollutants.

An expert in energy systems and power generation at the Polytechnic University of Turin in Italy, Chiaramonti wants land that is unused, marginal and degraded to produce clean fuels for jets.

Oil-rich plants

The fuels would come from oilseed plants such as Camelina sativa—native to Europe and central Asia—and replace kerosene, a fossil fuel that traditionally powers aircraft. Kerosene worsens climate change by releasing CO_2 and nitrogen oxides into the atmosphere.

Chiaramonti led a research project that aimed to increase supplies of the only type of sustainable aviation fuel currently available: hydroprocessed esters and fatty acids, known collectively as HEFA. Called BIO4A, the project wrapped up in mid-2023 after five years.

HEFA is a biofuel made mainly from used cooking oil and animal fat left over in meat production—sources that at best can meet 2% of aviation's fuel needs. Chiaramonti believes camelina, which is also known as false flax and grows in countries including Italy and Spain, can help overcome this bottleneck without impinging on crops grown for food.

"We focused on very poor soils—on land that is very dry and arid and lost to food production, but which could be recovered," he said.

As a result, camelina offers the prospect of increasing overall HEFA quantities and of addressing soil degradation, which plagues many countries especially in the Mediterranean region as a result of climate change and intensive agriculture.

"The biggest problem in sustainable aviation fuels today is sourcing sustainable lipids," said Chiaramonti, who is also president of an Italian renewable-energy research organization called RE-CORD. "We investigated how to produce sustainable lipids in marginal, degraded land."

Sky-high emissions

The global aviation industry's emissions of CO_2 have risen faster in recent decades than those of the road, rail and shipping sectors. Aviation now accounts for 2%–3% of global CO_2 discharges.

What's more, unlike with road and rail transport, electricity has yet to emerge as an option for aviation in general because battery technologies can currently power only light aircraft such as drones.

That intensifies the spotlight on sustainable aviation fuels, also known as SAF.

In October 2023, the EU's national governments approved legislation that will require suppliers of aviation fuels in Europe to ensure a SAF market share of at least 2% in 2025, 6% in 2030 and 70% in 2050.

The law is part of a major package of European legislation that underpins an EU goal to slash greenhouse-gas emissions by 55% in 2030 compared with 1990 levels. The 55% reduction target is more ambitious than a previous EU plan to cut emissions by 40% over that period.

Traditional success

HEFA has a similar chemical structure to fossil fuels, easing the task of making it fit for jet engines.

Even as they tested unused land to make HEFA from camelina, the BIO4A researchers advanced traditional production methods.

The project used a refinery that makes HEFA from waste cooking oil and animal fat left over from meat production at a full industrial scale.

This focus explains the participation in the project of two major European oil companies: Total in France and Italy-based Eni.

"We produced 1,000 [metric] tons of HEFA from residual oil, which so far was the largest volume ever produced industrially in Europe in the framework of the EU's research program," Chiaramonti said.

Crop rotation

Back on the unused land, the team was keen to show that producing HEFA from plants like camelina can be done while supporting the cultivation of crops for food and feed.

The idea centers on the use of compost as well as biochar, which is made from plant and animal biomass, improves soil quality and contributes to carbon neutrality or even carbon negativity.

The researchers believe cultivating energy crops could help farmers improve the quality of marginal soil so that biofuels and food production can coexist rather than compete.

Energy markets could pay farmers to restore soil quality with compost and biochar, according to Chiaramonti.

"Then one year the soil can deliver energy crops such as camelina and the next it can grow barley, for example," he said.

Plant residues would be composted and/or turned into biochar by heating at high temperatures and returned to the soil. That would not only improve soil health but also lock in carbon, further decreasing the environmental footprint of the resulting jet fuel.

"We demonstrated that biofuels can be carbon negative," said Chiaramonti. "That's a groundbreaking result."

The researchers tested their approach on plots of degraded land near the Spanish capital Madrid and in the Italian region of Tuscany.

They experimented with different methods of soil recovery and alternately grew barley and camelina, which tolerates drought better than other energy crops and has previously been used to produce HEFA-based jet fuel.

Parallel steps

While degraded land may boost HEFA supplies, many researchers think sustainable jet fuels will in any case have to be made also from more abundant resources like biomass waste that aren't rich in oils.

That's a good deal more complicated than making HEFA from oily biomass and is a challenge being tackled by another research project.

Called HIGFLY, the project lasts for four years until the end of 2024 and is run from Eindhoven University of Technology in the Netherlands.

The researchers are looking at agricultural residues, residues from the food industry and certain types of algae—anything that has sugars in it but isn't edible, according to Dr. Fernanda Neira D'Angelo, the HIGFLY principal investigator who is an expert in chemical engineering at the Dutch university.

This type of material is called lignocellulosic biomass.

Turning sugar-based matter into energy-packed oil that could enable planes to take off involves several steps, according to D'Angelo.

"The process requires much more energy and processing steps than turning oily biomass into HEFA jet fuel," she said.

The researchers are seeking to maximize the efficiency during each step so that most of the biomass and energy used in the process remains in the resulting fuel.

They process the biomass into cyclic organic molecules called furanics and then merge them to produce oils that can be further refined into fuels. The team aims to test initial samples of its biomass-based jet fuel in laboratories within months.

While the results of the project are promising, it will take years for such biomass-based fuel to power planes because certifying new fuels and bringing new technologies to market take time, according to D'Angelo.

"Depending on the results that we obtain in this project, we can evaluate possible improvements in the fuel's composition and also steps necessary for commercialization," she said.

Cost questions

Beyond the search for sufficient material for plant-based jet fuels, developing them faces a significant economic hurdle: cost.

HEFA-based jet fuels currently cost at least twice as much as fossil counterparts. And the price of fuels from biomass waste will be perhaps three times higher.

This mean that making plant-based aviation fuels competitive with fossil jet fuel will require policy changes and more investment in research and development, according to D'Angelo.

"We can make it competitive if we have the investment and the regulation supporting it," she said.

Chiaramonti agrees, saying progress will result from a range of steps including regulatory incentives and improvements in feedstocks production and supply.

"It will not be a solution coming just from a single measure," he said.

More information:

- BIO4A
- HIGFLY

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