HYDROGEN HUB STRATEGIES IN THE US AND EUROPE

—WITH EUROPEAN HUBS SERVING PRIMARILY AS IMPORT SITES, AND US HUBS AS PRODUCTION SITES, WHAT ARE THE IMPLICATIONS FOR JAPAN?—

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SUMMARY

- Europe and the US are strengthening their hydrogen strategies to promote decarbonization and address other challenges. Both strategies revolve around developing hydrogen hubs for efficient production, transportation, and storage, with the difference being that European hubs are intended as import sites, while US hubs are being developed as production sites.

- The assumptions for clean hydrogen demand in 2030 are also different. In industrial applications, Europe assumes demand will be driven by steelmaking, ammonia production, etc., while US demand is expected to be fueled by such things as petroleum refining, ammonia production, with no expectations of steel-related demand. This is because steelmaking in the US is mainly carried out using electric furnaces.

- Japan, which revised its Basic Hydrogen Strategy in June 2023, is expected to pursue an import-oriented hydrogen adoption strategy. As such, European initiatives can be used as reference, but strategies must be adapted to Japan's unique conditions by factoring difficulties, such as those regarding underground storage.

In Europe, the use of hydrogen is being actively promoted as a solution to the energy crisis and decarbonization issues in the wake of Russia's invasion of Ukraine, and plans call for importing hydrogen on a large scale through hydrogen hubs[1] located at ports. In the US, meanwhile, the US National Clean Hydrogen Strategy and Roadmap was announced in June 2023 and the selection of hydrogen hub regions was announced in October of the same year. This report attempts to compare the hydrogen hub strategies of Europe and the US, which are arousing interest in each respective region.

1. IMPLICATIONS OF EUROPE AND THE US PROMOTING HYDROGEN UPTAKE

Since COP26 was held in Glasgow in the UK in 2021, Western countries have been more active in their climate change mitigation initiatives, such as through efforts to encourage parties to the Paris Agreement to submit updated nationally determined contributions (NDCs) to achieve the target of limiting the global rise in temperature to 1.5 degrees Celsius. The major trends toward decarbonization are energy conservation and electrification to maximize the introduction and use of decarbonized power sources such as renewable energy. For needs that cannot be met with electrification, consideration is being given to the use of hydrogen, and the carbon capture methods of carbon capture and storage (CCS) and direct air capture (DAC). Expected

[1] In a hydrogen hub, production, storage, transportation, and use of hydrogen, which is difficult to transport and store, are conducted in one specific region to help ensure safe and efficient utilization of hydrogen.

applications of clean hydrogen include use in industry as a low-carbon fuel and feedstock, as a fuel for fuel cells, sustainable aviation fuel (SAF), methanol, etc., and for grid stabilization in power generation. The main hydrogen classifications are listed in Figure 1.

Figure 1: Main classifications of hydrogen

Classification	Description	Clean hydrogen (Note)
Grey hydrogen	Hydrogen produced from fossil fuels such as natural gas and coal	×
Blue hydrogen	Hydrogen produced from fossil fuels such as natural gas and coal, but with reduced emissions, achieved by capturing the carbon dioxide emitted and through other means	○
Pink hydrogen	Hydrogen produced using nuclear energy	◎
Green hydrogen	Hydrogen produced without emitting carbon dioxide in the manufacturing process, such as by using renewable energy	◎

Note: Defined by carbon intensity (the amount of carbon emitted per unit of energy). In the US, "clean hydrogen" is defined as hydrogen that emits less than 2 kilograms of carbon dioxide, equivalent to producing 1 kilogram of hydrogen.
Source: Compiled by MGSSI based on materials of the US Department of Energy, Japan's Agency for Natural Resources and Energy, and others

2. STATUS OF HYDROGEN UPTAKE IN EUROPE

2-1. European hydrogen adoption targets and demand

In Europe, the EU Hydrogen Strategy adopted in July 2020 set a target of producing up to 10 million tons of green hydrogen annually in the region by 2030. In May 2022, after Russia's invasion of Ukraine, the EU announced its REPowerEU plan to shift dependence away from Russian fossil fuels by initiating imports of 10 million tons, in addition to the 10 million tons of intra-regional production, thereby increasing its hydrogen adoption target to 20 million tons (Figure 2).

Figure 2: Comparison of clean hydrogen-related plans of the US, Europe, and Japan

Item		EU	US	Japan
Annual hydrogen adoption target	2030	20 million tons (10 million tons from domestic production and 10 million tons of imports)	10 million tons	3 million tons
	2040	–	20 million tons	12 million tons
	2050	–	50 million tons	20 million tons
Major related policies		July 2020 Hydrogen Strategy May 2022 REPowerEU Plan	August 2022 Inflation Reduction Act June 2023 National Clean Hydrogen Strategy and Roadmap	December 2017 Basic Hydrogen Strategy June 2023 Basic Hydrogen Strategy (revised)
Anticipated main drivers of demand		Petroleum refining, industrial heating, transportation, petrochemical manufacturing (e.g., ammonia), steelmaking, synthetic fuel production, others (2030 forecast)	Petroleum refining, petrochemical manufacturing, others (2030 forecast) Over the long term, industrial processes, heavy-duty vehicles, and energy storage	Use of heat and raw materials in power generation, fuel cells, industry, etc.
Blast furnace to electric furnace ratio in steel production		56:44	31:69	73:27

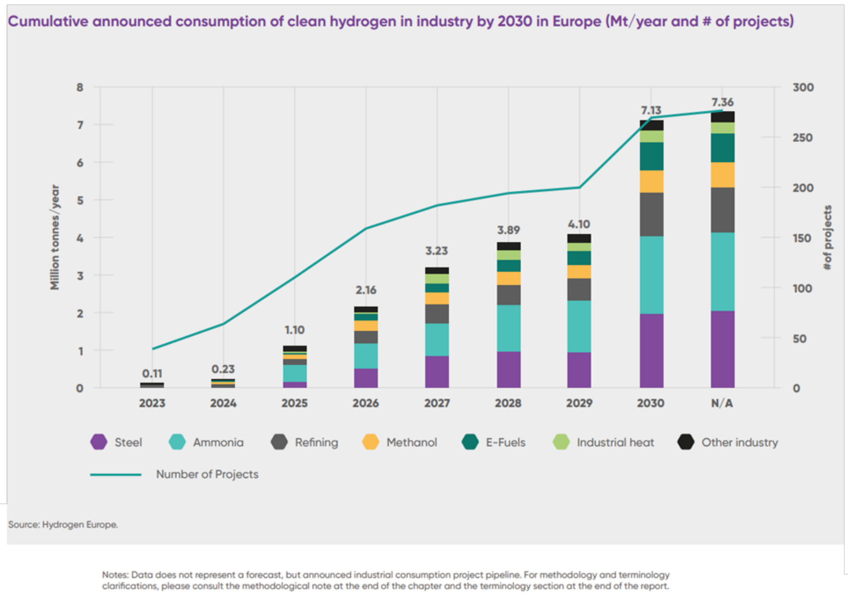
Source: Compiled by MGSSI based on materials of the European Commission, US Department of Energy, Japan's Agency for Natural Resources and Energy, etc.

Of the 20 million tons targeted for introduction, REPowerEU assumes demand of 17.6 million tons from industry in 2030, excluding for power generation and fuel use. However, in November 2023, Hydrogen Europe[2] announced that demand in industries with a backlog of projects is 7.1 million tons, far below the demand target

[2] An association representing the hydrogen industry and its stakeholders that promotes the use of hydrogen in Europe. It has in excess of 400 members, including more than 30 national associations from over 25 EU countries.

assumed by REPowerEU (Figure 3). This is because forecasts of demand have not kept pace with supply assumptions by REPowerEU, which has raised its supply targets in a hurry to both decarbonize and break Europe's dependence on fossil fuel imports from Russia. Analyzing the demand for hydrogen, it is interesting to note that the ammonia and steel industries are expected to account for approximately 2 million tons each in 2030, for a total of more than 4 million tons, or over 50% of demand. Hydrogen Europe's 2022 announcement showed that steelmaking alone would account for more than 50% of industrial demand, while the 2023 announcement shows a sharp increase in demand for ammonia production (this projected sharp increase in ammonia-related demand is very much indefinite because the projects are in the early conceptual stage and may disappear in the future). The main intended use of ammonia is not as a raw material for producing fertilizers or chemicals, but for use in transporting and storing energy, i.e., as an energy carrier. It is inferred that such transportation would be carried out by using ammonia as a carrier for hydrogen to transport hydrogen from Spain, Norway, and other countries to Germany and other markets where it is in demand. Steelmaking is expected to be a driver of demand because steelmaking plants in Europe have more blast furnaces than electric furnaces. As such, it is anticipated that there will be a push to introduce hydrogen-based steelmaking (use of hydrogen substituted for carbon as the reducing agent) to decarbonize the steel industry, and it is expected that demand will also be fueled by the forthcoming full-scale introduction of the EU Emissions Trading System (EU ETS).

Figure 3: Clean hydrogen demand in industry in Europe and number of projects (based on project announcements)



Source: Clean Hydrogen Monitor 2023（https://hydrogeneurope.eu/wp-content/uploads/2023/10/Clean_Hydrogen_Monitor_11-2023_DIGITAL.pdf）（accessed November 20, 2023）

2-2. Hydrogen hubs in Europe

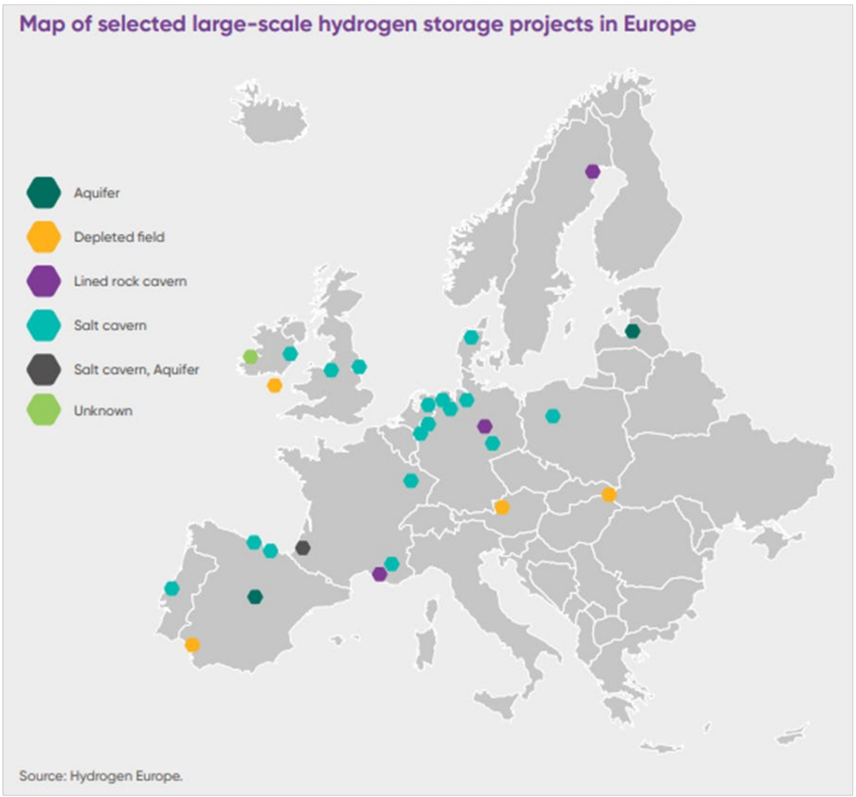
In Europe, since most of the demand is in Germany, the construction of large hydrogen hubs is being explored at ports around Germany, where large-volume hydrogen imports are under review.

Consideration is being given to importing using mainly ammonia as a carrier in suburban areas, such as the ports of Rotterdam in the Netherlands and Antwerp and Bruges (Zeebrugge) in Belgium; mainly using ammonia or liquid organic hydrogen carriers (LOHCs) in regions with a mixture of urban and suburban areas, such as the port of Hamburg in Germany; and primarily using LOHCs in urban areas, such as the port of Amsterdam. In addition to imports, production of hydrogen at these hubs is also being examined, and Shell has embarked on the construction of a 200-megawatt electrolyzer, one of the largest in the world, at the Port of Rotterdam, since reaching a final investment decision (FID) in 2022. Furthermore, in November 2023, Eneco, a subsidiary of

Mitsubishi Corporation, announced that it will build a green hydrogen plant (to ultimately have total installed electrolysis capacity of 800 megawatts).

The use of ammonia is suitable for the storage of hydrogen, which is imported in large quantities, because it liquefies at low pressure even at room temperature, and major Dutch infrastructure company Gasunie and others store ammonia as a substitute for hydrogen in storage tanks at their terminals. For storing hydrogen as it is, conversion of salt caverns used for natural gas storage and construction of new salt caverns are being considered (Figure 4).

Figure 4: Hydrogen storage under consideration in Europe



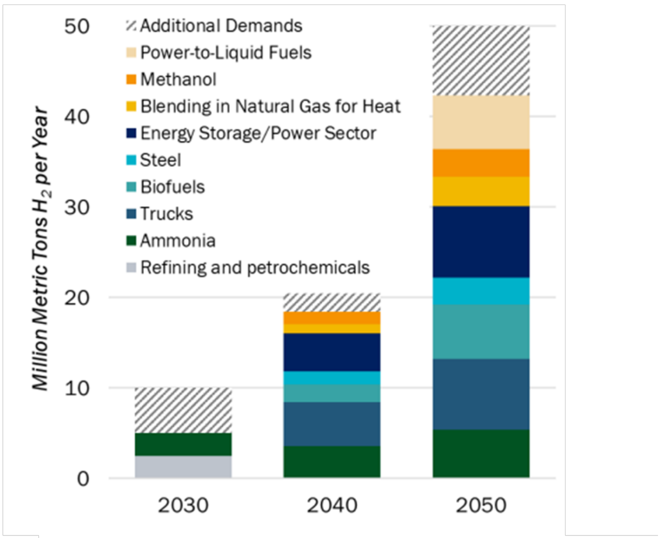
Source: Clean Hydrogen Monitor 2023（https://hydrogeneurope.eu/wp-content/uploads/2023/10/Clean_Hydrogen_Monitor_11-2023_DIGITAL.pdf）（accessed November 20, 2023）

3. STATUS OF HYDROGEN UPTAKE IN THE US

3-1. US hydrogen adoption targets and demand

As a means to achieving the goal of reducing greenhouse gas emissions by 50-52% below 2005 levels by 2030, the US released a draft report of its National Clean Hydrogen Strategy and Roadmap in September 2022, and the finalized report in June 2023. The Strategy and Roadmap targets annual clean hydrogen production of 10 million tons by 2030, which is equivalent to the amount of gray hydrogen currently produced in the US. The amount of known demand in 2030 will not change significantly from the current level, and the use of hydrogen for petroleum refining and ammonia production will continue to account for the bulk of that demand, while demand in 2040 is projected to include use for powering trucks, producing biofuels, storing energy/generating power, and manufacturing steel (Figure 5). Regarding steel-related demand, as electric furnaces account for a large proportion of furnaces at US steelmaking plants, demand for hydrogen for use in steelmaking is not as high as it is in Europe.

Figure 5: Projected US clean hydrogen demand

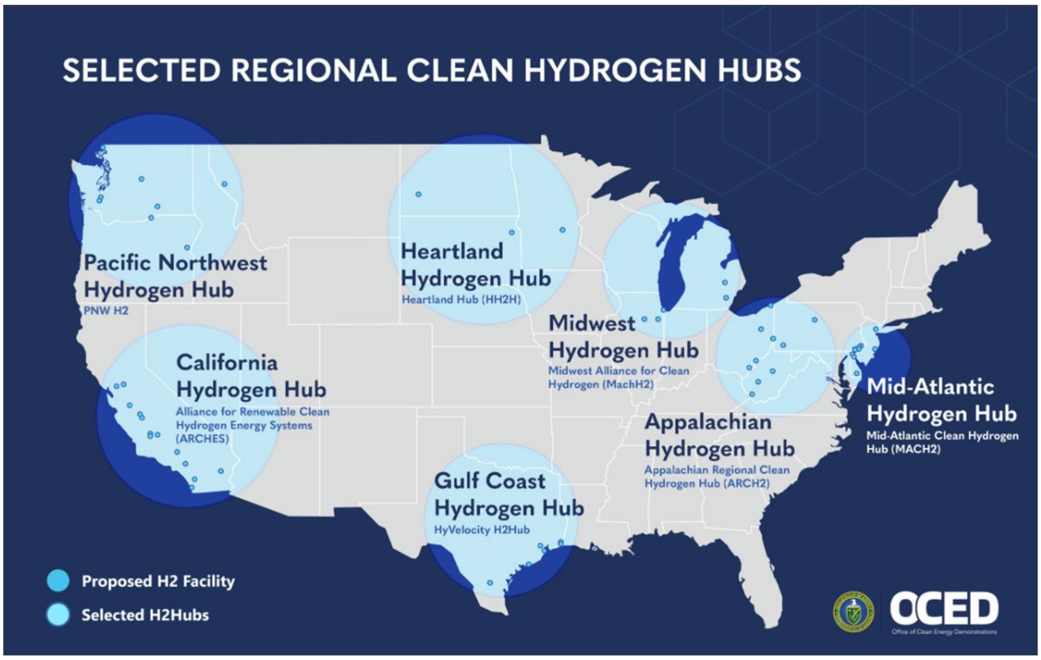


Source: US National Clean Hydrogen Strategy and Roadmap
(https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/us-national-clean-hydrogen-strategy-roadmap.pdf)
(accessed November 20, 2023)

3-2. Hydrogen hubs in the US

In the US, the Inflation Reduction Act of 2022 was passed in August of that year to provide tax credits for clean hydrogen production and investment. Previous to that, the Bipartisan Infrastructure Deal (Infrastructure Investment and Jobs Act) was passed in November 2021 to provide support for the establishment of clean hydrogen hubs, and in October 2023, the US announced the selection of hydrogen hubs in seven regions and funding totaling US$7 billion under the act (Figure 6).

Figure 6: Seven regions selected as hydrogen hubs in the US

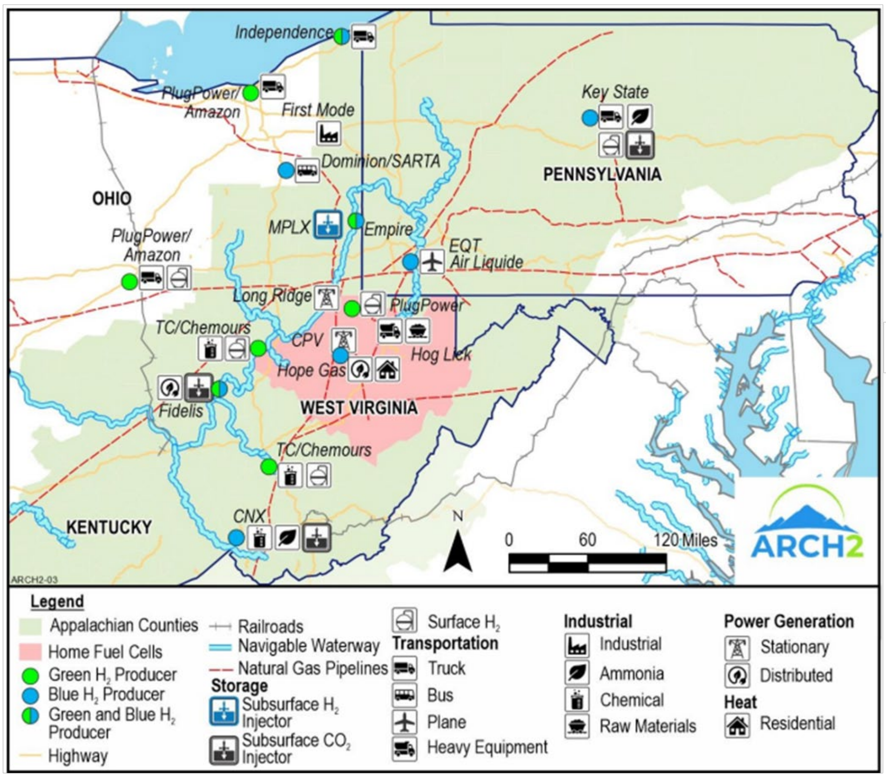


Source: OCED, DOE Regional Clean Hydrogen Hubs for Award Negotiations
(https://www.energy.gov/oced/regional-clean-hydrogen-hubs-selections-award-negotiations)
(accessed December 15, 2023)

The US hydrogen hub strategy is different from Europe's strategy in that the hubs are not intended to handle hydrogen imports, but rather, are distributed throughout the US where production is possible. For clean hydrogen production, two of the seven regions rely primarily on natural gas, three use electrolysis powered primarily by renewable energy or electricity from nuclear power or other sources, and the remaining two use a combination of mainly natural gas and electrolysis. Most of the hydrogen produced at the hubs is expected to be used to decarbonize the existing industrial sector.

The Appalachian Regional Clean Hydrogen Hub consortium is led by Battelle Memorial Institute[3] and has 15 other major project development partners, including EQT and CNX Resources, producers of natural gas; MPLX and TC Energy, which operate natural gas pipelines and undertake storage cavern projects; Dominion Energy, a gas and electricity retailer; and Air Liquide and Chemours, hydrogen-related companies (Figure 7). The region is capable of producing large volumes of natural gas at low cost, has good transportation infrastructure such as natural gas pipelines, railroads, and navigable waterways, and its depleted gas fields can be used for storing carbon dioxide. Therefore, it will promote a project of producing and using blue hydrogen through natural gas reforming. This will reduce carbon dioxide emissions by 9 million tons per year. The hydrogen produced will be used locally for producing ammonia and chemicals, as well as for powering fuel cell trucks and buses. The Adams Fork Energy ammonia project that was underway at the hub attracted much attention as it aimed to achieve an annual clean ammonia production capacity of 2.16 million tons (approximately double the annual ammonia consumption of Japan), but CNX Resources, with which the partnership was concluded, announced its withdrawal from the consortium in December 2023.

Figure 7: Appalachian Regional Clean Hydrogen Hub in the US

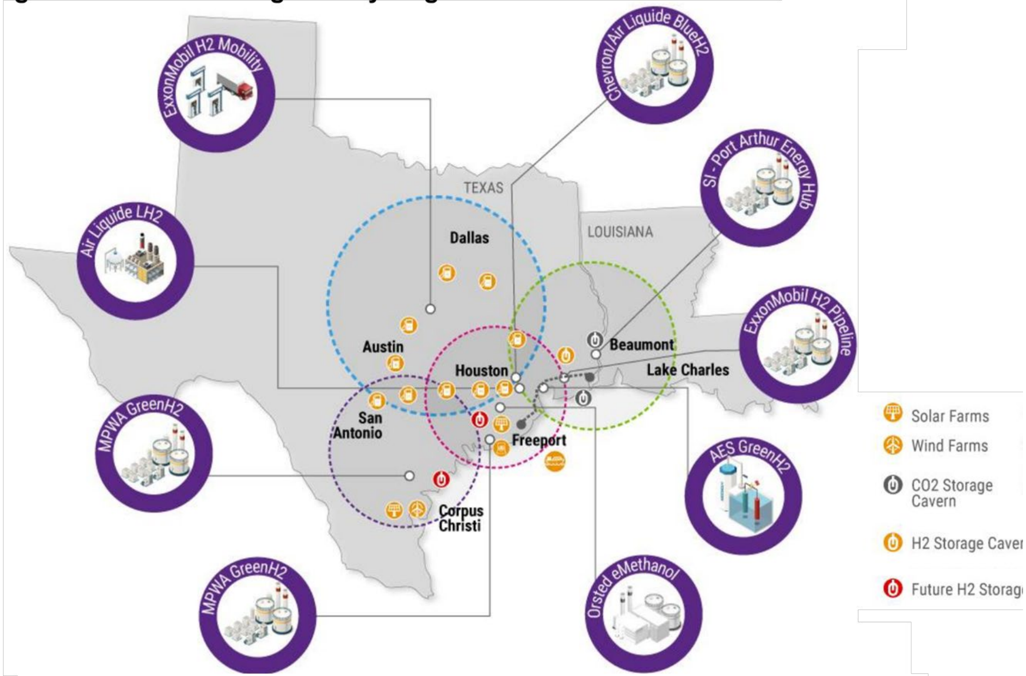


Source: OCED, DOE Regional Clean Hydrogen Hubs Appalachian Regional H2Hub Community Briefing (https://www.energy.gov/sites/default/files/2023-10/H2Hubs_Appalachian_Community_Briefing.pdf) (accessed December 15, 2023)

3 The institute was founded on the legacy of industrialist Gordon Battelle, who made a huge fortune in the steel industry. It focuses on research commissioned by the US government and corporations, and also undertakes contracted management of national laboratories in the US and the UK.

The Gulf Coast Hydrogen Hub extends from the area surrounding Houston, which has long been regarded as the energy capital of the US, to the Texas coast (Figure 8). The focus of the hub is the HyVelocity[4] project. Green hydrogen is produced from 36 gigawatts of wind power and 15 gigawatts of solar power, the largest renewable energy capacity in the US. Blue carbon is produced with a large supply of natural gas at low cost and over 24 gigatons of carbon storage capacity (about 10,000 times Houston's annual carbon emissions). The

Figure 8: US-Mexico regional hydrogen hubs



Source: OCED, DOE Regional Clean Hydrogen Hubs Gulf Coast Regional H2Hub Community Briefing (https://www.energy.gov/sites/default/files/2023-11/H2Hubs_Gulf_Coast_Community_Briefing.pdf) (accessed December 15, 2023)

project aims to produce green hydrogen through electrolysis and blue hydrogen through natural gas reforming and carbon capture on a large scale. In addition to this, over 1,000 miles of dedicated hydrogen pipelines and hydrogen storage caverns will be used to supply clean hydrogen to more than 17 offtakers. Major applications include fuel cell trucks, industrial processes, ammonia production, refineries, chemical manufacturing, and marine fuels such as low-carbon methanol. The project is aimed at cutting carbon dioxide emissions by 7 million tons per year.

4. IMPLICATIONS FOR JAPAN

The adoption of hydrogen in Japan, which announced a revised Basic Hydrogen Strategy in June 2023, will be centered on imports rather than production. Europe's hydrogen hubs will thus serve as a reference. However, underground hydrogen storage cannot be achieved easily in Japan because there are few salt caves and depleted gas fields, and there are also many earthquakes. Since plans call for the procurement of large volumes of ammonia for power generation purposes, ammonia stored at a hub with a power plant at its core, for example, could be utilized in other regional areas in Japan. Furthermore, it is efficient to procure hydrogen and ammonia at large-scale industrial complexes and utilize them in other areas, as evidenced by the announcement in August 2023 by four companies, including Mitsui & Co., of the start of their discussions on the construction of a hydrogen and ammonia supply network based in the Osaka waterfront industrial zone. It is thus conceivable that sites for domestic hydrogen hubs may be selected from this perspective. In addition, since low cost and abundant

[4] An industry-led collaborative organization of more than 90 stakeholders, including the following seven core project sponsors: AES Corporation, Air Liquide, Chevron, ExxonMobil, Mitsubishi Power Americas (a subsidiary of Mitsubishi Heavy Industries), Orsted, and Sempra Infrastructure.

supplies of hydrogen are difficult to obtain, decarbonization in steel production is expected to proceed not only through the use of hydrogen in blast furnaces, but also in combination with a switch to electric furnaces.