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HYDROGEN'S DAY OF RECKONING IS APPROACHING IN JAPAN

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Hydrogen's Day Of Reckoning Is Approaching In Japan

The next two years will make-or-break the fate of hydrogen in Japan, at least as far as the state-led hydrogen economy program plans to meet its 2030 targets.

The goal is for hydrogen-fired power generation to have a nominal but noticeable place in the national electricity mix, at 1% of the total by 2030. Instead of building new power capacity oriented on hydrogen, most of that 1%, which is equivalent to over 9 TWh of electricity, will come from so-called co-firing. This assumes that some gas power plants will add hydrogen into their fuel mix and some coal plants will do the same with its cousin, ammonia.

The challenges were, and remain, picking the most reliable, cost-effective, and environmentally clean technology. Booming interest in the hydrogen economy has revealed a plethora of technological solutions for both H2 and ammonia.

After years of testing and R&D, it's decision time. Supply chains from production to transport and storage to consumption must be up and running well before 2030 for Japan to hit that 1% target. Here, we review some of Japan's current solutions in hydrogen and ammonia.

IMPORTS AND DOMESTIC SOURCES

Japan's hydrogen economy program calls for the fuel, or ammonia, to account for 1% of national power generation and be used in manufacturing processes by replacing fossil fuels. The assumption is that hydrogen production costs will drop to ¥30/ Nm3 ex-plant by 2030, from the current level above ¥100/ Nm3 for hydrogen, and to ¥15-20/ Nm3 from ¥20-30/ Nm3 for ammonia.

Most of Japan's ammonia and hydrogen demand is expected to be met with overseas supply. While the government expects to initially use blue hydrogen that's made from natural gas, after 2030 the outlook is for green hydrogen (made with renewables) to become more popular.

With few low-cost renewable energy facilities, Japan doesn't expect to become a significant producer of green hydrogen. Since the hydrogen will originate from natural gas and be utilized by gas-firing power plants for co-firing, Japan plans to lean on its fossil fuel infrastructure.

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According to Agency of Natural Resources and Energy estimates, by 2030 Japan will require up to 300,000 tons of hydrogen for gas power plants' co-firing. Oil refining major ENEOS will convert its refineries into hydrogen supply bases. The company's desulfurization units could be converted for dehydrogenation (turning hydrogen from liquid to gas); its port terminals, piers, pipelines and storage tanks can offload and store H2.

Crucially, seven ENEOS refineries are located on the Pacific coast, close to half of Japan's gas-fired power plants. ENEOS has 12 crude oil tankers and 15 chemical tankers that can be adapted to carry hydrogen. The company favors MCH technology for transport, which it believes will allow for the procurement of large quantities of hydrogen from the Middle East, Australia and Southeast Asia.

MCH (Methylcyclohexane), already a widely used compound, can also be produced when converting hydrogen into a liquid using an element called toluene. This turns hydrogen into a compound that's relatively easy to transport.

LIQUID OR COMPOUND?

Five years ago, most efforts focused on finding ways to transport H2 in liquid form. Kawasaki Heavy Industries built the world's first liquified hydrogen carrier, the Suiso Frontier, which set sail in 2021. Japan's largest hydrogen producer, Iwatani Corporation, now uses the liquified form to transport locally produced hydrogen to fuel cell vehicle service stations.

Cooling hydrogen to the point of liquefaction (-253°C) is energy intensive. Initially, it was better because it had lower energy losses (25-35%) compared to MCH (35-40%). But MCH's advantage is that it can be transported at room temperature and pressure, avoiding the cost of cooling pure hydrogen.

MCH is also relatively safe due to limited chemical reactions regardless of ambient pressure or temperature changes. Now, ENEOS says it found a way for MCH to make up the energy losses by developing a green hydrogen process it calls Direct MCH.

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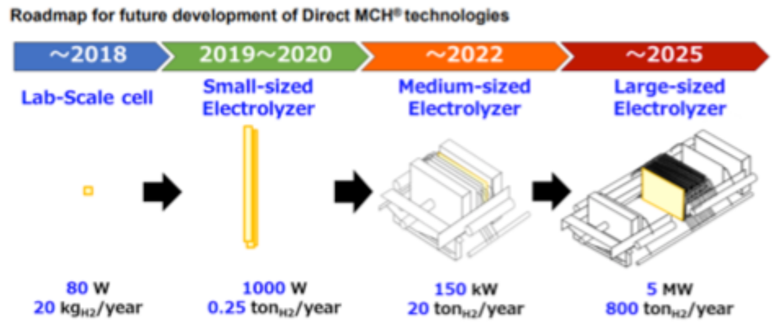
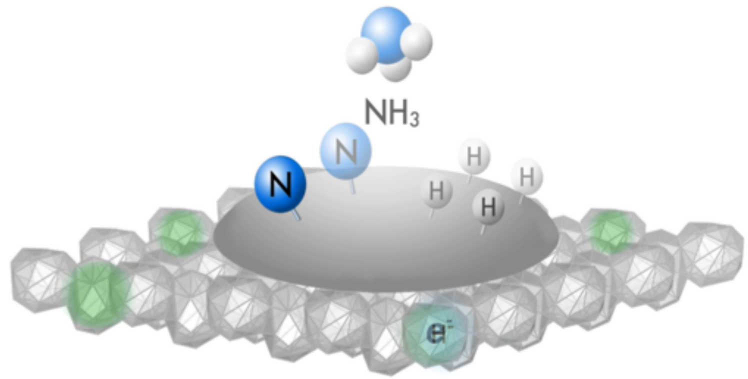
At present, green MCH has two steps: water electrolysis powered by renewables to separate hydrogen from water, and then toluene hydrogenation. Direct MCH allows for a direct reaction of toluene with water instead of hydrogen, eliminating the need to store hydrogen in tanks before the next toluene hydrogeneration phase. As a result, the cost of MCH is halved.



The company believes the innovation will help achieve the ¥30/ Nm3 goal. It's also developing MW-class large electrolyzers by expanding the electrode area and stacking cells. Research is underway for other technology alternatives: Ammonia can condense hydrogen by 1,300-fold. So, one Nm3 of ammonia can store 1,300 Nm3 of hydrogen and it's easier to transport it. The energy losses are also lower than with liquid hydrogen or MCH. However, it does cause equipment corrosion. Methane is another potential carrier, although its energy efficiency needs to be improved.

BREAKTHROUGH AMMONIA TECHNOLOGIES

Japan's ammonia demand is 1 million tons/ year, which might triple by 2030. Ammonia is manufactured using the Haber-Bosche process. Japanese manufacturers have to pay license fees to European firms for the process, so they've looked for an alternative for years.



Recently, startup Tsubame BHB developed an electride catalyst that produces ammonia at a lower temperature and pressure than Haber-Bosche. It can produce the gas at 300-400°C and in a 3-5 MPa environment, compared to Haber-Bosch's 400-500°C and a 20 MPa requirement.

So far, the catalyst has been used in smaller manufacturing plants with output of 500 to 50,000 ammonia tons/ year. Tsubame BHB has yet to find a way to apply the process to bigger facilities. The new catalyst raises cost issues, however. It contains platinum group metals (PGM) that are expensive and not easy to secure, with Russia one of the major global suppliers.

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Another Japanese oil refinery major, Idemitsu, says it has a PGM-free solution— a process that will employ molybdenum instead of PGMs. Idemitsu's catalyst is dinitrogen-bridged dimolybdenum, a combination of molybdenum and nitrogen. The company manufactures compounds with a similar composition for its oil products. Molybdenum is commonly found in copper ores and costs $20-50/ kg, a clear price advantage against over $20,000/ kg for ruthenium, a PGM.

Challenges still remain. Idemitsu needs to improve the energy efficiency of its ammonia production process and find a way to control the toxic substances generated as a byproduct. The oil refiner hopes to complete development by 2024 and to have a cartridge-based system that allows the scaling up of output by 2028. Tsubame BHB also hopes to develop a PGM-free version of its catalyst by 2024, and aims to be ready for pilot tests by 2027.

Japanese academics have stepped up research on new non-PGM catalysts. New possibilities include compounds composed of nickel, copper, manganese and others. Main challenges are improving the endurance and life cycle of the compounds, scaling up the process, as well as improving energy efficiency.

CATALYST TECHNOLOGIES IN ACADEMIC DEVELOPMENT IN JAPAN:

Nickel lanthalum oxide (NiLaN)	Tokyo Institute of Technology
Perovskite material (BaCeO3-xNyH2)	Tokyo Institute of Technology
Copper oxide on aluminum silicates and silica oxides (CuOz/3A2S)	Kumamoto University
Copper and nickel ions embedded in manganese dioxide compound	Yamaguchi University

Note: This cites the research based on the academic institutes that published the findings

DELIVERY INFRASTRUCTURE COSTS

In addition to establishing the production technologies, Japan is also investigating the feasibility of transportation and storage solutions needed to quickly and efficiently deliver the product to market. A recent review by the Ministry of Economy, Trade and Industry (METI) identified the cost for the infrastructure as outlined in the table below.

	LIQUID HYDROGEN	MCH	AMMONIA
Pipelines at supply terminals	¥145 million/ km	¥278 million/ km	¥66 million/ km
Tank storage	¥38.4 billion for storing 36,000 tons of H2	¥4.2 billion for 61,600 tons of toluene	¥11.6 billion for 56,700 tons of ammonia
High pressure pipeline	¥60 million	¥120 million	¥30 million
Low pressure pipeline	¥36 million	--	--
Tank truck	¥20 million	¥20 million	¥20 million

The ministry's base assumptions are that pipelines can be utilized for 40 years and that tanks can store an equivalent of 20 days of consumption, among other factors.

The industry view, however, is more nuanced that the numbers above indicate. An official from a major gas utility, for example, told a METI panel that it was still too early to forecast which production technology would become the breakthrough solution. The official noted that there seemed to be a bias in many of the discussions, with new technologies winning attention simply because of their novelty. Meanwhile, upgrades to legacy technologies could yield the most benefits.

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BUILD IT AND THEY WILL COME

Despite all the technical advances and progress, industry insiders and experts in Japan are concerned that all the efforts to create abundant hydrogen and ammonia supply and associated infrastructure will fall flat if the promised demand does not materialize.

As one METI committee panel on the matter noted in a recent debate, nearly all the R&D in the space is heavily weighted towards the supply chain. There's much less innovation among industrial end-users to actually deploy the hydrogen.

Consumers in the power sector, such as JERA, have committed to moving towards hydrogen and ammonia in the mid-to-long-term, but much depends on the technical testing of co-firing, such as the one JERA started at its Hekinan coal-fired power station last year.

If it goes well, JERA hopes to accelerate full commercialization of co-firing before a self-imposed 2030 deadline. In fact, the power utility this February launched a global tender for "up to" 500,000 tons of ammonia per year from FY2027. The utility also agreed with several domestic peers to look at joint procurement of ammonia in the future.

Ultimately, JERA's decision to pursue co-firing on a mass scale will depend on the cost of the ammonia it is offered via the tender as much as the success of co-firing pilot projects. Opportunities to promote co-firing not just in Japan but also in South East Asia and elsewhere are definitely there. But do the economics make sense? The data on this may not be available for several more years.

Despite the many uncertainties, one thing is clear: the window of opportunity to hit 2030 net-zero targets is closing. In the next two years, Japan may simply need to take a leap of faith.

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