SYNTHETIC METHANE COULD SMOOTH THE PATH TO NET ZERO

Researchers explore WAYS TO SUSTAINABLY SYNTHESIZE METHANE to reduce a reliance on natural gas.

Japan boasts the world's third largest economy, but, impressively, also often tops global lists of energy-efficient nations.

Along with more than 100 other nations, Japan aims to reach net zero emissions by 2050. There are many paths towards this goal, but Japanese utility provider Tokyo Gas, along with researchers at the Japan Aerospace Exploration Agency (JAXA) and Osaka University, is exploring one of the more unusual approaches: to replace natural gas, a fossil fuel, with a synthetic alternative.

The idea seems counterintuitive: after all, methane, the major component of natural gas, has been demonized by environmentalists for being a potent greenhouse gas. But a synthetic version could become a much cleaner fuel, says physical chemist, Hisataka Yakabe, who is spearheading research at Tokyo Gas to produce synthetic methane in two new ways.

Synthetic methane, or e-methane, is a so-called electrofuel. These 'e-fuels' are made from two raw materials: hydrogen that's produced from water via electrolysis (preferably using renewable energy), and CO_2 captured from the air around us or exhaust gases.

Although burning such fuels still produces CO_2, they are thought to be closer to carbon neutral when the gas can be captured and reused to make more synthetic fuel in a closed loop system or 'direct air capture' (DAC) is used. And e-methane is one of several synthetic fuels, including e-methanol, in development.

AID TO DECARBONIZATION

Natural gas, which provided roughly 24% of Japan's energy needs in 2021, is still the least harmful fossil fuel around, and further de-carbonization will take time. E-methane could help fill its role in the medium term, says Yakabe.

Methane can be produced in a lab, via a process that was first devised more than a century ago, when French chemist, Paul Sabatier, figured out how to combine hydrogen with CO_2 in the presence of a nickel catalyst to yield methane and steam ($4H_2+CO_2 \rightarrow CH_4+2H_2O$).

Today, the 'Sabatier method' remains the most popular approach for methane synthesis, but it is problematic for several reasons, explains Yakabe. For

▲ Tokyo Gas has been testing e-methane synthesis in Yokohama city, Japan. They plan to expand to roughly 30 times the size by 2025.

Sean Gladwell/Moment/Getty

a start, the reaction isn't very efficient. To make methane, hydrogen has to be produced via water electrolysis before being mixed with carbon dioxide, but combining these two processes yields an overall efficiency of between 50 and 60%, with nearly half of the input energy lost as heat, says Yakabe.

The Sabatier method is also incredibly exothermic — occurring at roughly 400—500°C — and therefore requires "highly sensitive thermal management," he adds. Moreover, the whole process involves complex equipment, such as electrolyzers, hydrogen storage tanks, and methane synthesizers, all of which increase production costs.

These drawbacks are partly what prompted Yakabe and his team at Tokyo Gas to start looking for alternative ways to manufacture methane. While their initial research for Sabatier began as far back as 2010, things have accelerated in the last three years, says Yakabe.

FROM SPACE TO EARTH

The firm — which imports some 12.6 million tonnes of liquefied natural gas a year to 8.6 million retail and wholesale customers, and for power generation — wants to find an alternative source of methane that has far less impact on the environment, says Yakabe.

This is why Yakabe and his team are currently pursuing two e-methane projects, financed in part by a ¥4 billion (US$30 million) grant from the Japanese government's Green Innovation Fund and managed by the New Energy and Industrial Technology Development Organization (NEDO). The aim, says Yakabe, is to replace a large portion of Tokyo Gas's supply with synthetic methane by 2050.

To reach this goal, Yakabe's team, along with JAXA, is

▲ Synthetic methane is made from two raw materials: hydrogen that's produced from water via electrolysis and carbon dioxide.

exploring a new production technique called the Hybrid Sabatier method. It involves, as the name suggests, water electrolysis and the formation of methane taking place within a single integrated device in a seamless fashion.

THE AIM IS TO REPLACE A LARGE PORTION OF TOKYO GAS'S SUPPLY WITH SYNTHETIC METHANE BY 2050.

IT Tech Science/Shutterstock

The benefits are two-fold, explains Yakabe. For one, the catalyst (a combination of nickel and other non-precious metals) enables the reaction to take place at a much lower temperature (roughly 220°C). The heat generated during methane production is also absorbed during endothermic water electrolysis, driving the reaction — a neat trick that promises to boost overall reaction efficiency to approximately 80%.

Space agencies such as JAXA have long been interested in the Sabatier method as a closed-environment water reclamation technology. For instance, for an astronaut's life-support, oxygen is produced by water electrolysis, and then water can be regenerated by reusing and reacting the hydrogen produced at the same time with the CO_2 emitted by astronaut's metabolism.

E-METHANE AND MORE

The second technique Tokyo Gas is exploring is the PEMCO_2 reduction method, which employs a Polymer Electrolyte Membrane (PEM) to simultaneously cause electrolysis of water and reduction of CO_2 to form methane.

Because methane is produced in a single step, instead of two, equipment configuration is compact, drastically cutting costs. The reaction also takes place between 60°C and 80°C — much lower than the other methods, and doesn't require the use of precious metals for the cathode. Its efficiency is expected to be roughly 70%, says Yakabe.

PEMCO_2 reduction may also offer the benefit of being able to produce other e-fuels in future, by swapping out the cathode and altering the electrolysis conditions. For example, using Fischer-Tropsch synthesis in the latter stages could help produce synthetic naphtha, gasoline, and jet fuel — greening the maritime and aviation industries.

Tokyo Gas hopes to commercialize both techniques by 2030, and also plans to fully transition to using green hydrogen to manufacture e-methane.

In light of the growing climate crisis, there are, of course, calls to produce less, rather than more methane, a greenhouse gas that has a heat-trapping potential roughly 20 times that of CO_2. But, Yakabe says, Tokyo Gas aims to produce and use its e-methane "in a completely closed system" that will be tightly monitored.

The team began testing the e-methane synthesis techniques at their labs in Yokohama city earlier this year, and plans to improve on the test site's sustainability within the next year by using recycled water and CO_2 from a nearby waste treatment plant. By 2025, they hope to expand testing to a facility that's roughly 30 times the size of the pilot set up.

The firm is also exploring the feasibility of producing e-methane internationally. "We believe the introduction of e-methane can contribute to carbon neutrality in the future and help to create a sustainable future globally," says Yakabe. ■

TOKYO GAS

www.tokyo-gas.co.jp/en