Intralink

British Embassy Tokyo

The Hydrogen Economy

Japan

Market Report

Prepared for the British Embassy Tokyo
& the Department for International Trade
by Intralink Limited

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Contents

APPENDICES 54

Figures & Tables

Exchange rates used in the report: GBP 1 = JPY 155 and GBP 1 = USD 1.31

1. Executive Summary

Intralink was tasked by the British Embassy Tokyo and the Department for International Trade (DIT) to undertake market research on the Japanese hydrogen ecosystem. During the initiative we interviewed key players to better understand areas of focus. All the companies we met have strong interest in the hydrogen economy and are actively looking for technologies to fast-track progress in developing the ecosystem. They have innovation activities in Europe so DIT can pursue both trade and FDI opportunities.

Potential Trade and FDI Opportunities

Stationary: Technologies and systems to accelerate the uptake of Micro CHP are of interest. For larger commercial systems of 10kW and above there is interest in technologies that can scale systems and reduce costs or increase efficiency. There may be opportunities for Japanese companies to sell existing CHP systems to the UK, potentially leading to FDI.

Mobility: Opportunities for collaboration lie with technologies to improve the safety and storage of hydrogen fuel for FCVs. There are also FDI opportunities for the development of hydrogen fuel for vehicles such as forklifts, trucks, and trains.

Marine: There are opportunities to develop systems related to auxiliary power and propulsion for ships. FDI opportunities are likely to arise from Japanese firms conducting joint research and development with UK companies or universities.

Industry: Companies developing on-site production and storage of hydrogen in industrial plants may be interested in collaborating with companies overseas. There may be FDI opportunities in R&D on hydrogen storage and in the development of industrial processes using hydrogen to reduce the carbon footprint of companies such as steel producers.

Infrastructure: Refuelling stations has been a key focus so trade and FDI opportunities lie in projects to develop the infrastructure in the UK. Power generation using a mix of ammonia, hydrogen, and renewable energy is also gaining traction so technologies to help develop solutions for this are of interest.

Supply Chain: Opportunities exist throughout the whole supply chain, from the source to the final use of hydrogen.

Nuclear Hydrogen: Nuclear hydrogen is still being developed so opportunities may lie in collaboration to help commercialise solutions.

1.1. Conclusions

- The total market size of the hydrogen industry in Japan is projected to grow to approximately GBP 7.2 billion by 2030.
- The Japanese government is developing the policy and regulatory framework to promote hydrogen to help Japan catch up with other developed economies. The 2018 hydrogen roadmap forms a key cornerstone of this activity.
- Establishing a hydrogen supply chain is a key focus, and technologies related to hydrogen storage and water electrolysis are being sought.
- All companies interviewed have overseas innovation activities of some sort and are keen to better understand UK strengths and where there are synergies there may be potential opportunities to collaborate.
- Japanese trading companies are also active in the hydrogen space and utilise their networks to collaborate with foreign companies.
- Japan's net zero targets are driving universities to accelerate efforts in hydrogen research through industry-academia collaboration.
- International investment in hydrogen is diversified and takes many forms including acquisition, collaboration, investment in start-ups, and R&D.

1.2. Recommendations

Based on the findings in this report Intralink recommends the Embassy/DIT does the following:

- Consider working with some of the larger companies outlined in the report to do reverse pitches to UK companies in the hydrogen space. IHI has specifically expressed interest and should be prioritised.
- Develop relationships with accelerator programme organisers in Japan and find ways to promote their programmes to relevant UK start-ups.
- Provide more public information on the UK's strengths in hydrogen to raise its profile and encourage more collaboration.
- Participate in upcoming trade shows and other industry events with a focus on hydrogen to introduce the UK's activities in this area.

2. Objectives and Methodology

The objectives of this initiative were to research the Japanese hydrogen economy in general to understand its size, current trends and business opportunities associated with key subsectors including stationary, mobility, industry, infrastructure, supply chains, hydrogen carriers, and any other areas of interest.

Outlining the market conditions and key players highlights any potential opportunities for the British Embassy Tokyo and the Department for International Trade (DIT) to target Japanese companies for potential investment projects. As such, the DIT wanted the following items to be included in the report:

- Overview of the hydrogen market in Japan.
- Outline of the opportunities for UK companies to sell/license technology, attract investment, and engage in R&D and academic collaboration.
- Interviews with key players in the hydrogen ecosystem to understand their activities and R&D interests.

2.1. Methodology

Intralink has obtained information from desk-based research for this initiative. In addition, we have drawn on a variety of secondary sources, particularly for quantitative (i.e., statistical) data, but we have taken care to obtain the most recent information and, wherever possible, cross-referenced this with other sources to validate the accuracy.

Further, Intralink has interviewed and met with 32 key stakeholders in both the private and public sector to obtain relevant information and ascertain interests. We have outlined the numbers in Table 1. The questions used for the direct interviews are outlined in Appendix A and contact details are in Appendix B.

Table 1: Types of organisations interviewed and met

Type of contact	Number
Direct interviews with companies	11
Direct interviews with universities	1
Companies met at Smart Energy Week	20
Total	**32**

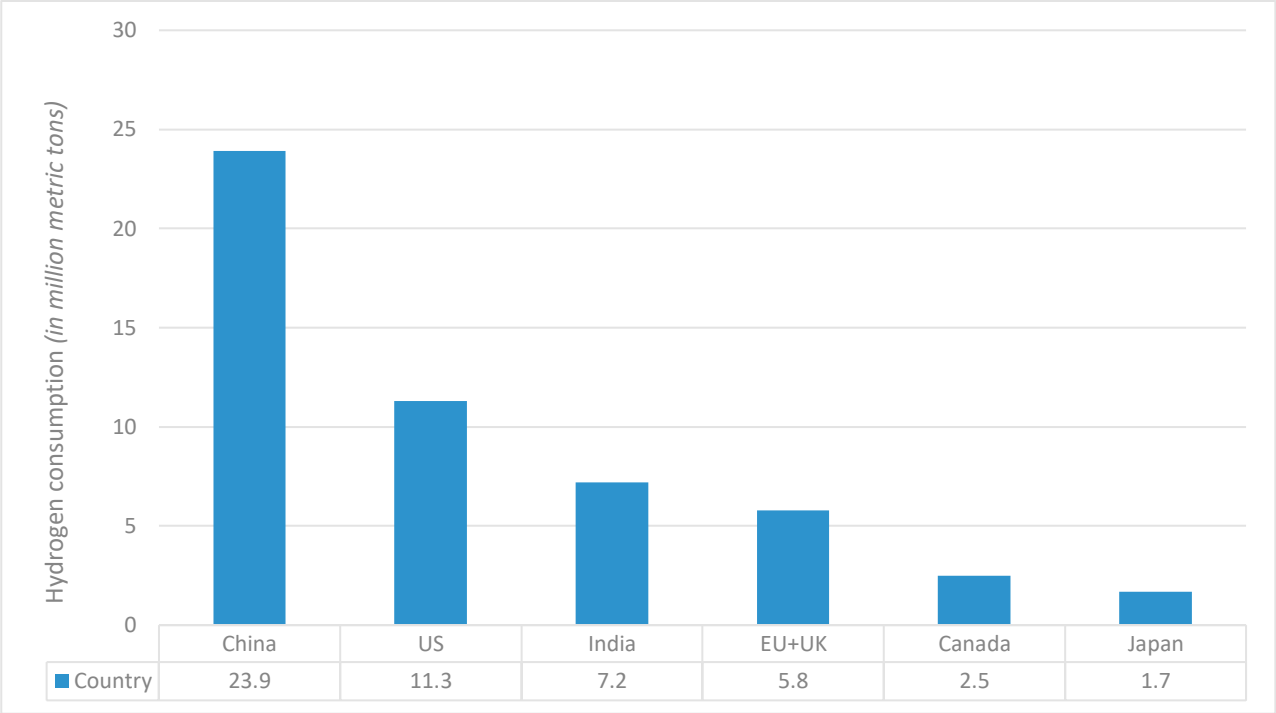
Source: Intralink research

3. The Hydrogen Industry

3.1. Overview of the Hydrogen Economy in Japan

According to the New Energy & Industrial Technology Development Organization (NEDO), the total market size of the hydrogen industry in Japan was GBP 4.2 billion in 2020.[1] It is forecast to grow to approximately GBP 7.2 billion by 2030. However, Japan is still behind other major worldwide economies when it comes to the consumption of hydrogen, having only consumed 1.7 million metric tons in 2020 as outlined in Figure 1.

Figure 1: Hydrogen consumption worldwide in 2020

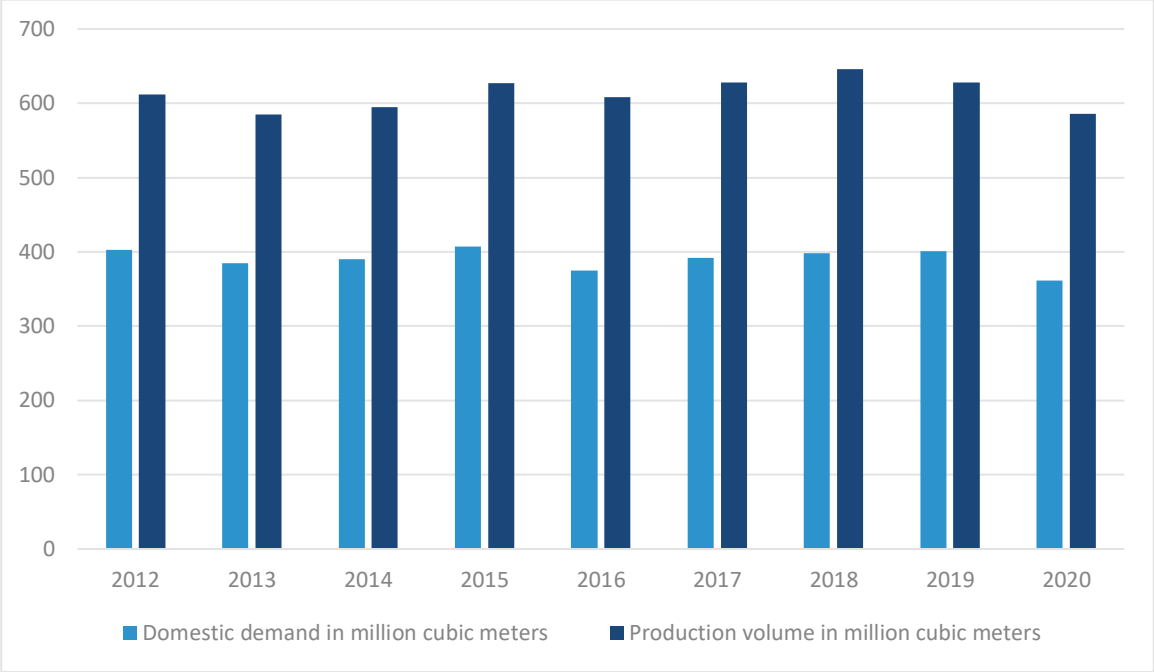


Source: Statista – Hydrogen consumption worldwide in 2020, by country

[1] Current situation and prospect on hydrogen energy market: https://www.nedo.go.jp/content/100639757.pdf

Over the past eight years, production and consumption has remained largely flat with production sustained at 585.43 million cubic meters in 2020 as outlined in Figure 2.

Figure 2: Domestic demand and production volume of hydrogen in Japan



Source: Statista -Domestic demand of hydrogen in Japan from 2012 to 2020

To determine industry-specific goals for 2050 and to stimulate the hydrogen economy, the Japanese government formed Japan's Basic Hydrogen Strategy in 2017 (see Section 3.2.1 for more details). Whilst the strategy aims to bring Japan in line with other industrialised economies, hydrogen for power generation remains a key focus. There are plans to boost consumption for power production by three million tons by 2030 and 20 million tons by 2050 for power production. GBP 14.28 billion is also being set aside for tax incentives for targeted capital spending to promote hydrogen-fuelled electric power generation and fuel cell vehicles (FCVs).[2] Given these factors, most of the growth in the industry is expected to come from the mobility (near-term) and power generation sectors (mid-term).

[2] Interim Report of Further Hydrogen Policy and Direction for Actions:
https://www.meti.go.jp/shingikai/energy_environment/suiso_nenryo/pdf/025_01_00.pdf

Table 2 outlines the top hydrogen suppliers in Japan. Iwatani dominates the market, supplying much of the industrial hydrogen and hydrogen for use in FCVs.

Table 2: Key hydrogen suppliers in 2020

Rank	Company	Annual Supply (Nm^3)	Market Share (%)
1	Iwatani	100,000,000	70.0
2	Taiyo Nippon Sanso Energy	100,000,000	18.0
3	Air Water	11,250,000	7.5
4	Air Liquide	6,750,000	4.5

Source: Intralink Research

Figure 3 shows the location of major hydrogen production plants in Japan, which are largely located in the major urban and industrial areas of Kanto and Kansai.

Figure 3: Map of main plant locations in Japan for top two producers

Source: Intralink Research

Key drivers for the hydrogen economy in Japan are varied. The 2011 Fukushima nuclear incident and the shutdown of much of Japan's nuclear capacity in the wake of the disaster has led to a greater adoption of alternatives, including renewable energy and hydrogen. The reduction of carbon dioxide (CO2) emissions is also key and was emphasised by former Prime Minister Suga announcing in 2020 that Japan will become net carbon zero by 2050.

3.2. Government Support and Regulations

3.2.1. Support for the Hydrogen Economy

Several government related organisations are involved in the promotion and development of the hydrogen economy in Japan, and they are outlined in Table 3.

Table 3: Main government organisations supporting hydrogen

Organisation	Overview
Department of Environment	Responsible for environmental policies and establishment of Smart Cities
The Ministry of Economy, Trade, and Industry (METI)	Responsible for the economic and industrial development of/and supply of mineral and energy resources including hydrogen
The Ministry of Land, Infrastructure, Transport, and Tourism (MLIT)	Responsible for the comprehensive and systematic use, development, and conservation of the nation's land, the promotion of transportation policy, meteorological services, as well as marine safety and security
The Ministry of Internal Affairs and Communications (MIC)	Responsible for establishing systems related to the basic structure of the nation such as fire and disaster prevention, information and communications, and postal administration
The New Energy and Industrial Technology Development Organization (NEDO)	NEDO is a national research and development corporation that creates innovation through the promotion of technological development necessary to achieve a sustainable society. It also develops new energy and energy-related solutions and conducts demonstration projects to expand the use of new energy

Source: Intralink research

Japan's Basic Hydrogen Strategy was laid out by the Ministry of Economy, Trade, and Industry in 2017 and it outlines goals to develop Japan's hydrogen economy by 2050. The key points are listed below with further details provided in Appendix B:

- Develop an action plan through to 2030 seeking to reduce the cost of carbon-free hydrogen.
- Ensure greater energy security and a higher self-sufficiency rate to reduce Japan's heavy dependence on overseas fossil fuels – about 90% of Japan's total fossil fuels in 2018 originated overseas.
- This strategy will provide new opportunities and economic development as companies develop more applications based on the use of renewables and hydrogen.

The country's motivation to develop this strategy is based on the potential of hydrogen to:

- Diversify Japan's energy supply sources to reduce supply risks.
- Reduce CO2 in power generation, transportation, heating, and industrial processes.
- Allow Japan to take centre stage globally in the effort to reduce CO2 emissions through world-leading hydrogen innovation.
- Allow Japanese hydrogen and fuel cell technologies to become the world's most advanced.
- Allow Japan to establish a new growth industry by expanding the hydrogen market domestically and overseas.
- Allow Japan to lead the world in developing a hydrogen-based society.

Figure 4 outlines the key elements of the hydrogen roadmap.

Figure 4: Hydrogen roadmap

		Targets in the basic strategy	Establishment of targets	Initiatives to achieve targets
Use	Mobility	FCV 200k units@2025 800k units@2030	2025 ➢ Price difference between FCV and HV (GBP 19.3k→GBP 4.5k) ➢ Cost of major FCV system (FC: GBP 129/kW → GBP 32/kW) (Hydrogen Storage: GBP 4.5k → GBP 1.9k)	In-depth regulatory reform and technological development
		ST 320 @2025 900 @2030	2025 ➢ Maintenance cost (GBP 2.2m → GBP 1.2m) ➢ Operational cost (GBP 219k → GBP 96k) ➢ Cost of ST components (Compressor: GBP 0.5m → GBP 0.3m) (Accumulator: GBP 0.3m → GBP 64k)	Expansion of nationwide ST network and business day Expansion of STs with petrol stations/convenience stores
		Bus 1200 @2030	Early 2020s ➢ FC bus vehicle prices (GBP 0.6m → GBP 0.3m)	Increase of HRS for FC bus
	Power	Commercialization by 2030	2020 ➢ Efficiency of hydrogen power generation (26 → 27%)	Development of high efficiency combustors
	FC	Early realization of grid parity	2050 ➢ Realization of grid parity in commercial and industrial use	Technological development of cell stacks
Supply	Fossil fuel + CCS	Hydrogen Cost 30円/Nm3 by 2030 20円/Nm3 in future	Early 2020s ➢ Manufacture: production costs from lignite gasification (a few pounds/Nm3 → GBP 0.07/Nm3) ➢ Storage & Transportation Size of liquefied hydrogen tanks (several thousands m^3 → 50,000 m^3) Hydrogen liquefaction efficiency (13.6kWh/kg → 6kWh/kg)	Larger and more efficient lignite classification furnaces Improved insulation and larger hydrogen tanks
	Re-energy hydrogen	Cost of hydrogen electrolysis system 5万円/kw by future	2030 ➢ Cost of hydrogen electrolysis equipment (GBP 1290/kW→GBP 322/kW) ➢ Hydrogen electrolysis efficiency (5kWh/Nm3 → 4.3kWh/Nm3)	Regional demonstration using Namie demonstration result Improved efficiency and durability of hydrogen electrolysis equipment Building a hydrogen supply chain using local resources

Source: METI Website: Over Overview of Quantitative Targets Provided by the Hydrogen and Fuel Cell Roadmap

The development of the hydrogen economy (as outlined in the Basic Hydrogen Strategy) is being supported by both the public and private sectors to develop new technologies and solutions associated with hydrogen. Table 4 outlines a couple of key programmes.

Table 4: Programmes to develop the hydrogen economy

Responsible organisation	Programme and details	Budget
METI	**The future direction of hydrogen station policy** This programme aims to ensure a cumulative total of 320 hydrogen stations by 2025, mainly in the four major metropolitan areas. Subsidies will be available for maintenance. METI will also work with local governments to strategically develop hydrogen stations in areas where hydrogen is not yet available.	GBP 70 million
Department of Environment	**Project to promote the use of hydrogen derived from renewable energy sources for the construction of a decarbonised society** This programme supports the production, storage, transportation, and utilisation of hydrogen from renewable energy sources. Projects will be supported to take advantage of the characteristics of hydrogen, such as the use of BCP, and support the use of hydrogen for mobility to decarbonise the transport sector and increase the demand for hydrogen.	GBP 49 million

Source: Intralink research

NEDO has been spearheading efforts to support specific projects to develop the hydrogen economy and Table 5 outlines some examples of projects related to hydrogen.

Table 5: Examples of NEDO projects related in hydrogen

Project	Outline of Project
Advancement of Hydrogen Technologies and Utilization Project	• Participating organisations: NEDO • Project overview: The goal is to establish a new carbon-free energy option and it focuses on high-efficiency/low-cost hydrogen production from renewable energy. It includes research and development of large-scale hydrogen utilisation technologies, basic technologies for ultrahigh-efficient power generation systems and energy-carrier systems. • Timeline: 2014 - 2022 • Budget: GBP 9.67 million

Project	Outline of Project
Development of Technologies for Realizing a Hydrogen Society	• Participating organisations: NEDO • Project overview: The goal of the project is to expand the utilisation of hydrogen for power generation. This project will look to develop hydrogen energy system technologies and large-scale hydrogen-energy utilisation technologies. To ensure greater energy security it will look at the production of hydrogen from renewable energy while making an energy system for transport, storage, and generation. • Timeline: 2014 -2025 • Budget: GBP 77.77 million
Development of Technologies for Hydrogen Refuelling Stations	• Participating organisations: NEDO • Project overview: This project aims to achieve global uptake of fuel-cell vehicles by developing technologies related to hydrogen refuelling stations. A key focus will be on cost reductions of solutions and exploring ways to develop international expansion and the development of mutual standards • Timeline: 2018 - 2022 • Budget: GBP 20.64 million
Fukushima Hydrogen Energy Research Field (FH2R)	• Participating organisations: Toshiba ESS, Tohoku Electric Power, and Iwatani • Project overview: The FH2R in Fukushima prefecture is a renewable energy-powered 10MW-class hydrogen production unit (the largest in the world). The project aims to maximise the use of hydrogen and reduce the costs of production • Timeline: 2017 - 2020 • Budget: GBP 29 million
Green Innovation Fund Project/ Large-Scale Hydro Hydrogen Supply Chain Development Project	• Participating organisations: NEDO, Iwatani, National Institute for Materials Science, JERA, Kansai Electric Power • Project overview: This R&D project aims to reduce the cost of supplied hydrogen on a large scale for hydrogen power generation through the following two themes: 1) the establishment of an international hydrogen supply chain and the development of evaluation infrastructure for liquefied hydrogen-related equipment, and 2) establishment of technologies to realise hydrogen power generation technology such as co-firing and dedicated firing[3]

[3] Green Innovation Fund project on METI Website: https://www.meti.go.jp/shingikai/sankoshin/green_innovation/energy_structure/pdf/002_04_00.pdf

Project	Outline of Project
	• Timeline: 2021 - 2030 • Budget: GBP 2.1 billion
Technology Development Project for Building a Hydrogen-based Society / Technology Development Project for Large-Scale Utilization of Hydrogen / Development and Demonstration Project for Low-NOx Hydrogen-fuelled Gas Turbine Combustion Technology	• Participating organisations: Kawasaki Heavy Industries, Obayashi Corporation, and NEDO • Project overview: Verification of technologies related to 100% hydrogen-fuelled gas turbine operation with dry low nitrogen oxides (NOx) combustion. Using a turbine developed by KHI this technology will improve efficiency compared to conventional combustion • Timeline: 2014 - 2025 • Budget: Undisclosed

Source: Intralink research

Smart Cities have and will continue to be used as a vehicle for demonstrator projects to develop decarbonisation technologies in general. Hydrogen Smart City Kobe aims to develop the hydrogen supply chain for use in several commercial and residential applications as well as mobility. Toyota Woven City will help to promote the development of hydrogen for mobility and production of green hydrogen. A list of Japan's Smart City projects is provided in Appendix D.

Table 6 outlines the key subsidy schemes for the hydrogen economy.

Table 6: Example subsidies to promote the hydrogen economy

Subsidy type (Managing body)	Details
For H2 supply equipment installation (Next Generation Vehicle Promotion Centre, via METI)	• Sector: Mobility • Applies to: Hydrogen Station Developers • Subsidy established to lower CAPEX costs for HRS construction • Subsidy amount varies from a half to a third of total cost depending on station type • An upper limit is applied and varies depending on station type • As an example: an on-site station compatible with buses can receive half of the construction cost in subsidy up to a maximum of USD 3.7m. This will increase to two thirds if the station is developed as a single packaged solution
For H2 transportation	• Sector: Mobility/Others

Subsidy type (Managing body)	Details
(METI)	• Applies to: Hydrogen Buyers • Subsidy in place to lower hydrogen transportation costs • As long as the expense is billed entirely as transportation (so separate from production cost) half of the transportation cost can be subsidised
For H2 distribution (METI)	• Sector: Mobility • Applies to: Hydrogen Distributors (from mother stations) • An HRS operator using a mother station to distribute hydrogen to other sub-stations may receive USD 570,000 per station, up to a maximum of ten 10 stations (so a total subsidy of USD 5.7 million)

Source: Intralink research
METI https://www.meti.go.jp/shingikai/energy_environment/suiso_nenryo/027.html
MLIT https://www.mlit.go.jp/report/press/content/001411806.pdf
ENV https://www.env.go.jp/earth/earth/ondanka/nergy-taisakutokubetsu-kaikeir04/gsyk04-30-2.pdf

3.2.2. Regulations and Certifications

Table 7 outlines the key laws and regulations related to hydrogen.

Table 7: Laws and regulations related to hydrogen

Organisation	Law	Details
METI	High-Pressure Gas Safety Act	Current technical standards applicable to the production of high-pressure gas at compressed hydrogen stations.
MIC	Fire Service Act	Allows gas stations and hydrogen stations to be closed.
MLIT	Building Standard Law	Removal of a cap on the amount of hydrogen that can be stored in urban areas to allow for a sufficient supply.
MIC	Act on the Prevention of Disaster in Petroleum Industrial Complexes and Other Petroleum Facilities	For the treatment of large quantities of hydrogen, a distinction is made between Type I and Type II according to the amount of hydrogen treated, and standards for disaster prevention are defined.
METI	Material Regulation	Expanded the use of steel at hydrogen stations. Revised safety factor from 4 to 9.6 for hydrogen station equipment.
MLIT	Location Regulation	Removal of the cap on the amount of hydrogen stored in city centres. Standards for the installation of liquefied hydrogen stations developed - 82 MPa stand installation standard.
METI	Distance Regulation	Allows gasoline stations and hydrogen stations to be installed side by side.
METI	Operation Regulation	Allows self-filling at hydrogen stations. Unmanned hydrogen stations can be operated through remote monitoring.
MLIT	Regulations for the Carriage and Storage of Dangerous Goods in Ships	Set out details of safe carriage standards for the shipment of dangerous goods by sea.

Source: Intralink research

4. Segments of the Hydrogen Economy

4.1. Stationary

This subsector includes the use of hydrogen for systems in residential, commercial, and industrial applications. The most common form of use is fuel cells powering combined heat and power (CHP) systems ranging in size from 3kW to 250kW and over. The fuel cell market in Japan is expected to grow at a CAGR of over 17% during the period 2020 to 2025. Growing concerns about environmental issues and increasing demand for clean electrical energy are expected to be the major drivers for the market. However, growth is being slowed by the relatively high cost of systems and the fact that it is a new technology.[4]

The ENE-FARM government-subsidised initiative has been successful in boosting the deployment of fuel cells for use in micro-CHP. At the end of 2020, there were 381,689 micro-CHPs units deployed across Japan, however, this is a long way behind the original 2020 target of 1.4 million systems and it remains to be seen if the target of 5.3 million units by 2030 will be met.[5]

There are some notable companies who are creating new initiatives in this subsector and Table 8 gives an overview of their activities:

Table 8: Examples of projects in the stationary sub-sector

Application	Details
Logistics	Seven-Eleven Japan and Toyota announced a joint project to reduce CO2 emissions at Seven-Eleven distribution centres and operations facilities in 2018. Toyota's stationary fuel cell generators, rechargeable batteries, and solar panels will be used to power stores throughout the country. The project also plans to integrate small new fuel cell trucks into the distribution process.[6]
Fuel Cell System	Miura announced a new fuel cell system (FC-5B) in October 2019. The system was created in partnership with Ceres Power in the UK and is a 4.2kW combined heat and power product (CHP) for use in the commercial building sector in Japan. These units operate on main gas supply and provide both clean energy and hot water to commercial buildings. Provides more stability on supply as can still operate during power outages.

Source: Intralink research

[4] Mordor Intelligence, Japan Fuel Cell Market – Growth, Trends, Covid-19 Impact, and Forecasts (2022-2027): https://www.mordorintelligence.com/industry-reports/japan-fuel-cell-market-industry

[5] Mordor Intelligence, Japan Fuel Cell Market – Growth, Trends, Covid-19 Impact, and Forecasts (2022-2027): https://www.mordorintelligence.com/industry-reports/japan-fuel-cell-market-industry

[6] Seven-Eleven Japan and Toyota to Joint Next-generation Convenience Store Project in Autumn 2019 toward Greater CO2 Emissions Reduction: https://newsroom.toyota.co.jp/en/corporate/22833613.html?adid=ag478_mail&padid=ag478_mail

Potential Trade and FDI opportunities

- As Japan has missed its targets for micro-CHP any technologies or systems that can help speed up deployment of more micro-CHP would be an opportunity. Especially technologies that help to reduce costs of systems or make them more efficient.
- For commercial CHP systems larger than 10Kw technologies that can help scale systems are needed.
- Japanese companies developing CHP systems include Panasonic, Fuji Electric, Hitachi Zosen, and Aisin.
- There may be opportunities for Japan to sell their existing CHP systems into the UK and through that expand their footprint which could lead to more FDI. This would be companies like Fuji Electric, Panasonic, Hitachi Zosen, and Aisin.

4.2. Mobility

Mobility covers applications where hydrogen is used to power vehicles such as e-bikes and passenger cars, trucks and buses, forklifts, and trains. Most of the near-term growth in the hydrogen economy is expected to come from this sub-sector as the demand for mobility and power generation is expected to reach 300,000 tons/year by 2030.[7]

A key driver of growth in this sub-sector is the reduction of carbon emissions. Transportation accounted for 19% of total CO2 emissions in Japan with passenger cars and trucks accounting for 85% of that share.[8] To help reduce emissions and develop the green economy, METI announced its Road Map for Electric Vehicles (EVs) and Plug-in Hybrid Vehicles (PHVs).

According to the Japan Automobile Manufacturers Association only 761 FCVs were sold in 2020, which is very low compared to EVs, PHVs, and hybrid vehicles (HVs). However, with the launch of Toyota's new Mirai, FCVs have seen double-digit growth.[9] The number of FCVs already in the market as of 2020 was 5,170 units.[10]

Japan has very ambitious targets for fuel cell car adoption of 200,000 FCVs by 2025 and 800,000 FCVs by 2030.[11] Japan is taking a holistic approach to help promote take up through regulatory reforms, technological development, and joint and strategic HRS development through public and private collaborations.

Japan H2 Mobility (JHyM) was formed in 2018 to help Japan achieve its goals. It is a government-backed consortium of hydrogen suppliers, financial investors, and leasing companies, hydrogen refuelling station (HRS) infrastructure manufacturers, developers, and operators as well as automobile manufacturers. As a single entity, it organises and oversees many of Japan's HRS developments, and these projects are built, financed, and operated by its members. JHyM's management body oversees the relevant approval and distribution of funds, and subsidy applications as well as general reporting. Examples of projects in mobility are outlined in Table 9.

Table 9: Examples of projects in the mobility sub-sector

Application	Details
Rail	The East Japan Railway Company, a major passenger railway company in Japan, has also recently unveiled the country's first hydrogen-powered train this year. It has been developed by East Japan Railway Co., together with Toyota Motor Corp., and Hitachi Ltd.

[7] Direction to further hydrogen station policy: https://www.meti.go.jp/shingikai/energy_environment/suiso_nenryo/pdf/027_02_00.pdf
[8] Transport and Environment in Japan 2019: http://www.ecomo.or.jp/22apan22i/pdf/tej2019.pdf
[9] Automobile Business Association of Japan: https://www.aba-j.or.jp/info/industry/14322/
[10] Next Generation Vehicle Promotion Center: http://www.cev-pc.or.jp/tokei/hanbai.html
[11] Japan's Hydrogen Society Ambition 2020 Status and Perspectives: https://www.ifri.org/sites/default/files/atoms/files/nagashima_japan_hydrogen_2020.pdf

Application	Details
Automotive	In 2020, Toyota Motor Corporation unveiled plans to build a prototype city of the future at the base of Mt. Fuji. Toyota's e-Palette autonomous battery-powered vehicles would be the main mode of transportation there. It plans to broaden its line of long-range buses, trucks, and other heavy vehicles.

Source: Intralink research

Potential Trade and FDI opportunities

- Whilst FCVs have been developed take up is slow and any opportunities could be around improving performance and efficiency and storage of hydrogen in vehicles for example increased safety and storage of hydrogen fuel. Japanese companies of relevance are Toyota, Nissan, Honda, Iwatani, Idemitsu, etc.
- For heavy duty applications such as trucks and trains there could be opportunities for the development of engines or range extensions for hybrid solutions. Japanese companies of relevance are Hino and Mitsubishi Fuso Truck and Bus Corporation.
- For off highway applications such as forklift trucks in warehouses and ports there are opportunities for small scale production and storage of hydrogen. Japanese companies of relevance are Toyota L&F and Mitsubishi Logisnext.
- There are opportunities for companies like Toyota L&F and Mitsubishi Logisnext to sell forklift trucks into the UK and through that expand their footprint which could lead to FDI.

4.3. Marine

Marine is defined as the use of hydrogen in applications related to the ocean and includes all aspects of shipping. With the growing need to reduce greenhouse gas emissions, marine engines are expected to transition away from fossil fuels to various alternative fuels based on ammonia and hydrogen. There are currently no commercial deployments for marine applications however interest and R&D is strong in Japan given its seafaring heritage and shipbuilding industry.

Kawasaki Heavy Industries (KHI), Yanmar Power Technology (Yanmar), and Japan Engine formed a consortium of Japanese engine manufacturers to pursue joint development of hydrogen-fuelled marine engines for ocean-going and coastal vessels towards establishing a world-leading position in hydrogen engine technologies.[12] These companies are targeting to complete developing a line of products that can meet various requirements for use as a main or auxiliary marine engine or a power generator.

KHI is planning to develop a medium-speed four-stroke engine. Yanmar will work at developing medium- and high-speed four-stroke engines, while Japan Engine is to tackle completing low-speed two-stroke engines. KHI and Yanmar are already participating in projects to develop small hydrogen-powered ferries for domestic routes. KHI and other Japanese firms, including shipping firm NYK Line are planning to launch pilot operations of a hydrogen-powered fuel cell passenger ferry at Yokohama port in 2024.[13] Examples of projects in marine are outlined in Table 10.

Table 10: Examples of projects in the marine sub-sector

Application	Details
Marine refuelling	Yanmar reported completing the first high-pressure hydrogen fuelling on a demonstration boat[14]. Yanmar said the fuelling took place in Osaka Bay using a specially licensed high-pressure filling facility and a newly prototyped long-hydrogen filling hose facility. The 70 megapascal (MPa) high-pressure hydrogen filling was carried out in collaboration with Toyota Tsusho Co. In the future, Yanmar reports it will obtain type approval from a ship class association so that the fuel cell system is ready to be installed on various ship types. The company aims to bring the hydrogen fuel cell system to market in 2023.[15]

[12]Japanese Manufacturers Cooperate on Development of Hydrogen Fueled Marine Engines: https://www.yanmar.com/media/news/2021/05/06071708/RELEASE210427-Hydrogen_Fuel_Research1.pdf
[13] Japanese firms develop hydrogen engines for large ships: https://www.argusmedia.com/en/news/2209358-japanese-firms-develop-hydrogen-engines-for-large-ships
[14] First High-Pressure Hydrogen Fueling Demonstrated in Japan: https://www.maritime-executive.com/article/first-high-pressure-hydrogen-fueling-demonstrated-in-japan
[15]The 2nd International Workshop on Liquefied Hydrogen Technology: https://www.jstra.jp/seminar/PDF/English_Report%20of%20The%202nd%20International%20Workshop%20on%20Liquefied%20Hydrogen%20Technology.pdf

Application	Details
Vessels	Compagnie Maritime Belge (CMB), a Belgian shipping and logistics company, has been working with Japanese shipping and shipbuilder Tsuneishi Group since 2019 to develop hydrogen-powered vessels for the Japanese market. They have created an 80-passenger hydrogen ferry.
Fuel Cell System	Corvus Energy is set to start development and production of sustainable, large scale maritime-certified hydrogen fuel cell systems. The production will take place in Bergen, Norway with Toyota onboard as a key partner and supplier of mass-produced fuel cell technology.
Shipping	In 2018, Japan launched the industry-government-academia Shipping Zero Emission Project. It seeks to eliminate emissions by 2100. The project encompasses a scenario for transitioning to liquefied natural gas by embracing carbon recycling and another scenario for expanding the adoption of energy from hydrogen and ammonia, the goal being to roll out the first generation of zero-emission ships by 2030.

Source: Intralink research

Potential Trade and FDI opportunities

- There are opportunities to develop systems associated with auxiliary power (replacing diesel) and propulsion on vessels. Fuel cells using hydrogen could be used for auxiliary power. Although ammonia is being heavily targeted for propulsion. Companies like Japan Marine, IHI and Mitsui E&S are working on target vessels and Yanmar and Toyota for smaller boats.
- FDI opportunities are more likely to lie is Japanese companies doing collaborative R&D with UK companies.

4.4. Industry

The industrial use of hydrogen is defined as the use of hydrogen in industrial processes such as steel making and oil refineries. Manufacturers can produce and purify hydrogen on-site or buy it in from external suppliers such as Iwatani, Taiyo Nippon Sanso, and Air Water. This can be delivered on tube trailers or via pipelines if adjacent to production sites. Where companies choose to make their supply, they can purchase equipment from companies like Toyo Engineering and Air Liquide Japan, who provide a variety of solutions from medium or large-scale SMR solutions to industrial scale plants.

Japan is currently expanding its hydrogen market from two million tons per year to three million tons per year by 2030. By scaling up the production, Japan also aims to drive down the cost of hydrogen to about one-third of the current level by 2030. The strong demand for the use of hydrogen for mobility and power generation will likely push industrial users further toward internal hydrogen production.

Table 11 below outlines some examples of projects in industry.

Table 11: Examples of projects in the industry sub-sector

Application	Details
Energy	Equinor is working with Idemitsu Kosan in the Norwegian Sea to bring renewables to offshore remote oil and gas operations. This is also the world's first project to ever do this.[16]
Steelmaking	Nippon Steel plans to explore a large-scale EAF and the use of hydrogen as part of efforts to achieve its 2050 decarbonisation goal.[17] The company also anticipates a 30% reduction in carbon emission by 2030 compared to 2013 through implementing a strategy to blast furnaces and basic oxygen furnace processes.[18]

Source: Intralink research

Potential Trade and FDI opportunities

- Opportunities for the use of hydrogen in industrial processes lie in the development of catalysts to make processes using hydrogen more efficient. Also, the development of on-site production and storage of hydrogen at industrial plants. Companies that could be targeted are Iwatani and Air Liquid and Osaka Gas.
- FDI opportunities could lie with R&D into the storage of hydrogen and developing industrial processes using hydrogen to reduce companies carbon footprints, such as Kobelco and JFE Steel.

[16] Submit a development plan of an offshore wind farm to the Norwegian Government – World's first attempt to power oil and gas platform with offshore wind farm: https://www.idemitsu.com/en/news/2019/191016.html

[17] Japan to speed up hydrogen-based steelmaking technology: https://www.argusmedia.com/en/news/2226998-japan-to-speed-up-hydrogenbased-steelmaking-technology

[18] Nippon Steel to decarbonise steel with hydrogen: https://www.h2bulletin.com/nippon-steel-to-decarbonise-steel-with-hydrogen/

4.5. Infrastructure

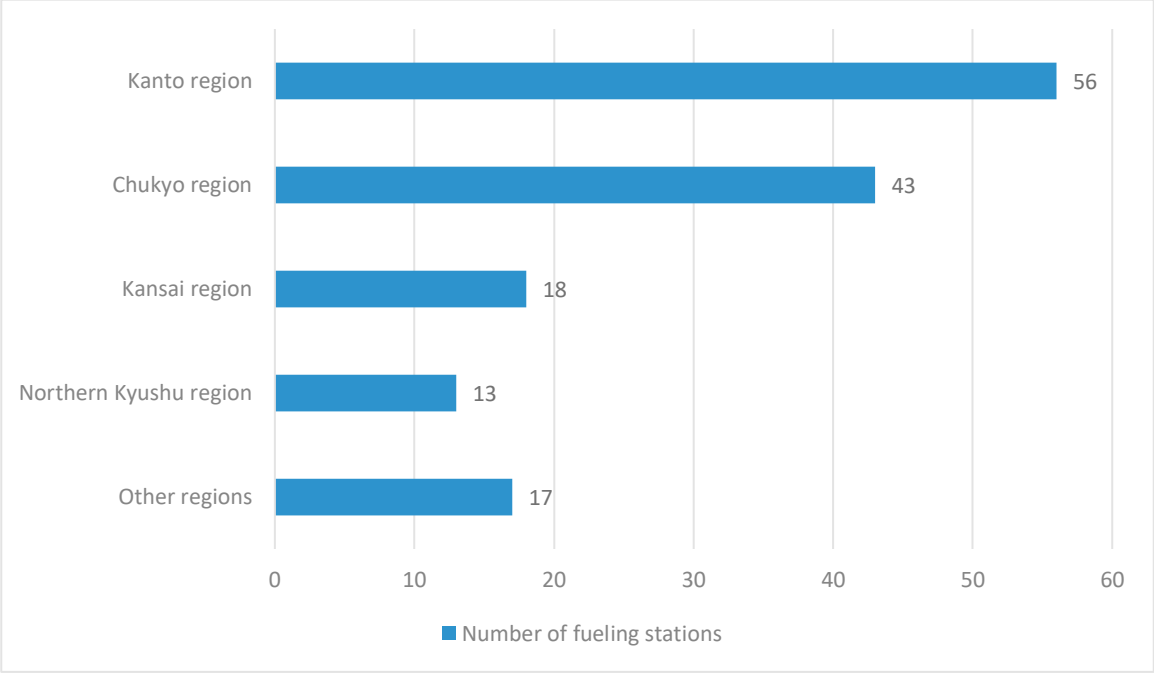
Hydrogen infrastructure is defined as the production and use of hydrogen related to large-scale engineering projects such as power generation and refuelling stations.

There are currently 134 refuelling stations in Japan, focused mainly in the urban areas of Kanto, Chubu, and Kansai.[19] Recently, refuelling stations are increasingly reaching other parts of Japan. Both the public and private sectors have been proactive in developing refuelling infrastructure.

From 2016 to 2018, METI provided GBP 67 million to fund R&D and GBP 410 million for construction subsidies to help develop more hydrogen refuelling stations. In 2018, a consortium of 11 companies, including Toyota and Nissan, established JHyM with the vision to build more refuelling stations in Japan.

As of June 10, 2021, the Kanto region had the highest number of refuelling stations at 56 and Figure 5 outlines the respective number across different regions of Japan.

Figure 5: Number of hydrogens refuelling stations for road vehicles in Japan by region



Source: Statista

[19] Global hydrogen fuel station by country 2021: https://www.statista.com/statistics/1026719/number-of-hydrogen-fuel-stations-by-country/#:~:text=Japan%20has%20the%20greatest%20number,refueling%20stations%20in%20the%20country.

Hydrogen refuelling stations (HRSs), both on-site and off-site, are on the rise in Japan. On-site HRSs are equipped with facilities to produce hydrogen from city gas, LPG, etc., while off-site stations are not and instead use trucking fleets to transport hydrogen produced outside the hydrogen stations. As of December 2021, there were 154 operational HRSs with 12 others undergoing maintenance.[20]

In April 2022, JERA Corporation, Kyushu Electric Power Company and Chugoku Electric Power signed an MOU stipulating that they will consider collaboration to introduce hydrogen and ammonia as fuels for power generation. The three companies will contribute to the early establishment of a stable and economical supply chain for next-generation fuels towards the realisation of a decarbonised society by promoting collaboration among the major power companies in Japan.[21]

Large-scale power generation using hydrogen is largely still in development however progress is being made towards commercialisation. NEDO, KHI, and Obayashi Corporation announced a world first for the successful verification of combustion technology using a 100% hydrogen-fuelled gas turbine, operating with dry low nitrogen oxides (NOx). Nikkei Asia recently reported that an independent power supplier eRex will build Japan's first commercial hydrogen power plant to initially supply zero-emission electricity to around 100 households in the following year.[22] Table 12 outlines projects in infrastructure.

Table 12: Examples of projects in the infrastructure sub-sector

Application	Details
Fuelling station	ENEOS has created 45 commercial hydrogen refuelling stations in the four major metropolitan areas in Japan. ENEOS is also developing technologies that facilitate hydrogen production and are building an entire supply chain based on carbon-free hydrogen.[23]
LNG Thermal Power Plant	JERA aims to conduct a demonstration project related to hydrogen utilisation at an LNG thermal power plant in Japan under NEDO's Green Innovation Fund program. With this project, JERA aims to achieve the practical use of hydrogen at existing NG thermal power plants to generate electricity.[24]

Source: Intralink research

[20] Direction to further hydrogen station policy:
https://www.meti.go.jp/shingikai/energy_environment/suiso_nenryo/pdf/027_02_00.pdf

[21] JERA, Kyushu Electric Power, and Chugoku Electric Power to Consider Collaboration Aimed at the Adoption of Hydrogen and Ammonia: https://www.kyuden.co.jp/press_h220420-1.html

[22] Japan's first commercial hydrogen power plant was built by eRex:
https://www.nikkei.com/article/DGXZQOUC159QG0V10C21A9000000/

[23] ENEOS and Toyota Come Together to Make Woven City the Most Hydrogen-Based Society:
https://global.toyota/en/newsroom/corporate/35298631.html

[24] JERA Starts Hydrogen Utilization Demonstration Project at an LNG Thermal Power Plant in Japan:
https://www.jera.co.jp/english/information/20210826_748

Potential Trade and FDI opportunities

- For refuelling stations technologies to help improve safety and efficiency of storage and dispensing hydrogen to vehicles are key challenges.
- For power generation Japan is heavily focussed on the use of ammonia and linking renewable energy to storage by using electrolysis. Companies like IHI, Jera Toshiba ESS are targets.
- Potential FDI opportunities could lie with Japanese companies participating in infrastructure related projects around renewable energy and hydrogen.
- At the R&D level if there are any UK/EU projects around green hydrogen Japanese companies would likely want to participate. Trading companies as well as the heavy industry companies could be especially interested.

4.6. Supply Chain

Supply chain refers to the large-scale transportation and use of hydrogen. This sub-sector is dominated by three companies: ENEOS, Iwatani, and KHI. In 2021, the three companies secured funding from the Japanese government to develop a liquefied hydrogen supply chain by 2030. A key objective is to commercialise the project and develop a supply of more than 200,000 metric tons per year.[25]

ENEOS was also awarded NEDO grants for its hydrogen projects until FY 2030-2031. One of the biggest projects includes an 30approx. GBP 576m project for a large-scale demonstration project of a methyl cyclohexane (MCH) supply chain.

Under the Strategic Energy Plan, Japan aims to launch commercial hydrogen supply chains by 2030 and bring down the supply cost of hydrogen to GBP 2.1 per kg from the current GBP 7 per kg. Under the plan Japan also intends to introduce 1% of hydrogen/ammonia to its energy mix by 2030. To achieve this, it will be necessary to have 30% co-burning of hydrogen at gas-fired power plants or mono-burning of hydrogen for power generation, and 20% co-burning of ammonia at coal-fired power plants.

Table 13 outlines the key players in the supply chain.

Table 13: Companies involved in Japan's hydrogen supply chain

Area of supply chain	Main companies involved
Production	J Power, ENEOS, NEDO, Biocoke Lab, Air Water, Hydrogen Power Corporation, Honda Motor, Nissan Motor, Toshiba
Transportation and Supply (Supply Chain)	ENEOS, Marubeni Corporation, Air Water, Nihon Shipyard
Use	JERA, IHI, ENEOS, INPEX

Source: Intralink research

KHI has also completed the world's first liquefied hydrogen transport tests by sea as part of its ambitious project to commercialise a hydrogen supply chain including the production, storage, and utilisation stages by 2030. In conjunction, KHI introduced the world's first marine carrier that transports liquefied hydrogen.

[25] Japan scaling up liquefied hydrogen supply chain with government funding: https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/082621-japan-scaling-up-liquefied-hydrogen-supply-chain-with-government-funding

Table 14 outlines the key supply chain in Japan.

Table 14: The hydrogen supply chain in Japan

Production	Transportation and Supply (Supply Chain)	Use in the industrial sector
Domestic Fossil Fuels (city/ LP gas, by-product hydrogen)	Hydrogen station	FCVs
Overseas Unused Energy (brown coal, by-product hydrogen, overseas renewable energy)	Large-scale hydrogen ocean transportation network	Fuel cell generators
Renewable Energy (solar, wind power)		Hydrogen generation

Source: Intralink research

Table 15 outlines examples of projects in the supply chain.

Table 15: Examples of projects in the supply chain sub-sector

Application	Details
Hydrogen production	ENEOS and Toyota Motor have signed a joint agreement to explore carbon-free hydrogen production and usage at Woven City, a smart city that Toyota has started to develop in Susono City, Shizuoka prefecture.
Hydrogen production	ENEOS, Asahi Kasei, Showa Denko, Toshiba Energy Systems and Solutions, East Japan Railway, Ajinomoto, and KHI plan to build a supply chain in Kanagawa prefecture. They are target generating and clarifying hydrogen demand in the area to urge suppliers to boost imports and production while lowering purchasing costs.[26]

Source: Intralink research

[26] Japanese firms target hydrogen supply chain in Kawasaki: https://www.argusmedia.com/en/news/2316853-japanese-firms-target-hydrogen-supply-chain-in-kawasaki

Potential Trade and FDI opportunities

- Opportunities lie throughout the whole supply chain from source to final use. A key challenge is safe and efficient storage of hydrogen in transportation. Companies that could be engaged for this include MHI and Toyota.
- Any FDI opportunities likely lie with R&D into the storage of hydrogen.

4.7. Nuclear Hydrogen

Nuclear hydrogen is the low-cost production of hydrogen by nuclear heated steam methane reforming. It is a concept still in development, but it has the potential to become a very cost-effective method of producing hydrogen, especially considering the anticipated cost hikes of natural gas.

Kansai Electric Power announced its 2050 net-zero commitment, which aims to reduce CO2 emissions from power generation and other business activities to zero. In terms of supply-side decarbonisation, the goal is to realise new and upgraded facilities with consideration for next-generation light hydrogen reactors, high-temperature gas reactors (HTGRs), and small modular reactors (SMRs).

The Japan Atomic Energy Agency (JAEA) is developing a new type of reactor, called the "High-Temperature Engineering Test Reactor" (HTTR), in the town of Oarai, Ibaraki Prefecture. The project is looking to develop HTGR technology and heat utilisation technology. In principle, the technology is seen as safe and the HTTR is not susceptible to core meltdowns. In a 2019 trial run, 30 litres of hydrogen per hour was successfully produced continuously for 150 hours. The steel industry has high CO2 emissions accounting for approximately 40% of the total emissions in the industrial sector.[27] To this end, the wider use of hydrogen is being considered to reduce the emissions using large quantities of hydrogen generated by HTTR. Another major advantage is the high thermal efficiency. If the turbine is operated using helium gas at 950C, the thermal efficiency can be increased to 50%.[28] JAEA and the Polish National Nuclear Research Centre are jointly researching to start operations of a research reactor for HTTR in Poland after 2025. JAEA is aiming to apply the knowledge gained from HTRR abroad. Table 16 gives an overview of R&D into nuclear hydrogen.

Table 16: Overview of nuclear hydrogen R&D in Japan

Organisation	Details
CRIEPI & Hitachi	Hydrogen production method: Electrolysis of water Materials used: Water Energy used for production: Electricity Nuclear reactor types: Light water reactor (LWR)
Toshiba	Hydrogen production method: High temp. electrolysis of steam Materials used: Water Energy used for production: Electricity + Heat (high temp.) or + Heat (medium temp.) Nuclear reactor types: Very-high-temperature reactor (VHTR), sodium-cooled fast reactor (SFR), supercritical water reactor (SCWR)

[27] Website of Agency for Natural Resource and Energy: https://www.enecho.meti.go.jp/about/special/johoteikyo/course50.html
[28] Newswitch: https://newswitch.jp/p/26984

Organisation	Details
Central Research Institute of Electric Power Industry (CRIEPI), JNC	Hydrogen production method: Thermochemical splitting of water (Hybrid) Materials used: Water Energy used for production: Heat (high temp.) or Heat (medium temp.) + electricity Nuclear reactor types: VHTR, SFR, SCWR
JAEA	Hydrogen production method: Steam reforming of methane Materials used: Natural Gas + Water Energy used for production: Heat (high temp.) Nuclear reactor types: VHTR
MHI-ARTEC-TGC-NSA, Tokyo Institute of Technology	Hydrogen production method: Steam reforming of methane Materials used: Natural Gas + Water Energy used for production: Heat (medium temp, membrane, or sorption enhanced reaction) Nuclear reactor types: SFR, SCWR
Tokyo Tech	Hydrogen production method: Steam reforming of methane (On-board, sorption enhanced) Materials used: Synthesised methane + water Energy used for production: Synthesised methane + water Nuclear reactor types: VHTR
Toshiba	Hydrogen production method: Steam reforming of dimethyl ether (DME) Materials used: DME + water Energy used for production: Heat (low temp.) Nuclear reactor types: LWR
CRIEPI	Hydrogen production method: Radio catalysis of water Materials used: Water Energy used for production: Gamma Ray Nuclear reactor types: Spent fuels

Source: OECD/NEA Third Information Exchange Meeting on the Nuclear Production of Hydrogen[29]

[29] Research and Development for Nuclear Production of Hydrogen in Japan: https://www.oecd-nea.org/science/hydro/iem3/papers/4_M_Hori_NSA.pdf

Potential Trade and FDI opportunities

- Opportunities may lie with engaging with the key players in Japan in this are Toshiba, Fuji Electric, and KEPCO.
- Any FDI opportunities lie with the R&D of nuclear hydrogen.

5. Ecosystem and Key Players

5.1. Company Overview

Japan has a diverse range of companies participating in the hydrogen economy and Figure 6 outlines the key players in their respective sub-sectors.

Figure 6: Key companies involved in the hydrogen ecosystem

Source: Intralink research

Japan has universities, national institutes, and government agencies participating in the hydrogen economy and Figure 7 outlines the key government agencies and research institutes in the hydrogen ecosystem.

Figure 7: Key government bodies and research institutes involved in the hydrogen ecosystem

Source: Intralink research

Table 17 outlines the sub-sectors the key players operate in.

Table 17: Major players involvement in various sub-sectors of the hydrogen ecosystem

Company	Stationary	Mobility	Marine	Industry	Infrastructure	Supply Chain
ENEOS					✓	✓
Idemitsu Kosan					✓	✓
IHI Corporation			✓		✓	✓
Iwatani				✓	✓	✓
JGC				✓		
Kansai Electric Power				✓		✓
Kawasaki Heavy Industries			✓	✓		✓
Kobelco				✓	✓	
Mitsubishi Heavy Industries (MHI)	✓		✓	✓		✓
Toshiba ESS	✓					
Toyota		✓	✓			

Source: Intralink research

5.2. Interviews

During the initiative, Intralink interviewed eleven major players involved in the various sub-sectors and identified innovation overview, R&D focus, example of investment, and potential opportunities for each player.

5.3. Trading Companies

The major trading companies in Japan are all active in hydrogen space and use their own networks to identify and collaborate with companies overseas. They have been especially active in hydrogen production and the supply chain given Japan's lack of energy resources and government efforts to bolster energy security. Australia has received a lot of attention given it vast natural resources.

Table 29 below outlines the main trading companies and their interests in energy and hydrogen.

Table 29: Major trading companies in Japan

Company	Overview
Itochu	Profile: Itochu is a major trading company operating across many industrial sectors. Itochu's Energy & Chemicals Company has three divisions. The Energy Division handles the trading of general energy-related products, including hydrogen. The Power & Environmental Solution Division looks at the next-generation power business. Main Sub-sectors: Supply chain, stationary, and Industry Example of investment: Itochu and Air Liquid announced plans to build liquefied hydrogen production plants in the Chubu region of Japan in the mid-2020s.[47] The hydrogen will be generated from LNG, and the daily production capacity is expected to be approximately 70% of the liquefied hydrogen currently produced in Japan, which is similar in scale to the world's largest plant built by Air Liquide in the US.
Marubeni	Profile: Marubeni is a Japanese trading company that engages in a wide range of businesses in the field of the Life industry, Power & Plant, Energy & Metal, Materials, Power Plant, and Transportation. Main Sub-sectors: Supply Chain, and infrastructure Example of investment: Marubeni has commenced a demonstration project to produce low-cost renewable energy (green hydrogen) in South Australia, transport it to Indonesia using a hydrogen storage alloy, and the utilisation of hydrogen through fuel cells.[48]
Mitsubishi Corporation	Profile: Mitsubishi Corporation operates across a wide range of industries in ten groups: natural gas, integrated materials, petroleum and chemical solutions, metal resources, industrial infrastructure, automobiles and mobility, food industry, consumer industry,

[47] ITOCHU Announces Strategic Joint Venture with Air Liquide on Hydrogen Value Chain Development: https://www.itochu.co.jp/en/news/press/2021/210226.html

[48] Commencement of PoC for Green Hydrogen Production, Transportation and Utilization in Australia and Indonesia: https://www.marubeni.com/en/news/2022/release/00003.html

Company	Overview
	power solutions, and urban development complexes. It is involved in all parts of the value chain. Main Sub-sectors: Supply Chain Example of investment: Mitsubishi Corp has entered a strategic alliance with Singapore's Sembcorp industries and Chiyoda Corporation to realise a hydrogen value chain business in Singapore based on the use of Chiyoda's hydrogen storage and transport technology.[49] Another example of investment is that Mitsubishi Corporation, together with Shell, a British recourse company began producing renewable energy-derived "green hydrogen" in Europe. The total project cost is expected to be GBP 2.1 billion including MC's huge investment in the project.[50]
Mitsui	Profile: Mitsui has diversified business and operates in the fields of mineral resources, energy, projects, mobility, chemicals, steel products, food, distribution, wellness etc. In the hydrogen sector, Mitsui gets involved in businesses related to hydrogen stations in the US and New Zealand. [51] Main Sub-sectors: Infrastructure Example of investment: Mitsui & Co subscribed for GBP 8.7m of convertible bonds of Lyfe from France, a company that produces green hydrogen in Europe using renewable energy sources and emitting no CO2 in the production process. Mitsui has invested in Hexagon Composites in Norway, which manufactures and sells high-pressure gas tanks, including those for hydrogen, and FirstElement Fuel, a hydrogen station business in the US.[52]
Sojitz	Profile: Sojitz is one of the largest trading companies in Japan that engages diversified businesses such as import/export, manufacturing, and sales in the field of automotive, aerospace & transportation, infrastructure & healthcare, metals, resources & recycling, chemicals, and retail & consumer services. Main Sub-sectors: Infrastructure

[49] Mitsubishi Corporation, Chiyoda Corporation, and Sembcorp Industries Sign MOU to Explore Supply Chain Commercialization of Decarbonized Hydrogen: https://www.mitsubishicorp.com/jp/en/pr/archive/2021/html/0000047866.html

[50] Mitsubishi Corporation, together with Shell, a British recourse company began producing renewable energy-derived "green hydrogen" in Europe, Newswitch Website: https://newswitch.jp/p/31646

[51] Mitsui & CO Company Website, Services & Products: https://www.mitsui.com/jp/ja/company/business/units/es/index.html

[52] Mitsui & CO., Ltd. Invests in the French Renewable Green Hydrogen Manufacturer, Lhyfe Operating in Europe by taking part in Lhyfe's Fundraising: https://www.mitsui.com/jp/ja/topics/2022/1243213_13393.html

Company	Overview
	Example of investment: Sojitz has commenced a demonstration project to promote the production of green hydrogen in Australia with CS Energy and Dainippon Consultants Ltd, and its hydrogen will be transported to the Republic of Palau and used in fuel cells. The project is scheduled to run for three years, from 2021 to 2023.
Sumitomo Corporation	Profile: Sumitomo Corporation has six key businesses including of metal products, chemicals, fuel, food products, and textiles. The company also operates in the transportation & construction systems, media & digital, and real-estate businesses. Main Sub-sectors: Supply Chain and Stationery Example of Investment: Sumitomo has been conducting the world first demonstration test for the construction of an international liquefied hydrogen supply chain in Australia. In this demonstration test, hydrogen is produced from lignite coal produced in Victoria. The hydrogen is liquefied, loaded, and transported to Kobe in Japan in order to demonstrate the technology required to establish a supply chain.
Toyota Tsusho	Profile: Toyota Tsusho has expanded its business fields with a focus on spinning machinery and has been involved in the import, export, and domestic sales of machinery, vehicles, steel, textiles, fuel, cotton, and wool. Main Sub-sectors: Stationery and supply chain Example of investment: In October 2020, Toyota Tsusho Corporation invested in Enoah Corporation, a company involved in the design and manufacture of hydrogen fuel cells and water electrolysis systems, with the aim of building a supply chain for hydrogen-based renewable energy.[53] Another example of investment is a project to decarbonise ports in the central UK in 2021. The project aims to convert the power source for cranes and forklifts used at the port from heavy oil and diesel to fuel cells that use hydrogen. The project will also produce hydrogen derived from renewable energy sources in cooperation with the aim of commercializing the technology in 2025.[54]

Source: Intralink research

[53] Toyota Tsusho Invests in Enoah, a Company Involved in Hydrogen Fuel Cells and Water Electrolysis Systems: https://www.toyota-tsusho.com/press/detail/210413_004806.html

[54] Toyota Tsusho Operates Hydrogen Businesses in UK: https://www.nikkei.com/article/DGXZQOFD058VT0V01C21A0000000/

5.4. Other Ecosystem Players

Intralink also met several ecosystem players at Smart Energy Week (SEW) 2022 and briefly discussed their general interests regarding R&D interest. This key relevant information is outlined in Table 30 below.

Table 30: Other ecosystem players Intralink interviewed at SEW 2022

Company	General areas of interest
Air Liquide	The industrial contact did not provide a specific area of interest but any technology that could support its entire hydrogen supply chain from generation, transportation, and storage is helpful.
Chiyoda	As an EPC and working in the supply chain, anything to do with plant development is an area of interest (i.e., chemical engineering). The company has developed its catalyst so processing technologies are also of interest
Fuji Electric	Fuji Electric provides lithium-ion capacitors for Toyota and Panasonic's V2H charging stands.
Hydrogen Power Corporation	Conducts research and development in two areas: 1) development of MEA, 2) Fuel cell system configuration design.
Iwatec	EPC operating in renewable energy projects. Is interested in any technologies that can make that better or more efficient use of renewable energy (i.e., biogas, PV & solar, electrolysis of hydrogen etc).
Kiz Corporation	The main area is technologies that could help the production, transportation, and storage of liquefied hydrogen.
Nippon Steel Corporation	Provides stainless steel for high-pressure hydrogen and is not interested in R&D with companies overseas.
Osaka Gas / Osaka Gas Liquid	Any technologies related to on-site hydrogen production equipment are helpful.

Source: Intralink research

We met one company below that has interest beyond hydrogen but wants more information on the UK. See Table 31 below.

Table 31: Other ecosystem players expressing R&D interest other than hydrogen

Bio Coke Lab	Has magnesium block storage technology and would like an intro to a UK company. President discussed wanting to combine their technology with Aquapura's – a water purification plant company - to improve water purification. However, hydrogen interests would be in technology that could help store more hydrogen into magnesium blocks.

Source: Intralink research

5.5. International Cooperation in Hydrogen

5.5.1. Mechanisms to Promote Collaboration and Innovation

There are many ways that British and Japanese organisations can collaborate and put mechanisms into place to help foster this. Table 32 outlines the key incubators in the energy space where British start-ups could participate to gain access to Japan.

Table 32: Key incubators in energy and hydrogen

Name of incubators	Detail
ENECHANGE Insight Ventures	An accelerator programme that focuses on the field of Japan's "Carbon Neutrality 2050" and calls for venture companies in various countries, mainly in Europe and the US, that have cutting-edge technology in the field.
Energy	New accelerator programme was established by Plug and Play Japan to quickly build a start-up ecosystem in the energy area. The focus areas include de-carbonisation, smart cities, CCUS, etc.[55]
Google for Start-ups Accelerator Tokyo	The programme provides mentoring by Google, access to Google's technology and a range of training for start-ups. Key focus areas include the ageing society and declining workforce, energy, environment, and sustainability.
Hitachi Innovation Challenge for Circular Economy	Water & Environment Business Unit from Hitachi in collaboration with Hitachi Corporate Venturing Office and Agorize Japan, a global open innovation platform, is inviting business ideas from start-ups.
Plug and Play Japan	Founded in Tokyo in 2017 as an accelerator and venture capital with a mission to accelerate innovation worldwide by connecting start-ups, major companies, and investors.
Smart City X	A global open innovation programme that accelerates studies for business co-creation between large companies and both domestic and international start-ups. Also promotes consumer-oriented DX that will be the driving force behind "Society 5.0 x New Normal".
Start-up bootcamp Scale Osaka	A market entry programme that connects Japanese partners with international start-ups. It is looking for start-ups seeking to enter the Japanese market key impact areas including transport and mobility.

[55] New Accelerator Program, Energy: https://prtimes.jp/main/html/rd/p/000000094.000028153.html

Name of incubators	Detail
Xhub Tokyo	Provides information for entrepreneurs aiming to enter the global market with the potential to become global start-ups from Tokyo.

Source: Intralink research

Table 33 outlines the Japanese government funds in the energy and hydrogen space where British start-ups could participate to collaborate with Japanese association.

Table 33: A major Japanese government fund in energy and hydrogen

	Detail
Japanese government funds	To achieve carbon neutrality by 2050, Japan Prime Minister Office and other government bodies such as METI have accelerated the development of funds for fourteen areas, including hydrogen. • Green Innovation Fund (https://green-innovation.nedo.go.jp): – Fund description: The fund is to be developed as a part of NEDO by METI for a total investment of GBP 12 billion. – When overseas companies apply for a project, certain conditions must be met for acceptance: 1) the company must apply as a Japanese subsidiary of an overseas company; 2) the company must strengthen Japan's industrial competitiveness; 3) the international competitiveness of Japanese technology and similar R&D trends overseas, and 4) whether a spillover effect on the domestic economy can be expected. Projects undertaken by the fund are only supported domestically, so it is not possible to establish a research base abroad. – Target: Small to medium sized companies, universities, and research institutes. – Fund duration: Long-term (10 years) for supporting from R&D to implementation. – Application process: 1) Select a project to apply for, 2) Attend the information session of an interesting project either online or physically, 3) Visit NEDO or Green Innovation Fund website once it comes to application date, 4) Fill in the required information on the web application form, upload your proposal and related documents to apply, 5) Register the proposal in e-Rad as a final step

Source: Intralink research

Table 34 outlines the university conduct international collaboration in hydrogen area.

Table 34: International university collaborations in hydrogen area

	Detail
International university collaborations in Hydrogen	University of Yamanashi announced the launch of collaborative R&D with two European universities for the development of new electrode catalysts for hydrogen fuel cells. It is looking to conduct the research from April 2022 for three years, with the budget of GBP 0.8 million.[56] Global Energy Research Unit (GHEU) of the Tokyo Institute of Technology invited Dr. Mao from Tsinghua University in China to a symposium about hydrogen in China.

Source: Intralink research

Table 35 outlines the list of upcoming tradeshows with focus on hydrogen in Japan.

Table 35: Upcoming tradeshows with focus on hydrogen

	Detail
Tradeshow	Visiting and/or exhibiting at the following tradeshows enables interactions with companies in person and promotes international cooperation. • FC EXPO 2022: – Date: 31 August – 2 September 2022 – Location: Makuhari Messe – Description: the world largest business show for hydrogen and fuel cell – Website: https://www.fcexpo.jp/en-gb.html • FC EXPO 2023: – Date: 15- 17 March, 2023 – Location: Tokyo Big Sight

Source: Intralink research

[56] Academic Collaboration between University of Yamanashi and Europe University: https://www.nikkei.com/article/DGXZQOCC1682M0W1A211C2000000/

5.5.2. International Investment in the Hydrogen Sector

This section explains the current state of international investment in the Hydrogen sector. As the case studies in Table 19 illustrate, Japan's overseas investments are diverse and take many forms. Investment has been made in various sectors rather than in one specific area, but the most notable area of investment has been hydrogen stations. This is because there is an active public-private strategic development of hydrogen stations in Japan. Private sector cooperation in the establishment of stations and the Japan Hydrogen Station Network LLC is another reason for the high level of interest in the sector. Large Japanese companies seem to be particularly active in investing in the United States, Australia, and other Asian countries, but not the United Kingdom. Table 36 outlines examples of international investments in the hydrogen sector.

Table 36: Recent examples of investment in the hydrogen sector

Company Name	Type of Investment	Overview of Investment
Chiyoda Corporation	Strategic partnership	Chiyoda Corporation is cooperating with Sembcorp Industries in Singapore with Mitsubishi to investigate and implement a commercial scale clean hydrogen supply chain in the Republic of Singapore using Chiyoda's SPERA hydrogen. [57]
ENEOS	Collaboration	ENEOS has collaborated with Neon Australia Pty Ltd to construct a CO2 free hydrogen supply chain. The project will be carried out in south Australia and will enable the two companies to test the feasibility of supplying hydrogen from renewable energy sources at a low cost and on a stable yet advanced and affordable basis. [58]
Iwatani	Acquisition	In 2019, the Iwatani Corporation of America purchased 4 hydrogen stations located in California and managed by Messar. This was the first instance of a Japanese company to initiate management in the United States. The advancement leads to the accumulation of knowledge regarding hydrogen station management.[59]
Marubeni	Collaboration	Marubeni Corporation will start the production of economical green hydrogen in South Australia, the transportation of hydrogen by metal hydride tanks to Indonesia and the utilisation of hydrogen through fuel cells. The PoC has been adopted under the Japanese Ministry of the

[57] Chiyoda Corporation Announced Strategic Partnershipw with Mitsubishi Corporation and Sembcorp Industries: https://www.chiyodacorp.com/media/211004.pdf

[58] ENEOS Begins Joint Study with Neoen for Development of a Japan-Australia CO2-free Hydrogen Supply Chain in South Australia: https://www.eneos.co.jp/newsrelease/20210802_01_02_1170836.pdf

[59] Purchase of four hydrogen stations in the US by Iwatani Corporation of America: https://xtech.nikkei.com/dm/atcl/news/16/040512107/

Company Name	Type of Investment	Overview of Investment
		Environment's "Financing Programme for Joint Crediting Mechanism Model Projects in FY2021".[60]
MHI	Fund	Mitsubishi invested in Monolith Materials, a next generation chemical and energy company with a unique and environmentally superior process for converting natural gas into carbon black and hydrogen using renewable energy to strengthen and diversify the hydrogen value chain. [61]
Mitsui	Investment	Mitsui has invested a total of USD 25 million in First Element Fuel, the biggest developer and operator of hydrogen stations in California. [62]
Sojitz	Investment	Sojitz Corporation (Sojitz) has invested in Universal Hydrogen Co. (UH2), a company headquartered in California and is engaged in the development and practical implementation of hydrogen fuel-powered aircraft and construction of a hydrogen supply network for aviation. Through this partnership with UH2, Sojitz is making its foray into the hydrogen aviation business. [63]
Sojitz	Collaboration	Sojitz will begin a demonstration project with CS Energy Ltd. and Nippon Engineering Consultants Co., Ltd. to transport renewable hydrogen produced in Australia to the Republic of Palau (an archipelago of islands) for utilisation in fuel cells and hydrogen fuel cell vessels. Sojitz's application for this green hydrogen project was selected by the Ministry of the Environment of Japan (MOEJ). [64]
Sumitomo Corporation	Collaboration	Rio Tinto and Sumitomo Corporation recently announced a partnership to study the construction of a hydrogen pilot plant at Rio Tinto's Yarwun alumina refinery in Gladstone and to explore the potential use of hydrogen at the refinery.[65]

[60] Commencement of PoC for Green Hydrogen Production, Transportation and Utilization in Australia and Indonesia: https://www.marubeni.com/en/news/2022/release/00003.html

[61] Mitsubishi Heavy Industries Invests in Monolith Materials: https://www.mhi.com/news/201130.html?style=preview

[62] Expansion of Collaboration with Hydrogen Station Operator California: https://www.mitsui.com/jp/en/topics/2020/1231534_11245.html

[63] Sojitz Invests in Universal Hydrogen Co. to Enter the Hydrogen Fuel Aviation Business: https://www.sojitz.com/en/news/2021/04/20210423-01.php

[64] Sojitz Invests in Universal Hydrogen Co. to Enter the Hydrogen Fuel Aviation Business: https://www.sojitz.com/en/news/2022/01/20220112.php

[65] Rio Tinto and Sumitomo Corporation to Assess Hydrogen Pilot Alumina Refinery: https://www.sumitomocorp.com/en/jp/news/release/2021/group/14990

Company Name	Type of Investment	Overview of Investment
Toshiba	Technology partnerships	Toshiba has concluded a technology partnership with Shandong Energy Group regarding a pure hydrogen fuel cell system. Toshiba will support the development of a stationary pure hydrogen fuel cell system for Shandong Energy.[66]
Toyota	R&D	Toyota—Six companies that share a common vision for the widespread use of fuel cell electric vehicles (FCEVs) in China signed a joint venture agreement for the establishment of United Fuel Cell System R&D (Beijing) Co., Ltd for the creation of a Hydrogen-based Society in China.[67]

Source: Intralink Research

[66] Technology Alliance with Shandong Energy Group for Pure Hydrogen Fuel Cell System: https://www.toshiba-energy.com/en/info/info2021_1227.htm

[67] Six Companies Establish R&D Joint Venture for Commercial Vehicle Fuel Cell Systems for the Creation of a Hydrogen-based Society in China: https://global.toyota/en/newsroom/corporate/32732372.html?_ga=2.36068960.1798027709.1644464106-1658747760.1644464106

5.6. Academic Environment

This section outlines universities conducting hydrogen research and trade associations.

In line with the government's carbon neutrality target, Japanese universities have, in recent years, accelerated the focus on hydrogen research through industry-academia partnerships. Research areas vary from university to university. The scope ranges from the development of the entire supply chain, hydrogen generation to utilisation, to specific areas such as fuel cell systems. International collaboration is very active among Japanese universities, regardless of the field of study. Hydrogen research is being conducted on a global scale, with the University of Yamanashi collaborating with European universities and the Tokyo Institute of Technology with a professor in China. Table 37 outlines more examples of leading universities involved in hydrogen research.

Table 37: List of universities conducting hydrogen related research

University	Areas of research
Kyushu University	Department name: International Research Centre for Hydrogen Energy Areas of research: Materials, fuel cell systems, hydrogen storage systems, and advanced hydrogen energy systems Relevant information: Actively collaborates with industry, academia, and government to conduct joint research and demonstration projects in the hydrogen space. [68]
Tokyo City University	Department name: Research Centre for High Efficiency Hydrogen Engines Areas of research: High efficiency hydrogen engines Relevant information: Deals with variety of research topics including low-loss ultra-high thermal efficiency I. C. engines, reducing mechanical friction, loss of gasoline/diesel engines, cooling, loss reduction of gasoline / diesel engines, oil consumption, high thermal efficiency and low NOx hydrogen fuelled engines.
Tokyo Institute of Technology	Department name: Global Hydrogen Energy Research Unit Areas of research: Oxygen-Hydrogen Combustion Turbine Power Generation System Relevant information: The aim of the research unit is to establish a global-scale hydrogen supply chain. The Oxygen-Hydrogen Combustion Turbine Power Generation System is assumed to be in practical use by the 2040s. International collaboration includes lectures at the GHEU Open Symposium with researchers such as the project director of CarbonNet

[68] Kyushu University: https://h2.kyushu-u.ac.jp/english/index.html

University	Areas of research
	and Dr. Mao from Tsinghua University participating. Institutes such as Trafigura, EDF Executive and entrepreneurs in Groningen province often frequent the GHEU as well. [69]
Tokyo Metropolitan University	Department name: Research Centre for Hydrogen Energy-based Society (ReHES) Areas of research: Hydrogen atmospheric environment, high performance fuel cell systems, and hydrogen supply systems and carriers Relevant information: The research centre is working with relevant companies, AIST, and institutes related to Tokyo Metropolitan Government to increase the usage efficiency of energy, use renewable energy and biomass, implement manufacturing and supplying system of hydrogen, develop a highly qualified fuel cell, and secondary batteries. Using this research, the institute is proposing policies to the Tokyo Metropolitan Government and is giving out information to the citizens to promote hydrogen energy.[70]
University of Hyogo	Department name: Collaborative Research Centre for Hydrogen Energy Areas of research: Generation, storage, carriage, and usage of hydrogen Relevant information: The centre is collaborating with other universities and institutes and forming industry-academia consortiums for social contribution.
University of Tohoku	Department name: Collaborative Research Centre on Energy Materials, Institute for Materials Research, Development of Hydrogen Energy System Areas of research: new technologies for hydrogen energy systems. Relevant information: Using the specific technology to convert electricity generated from renewable energy to hydrogen energy, the university is trying to build an energy system that is clean and stable with a large capacity.
University of Tsukuba	Department name: Energy Interface Technology Group Areas of research: N/A Relevant information: N/A

[69] Tokyo Institute of Technology, Institute of Innovation Research, Global Hydrogen Energy Research Unit: http://www.ghe.iir.titech.ac.jp/index-e.html

[70] Tokyo Metropolitan University, Research Center for Hydrogen Energy-based Society (ReHES): https://www.comp.tmu.ac.jp/hydrogen/en/index.html

University	Areas of research
University of Yamanashi	Department name: Division of Solar Energy Conversion Research, Clean Energy Research Centre Areas of research: Artificial photosynthesis, converting solar energy into chemical energy Relevant information: The research centre is welcoming researchers and students from overseas for future corporation with Asian countries. In December 2021, the university announced that it would collaborate with Technische Universität Braunschweig (Germany) and the University of Bern (Switzerland). The project will focus on the development of new catalysts for electrodes as a part of International Collaborative Research Programme on Hydrogen Fuel Cells.
Yokohama National University	Department name: Green Hydrogen Research Laboratory Areas of research: new materials Relevant information: N/A

Source: Intralink research

Intralink interviewed with Dr. Horita, Director of Fuel Cell Group from The National Institute of Advanced Industrial Science and Technology (AIST) to understand activities of AIST and the status on collaboration between Japanese and UK. The key points raised were as follows:

- His department focus on energy conservation and SOFC
- International collaborations are done through the Global Zero Emission Centre (GZR).[71]
- Collaboration tends to be ad-hoc level between researchers with common interests
- AIST does not have many opportunities to cooperate with the UK in energy
- In the field of renewable energy, research is also being conducted on hydrogen-based systems and the system analysis. This involves research into optimizing systems and components and collaboration with Japanese companies in this area

[71] AIST, Department of Energy and Environment: https://www.gzr.aist.go.jp/en/

5.7. Trade Associations

The number of associations established in the past decade testifies to the increased level of attention that Japanese companies are now paying to the industry. Key companies committed to the development of the hydrogen industry such as Toyota, Iwatani, and ENEOS hold positions as board members. Many organisations are promoting global collaboration within the industry, and the formation of Hydrogen supply chains. Table 38 outlines examples of hydrogen related trade associations.

Table 38: List of trade associations in Japan

Name	Activities	Website
JHyM	JHyM, established in 2020, is working on the further facilitation of hydrogen refuelling stations and FCVs.	Link
HySUT	HySUT, established in 2016, engages in activities such as technological development, surveys and research, education, and outreach to ensure the stable supply and safe distribution of hydrogen.	Link
HESS	HESS, established in 1973, aims to advance the transition to a sustainable hydrogen economy through research and activities to exchange information among related groups.	Link
JH2A	To achieve a hydrogen society, JH2A, established in 2020, provides discussion opportunities to unite people, industries, and governments.	Link
FCCJ	FCCJ, established in 2020, makes policy recommendations, conducts investigations, offers, and exchanges information.	Link
HySTRA	HySTRA, established in 2016, is working on creating a CO2 free hydrogen energy supply chain including production, transportation, storage, and utilisation of hydrogen. They aim to establish this chain around 2030.	Link

Source: Intralink research

APPENDICES

A. Questions for Interviews

Questions – General

- What are you company's mid to long-term plans regarding your role in a hydrogen economy?
  - Supply chain: What is your role in the supply chain?
- Some common buzzwords are "Hydrogen Economy","2050 Carbon Neutral" and "Decarbonised Society"
  - What are your company's carbon neutral goals? How vital is hydrogen to your carbon neutral goals?
  - Do you think Japan will reach the 2030 goals, 2050 goals?
- What do you see as main drivers for hydrogen adoption in Japan?
  - Is there a sweet spot (adoption/cost/supply) you are striving for?
- What are perceived barriers to hydrogen adoption in Japan?
- How much has your company invested (time and/or money) into hydrogen technology?
- Was there a sudden shift in corporate planning or did you see a gradual shift in your organisation?
- What do you believe is the most critical policy necessary to promote more hydrogen technology adoption in Japan?
- What organisations/associations have been most driven in Japan? (Hystra, JH2A, NEDO collab)?
- What policies today have enabled your company to invest deeper into hydrogen technologies?
- What kind of incentives have motivated/enabled your company to commit to more hydrogen?
- We understand the government has proposed a hydrogen roadmap, but it has essentially told the commercial sector to figure it out themselves. Other than funding, what would you like to see change in Japanese policies or regulations?
- Have other countries been [more] supportive to collaborate abroad?

Questions – Future Innovation Plans

- What key technologies are you prioritizing for development in Hydrogen?
  - The more specific the better
- How does your company gather intel about technologies abroad?
- Would you say your overseas outreach excels in a particular geographical location (Silicon Valley, EU, Israel, etc.)?
- Does your company have any of the following departments/groups focused on innovation and/or partnerships in Europe/UK? Please give us details:
  - Innovation Hub – small team of (1-10 people) with partial focus on technology scouting, trend analysis, etc

  - Innovation Lab – medium-sized team (10-30 people). Similar to an 'innovation hub' but with more established activities. This could involve, for example, running PoC trials, or local European/UK accelerator/incubator projects
  - R&D Centre – an office focussed on research and development, with closer ties to universities and larger industry partners
  - Investment – e.g., a CVC office
  - NO INNOVATION-FOCUSED TEAM – e.g., regional sales office or other department(s) only gather information
- Does your company plan to launch any 'innovation' related activities in Europe/UK in the future?
  - e.g., technology scouting, start-up partnerships, investment, accelerators, etc?
  - If 'yes', please can you kindly describe what kind of activity this will be, in a few sentences?
  - *This information will just be used for Intralink's internal references, and will not be included in the report*
- What would help you get more information about opportunities in the UK?
- Is your company interested in/willing to partner with UK companies on major projects?

Questions - Infrastructure & Mobility

- What are your future plans for FCVs and hydrogen stations?
- Looking back, what did you struggle with in the process of opening the hydrogen station?
- How did the project in _____ begin?
  - Why did you choose to work with _____?
  - How were the other Japanese companies brought on board?

Questions – Academia

- What involvements are you most excited for happening abroad between Japan and the West?
- What involvements are you most excited for that Japan is not yet apart of?

B. Japan's Basic Hydrogen Strategy

The key elements of Japan's Basic Hydrogen Strategy are outlined below.[72]

- Realizing low-cost hydrogen use by reducing the hydrogen procurement and supply cost
  - Target is JPY 30/Nm^3 by 2030, and JPY 20/Nm3 in the future to allow it to have the same cost competitiveness as traditional energy sources (when environmental impact cost adjustments are incorporated)
  - Two basic approaches:
    - Combine cheap, unused energy from overseas with Carbon dioxide Capture and Storage (CCS)
    - Procure massive amounts of hydrogen produced with cheap, renewable energy electricity
- Developing an international supply chain
  - Japan will look to establish an international supply chain through innovations in storage and transportation infrastructure, focusing on developing a liquified hydrogen supply chain and its commercialisation by mid-2020s
- Expanding the use of hydrogen from renewable energy in Japan
  - Longer term strategy to commercialise Power-2-Gas technology, specifically water electrolysis for "carbon-free" hydrogen
  - The key point is cost reduction of both renewable energy production and water electrolysis technology
  - Not expected to be commercialised before 2032 and to be cost-competitive to imported hydrogen until well after
- Expanding the use of hydrogen in power generation
  - Hydrogen can be an important source of energy for regulated or backup power supply, needed with a higher penetration of renewables
  - Aim to introduce the use of CO2 free ammonia in power generation by the mid-2020s
  - Overall, the power generation target is 1GW by 2030 at JPY 17/kWh
- Commercialising the use of hydrogen for mobility
  - Aim to increase FCEV numbers to 800,000 units and HRS to around 1,000 by 2030
  - HRS targeted to operate independently without subsidies by mid-2020s
  - Japan is putting great effort into this effort through regulatory reforms, technological development, joint and strategic HRS development through public and private collaborations
    - JHyM is a key element of this, as a government backed consortium of hydrogen suppliers, financial investors and leasing companies, HRS infrastructure manufacturers, developers, and operators as well as automobile manufacturers

[72] Basic Hydrogen Strategy: https://www.meti.go.jp/english/press/2017/pdf/1226_003b.pdf

- As a single entity, it organises and oversees a large number of Japan's HRS developments
- The HRSs are built, financed, and operated by its members
- JHyM's management body manages the relevant approval, distribution of funds and subsidy application and reporting

C. Smart City Projects

Table 41: Key smart city projects in Japan

Smart City	Outline of Project
Toyota Woven City (Shizuoka)	Woven city is developed as a place for 2000 people to live in a real-world laboratory. ENEOS, Toyota, and Woven Planet are working together to make this city powered by a hydrogen fuel cell system. They are implementing 4 ideas; to build a hydrogen refuelling station nearby, to produce "green hydrogen" using stationary fuel cell generators, to promote the use of hydrogen-powered fuel cell mobility, to conduct joint advanced research on hydrogen supply.[73]
Yokohama Smart City Project (YSCP) (Kanagawa)	The mission for YSCP is to build the world's no.1 smart city model in Yokohama, where 3.7 million people reside, and export solutions to the world. Scalable, Speed, Sophisticated, and Satisfaction are the keywords to achieve this mission. To build a low-carbon society, YSCP is introducing renewable energy on a large scale and an energy management system on top of changes in transportation and lifestyle system. For energy management in collected houses, YSCP is using fuel cells and batteries, including nickel-metal hydride battery.[74]
Good City Shibuya (Tokyo)	With the theme, "consumer-driven smart city," Mitsui & Co., Ltd.; and HAKUHODO Inc. are working on a digital application. With the participation of citizens, it enables consumers to use services contributing to social issues. The services include converting to renewable energy, returning the price to social activities.[75]
Kashi-no-ha Smart City (Chiba)	Kashi-no-ha Smart City aims to "create a new vision for the cities of tomorrow" with three themes: symbiosis with the environment, health and longevity, and new industry creation. For the environment, this smart city

[73] ENEOS and Toyota Come to Together to Make Woven City the Most Hydrogen-Based Society: https://global.toyota/en/newsroom/corporate/35298631.html?_ga=2.81311447.1793956737.1645414468-351022812.1645414468

[74] Yokohama Smart City Project:https://www.city.yokohama.lg.jp/kurashi/machizukuri-kankyo/ondanka/etc/yscp/yscp01.files/YSCP_MP.pdf

[75] Shibuya good pass established by Hakuhodo: https://www.hakuhodo.co.jp/uploads/2020/11/20201113.pdf

Smart City	Outline of Project
	harnesses energy efficiency with AEMS and Smart Centre, and conserves energy with using HEMS. By 2030, it aims to lower emissions by 60%.[76]
FUKUOKA Smart EAST (Fukuoka)	With large land, this smart city in Hakozaki aims to become a hub of innovation with many different approaches. There are many unique innovations including shopping without cashiers and paying automatically using data. It is trying to use hydrogen for electricity storage and using FCVs which only emit water.[77]
Kitakyushu Smart Community (Fukuoka)	The country aims to make smart grid a new industry, and Kitakyushu aims to change into a new lifestyle and build a new transportation system. With 77 companies and institutions on board, they work to prevent global warming, building a recycling low-carbon society, and managing the town's environment. It is trying to introduce 10% new energy, including hydrogen in both factories and houses.[78]
Hydrogen Smart City Kobe (Hyogo)	The smart city aims for many residents to use hydrogen and is working on 2 demonstration projects to build a supply chain. One is to carry liquid hydrogen by ferries from other countries and the other is to supply electricity and heat made of hydrogen to the city.[79] In 2018, it succeeded in supplying electricity and heat made by 100% hydrogen to a public facility. Also, to introduce FCV more to citizens, it is increasing the number of hydrogen stations.

[76] Kawashima no ha Smart City: https://www.kashiwanoha-smartcity.com/en/
[77] Fukuoka Smart EAST: https://www.city.fukuoka.lg.jp/data/open/cnt/3/76942/1/fukuokasmarteast.pdf?20201015083239
[78] Kyushu Smart Community: https://www.city.kitakyushu.lg.jp/files/000689061.pdf
[79] Kobe Smart City: https://www.city.kobe.lg.jp/a36643/shise/kekaku/kikakuchosekyoku/energy/hydrogen/20190106040301.html

D. The High-Pressure Gas Safety Act

The Act plays a central role in the legality and other regulations that apply to hydrogen. Table 42 below gives an overview of the act.[80]

Table 42: Structure of the high-pressure gas safety act

Type of categories	Contents	Details
Government Decree	• Order for Enforcement of the High-Pressure Gas Safety Act • Order on Fees and Charges Related to the High-Pressure Gas Safety Act	Set by the Cabinet of Ministers, e.g., required values for production and storage permits and notifications.
Ordinance, Regulations	• General High Pressure Gas Safety Regulations Liquefied • Petroleum Gas Safety Regulations • Safety Regulations for Industrial Complexes, etc. • Refrigeration Safety Regulations • Container Safety Regulations • Regulations for the Inspection of Specified Equipment	Technical standards established by the Minister of Economy, Trade and Industry and application procedures.
Public Notice	• Related to the enforcement order of the High-Pressure Gas Safety Act • Specifying details of technical standards for location, structure and equipment of manufacturing facilities and manufacturing methods, etc. • Seismic design standards for high pressure gas facilities • Notification to specify the method of safety inspection, etc.	Technical standards established by the Minister of Economy, Trade and Industry.
Others	• Operation and interpretation of the High-Pressure Gas Safety Act and related government ordinances	Examples of detailed standards that meet the technical requirements set out in the Ministerial Order

[80] Overview of the High-Pressure Gas Safety Act in Japan: https://www.khk.or.jp/english/overview_of_hpg_safety_act.html

Type of categories	Contents	Details
	• Safety inspection standards (KHKS series), etc. - Example standards related to the High-Pressure Gas Safety Law	

Source: Overview of the High-Pressure Gas Safety Act in Japan by The High-Pressure Gas Safety Institute of Japan

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