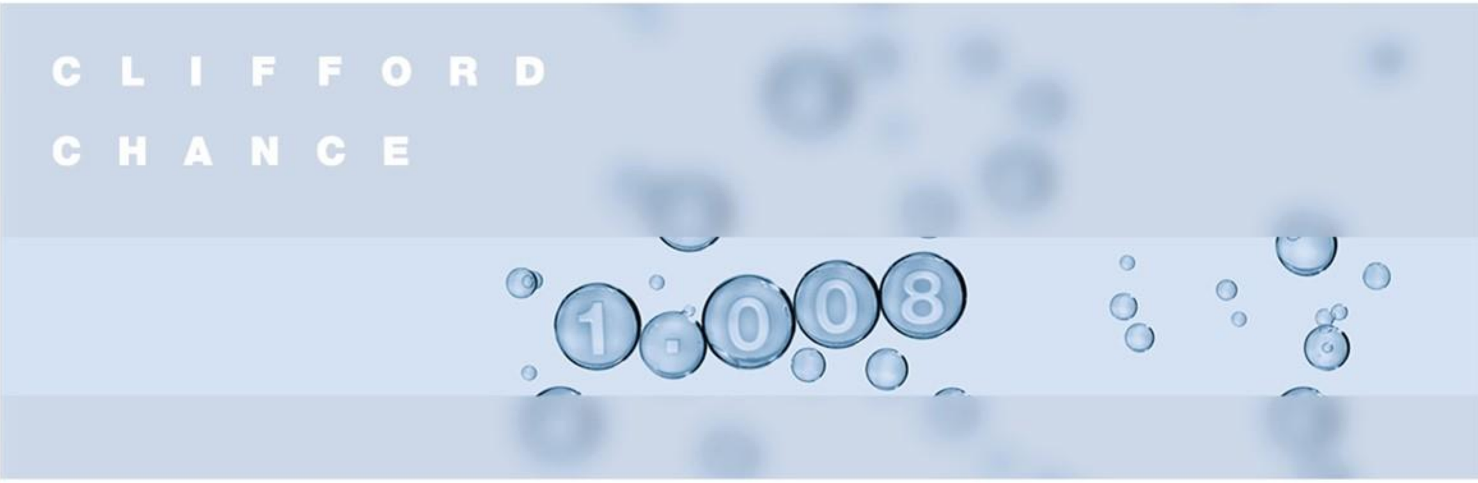

FOCUS ON HYDROGEN: JAPAN'S ENERGY STRATEGY FOR HYDROGEN AND AMMONIA

The Japanese government has set ambitious goals for a carbon-neutral future to enhance its energy security. It plans to establish a full-scale international hydrogen supply chain to cut the cost of hydrogen by 2030 and to encourage the use of ammonia in thermal power generation as a low-carbon transition fuel.

In this briefing, we look at Japan's hydrogen strategy and the policy and regulatory initiatives underpinning the development of the sector. We also explore the pioneering research and development being carried out in Japan, including transportation technologies, and consider the challenges to be overcome in order to establish hydrogen as a core pillar of the Japanese energy system.

Key points

- Hydrogen and ammonia will play a central role in decarbonising the Japanese energy system.
- The Japanese government's policy initiatives focus on:
  - developing the hydrogen supply chain (including storage)
  - expanding domestic demand for hydrogen and ammonia
  - substantially reducing the delivered cost of hydrogen.
- Aiming for a delivered cost of hydrogen of JPY30/Nm^3 by 2030.
- Hydrogen and ammonia to decarbonise thermal power generation:
  - 20% ammonia co-firing in coal power plants by 2030
  - 30% hydrogen co-firing in gas power plants by 2030.
- Hydrogen/ammonia to comprise 1% of Japan's overall power mix by 2030.
- Substantial ongoing public-private co-investment in R&D and pilot projects, particularly in relation to hydrogen transportation technologies.
- "Power to gas" envisioned as a solution to renewable power intermittency and an efficient route to domestic hydrogen production.
- Regulatory frameworks will need revision to support more widespread use of hydrogen and ammonia.

ROADMAP TO 2030

In December 2017, the Ministry of Economy, Trade and Industry of Japan (METI) issued the "Basic Hydrogen Strategy" (the Basic Strategy), the world's first national strategy for hydrogen. In March 2019, METI followed up with the "Strategic Roadmap for Hydrogen and Fuel Cell" (the Strategic Roadmap). Together, the Basic Strategy and the Strategic Roadmap set out the broad policy framework for the development of the Japanese hydrogen economy for the next decade and beyond, including the following key objectives:

Developing an integrated hydrogen supply chain

- Establishing an integrated international hydrogen supply chain by 2030 encompassing upstream (production), midstream (transportation and storage) and downstream (consumption).
- Sourcing "blue hydrogen" (produced from fossil fuels, where the CO_2 emitted is sequestered via carbon capture and storage) and "green hydrogen" (low or zero-emission hydrogen produced using electrolysis powered by renewable energy) from low-cost, stable producers globally, and transporting hydrogen to Japan using methylcyclohexane (MCH), ammonia or methane as energy carriers and a dedicated shipping fleet, for consumption by industrial and other end-users in Japan.

Reducing hydrogen production costs

- Overall cost reduction: lowering the delivered cost of hydrogen to a level comparable to that of existing energy sources. It targets: (i) JPY30/Nm^3 by around 2030 and (ii) subsequently JPY20/Nm^3.[1]
- Green hydrogen: reducing the cost of water electrolysis systems by 75% to JPY50,000/kW, and pursuing enhanced technical specifications for alkaline water electrolysis and polymer electrolyte membrane (PEM) water electrolysis systems.
- Production: reducing the cost of hydrogen produced using brown coal gasification from several hundred JPY per Nm^3 to approximately JPY12/Nm^3 by 2022/23, together with a reduction in the cost of carbon capture and storage (CCS) technology.

Enhancing storage and transportation of hydrogen

- Storage: increasing the capacity of above ground liquefied hydrogen storage tanks from several thousand cubic metres to approximately 50,000m^3 by 2022/23.
- Transportation: improving the efficiency of hydrogen liquification process technology.

Expanding industrial and consumer use of hydrogen and ammonia

- Gas to power: supporting research and development activities to commercialise the use of hydrogen and ammonia as fuel for power generation by 2030.
- Fuel cell vehicle (FCVs) and hydrogen refuelling stations (HRS): increasing the number of FCVs to 200,000 by 2025 and 800,000 by 2030, and constructing HRS in 320 locations by 2025, with a view to creating a self-sustaining HRS sector by the late 2020s.

Vision 2050

In October 2020, shortly after assuming office, then-Prime Minister Suga announced his vision of a carbon-neutral Japanese society by 2050, with hydrogen and ammonia identified as playing a key role. In line with this policy statement, in December 2020 the Japanese government issued its ambitious "Green Growth Strategy through Achieving Carbon Neutrality in 2050", which was subsequently updated in June 2021 (the Green Growth Strategy), identifying 14 growth sectors for the Japanese economy, including hydrogen and ammonia, and presenting a concrete national vision and goals.

Hydrogen and ammonia sit at the core of the Green Growth Strategy and are positioned as "new resources" with significant potential to reduce Japan's reliance on carbon-intensive fossil fuels such as coal and oil. The Green Growth Strategy established the following core targets:

- to increase annual hydrogen consumption to 3 million tonnes per year by 2030 and 20 million tonnes per year by 2050;

[1] Nm^3 refers to 'normal cubic metre'.

- to reduce the delivered cost of hydrogen to JPY30/Nm3 by 2030 and JPY20/Nm3 by 2050 – in line with the Basic Strategy and the Strategic Roadmap and a level competitive (by 2050) with fossil fuels; and
- in the short term (up to 2030), to introduce co-firing (20% ammonia and 80% coal) in certain coal-fired power plants and, in the long term (up to 2050), to promote the development of technologies enabling a higher co-firing ratio (ammonia of 50% or more).

In addition, the Green Growth Strategy sets out, among others, the following action items:

- commercialising the use of hydrogen in the power sector and other heavy industries, including development of hydrogen-fired power generation turbines and ammonia co-firing for power generation;
- widespread deployment of FCV trucks and encouraging hydrogen reduction steelmaking;
- installation of stationary hydrogen fuel cells for off-grid electricity generation; and
- supporting R&D related to liquefied hydrogen carrier vessels and water electrolyser technologies.

On 26 May 2021, the Japanese parliament passed legislation to amend the Act on Promotion of Global Warming Countermeasures (Act No. 117 of 1998, as amended) enshrining into law the government's objective of achieving net zero greenhouse gas emissions by 2050.

Subsequently, in October 2021, and just a few weeks before COP26, METI published the sixth iteration of its "Strategic Energy Plan", setting out the key objectives for energy supply and requisite actions in the relevant industries (the 6th Strategic Energy Plan). The 6th Strategic Energy Plan puts climate change and decarbonisation at the top of the agenda and adopts the core targets for hydrogen/ammonia under the Green Growth Strategy (as described above) as well as the following additional new targets:

- by 2030, introduction of co-firing (30% hydrogen 70% natural gas) in gas-fired power plants and the construction of pure hydrogen-fired power plants; and
- hydrogen/ammonia to comprise 1% of Japan's overall power generation mix by 2030.

PUBLIC AND PRIVATE SECTOR INVESTMENT

To progress towards achieving the medium- and long-term goals under the Basic Strategy, the Strategic Roadmap, the Green Growth Strategy and the 6th Strategic Energy Plan, and to achieve the Japanese government's ambition of a "hydrogen society", the government has been consistently allocating significant sums from the national budget (e.g., JPY98.9 billion for FY2022 alone for, among others, research and development activities relating to fuel cell and water electrolyser technologies and verification testing for co-firing of ammonia in coal-fired power plants).

In addition, the New Energy and Industrial Technology Development Organisation (NEDO), a government and METI-controlled research and development agency, has established the Green Innovation Fund with a budget of JPY2 trillion (approximately USD14.5 billion at current exchange rates). The Green Innovation Fund is available to support companies and other organisations which are striving towards carbon-neutrality for their business or operations, by providing funding for R&D, demonstration projects and wider social deployment of new technologies, processes and methodologies. JPY370 billion has been specifically earmarked for hydrogen projects (JPY300 billion for hydrogen supply chain projects and JPY70 billion for development of water electrolysis plants).

Developing an international hydrogen supply chain

Since Japan will be a net importer of hydrogen, establishing a full-scale international hydrogen supply chain is one of the key targets. This will require a substantial build-out of upstream production overseas, midstream transportation, and storage infrastructure for liquefied hydrogen, MCH and ammonia to achieve the economies of scale necessary to drive a rapid reduction in the delivered cost of hydrogen. Set out below are examples of some such projects that are currently underway.

Brunei Project – Organic Hydrides Technology

This was the world's first international hydrogen supply chain project, developed by a consortium of Japanese companies with the support of the Japanese and Brunei governments and with financial support from NEDO. In this project, (i) hydrogen is chemically bonded to toluene and converted to liquid MCH using liquid organic hydrides technology at a hydrogen plant in Brunei; (ii) the MCH is transported to Japan by ship; (iii) in Japan, the MCH is separated into hydrogen and toluene through dehydrogenation technology; (iv) the hydrogen is used to power a gas turbine for power generation; and (v) the toluene is recycled and shipped back to Brunei for reuse.

Although hydrogen becomes liquid only at -253°C at atmospheric pressure, this innovative method using MCH can transport hydrogen at ambient temperature and pressure and at a compressed volume of approximately 1/500 compared with hydrogen gas. The project completed 10 months of testing in December 2020, and demonstrated that the system is technically feasible and ready for commercial-scale deployment.

Australia Project – Hydrogen from Brown Coal

In this project, the CO_2-free Hydrogen Energy Supply-chain Technology Research Association (HySTRA, formed by a group of Japanese companies) with financial support from NEDO, and a consortium of Australian and Japanese companies with financial support from the Australian national and Victorian state governments, are developing an international supply chain between Australia and Japan involving (i) brown coal gasification and hydrogen production at Latrobe Valley in Australia; (ii) hydrogen liquefaction and storage at Hastings in Australia; (iii) marine transportation of liquefied hydrogen from Australia to Japan; and (iv) unloading and storage of liquefied hydrogen in Kobe, Japan.

This project will deploy the world's first purpose-built liquefied hydrogen carrier, the "Suiso Frontier", capable of transporting 1,250m^3 of liquefied hydrogen at 1/800 of its gaseous-state volume and at temperatures lower than -253°C. On 20 January 2022, Suiso Frontier completed its maiden voyage to Australia where it loaded a cargo of liquefied hydrogen and safely returned to Japan on 25 February 2022, where it unloaded its liquefied hydrogen cargo to a landside storage tank.

If successfully deployed at commercial scale, this demonstration project has the potential to give brown coal, the cheapest, least energy-efficient and most environmentally polluting form of coal, a new lease on life as a source of abundant low-cost clean hydrogen. Through the technology used in this project, the brown coal reserves in Australia alone have the potential to meet Japan's future hydrogen demand for hundreds of years. However, one key challenge will be to perfect the carbon capture, utilisation and storage (CCUS) technology needed to ensure that hydrogen produced from brown coal can be classified as "clean". In the absence of such technology, significant question marks will remain over the extent to which hydrogen from brown coal can be considered CO_2-free on an end-to-end basis.

Revolution in storage technology – "Power to Gas"

Ramping up Japan's installed renewable power-generating capacity is also a key pillar in the government's net zero plans. However, because of its intermittency, renewable power generation cannot be relied upon to balance supply and demand in the electricity grid. An increase in installed renewable power capacity is also likely to result in higher frequency of curtailment (where a renewable power generator is required to reduce power output below what could have been produced in order to balance energy supply and demand, or due to transmission constraints) for operators of renewable power plants in the future.

"Power to Gas" technology is a potential solution to these problems. It uses electricity to produce hydrogen gas through water electrolysis. Through this process, excess renewable power generation, which would otherwise be curtailed and wasted, can be deployed to produce green hydrogen. This provides additional revenue for renewable power generators and increases the overall production of green hydrogen. The hydrogen could then be used in gas turbines to provide baseload power-generating capacity or in smaller turbines to provide grid supply-demand balancing services.

The Fukushima Hydrogen Energy Research Field (the Fukushima Research Field), the world's largest green hydrogen production facility when it was launched in 2020 and equipped with 20MWp of PV solar power capacity, 10MW of hydrogen electrolyser capacity, and the ability to produce 1,200 Nm^3/h of hydrogen, has been conducting a demonstration experiment of this "Power to Gas" approach since March 2020.

The Strategic Roadmap refers to the Fukushima Research Field as a pioneering demonstration project to promote the commercialisation and installation of "Power to Gas" systems in Japan. According to a report issued by METI in June 2020, some of the government's targets for 2030 in relation to water electrolysis systems have already been achieved as a result of the experiments conducted at the Fukushima Research Field.

Another example of Japanese companies pioneering the development of "power to gas" technologies is the Advanced Clean Energy Storage Project (ACES) in Utah, USA, in which Mitsubishi Power Americas, Inc. is a lead sponsor. Set to be one of the world's largest industrial clean hydrogen facilities, ACES will use 220MW of alkaline electrolysers powered by renewable energy to produce green hydrogen which will be stored in two salt caverns (capable of holding more than 5,500 metric tonnes of hydrogen) for use as fuel in the Intermountain Power Agency’s (adjacent, but separate) proposed IPP Renewed Project – an 840MW hydrogen-capable gas turbine combined cycle power plant supplied by Mitsubishi Power that will initially run on a blend of 30% green hydrogen and 70% natural gas starting in 2025 and incrementally expand to 100% green hydrogen by 2045. In June 2022 ACES received a US$504.4 million loan guarantee from the US Department of Energy to finance the development of the hydrogen production and storage project.

Exploring the feasibility of green hydrogen

The Fukushima Research Field also targets the creation of a model for a future green hydrogen-based society. To this end, hydrogen produced at the Fukushima Research Field is transported and used for hydrogen refuelling stations, fuel cell power generators, FCVs and other fuel cell-based mobility, or used in public facilities and plants and for various other purposes to demonstrate the practical uses and viability of green hydrogen.

The Ministry for the Environment is funding several other similar demonstration projects throughout Japan with the objective of demonstrating that fuel cells and green hydrogen can be used to power hotels, stores, swimming pools, hot spring facilities and residential gas-powered appliances.

Emphasis on mobility

Under the Strategic Roadmap, the public uptake of FCVs is regarded as important in recognising a hydrogen economy, and targets have been set to (i) mass produce low-cost FCVs (up to 800,000 FCVs, 1,200 fuel cell buses and 10,000 fuel cell forklifts by 2030) and (ii) establish a hydrogen refuelling station network to support the entry of these new FCVs into the market (up to 320,000 by 2025).

In the private sector, major Japanese automobile companies including Toyota Motor Corporation, Isuzu Motors Ltd., Honda Motor Co. and Hino Motors, Ltd. have been actively involved in developing, selling and leasing new models of FCVs and fuel cell trucks, recognising the government's support for hydrogen-fuelled transportation. Interestingly, this strong support for FCVs is not shared by the auto industry outside Japan, which is instead betting on battery-powered electric vehicles.

Several private companies (including companies installing and operating hydrogen refuelling stations, automobile manufacturers, financial institutions and other stakeholders) have established the Japan Hydrogen Station Network Joint Company (JHyM) to accelerate the development of hydrogen refuelling stations for the expansion of FCVs.

REGULATORY FRAMEWORK

There is no specific regulatory framework in Japan for hydrogen and ammonia; however, they are subject to existing regulations regarding dangerous gases in each stage of the supply chain. It seems clear that it was not envisioned that these regulations would at some point in the future apply to the large-scale commercial use of hydrogen and ammonia (and associated activities such as the installation of facilities, production, shipping and storage) beyond the manufacture of fertiliser and other specialist industrial purposes.

Due to hydrogen's explosivity and combustibility, the High Pressure Gas Safety Act (Act No. 204 of 1951, as amended) (the HPGSA) introduced regulations regarding the production and storage of hydrogen. Under these regulations, a business operator must obtain approval from the prefectural governor if it wishes to produce $100m^3$ or more of hydrogen per day, or, if less than 100m, it must file a notification with the prefectural governor. Likewise, a business operator must obtain approval from the prefectural governor if it wishes to manage a hydrogen storage facility with a capacity of 1,000m³ or more, or must file a notification with the prefectural governor if it plans to manage such a facility with a capacity of 300m³ to 1000m³. As for the transportation of hydrogen, the Ship Safety Act (Act No.11 of 1933, as amended) sets technical criteria for containers or loading methods to be used when shipping hydrogen.

Ammonia, like hydrogen, is subject to the HPGSA regulations. When producing or storing ammonia, approval from the prefectural governor is required if the business operator and production/storage facilities satisfy the requirements mentioned in the preceding paragraph. In addition, the Ship Safety Act also applies to the containers or loading methods to be used to ship ammonia. Unlike hydrogen, however, ammonia is designated as a "deleterious substance" under the Poisonous and Deleterious Substances Control Act (Act No.303 of 1950, as amended). It is prohibited for a person to manufacture or transport ammonia for the purpose of selling it unless the person has been registered as a commercial manufacturer or commercial seller of ammonia by the State or a prefecture.

As noted above, these existing regulations do not directly address activities associated with the use of hydrogen and ammonia as primary sources of energy. To support a wider and more large-scale use of hydrogen and ammonia, the Japanese government has been looking into the necessary amendment of the existing regulations or the implementation of a new regulatory framework.

CONCLUSION

Japan has one of the world's most ambitious hydrogen strategies and has demonstrated a clear commitment to the sector by allocating a pivotal role to hydrogen and ammonia in realising a carbon-neutral Japanese society by 2050.

The twin priorities of (i) establishing a full-scale international hydrogen and ammonia supply chain and (ii) stimulating demand for hydrogen and ammonia among Japanese industries and the general public, are clear, and the Japanese government is certainly directing a significant amount of investment and financial support towards the first of these priorities in particular. However, it is also clear that Japan will need to partner with other countries where hydrogen and ammonia can be produced at a commercially competitive price in large volumes, and foster the development of new technologies. Success will also require clear, consistent and appropriately tailored regulatory regimes at national and international levels in relation to matters such as technical standards, guarantees of origin, health and safety, and environmental protection. All of the foregoing is necessary to give investors the confidence to make the huge capital investments required on the production and supply of hydrogen and ammonia.

In parallel, it is crucial that domestic Japanese demand for hydrogen and ammonia ramps up. Regulation has an important role to play here in terms of incentivising hydrogen and ammonia use, and in addressing the hidden carbon costs of existing energy sources in order to accelerate the time frame within which clean hydrogen and ammonia achieve price parity with fossil fuels.

The Japanese government is aware of the need for new or modernised regulations in relation to hydrogen and ammonia, and indeed the 6th Strategic Energy Plan expressly states that it is important for Japan to take a lead role in international rule-making. While developments from Japan in terms of regulation and rule-making have been limited to date as compared with the pioneering role played by Japanese companies, with the support of substantial government funding, in driving technological innovation in the sector, the success of the next stage of the hydrogen revolution will depend on a co-ordinated and consistent regulatory framework. As one of the early adopters of hydrogen technology and prospectively one of the largest future net importers of hydrogen, Japan can and should be at the forefront of these regulatory developments.

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ABOUT

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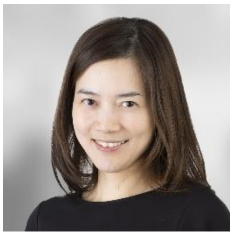

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