The push to turn climate culprit carbon dioxide into a green force

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Credit: AI-generated image (disclaimer)

The major greenhouse gas contributing to global warming could become a prime resource for biofuels that can cut car, plane and ship emissions.

Laura Martinelli has bittersweet recollections about a clean-fuels project that she managed. It was interrupted by the sudden death of a leading researcher but ended up breaking important ground in the field.

Martinelli says the project's ultimate success would have been impossible without the contribution of the late researcher, Arren Bar-Even, an Israeli biochemist who died at the age of 40 in September 2020 little more than halfway through the four-year initiative.

Tribute and achievement

Bar-Even worked at the Max Planck Institute for Molecular Plant Physiology in Germany and pioneered the project, which was called eForFuel and received EU funding to develop biofuels from CO_2. Specifically, it experimented with E. coli bacteria to produce propane and isobutene, which can be converted into fuel substitutes.

"He obtained some of the pathways for turning CO_2 into useful compounds," said Martinelli, who is chief executive officer of an Italian technological research firm called INsociety. "Without him, it wouldn't have been possible. He contributed to our chances of decarbonizing our society."

The idea of turning CO_2, the main greenhouse gas blamed for global warming, into an ally in the battle to green the European economy is gaining momentum as research into biofuels expands.

Biofuels, a form of renewable energy, can be used to power cars, planes and ships. Depending on the production process and mixture, they can emit less CO_2 than petrol, diesel, kerosene and other conventional fuels.

Most biofuels are currently produced from crops such as sunflowers and soybeans, causing strains on food supply. That's why the EU limits the amount of such first-generation biofuels and promotes research on alternatives that are not derived from food crops.

Cleaner transport

As for propane and isobutene, they could be used to reduce emissions from shipping and aviation. Those two industries are each responsible for around 2.5% of global CO_2 discharges.

"Not all forms of transport can be electrified," said Martinelli. "Particularly heavier vehicles, like airplanes or ships, will in the short-term need biofuels."

The eForFuel team showed that E. coli bacteria could produce propane and isobutene in a process that involves the use of electricity.

E. coli is commonly found in the intestines of warm-blooded animals and helps their digestion. The bacteria can also be grown in laboratories.

A team under the leadership of Bar-Even managed in 2020 to reprogramme E. coli to feed on CO_2.

The project, which ended in April 2022, also found that the potential energy generated would outweigh the amount put in.

"We proved that the reaction was possible," said Martinelli. "We proved that we could create these fuels from CO_2."

Even after the breakthrough, research in this area will continue for the foreseeable future in an effort to make large-scale output possible.

"We need to make the process efficient enough to use it at an industrial scale, which can take years," said Martinelli.

Testing steel's mettle

Another research project—STEELANOL—is seeking to recycle emissions from the steel industry, eventually turning them into biofuels.

Outside the Belgian city of Ghent, far away from the tourists in the medieval center, is one of Belgium's biggest CO_2 emitters: a steel plant belonging to ArcelorMittal, the world's second-largest producer of the metal.

The Ghent factory belches out more than 9 million tons of the pollutant a year—equal to around 8% of the greenhouse-gas emissions from all of Belgium.

In a process known as carbon capture and utilization (CCU), some of that carbon-rich gas—a combination of CO and CO_2—is captured and pumped into four reactors that are each 34 meters high. Inside, microbes eat the carbon and transform it into ethanol, a fuel that can reduce emissions in everything from planes to cosmetics.

"The steel industry is a hard industry to decarbonize," said Wim Van der Stricht, responsible for CO_2 technology strategy at ArcelorMittal. "It will take years at the least. This new technology allows us to do something useful with these emissions in the meantime."

Big bioreactors

The gas fermentation reactors now converting carbon emissions in Ghent were built as part of STEELANOL and were only recently completed. They produced their first ethanol from carbon emissions in June 2023.

Inside the reactors, a carefully calibrated environment supports living microbes that are fed the CO_2.

"These microbes have existed for a long time and you can find them everywhere in nature," said Van der Stricht. "We, however, stimulated them to convert carbon emissions into ethanol."

The process, developed by a US-based company called LanzaTech, is similar to the fermentation certain foodstuffs such as beer or cheese go through.

While the resulting ethanol can serve as transport fuel, the uses are potentially broader and extend to industries including cosmetics and plastics.

"We're also talking to cosmetics companies because they want to sustainably source solvents," said Van der Stricht. "But our ethanol can just as well help make plastic production greener."

Expansion goals

The industrial site in Ghent took several years to build and STEELANOL itself is a near decade-long initiative due to run until end-March 2024.

Even though the first ethanol under the project has been produced, scaled-up production will take time. By the end of STEELANOL, the site should produce around 80 million liters of ethanol a year.

Scaling up, however, will be a challenge, according to Van der Stricht.

"We need to maintain the ideal environment for the microbes," he said. "They want temperatures of around 37 °C. And just like humans they need vitamins and minerals, which we need to add to the process. We're continually monitoring and optimizing the bioreactors."

In addition to technological questions, regulatory ones will play a role in the development of fuels from CO_2.

Determining whether fuels produced by CCU processes qualify as sustainable has often fallen into a gray zone, hindering companies developing the technology.

"The past few years there was significant uncertainty around this," said Van der Stricht.

A forthcoming update of renewable-energy legislation will bring more clarity to the industry. If the EU co-legislators agree to strengthen provisions on CCU-fuels and their role in reducing emissions, they will be ready for another leap ahead in Europe.

"We're going forward at rapid speed," said Martinelli. "Ten years ago we didn't know whether this was feasible at such a scale. Today we're seeing the first factories become a reality."

More information:

- eForFuel
- STEELANOL
- EU-funded energy research and innovation

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