Green methanol may be on the verge of a breakthrough

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From Lemvig Biogas's large plant in the background, biogas is transported to the white domes and on to DTU's reactor in the blue container. Here the first green methanol has been produced. Credit: DTU

One of the promising alternatives to fossil fuels is methanol, in which the global shipping and logistics company Maersk, among others, is investing for its future fleet of container ships. However, there is a problem when it comes to methanol. Today, 99% of methanol

production is based on coal and natural gas, and that's as far from green as it gets. DTU has contributed to developing a new method for producing biogas-based methanol.

"When methanol is produced from biogas, methanol is green because it comes from a renewable source. Biogas is a product of degraded waste from households, agriculture, and production," explains Associate Professor Philip Fosbøl, DTU Chemical Engineering, one of the researchers behind the project.

In the autumn of 2022, the technology was installed in a 40-foot container at Lemvig Biogas, and a year later the plant produced the first liters of methanol.

Methanol without hydrogen added

Traditionally, green methanol is produced from CO_2 by adding hydrogen. The hydrogen is obtained through a process called electrolysis, where water molecules are split into hydrogen and oxygen. But electrolysis requires a large energy supply in the form of electricity, and although electricity prices have fallen, it is still so expensive that this form of methanol production cannot compete with methanol produced from fossil sources. DTU's new method does not require the addition of hydrogen to form methanol.

"We take biogas and turn it into synthesis gas, and then we take the synthesis gas and turn it into methanol. And we have a plant that can recycle and use CO_2 together with hydrogen and produce even more methanol," says Fosbøl.

Biogas typically consists of two-thirds methane and one-third CO_2. Synthesis gas consists of carbon monoxide and hydrogen. To get from biogas to synthesis gas, a catalyst is required to make the process

happen, and usually problems arise with deposition of coal on the catalyst. But using a new and innovative catalyst, DTU researchers eliminate this problem.

Since hydrogen is produced by the formation of synthesis gas, there is no need to add hydrogen to produce methanol. However, since biogas contains one-third CO_2, you need to recirculate CO_2 together with hydrogen from the synthesis gas in order to also convert CO_2 into methanol. This process is brand-new and patented, and is one of the secrets of great efficiency. The finished product consists of 95% pure methanol, and 99.9% can be achieved if additional hydrogen from another source is added. Overall, the method has been a breakthrough for green methanol production.

"I do believe we're the first ever to demonstrate that you can produce methanol from biogas," says Fosbøl.

The key word is flexibility

The large biogas plants have generally focused on producing biomethane for the gas grid. The technology DTU researchers are working on here is also intended for small biogas plants that cannot send their biomethane into the gas grid. Instead, they are forced to burn the biogas for heat or electricity production.

There are also biogas plants that are located at too great a distance from hydrogen producers, and therefore do not have the opportunity to convert CO_2 into biogas via hydrogen input. There are many such plants not only in Denmark, but also in Germany, where there are about 10,000 of these smaller biogas plants, and here the new technology can be extremely attractive, says Fosbøl. For the DTU researcher and his colleagues, it has been crucial to create a methanol plant that was flexible, because future needs can change quickly.

"Our plant is designed to operate in a future where you adapt to changing needs. We can operate with different feed gases and switch very quickly," he says.

This means you can occasionally utilize the entire biogas, so both methane and CO_2 are converted to methanol. Sometimes you can only produce methanol from methane, and other times you can choose to make methanol only from CO_2, while the methane is utilized for gas production. This makes it incredibly flexible, explains Fosbøl.

If biogas cannot be disposed of for the gas grid, there will also be a need for storage. And converting the biogas into liquid in the form of methanol is an obvious solution, as it occupies a much smaller volume, and then the biogas plants themselves can store the fuel over a longer period of time.

Methanol produced from biogas is much cheaper than traditional e-methanol produced from CO_2 and hydrogen. But it is still more expensive than methanol produced from coal and natural gas. One solution that Fosbøl envisions is to tax black methanol for a period of time, making it more expensive than green methanol. In this way, green methanol can become profitable to produce, and as production methods are developed, green methanol will become competitive on normal market terms.

Next steps

The methanol plant that is now up and running is a demonstration plant. This means that it is no longer just on a laboratory scale, but has "moved into reality," as the DTU associate professor phrases it. It can produce 400 liters of methanol daily if it runs 24/7, but the daily production has been less than 100 liters because production has only run during the daytime.

"The big breakthrough is that we've been able to do this without any breakdowns," states Philip Fosbøl, who explains that the longest continuous production period has been 72 hours. The next milestone will be production for 500 hours straight.

The plant at Lemvig Biogas can convert 10 m^3 biogas per hour. The next step will be upscaling to 200 m^3 per hour, equivalent to a full-scale commercial facility. But this requires large-scale support.

"The research project we have carried out has a budget of just under DKK 20 million, but the next scale-up can easily cost in the region of DKK 100 million, so it's obviously something that requires public support," says Fosbøl.

The project has so far been supported by the Danish Energy Agency's Energy Technology Development and Demonstration Programme (EUDP), which has included three partners in addition to DTU. Pentair Union has headed the construction of the processing plant, while the demonstration plant was built by Elplatek. Lemvig Biogas has supplied biogas to the demonstration plant.

When DTU's technology is fully developed, it will be able to produce up to 60,000 tons of methanol from a typical large Danish biogas producer. With an annual requirement of 750,000 tons of methanol for Maersk's future fleet of 25 methanol-powered container ships, it will require a large number of biogas plants just to cover this need.

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