March 11, 2024

Challenges and solutions to deploying floating offshore wind power in Japan (2)

Floating Offshore Wind Power as an Industrial Policy

Kan Sichao, Hiroko Nakamura, Takahiro Nagata, Yoshiaki Shibata

The Institute of Energy Economics, Japan

Introduction

Given Japan's small land area and limited land for renewable energy, offshore wind power generation is a promising technology for the massive introduction of renewable energy. However, the waters surrounding Japan have limited sea area with a depth of 50-60m, which is suitable for mature fixed-bottom offshore wind power technologies; and therefore, floating offshore wind power technologies are called for. In addition, Japan has an urgent need to harness offshore wind power in its Exclusive Economic Zones (EEZs), which is one of the largest in the world.

The Japanese government, in its Working Group of Experts for the Realization of GX, has also stated its intention to "to ensure predictability for operators and promote domestic and foreign investment by setting up targets specifically for floating offshore wind power." A concrete industrial strategy focused on floating offshore wind power is increasingly called for.

While demonstration projects are necessary to establish the technology, the floating offshore wind power demonstration projects currently considered, including the Green Innovation Fund Phase 2 (floating offshore wind pilots) are too small in scale to attract foreign wind turbine manufacturers, who are developing projects over 300-500MW. In order to advance floating offshore wind power in Japan, it is essential to offer foreign wind turbine manufacturers a clear picture that Japan has a huge and promising market. Therefore, it is important that in addition to technology demonstrations, commercial full-scale projects be launched based on established technology.

This report is the second in a series of three articles on the challenges and prospects for the introduction of floating offshore wind power in Japan: "Developing offshore wind power in the Exclusive Economic Zone," "Floating Offshore Wind Power as an Industrial Policy," and "Toward the Massive Deployment of Floating Offshore Wind Power in Japan".

1 Technical barriers to massive offshore wind deployment

Japan has limited land area with vast mountain coverage, which limits the installation of wind farms on land, but offshore wind power is a promising technology for large-scale deployment in Japan, which is surrounded by the ocean. In particular, Japan's territorial waters and exclusive economic zones (EEZ) together have the sixth largest area in the world, and studies have shown that if the EEZ is included, Japan's offshore wind power potential could reach 500-900 GW[1][2]. However, even in waters within 10 km of the coastline, much of Japan's territorial sea is deeper than 50-60 m[3], exceeding the depth suitable for bottom-fixed offshore wind turbines.

---

[1] Renewable Energy Institute (2023), "[Analysis Report] Japan's Offshore Wind Power Potential: Territorial Sea and Exclusive Economic Zone", https://www.renewable-ei.org/en/activities/reports/20231219.php

[2] EX Research Institute, Asia Air Survey (2020), "Report on the Commissioned Work for the Development and Publication of Basic Zoning Information on Renewable Energy in Fiscal Year 2019", Ministry of the Environment, https://www.renewable-energy-potential.env.go.jp/RenewableEnergy/report/r01.html

[3] Hiroshi Nagai, Tatsuya Ikegaya, Masaharu Itoh, Toru Nakao (2010), "Offshore Wind Power Potentials in Japanese Coastal Waters," *Journal of JWEA* Vol.34, No.1, https://www.jstage.jst.go.jp/article/jwea/34/1/34_103/_pdf

The EEZ is even deeper; and therefore, floating offshore wind technology is needed. This technology involves keeping a floating foundation in position using a mooring system.

Floating offshore wind power generation has already entered the commercialization stage in Europe and other countries. However, compared to onshore wind power and bottom-fixed offshore wind power, there are fewer examples of its installation; and therefore, there are not only technological challenges but also engineering and cost issues pertaining to the relevant infrastructure and installation

1.1 Technological challenges of floating offshore wind power

A floating wind farm comprises wind turbines, floating platforms, mooring cables/anchors, electric power cables, substations, and other components. The following subsections discuss the challenges and potential solutions regarding major components.

1.1.1 Floating foundations and wind turbines

For floating offshore wind power, the current mainstream structure consists of a horizontal axis wind turbine mounted on a floating foundation. Although floating wind turbines need to be designed to take wave and surge motion into account, horizontal-axis wind turbines are often applied because they are widely used in both onshore and fixed-bottom offshore wind power generation systems. The development of floating offshore wind power has been actively promoted in the United Kingdom and other countries. It is necessary to determine the most appropriate type of floating foundation, taking into account the water depth, seabed features, environmental conditions, social conditions such as fisheries, and the frequency of earthquakes and tsunamis of each ocean area.

In 2021, the top five wind turbine suppliers in the world, including both onshore and offshore wind power, were Vestas (Norway, 17.7%), Goldwind (China, 11.8%), Siemens Gamesa (Spain, 9.7%), Envision (China, 8.6%), and GE Renewable Energy (U.S., 8.5%), collectively accounting for over half of the global market.[4] Thus, due in part to the limited number of manufacturers that can supply wind turbines, offshore wind construction often involves different suppliers for wind turbines and floating foundations. For example, at the Hywind Scotland floating offshore wind farm off the coast of Scotland which began commercial operation in 2017 as the world's first floating offshore wind farm, the main operator is Equinor (then Statoil), with Siemens Gamesa supplying the wind turbines, the foundation, Aibel supporting the engineering and procurement of the foundations, towers, and mooring systems, and Navantia-Windar manufacturing the floating foundation.[5]

Currently, there are no large-scale wind turbine manufacturers in Japan and therefore, Japan needs to rely on foreign manufacturers for wind turbines in developing offshore wind power. While international competition may make it difficult to develop a domestic wind turbine industry in the future, as the world's third largest shipbuilder, Japan has a strong foundation in shipbuilding technology and excellent quality control[6], and can thus strategically foster domestic companies that specialize in this field to lead both domestic and overseas markets. However, it should be noted that competition in the floating foundation market is also expected to intensify in the future, as new technologies are being developed outside of Japan; for example,

---

[4] GWEC (2022), “Global Wind Development Market Supply Side Data 2021”, https://gwec.net/wind-turbine-suppliers-see-record-year-for-deliveries-despite-supply-chain-and-market-pressures/

[5] JETRO Research Department, London Office (June 2023), “Study on Offshore Wind Supply Chain Trends in the UK - Part 1: General Discussion: Supply Chain”, https://www.jetro.go.jp/ext_images/_Reports/01/80a7a99f692a5876/20230010_02.pdf

[6] Public-Private Council for Enhancing the Industrial Competitiveness of Offshore Wind and NEDO (April 1, 2021), "Technology Development Roadmap for Enhancing the Industrial Competitiveness of Offshore Wind", https://www.enecho.meti.go.jp/category/saving_and_new/saiene/yojo_furyoku/dl/roadmap/roadmap20210401.pdf (accessed in January 2024)

Gazelle Wind Power[7] is developing floating structures with a dynamic mooring system that responds to waves so that the platform can move horizontally and vertically to minimize tilting.

1.1.2 Mooring systems

Steel anchor chains are currently often used for offshore mooring systems. However, in Japan's surrounding waters and EEZ, the water is deeper, thus increasing the weight of mooring cables. This makes their manufacturing and transportation challenging. This issue is being addressed by considering the possibility of using synthetic fiber cables[8]. Synthetic fiber cables are lightweight and can be reeled, reducing the size of offshore wind vessels and the space required for cargo handling. Synthetic fibers have different physical properties, including water resistance, elongation, and strength, depending on the material used; and therefore, it is necessary to select the material in accordance with the conditions of use. Japanese manufacturers already have experience supplying synthetic fibers for mooring cables for floating offshore wind in the U.K.[9]. Furthermore, in Japan, a hybrid mooring system using both steel chains and synthetic fiber ropes is being tested off the coast of Akita.[10]

Floating offshore wind turbines also have significant mooring costs on the seafloor in deep water. Therefore, not only developing materials but also the new mooring system is being considered. Several studies have concluded that the introduction of a shared mooring system, in which mooring ropes and anchors are shared among multiple wind turbines, not only reduces the number of components required, but also saves installation costs, thus leading to reduced mooring costs[11],[12]. Equinor's Hywind Tampen project adopts a shared anchor system using 19 anchors for the mooring of 11 wind turbines, demonstrating a significant reduction compared to Hywind Scotland, which follows a conventional design that uses 15 anchors for 5 wind turbines.

1.1.3 Transmission lines

Floating offshore wind farms tend to be located further offshore than fixed-bottom systems, and the longer distance poses a challenge in terms of power transmission. In the case of 230 kV alternating current (AC) cables, the transmission distance will be limited to 30-50 km due to the large transmission loss caused by the distance. With direct current (DC) cables, there is less loss over long distances and cables can be made thinner than in the case of AC cables. However, the substations will need to be larger, thus increasing the associated costs.

Major technical challenges in floating offshore wind power transmission cables are installing them at large depths and handling turbulence. Based on experience with conventional submarine power cables, installation at depths of up to around 300 m is feasible. Currently, cables that can be laid in deep waters of 1500 m below water level are under development for floating offshore wind power systems in waters with greater water

---

[7] Gazelle Wind Power website, https://gazellewindpower.com/what-we-do/technology/ (accessed in January 2024)

[8] Toshiki Nakajo (2021), "Designing Mooring Systems with Synthetic Fiber Cables for Floating Offshore Wind Power", (Institute of Maritime, Port and Aeronautical Technology, Research Presentation) https://www.mpat.go.jp/pdf/202112_2.pdf ,

[9] Wind Journal (March 6, 2023), " World's first! Synthetic fiber cables are used for TLP type floating offshore wind power generation. Reduce costs by reducing weight", https://windjournal.jp/115617/#

[10] Japan Marine United (August 30, 2022, press release) “Scale Model Testing for Hybrid Mooring for the GI Fund Project "Development of Technology and Construction Technologies for Semi-Submersible Floating and Hybrid Mooring Systems,” https://www.jmuc.co.jp/news/assets/windfarm_scalemodel_20220830.pdf

[11] Hang Xu et al (2024), “Shared mooring systems for offshore floating wind farms: A review,” Energy Reviews Volume 3, Issue 1, March 2024, https://www.sciencedirect.com/science/article/pii/S2772970223000500

[12] NREL (2022), “Shared Mooring Systems for Deep-Water Floating Wind Farms: Final Report” prepared for National Offshore Wind Research and Development Consortium, https://nationaloffshorewind.org/wp-content/uploads/142869_Final-Report.pdf

depth[13] along with dynamic cables that can withstand dynamic motion caused by waves and tidal currents[14]. Efforts are also being made to improve the manufacturability and cost and facilitate the installation of submarine power cables[15]. A Japanese company[16] leads the world in submarine DC cable manufacturing by developing unique materials; and therefore, Japan promises to have an advantage in this area.

1.1.4 Emerging technologies

New types of wind power generation are being developed in order to find solutions to various technological obstacles. Many of these new approaches are being made by startups.

World Wide Wind's Counter-Rotating Vertical Axis Turbine (CRVT) has an upper and lower turbine vertically set up that counterrotate, thus increasing the power generated. Furthermore, the lower wake turbulence reduces the impact on other wind turbines located downstream; and therefore, the distance between turbines can be reduced.[17]

The wind turbine blades of Albatross Technology's floating axis wind turbine (FAWT)can be manufactured in lengthwise sections with the same cross-sectional shape, which enables mass production using an automated continuous manufacturing process. Additionally, this design eliminates the need for large-scale manufacturing factories and facilitates transport. Therefore, it is suitable for production and transport in Japan, where limited land and accessible roads make it difficult to secure manufacturing yards and transport. [18] Albatross Technology has signed a joint research agreement with J-Power, TEPCO, Chubu Electric Power, and Kawasaki Kisen Kaisha in May 2023, and the Development Bank of Japan (DBJ) invested in the project in December 2023, acknowledging the cost reductions expected from eliminating the need for large vessels and domestic procurement of blade materials[19].

These technologies are yet to be fully developed[20] and a variety of issues must be resolved through pilot demonstrations before they can be scaled up and commercialized. Yet, there are examples of emerging companies entering the market; Hexicon, a company specializing in offshore wind power founded in 2009 was awarded a project at TwinHub (U.K) that will use its "TwinWind" technology which mounts two wind turbines on one floating foundation[21]. It will be important to take prompt actions to welcome new technologies with a spirit of trial and error and to develop a policy instrument to help support them.

---

[13] Ryosuke Kuwahara et al. (2022), " Technological Trends, Development Tasks and Initiatives for Submarine Power Cable Systems: Contribution to the Achievement of SDGs", *Furukawa Electric Jiho* No. 141, April 2022, https://www.furukawa.co.jp/rd/review/fj141/fj141_08.pdf

[14] Ryota Taninoki et al. (2017), "Dynamic Cable System for Floating Offshore Wind Power Generation," *SEI Technical Review*, No. 190, January 2017, https://sei.co.jp/technology/tr/bn190/pdf/190-09.pdf

[15] Yukito Ida, et al. (2022),"Characteristics of Water Tree in Submarine Cable (Wet-Design) for Offshore Wind Power Generation" *Sumitomo Electric Technical Review* No. 200, January 2022, https://sumitomoelectric.com/jp/sites/japan/files/2022-01/download_documents/J200-07.pdf

[16] Sumitomo Electric Industries, Ltd. website, "DC Submarine Cable." https://sumitomoelectric.com/jp/products/submarine-cable

[17] World Wide Wind website, https://worldwidewind.no/pages/technology

[18] Albatross Technology, Inc. website: https://www.albatross-technology.com/

[19] DBJ (December 6, 2023, press release), "Investment in Albatross Technology, Inc.-Supporting the development of 'floating axis wind turbines,' a new option for floating offshore wind turbines", https://www.dbj.jp/topics/dbj_news/2023/html/20231206_204574.html

[20] These floating offshore wind turbines are small-scale, and some concepts use aluminum instead of steel for the towers and wood for the floating structures. Aluminum is easier to recycle than steel, despite possible issues regarding the strength of the material. Using domestic wood could contribute to building a domestic supply (see Chapter 3).

[21] Searade Maritime News (July 8, 2022), "Hexicon wins 15-year package for Celtic Sea floating wind project," https://www.setrade-maritime.com/offshore/hexicon-wins-15-year-package-celtic-sea-floating-wind-project

1.2 Developing industrial strategies

The development of floating offshore wind power has significantly more components and thus involves a vast number of stakeholders compared to onshore and fixed-bottom offshore wind. Although Japan currently has no large-scale wind turbine manufacturers, there is potential for floating offshore wind power-oriented industrial development led by other industries where Japan can exert its strengths: the shipbuilding and construction industries; for mooring cables, the steel industry and chemical industry, including manufacturers of synthetic fibers; for submarine cables, the electric wire manufacturing industry; and for assembly and installation, the shipbuilding, construction, and marine civil engineering industries. Furthermore, startups are developing technologies based on new concepts. The Netherlands, Spain, and Taiwan also have no wind turbine manufacturers, but are nevertheless developing strategies to seize global market share while domestically promoting their offshore wind power through developing base ports for offshore wind power and fostering and promoting peripheral industries[22]. This may serve as a reference for promoting floating offshore wind power in Japan.

The Japanese government, in its Working Group of Experts for the Realization of GX[23], has also stated its intention to "to ensure predictability for operators and promote domestic and foreign investment by setting up targets specifically for floating offshore wind power." A concrete industrial strategy focused on floating offshore wind power is called for.

While demonstration projects are necessary to establish the technology, the floating offshore wind power demonstration projects currently considered, including the Green Innovation Fund Phase 2 (floating offshore wind pilots)[24] are too small in scale to attract foreign wind turbine manufacturers, who are developing projects over 300-500MW[25]. In order to advance floating offshore wind power in Japan, it is essential to offer foreign wind turbine manufacturers a clear picture that Japan has a huge and promising market. Therefore, it is important that in addition to technology demonstrations, commercial full-scale projects be launched based on established technology. In fact, with announcements of GW-scale projects overseas, floating offshore wind power is shifting from the technology-push phase to the market-pull phase.

Enhancing the domestic supply chain will not only create jobs and contribute to economic growth but reduce the impact of global supply constraints that may occur due to increased global demand. In this regard, it is important that the Japanese government formulate a detailed industrial strategy, addressing offshore wind power as an important pillar of its economic and industrial policy, in addition to achieving cost reductions in offshore wind power as part of its energy policy.

2 Supply chain challenges and solutions

2.1 Security issues

The invasion of Ukraine by Russia has renewed awareness of the importance of energy and economic security. China currently accounts for more than half of the global wind turbine production[26]. Chinese-

---

[22] Tetsuro Nagata (2019), "Strategies for Countries without Wind Turbine Manufacturers," Research Project on Renewable Energy Economics No. 139 (August 1, 2019), Graduate School of Economics, Kyoto University, https://www.econ.kyoto-u.ac.jp/renewable_energy/stage2/contents/column0139.html

[23] Cabinet Secretariat GX Office (2023), "Investment Strategies by Field (5)" material delivered at the Fifth Meeting of the Expert Working Group for the Realization of GX (December 7, 2023), https://www.cas.go.jp/jp/seisaku/gx_jikkou_kaigi/senmonka_wg/index.html

[24] METI (October 3, 2023, press release), *op. cit.*

[25] Based on interviews with domestic offshore wind power stakeholders. Regardless of the project scale, the manpower and costs required for the front-end engineering and design (FEED) are not so different; and therefore, smaller projects are less cost efficient and are less attractive.

[26] GWEC (2022), *op. cit.*

manufactured wind turbines can be more attractive when cost is prioritized. However, excessive dependence on a particular country for products raises concerns about risks to stable supply in the event of supply chain disruption. While economics is an important factor in deploying offshore wind power, the energy and economic security perspective must not be forgotten.

There are other security challenges. While the operation and maintenance (O&M) of solar power systems can be conducted by parties other than the panel manufacturer, wind farms often depend on wind turbine manufacturers for maintenance and other services[27]. When wind turbines are supplied by a certain manufacturer or when their maintenance services are provided by a particular company, they will risk suspension of the remote monitoring system, and consequently massive power outages[28]. Furthermore, if they are controlled remotely by a foreign wind turbine manufacturer, they will risk suspension that will be difficult to recover in the event of war or other contingencies. The risk level will be particularly high in the case of large-scale offshore wind farms; and therefore, careful consideration is called for when relying on foreign manufacturers for the O&M of wind farms. In addition, the installation of wind turbines by a foreign manufacturer would also offer them the opportunity to survey the seafloor of Japan's waters, which could lead to defense-related issues.

While it is currently difficult to build a supply chain consisting entirely of domestically produced goods, the ratio of domestically produced goods should be increased as much as possible to address the security challenge. The U.S. has placed restrictions on Chinese solar PV imports and the tax incentives of the Inflation Reduction Act (IRA) are designed to promote internal production[29]. With a target to achieve a 60% domestic procurement ratio by 2040[30], the Japanese offshore wind power industry is currently building the foundations and nacelles for fixed-bottom offshore wind power, as well as the vessels needed for construction and O&M[31]. The Japanese government is also aiming to establish a domestic manufacturing supply chain through the GX Supply Chain Establishment Support Project[32].

It is also important to develop and secure the human resources essential for domestic manufacturing. The Japanese government is also providing support for the creation of curricula and the development of training facilities for training engineers and specialized workers for the offshore wind power industry[33]. Given that engineers are currently concentrated in fixed-bottom type, human resource development for the floating offshore wind power type is also called for in the future. Such human resource development projects will also contribute to reskilling workers from existing industries that may decline in the path towards decarbonization.

---

[27] Kunihiko Toda and Shoko Takaragawa (2021), "Offshore Wind Power Projects in Japan - Points to Consider in Light of Differences with Europe", *Sompo Japan RM Report* 221, November 22, 2021, https://image.sompo-rc.co.jp/reports/r221.pdf

[28] For example, in Europe, major wind turbine makers Enercon and Nordex, as well as Deutsche Windtechnik AG, a company specializing in the maintenance of wind turbines have experienced cyber-attacks.（WSJ Pro (April 25, 2022), "European Wind-Energy Sector Hit in Wave of Hacks", https://www.wsj.com/articles/european-wind-energy-sector-hit-in-wave-of-hacks-11650879000）

[29] JETRO (April 3, 2023), "Import Restrictions on Chinese Products Create Headwind for Tight U.S. PV Supply and Demand (Part 2)," *JETRO Area Report*, https://www.jetro.go.jp/biz/areareports/2023/f21b8789fbc9baa0.html (accessed in January 2024)

[30] Public-Private Council on Enhancement of Industrial Competitiveness for Offshore Wind Power Generation (2020) *op. cit.*

[31] ANRE (September 8, 2023), "Next-Generation Technologies Related to Renewable Energy," Document 1 delivered at the 54th meeting of the Subcommittee on Mass Introduction of Renewable Energy and Next-Generation Electricity Networks, Committee on Energy Efficiency and Renewable Energy/Subcommittee of Electricity and Gas Industry, Advisory Committee for Natural Resources and Energy, METI, https://www.meti.go.jp/shingikai/enecho/denryoku_gas/saisei_kano/pdf/054_01_00.pdf)

[32] METI (September 4, 2023), "GX Support Measures Expenses" (List of presentation materials for METI FY2024 budget request), https://www.meti.go.jp/main/yosangaisan/fy2024/pr/gx/keisan_gx_01.pdf,"

[33] ANRE (September 8, 2023), *op. cit.*

2.2 Building a domestic supply chain: materials and recycling

The supply chain for floating offshore wind, includes study and design, port development, manufacturing wind turbines, floating foundations and other equipment, shipping equipment and components, assembly and installation of turbines and transmission lines (submarine cables), operation and maintenance, and decommissioning. Japan has no domestic manufacturing base for wind blades and lacks the experience in the offshore oil and gas operations that many North Sea countries possess. Yet, there are many Japanese companies with individual elemental technologies along the supply chain.

It is essential from an economic and energy security perspective that most of the supply chain be covered domestically, while improving and reducing the cost of current technologies, and at the same time exploring new technologies to solve challenges unique to Japan, such as land constraints related to manufacturing and transporting equipment. Stronger incentives should be provided for building factories and supply chains in Japan to encourage domestic manufacturing and procurement.

It is also important to enhance recycling and reuse efforts. For some time now, concerns have been raised regarding the mass disposal of solar and wind power generation, and the need for recycling and reuse has been pointed out in light of properly disposing industrial waste[34,35]. A supply chain with enhanced domestic recycling and reuse can contribute not only to the development of a circular economy and the enhancement of sustainability through the reduction of industrial waste load, but also to security. Not all components of a floating offshore wind power turbine can be recycled or reused, but it will help retain critical resources within Japan and reduce imports, thus contributing to enhancing economic and energy security. In addition to technological development, economic support measures, and regulations, it will be important to draw a picture in which venous industries, especially recycling, contributes to the promotion of domestic industry and the economy.

In order to promote the development of floating offshore wind power in Japan and to increase the involvement of domestic players, the Japanese floating offshore wind power market must be more attractive not only to foreign companies but also to domestic companies. This will require a clear demonstration by the government that it is committed to promoting floating offshore wind as a major pillar of its industrial development policy.

2.2.1 Turbine blades

Glass fiber reinforced plastics (GFRP) have conventionally been used for turbine blades, but as blades become larger in size, stiff carbon fiber reinforced plastics (CFRP) have become mainstream in order to avoid the risk of blade damage from collisions with the tower due to wind-induced blade deflection[36]. CFRP is widely used in aircrafts, automobiles, industrial equipment, and daily necessities. While it is mostly treated as industrial waste after used and sent to landfills, there are efforts to recycle CFRP in Japan[37,38,39]. There are a

---

[34] MRI (2015), "Report on the Commissioned Work for the FY 2014 Pilot Study on the Promotion of Recycling Used Renewable Energy Facilities" (FY2014 project Commissioned by the Ministry of the Environment) https://www.env.go.jp/content/900535821.pdf

[35] ANRE (July 24, 2018), "Massive waste solar panels in 2040? Renewable waste issues", https://www.enecho.meti.go.jp/about/special/johoteikyo/taiyoukouhaiki.html

[36] Note that CFRP is used for turbine blade girders, but GFRP is also used for blade surfaces.

[37] Toru Kamo (2018), "Current Status and Challenges of Recycling Carbon Fiber Reinforced Plastics (CFRP)" *Journal of the Japan Society of Material Cycles and Waste Management*, Vol. 29, No. 2, pp. 133- 141, https://www.jstage.jst.go.jp/article/mcwmr/29/2/29_133 /_pdf

[38] International Aircraft Development Fund (2018), "Reuse Technology for Recycled Carbon Fiber", Aircraft International Development Fund [Explanatory Overview 2022-4], http://www.iadf.or.jp/document/pdf/2022-4.pdf)

[39] Toray website, "Recycling", https://www.cf-composites.toray/ja/aboutus/sustainability/recycling.html)

variety of CFRP recycling methods, but most involve removing CFRP resin by pyrolysis or chemical decomposition, from which only carbon fiber is recovered. It is difficult to reuse CFRP for its original application because CFRP is cut into smaller pieces in an earlier process and cannot be restored to its original length, and because the mechanical properties of recycled CFRP can be more diversified than that of unused materials. Therefore, at present, recycled CFRP is mostly used for concrete reinforcement or in injection molded or press-molded products.

Outside of Japan, there are a number of initiatives dedicated to the recycling of wind turbine blades as a measure to address waste from the future replacement of components of the rapidly expanding wind turbine fleet[40]. Although "blade to blade" recycling is currently difficult for some materials, advancements have been seen in various efforts, including technology development: and therefore, future trends in the recycling field needs to be closely followed.

2.2.2 Towers

Since towers are made of steel, they can be fed into electric furnaces as scrap after use to manufacture new products, but it is said that the problem of impurities in the tower paint and other materials makes it difficult to transform them into products that meet the quality standards required for offshore wind towers. On the other hand, in recent years, there have been efforts[41],[42] to produce high-grade steel in electric furnaces, and if quality can be ensured through future technological development, there is a possibility that the steel could be reused for offshore wind towers. If this happens, an intra-regional circulation of steel will be formed with offshore wind power bases at the core, contributing to a stable supply of materials and strengthening security.

2.2.3 Rare metals

Neodymium magnets are often used as permanent magnets in wind power generators. The production of neodymium, a rare metal, and neodymium magnets is highly dependent on China. The Ministry of Economy, Trade and Industry's "Policy on Initiatives to Secure a Stable Supplies of Permanent Magnets"[43] states the need to strengthen neodymium magnet manufacturing facilities and recycling facilities in Japan. The policy sets the goal of securing production capacity to meet domestic demand expected in 2030 for manufacturing and doubling the recycling capacity from 2020 levels in 2030. In addition, Japan aims to develop neodymium magnet alternatives and neodymium magnets that can halve the amount of neodymium used within the next

---

[40] Wind Europe (February 12, 2020), "Circular Economy: Blade recycling is a top priority for the wind industry" https://windeurope.org/newsroom/news/blade-recycling-a-top-priority-for-the-wind-industry

[41] Denki Shimbun (October 4, 2019), "Carbon-free steel manufacturing with technological innovations in electric furnaces" https://www.denkishimbun.com/sp/45183

[42] Japan Metal Bulletin (May 30, 2022), "JFE Metal to produce high-quality metal in electric furnace: capital investment in Sendai for mass production" https://www.japanmetal.com/news-t20220530118316.html

[43] METI (January 19, 2023), "Policy on initiatives to secure stable supplies of permanent magnets" https://www.meti.go.jp/policy/economy/economic_security/magnet/magnet_hoshin.pdf

five years. Various rare metal recovery technologies are under development in Japan by companies including I'MSEP[44], CMC Technology[45], and Suzuki Shokai[46].

2.2.4 Challenges in recycling and reusing wind turbines

Even if "turbine to turbine" recycling is difficult, recycling turbines for other applications will contribute to security from a macro perspective. Introducing environmentally friendly design based on recyclability and including recycling efforts as an evaluation point in the criteria for selecting of offshore wind power developers can contribute to promoting recycling and reuse. Furthermore, from a recycling perspective, it may also be necessary to change the structure of floating offshore wind power facilities. If we aim to establish a domestic flow of manufacturing, use, disposal, transportation, and recycling, the unique solution for Japan may be to pursue mass production and recyclability by downsizing and introducing sub-assembly manufacturing, rather than following the global trend of building larger wind turbines.

It is also important to address recycling as an opportunity not only to enhance economic security but also to contribute to Japanese industry and economy. To this end, specific strategies should be developed for industrial promotion policies that promote not only the arterial industry, but also the venous industry based on recycling. For example, for neodymium magnets, used generators and motors are currently exported and recycled in Thailand for economic efficiency, but a strategy to develop domestic industry by establishing a system to domestically circulate these materials is also required.

2.3 Infrastructure-related challenges

Floating platforms are key to developing floating offshore wind power. Western oil majors can utilize the offshore platform-related technology and know-how acquired in drilling oil and natural gas fields offshore to date in the development of floating offshore wind and substations. New floating offshore wind platforms are also being developed[47]. Although Japan lacks offshore platform-related technologies, it possesses shipbuilding and engineering technologies that can serve as the basis of platform technologies, and it is important to build on these strengths to these to quickly enhance its technological capabilities in this field.

Using foreign Self Elevating Platform (SEP) vessels for floating offshore wind power construction will involve supply-demand balance issues. Growing global demand will make it difficult to stably secure SEP vessels; and therefore, it is essential to promote domestic production. It is significant that Shimizu Corporation and Japan Marine United have manufactured one of the world's largest SEP vessels[48].

---

[44] I'MSEP has developed a selective recovery process for recovering rare earth metals from neodymium magnets by molten salt electrolysis, thus avoiding the conventional high-temperature pretreatment at more than 1000°C and the large consumption of acid and alkali. (I'MSEP website "Recycling rare metal, rare earths" http://www.imsep.co.jp/recycle_rare_earth_element/)

[45] CMC Technology Development Co., Ltd. website, http://www.cmctd.co.jp

[46] Suzuki Shokai seeks to use AI technologies to classify used motors based on image analysis, recover rare metals such as neodymium, and recycle them to a reusable grade in Thailand. (Japan Metal Daily (November 6, 2023), "Suzuki Shokai, Hokkaido's major metal recycling business initiates development of neodymium recycling technologies: Awarding of NEDO funds to establish a rational manufacturing process harnessing AI technologies,") https://news.yahoo.co.jp/articles/88e2fbaea06964a5064d1a0e91c5f2689accf4a0 (accessed January 2024)

[47] For example, Gazelle Wind Power (aforementioned) and Tugdock, a developer of road-transportable floating dry docks, have signed a Memorandum of Understanding to jointly develop a modular offshore wind assembly system, that is expected to dramatically drive down costs and increase production of floating offshore wind farms .(Gazelle Wind Power (December 21, 2023 press release), "Gazelle Wind Power And Tugdock Work Together to Reduce Cost of Floating Offshore Wind Platform", https://gazellewindpower.com/2023/12/gazelle-wind-power-and-tugdock-work-together-to-reduce-cost-of-floating-offshore-wind-platform

[48] Shimizu Corporation (October 6, 2022, press release) "Shimizu's "BLUE WIND", World's Largest Class SEP Vessel Completes — She Will be Used in March 2023 Following Various Tests and Training for Engineers and Crew —," https://www.shimz.co.jp/en/company/about/news-release/2022/2022046.html

As for offshore wind power base ports, the Port of Esbiau in Denmark is well known as a base port for offshore wind power generation in the Baltic Sea. The Port of Esbiau has attracted industries in the construction, operation, and maintenance of offshore wind power, creating approximately 8,000 jobs and thus contributing to regional revitalization[49]. In Scotland, a government-commissioned study identified five ports as potential offshore wind base ports based on factors including location and cost and designated the Port of Inverness and Cromarty Firth[50] as a Green Freeport[51] which focuses on floating offshore wind farms[52].

NREL also focused on the importance of domestic supply chain that can supply 4–6 GW of projects per year to achieve its target to deploy 30GW of offshore wind power in 2030. It concluded that half of the U.S. offshore wind energy projects in the pipeline are at risk of being delayed beyond 2030 because of limited port and vessel infrastructure.[53]

Plans are underway across Japan to develop Carbon Neutral Ports (CNP) to decarbonize ports and adjacent areas through receiving imported low-carbon hydrogen and ammonia. On the other hand, no specific infrastructure plans related to offshore wind power have been announced at potential CNPs located within "promotion zones” under the Marine Renewable Energy Act, even if they have been designated base ports under the revised Port and Harbor Law. It has also been announced that future decisions on the designation of new base ports will be based on the status of offshore wind power project development, maximizing the use of already designated base ports and responding to increased needs for the designation of base ports. However, port development is said to require five years; and therefore, late decisions may delay the development of offshore wind power projects. It is worthwhile to specifically consider the efficiency of building new energy and industrial infrastructure by linking CNP development plans with offshore wind base port development plans.

2.3.1 Operation and maintenance

Operation and maintenance (O&M) costs are said to account for 30- 40% of the total cost of the entire fixed-bottom offshore wind supply chain[54]. Naturally, the reduction of O&M costs is called for, but at the same time, if domestic operators can assume O&M, it will contribute to the development of the domestic industry. As indicated in 3.1, the Japanese government is providing support for the training of skilled personnel specializing in the construction and maintenance of offshore wind power facilities. For example, in one of its subsidized projects, NYK Line has been implementing educational programs for specialized workers and developing training facilities in order to strengthen the operational scheme and human resource development for crew

---

[49] Public-Private Council on Enhancement of Industrial Competitiveness for Offshore Wind Power Generation (2020), *op. cit.*

[50] Inverness and Cromarty Firth Green Freeport website, https://greenfreeport.scot/about/

[51] A Green Freeport is a large special economic zone with the key policy objectives of job creation, promoting decarbonization and a just transition to a net zero economy, establishing hubs for global trade and investment, and fostering an innovative environment. Companies that locate there will benefit from tax and other incentives. Two ports have been designated as of January 2024.

[52] Ironside Farrar (2021), “Port Enhancements for Offshore Wind: An Assessment of Current and Future Marshalling and Assembly Capacity in Scottish ports”, Scottish Enterprise, Highlands & Islands Enterprise, Crown Estate Scotland, https://www.evaluationsonline.org.uk/evaluations/Documents.do?action=download&id=987&ui=basic (accessed in January 2024)

[53] NREL (2023), *A Supply Chain Road Map for Offshore Wind Energy in the United States,* https://www.nrel.gov/docs/fy23osti/84710.pdf

[54] Toshiki Nakajo (2021), *op. cit.*

transport vessels (CTV) that carry maintenance workers ¥ to and from the sites[55]. A number of other private companies are also engaged in offshore wind power O&M services[56],[57],[58].

From the viewpoint of contributing to the local economy, local fishermen can also be employed to transport offshore wind project personnel to offshore sites[59]. Furthermore, a CTV order was made to a domestic shipbuilder with the intention of activating the domestic shipbuilding and related industries in relation with the offshore wind industry[60].

3 Exploring the development of local industrial hubs

3.1 Grid integration of offshore wind power

Grid connection is an important issue for the future development of offshore wind power. In Japan, the grid capacity available for new renewable power connection is becoming increasingly limited. Curtailment of renewable power generation occurs in all service areas except in that of Tokyo Electric Power Company (TEPCO). In the short term, to facilitate offshore wind development, new offshore wind projects can be connected to the grid under the “Grid Securing Scheme”. The detailed design of the Grid Securing Scheme is now under discussion[61]. Under the Grid Securing Scheme, utility companies will provide connection for new offshore wind projects under the “non-firm” connection rule. Under the “non-firm” connection rule, a new power generation plant can be connected to the grid even if there is no spare grid capacity, on the condition that its output will be the first in line to be curtailed without compensation in the event of grid congestion.

Given that the frequency and amount of curtailment under the “non-firm” connection rule is difficult to predict, the bankability of a project subject to the “non-firm” connection rule may be undermined. Changing the grid utilization rules from “first-come-first-served” to rules based on the carbon intensity and power generation cost of each power plant can help improve the bankability of not only offshore wind power projects but also all new renewable power projects without having an impact on grid stability.

In the longer term, further expansion and reinforcement of transmission capacity, especially inter-regional transmission connection capacity, is needed. The Organization for Cross-regional Coordination of Transmission Operators (OCCTO) has released a Master Plan for the future transmission grid network system[62]. Expected

---

[55] ANRE (September 8, 2023), *op. cit.*

[56] JFE Engineering Corporation website, “O&M (Operation and Maintenance) Services”, https://www.jfe-eng.co.jp/products/life/owp03.html

[57] Nittetsu Engineering Corporation (January 18, 2023), “Establishment of O&M Service Implementation Scheme for Offshore Wind Power Facilities with Fukada Salvage Construction”, https://www.eng.nipponsteel.com/news/2023/20230118.html

[58] Mitsubishi HC Capital Corporation and Horizon Ocean Management Corporation (September 8, 2023, press release), “Mitsubishi HC Capital and Horizon Ocean Management Agree on Business Alliance to Stabilize and Streamline O&M Operations in Domestic Offshore Wind Power Business”, https://www.mitsubishi-hc-capital.com/investors/library/pressrelease/pdf/2023090801.pdf

[59] ANRE (2022) “Case Studies of Measures to Promote Regional and Fishery Development through Offshore Wind Power Generation,” Document 6 distributed at the 2nd meeting of the Council for Offshore Oga City, Katagami City, and Akita City, Akita Prefecture (held on May 10, 2022), https://www.enecho.meti.go.jp/category/saving_and_new/saiene/yojo_furyoku/dl/kyougi/akita_oga/02_docs06.pdf

[60] NYK (February 20, 2024, press release), “First CTV for offshore wind power made to a domestic shipbuilder: contributing to the deployment of sustainable energy and activiation of the shipbuilding industry”, https://prtimes.jp/main/html/rd/p/000000085.000120868.html

[61] ANRE and MLIT (June 2023), “Review of the grid securing scheme” (Document 1 delivered at the 19th Joint meeting of the Working Group on Promoting Offshore Wind Power Generation (METI) and the Subcommittee for Promoting Offshore Wind Power Generation (MLIT) (June 16, 2023) https://www.meti.go.jp/shingikai/enecho/denryoku_gas/saisei_kano/yojo_furyoku/pdf/019_01_00.pdf

[62] OCCTO (2023), *Long-term Plan for Cross-regional Grid (Master Plan of Cross-regional Transmission Grid)*, https://www.occto.or.jp/kouikikeitou/chokihoushin/files/chokihoushin_23_01_01.pdf

future offshore wind power installations were also considered in the development of the master plan. However, the future inter-regional transmission capacity under construction and in planning is around 10 GW (Figure 5-1) and may not be enough to accommodate future offshore wind power projects. In addition to the further expansion of inter-regional transmission lines, transporting offshore wind power resources in other forms such as hydrogen, or relocating energy demand to places with abundant offshore wind power potential can also be solutions to overcome grid capacity constraints.

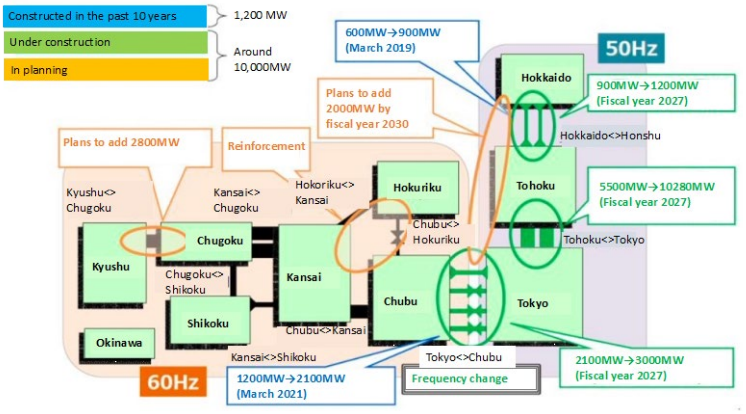


FIGURE 5-1 FUTURE TRANSMISSION NETWORK REINFORCEMENT PLAN

Source: ANRE (February 2023)[63]

3.2 Converting offshore wind power to other energy carriers

Considering the imbalance between offshore wind power potential and grid constraints, measures can be taken to fully utilize energy from offshore wind. An example is using it in other forms such as hydrogen. In the future, if the generation cost of offshore wind power becomes low enough, using offshore wind power for local green hydrogen production can be more economic than using electricity from the grid, since transmission and distribution costs will not be needed. Furthermore, when offshore wind power generation costs are reduced, green hydrogen produced from local offshore wind power can also be competitive against imported green hydrogen as hydrogen carrier conversion/reconversion costs and costs associated with long-distance transportation and storage of hydrogen can be avoided. Yet, it should be noted that costs related to transporting hydrogen by pipeline from the offshore hydrogen production site to coastal area will be added to the total hydrogen supply cost.

Hydrogen production using offshore wind power is being promoted especially in Europe where offshore wind development is more advanced. For example, the Westküste 100[64] project in Germany, uses electricity from an offshore wind farm and solar PV to produce green hydrogen, which is used to produces synthetic fuels with CO_2 captured from a nearby cement factory. In this project, green hydrogen is produced using electricity from an existing offshore wind project that already has transmission lines in place to deliver electricity onshore and the hydrogen production facility is located in the coastal area.

There are also offshore wind power projects dedicated to hydrogen production under development. For example, in the United Kingdom, the Deepwater Offshore Local Production of Hydrogen (DOLPHYN) project plans to use a dedicated floating offshore wind farm to produce hydrogen. The project examined several design options for the floating offshore wind power generation and electrolysis system. According to the cost analysis, the hydrogen supply cost (including production and transportation costs) is lowest in the case with a

---

[63] ANRE (February 2023), “Next-generation electric power system” (Document 3 delivered at the 49th meeting of the Subcommittee on Mass Introduction of Renewable Energy and Next-Generation Electricity Networks (February 9, 2023), https://www.meti.go.jp/shingikai/enecho/denryoku_gas/saisei_kano/pdf/049_03_00.pdf

[64] Westküste 100 website, https://www.westkueste100.de/

semi-submersible floating offshore wind platform with a hydrogen export pipeline to the shore. In this case, hydrogen production facilities (desalination unit and electrolyzer) are integrated on each floating offshore wind platform. [65]

Furthermore, companies from North Sea countries are developing offshore wind power and hydrogen production projects such as the North Sea Wind Power Hub（NSWPH）project. The NSWPH project aims to build several offshore wind energy supply hubs in the North Sea that produce both electricity and. The NSWPH consortium comprises utility companies, including Gasunie, Energinet, and TenneT. The consortium examines the optimal system design for integrating offshore wind power into the energy system, supplying both electricity and hydrogen to countries in the North Sea region in the most efficient way. The study[66] found that, rather than dedicating all the offshore wind power to offshore hydrogen production, or to export all the electricity to the onshore power grid, a hybrid grid-integrated Power to Gas (PtG) system, that for example produces hydrogen, can harvest the maximum offshore wind power and integrate it into the energy system. The hybrid grid-integrated PtG system will initially supply electricity to the onshore electricity grid and use the surplus electricity that could not be absorbed by the grid for offshore hydrogen production. The hydrogen will be exported to coastal regions via hydrogen pipeline.

3.3 Infrastructure

Transmission lines and hydrogen delivery measures are of great importance in delivering the electricity or hydrogen from offshore wind farms to end users. The transmission and delivery infrastructure comprises two parts: offshore transmission and delivery infrastructure (to export energy generated from offshore facilities to shore), and onshore transmission and delivery networks.

3.3.1 Offshore transmission and delivery infrastructures

Submarine transmission lines or oil/gas pipelines are mature technologies that have already been used in many projects (Table 5-1). According to current projects, the depth of submarine electricity transmission cables can reach as deep as 1,600 m.

Onshore hydrogen pipelines are established technology. Although submarine hydrogen pipelines do not yet exist, experience from submarine oil/gas pipelines can be used in building submarine hydrogen pipelines. Furthermore, some oil/gas pipelines can be repurposed for hydrogen transport in some cases. Currently, submarine oil/gas pipelines are found mainly in the U.S. Gulf of Mexico, West Africa, Brazil, and Northern Europe. According to Mark J. Kaiser & Siddhartha Narra (2019)[67], the U.S. Gulf of Mexico is one of the most developed regions in the oil and gas industry and there are around 21,872 miles (35,200 km) of active oil and gas pipelines of which about 9,462 miles (15,228 km) are underwater in depths of more than 400ft (122 m). Gas pipelines can be installed in waters as deep as 2,000 m[68].

---

[65] ERM (2019), *Dolphyn Hydrogen Phase-1 Final Report* (Submitted to Department for Business, Energy & Industrial Strategy, United Kingdom), https://assets.publishing.service.gov.uk/media/5e4ab9be40f0b677c1344ec8/Phase_1_-_ERM_-_Dolphyn.pdf

[66] NSWPH (2022), “Grid-integrated Offshore Power-to-Gas Discussion Paper #1”, https://northseawindpowerhub.eu/knowledge/nswph-discussion-paper-on-grid-integrated-offshore-power-to-gas

[67] Mark J. Kaiser & Siddhartha Narra (2019), “U.S. Gulf of Mexico pipeline activity statistics, trends and correlations”, *Ships and Offshore Structures*, 14:1, 1-22, https://www.tandfonline.com/doi/abs/10.1080/17445302.2018.1472517

[68] TechnipFMC (August 23, 2013 press release), “Technip to lay the world’s deepest gas pipeline, for Shell in the Gulf of Mexico”, https://www.technipfmc.com/en/investors/archives/technip/press-releases/technip-to-lay-the-world-s-deepest-gas-pipeline-for-shell-in-the-gulf-of-mexico/

Table 5-1 Examples of Submarine Electricity Transmission Cables

Electricity Transmission Cable	Voltage	Length	Max. Depth	Operation Year
NorNed (Norway-Netherlands)	±450kV (DC)	580 km	410 m *1	2008
NordLink (Norway – Germany)	±525kV (DC)	623 km *2	410 m	2021
SA.PE.I (Mainland Italy – Sardinia)	±500kV (DC)	435 km	1640 m	-
ELMED (Italy – Tunisia)	500kV (DC)	220 km *3	800 m	To be completed by 2028*4
Kitahon HVDC Link (Japan/ Hokkaido-Honshu)	±250kV (DC)	167 km (submarine cable: 42km)	300 m	Latest cable expansion in 2014
Maritime Link (Canada)	±200kV (DC)	170 km	470 m	2017

Source: compiled by authors based on various sources*5

Notes:
*1: 420 km of cable in shallow waters (up to 50m) and 160 km of cable in depth of up to 410 m;
*2: 516 km of submarine cable;
*3: 200 km undersea;
*4: Procurement phase started in 2023. In 2023, the World Bank Loan to Tunisia was approved and EU Grant, signed.
*5: Jan-Erik Skog et. al. (2006)[69], T&D World (2008)[70], Magnus Callavik and Ola Hansson (2015)[71], KfW[72], Terna Diving Energy[73], ELMEDProject[74], J-Power (2021)[75], Nexans (2018)[76], Hitachi Energy[77]

3.3.2 Onshore transmission and delivery infrastructures

To deliver clean electricity or hydrogen to end users, onshore transmission and delivery infrastructures are also essential. As aforementioned, Japan has already developed a Master Plan for future transmission network expansion and reinforcement. The future electricity supply from offshore wind was also considered in the development of the Master Plan.

Europe already has plans to develop a Europe-wide hydrogen pipeline network, most of which will comprise repurposed natural gas pipelines, but there are no such plans in Japan yet. Main hydrogen delivery measures in Japan are currently high pressure compressed hydrogen trailers and liquefied hydrogen tank trucks. At the early stage of market scaleup, when hydrogen consumption amounts are small, such delivery measures can

---

[69] Jan-Erik Skog, Kees Koreman, Bo Pääjärvi, & Thomas Andersröd (2006), "The Norned HVDC cable link–A power transmission highway between Norway and The Netherlands," *ENERGEX 2006*, https://library.e.abb.com/public/f3a6c2afe601d185c125718e002e3823/THE%20NORNED%20HVDC%20CABLE%20LINK.pdf

[70] T&D World (May 9, 2008), "NorNed, the Longest Electricity Cable in the World, is Operational", https://www.tdworld.com/overhead-transmission/article/20956052/norned-the-longest-electricity-cable-in-the-world-is-operational

[71] Magnus Callavik and Ola Hansson (2015), "NORDLINK Pioneering VSC-HVDC interconnector between Norway and Germany", (White Paper from ABB), https://library.e.abb.com/public/aaa99cf7067cd258c1257e0d002c9a7b/Nordlink%20White%20Paper%20from%20ABB.pdf

[72] KfW website, "Green electricity from Norway", https://www.kfw.de/stories/environment/renewable-energy/nordlink/

[73] Terna Diving Energy website, "SA.PE.I", https://www.terna.it/en/projects/sapei

[74] ELMEDProject website, https://elmedproject.com/#:~:text=The%20power%20line%20will%20run,along%20the%20Strait%20of%20Sicily.

[75] J-Power (2021), "Study group for the development of long-distance submarine DC power transmission: Inter-regional interconnection by submarine DC transmission" (Document 6 distributed at the 1st meeting of the Study group for the development of long-distance submarine DC power transmission), https://www.meti.go.jp/shingikai/energy_environment/chokyori_kaitei/pdf/001_06_00.pdf

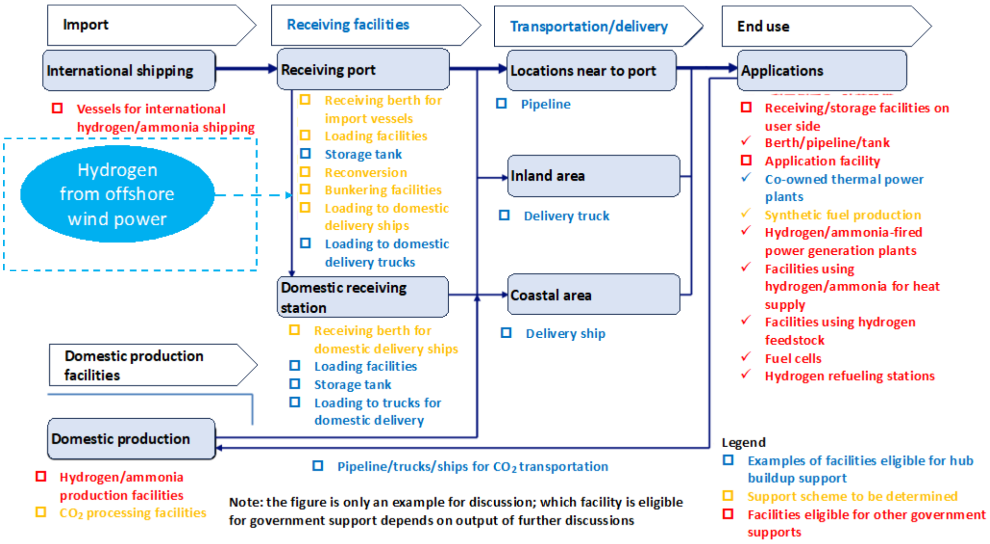
[76] Nexans (February 18, 2018, press release), "Nexans Delivered North America's Longest Submarine Cable to Provide Cleaner Energy to Eastern Canada", https://www.nexans.com/en/newsroom/news/details/2018/01/Nexans-Delivered-North-America-Longest-Submarine-Cable-to-Provide-Cleaner-Energy-to-Eastern-Canada.html

[77] Hitachi Energy website "Maritime Link", https://www.hitachienergy.com/about-us/customer-success-stories/maritime-link

be used for distribution to hydrogen end users, such as hydrogen refueling stations. However, for larger volumes of concentrated hydrogen demand, hydrogen pipelines are more efficient. In the longer term, when the hydrogen market is more developed, the installation of hydrogen pipeline networks could also be considered in regions with high hydrogen demand.

3.4 Synergy with local/regional hydrogen hubs

To further develop the domestic market for hydrogen and its derivatives, the Japanese government is considering building several hydrogen hubs in Japan. Some of the cost will be supported by the government. An important criterion for the selection of potential hub locations is the potential demand for hydrogen and its derivatives. The hubs will have large-scale hydrogen users, such as hydrogen- and ammonia-fired thermal power plants, refineries, and large industrial users. There will be hydrogen pipelines for hydrogen delivery as well as ports with import facilities for hydrogen and its derivatives. In the future, if offshore wind-powered hydrogen production sites can be well planned to take advantage of infrastructure synergy and supply hydrogen to the hydrogen hubs, the total cost for infrastructure buildup may be reduced (Figure 5-3).



Note: the figure is only an example for discussion; which facility is eligible for government support depends on output of further discussions

FIGURE 5-2 IMAGE OF HOW OFFSHORE WIND POWER CAN BE INTEGRATED INTO THE HYDROGEN HUBS UNDER DISCUSSION IN JAPAN

Source: Compiled by authors based on METI[78]

3.5 Relocation of energy demand to create local industrial hubs

In the longer term, to fully utilize the offshore wind potential, demand side measures should be considered in addition to those on the energy supply side. With the growing demand for green products and stricter regulations regarding the carbon footprint of products, industry users are increasingly in need of low-cost clean energy supplies. In the longer term, even when offshore wind power generation costs can be significantly lowered the cost of power transmission and/or hydrogen transportation costs when producing hydrogen from offshore wind power. Therefore, the distance of power transmission or hydrogen transport should be minimized for the highest cost efficiency. In that sense, increasing local energy demand by shifting demand centers to such areas with abundant offshore wind potential, such as Hokkaido, is a solution for optimizing

---

[78] METI (December 2023), *Interim Report of Joint Meeting of Hydrogen Policy Subcommittee and Ammonia and Low Carbon Fuels Subcommittee*, https://www.meti.go.jp/shingikai/enecho/shoene_shinene/suiso_seisaku/pdf/007_02_00.pdf

future energy supply and demand, as huge investment in new energy infrastructure, such as pipelines and transmission lines to distant demand centers can be avoided.

Potential energy end users in areas with high potential for offshore wind power include industries related to the offshore wind supply chain, such as turbine manufacturers, equipment suppliers, assembly companies, and recycling companies, as described in Chapter 3. In addition, industries with enormous needs for low-cost clean electricity or hydrogen can also create new energy demand. Some examples are data centers consuming large amounts of electricity and steel manufacturing plants with large demand for high temperature heat.

Further advances in digitalization will make data centers one of the top electricity consumers in the future. Data center providers and operators, such as major IT companies, are increasingly sourcing their electricity supply from clean energy sources, mainly renewable energies. Data centers require Uninterruptible Power Supply (UPS), which requires backup generators in case of power outage. Microsoft is testing the use of hydrogen fuel cells as the backup generator of its data centers[79]. In the future, the offshore wind power system will be able to provide both clean electricity and fuels (e.g. green hydrogen) for backup generators supporting the data center.

The iron and steel industry is a so-called “hard-to-abate (difficult to decarbonize by clean electricity)” industry. An effective decarbonization solution is Direct Reduced Iron (DRI) production using hydrogen as the reducing agent and as fuel to provide high temperature heat. The production of 1 ton of crude steel using the DRI process requires 45~55 kg of hydrogen (Hydrogen Europe[80]). For a typical steel plant with 4 million tons of crude steel production per year, the annual hydrogen demand is 180,000~220,000 tons. According to IEA (2019)[81], 10GW of offshore wind can produce around 1 million tons of hydrogen per year. To provide green hydrogen to a steel plant producing 4 million tons annually, around 1.8~2.2GW offshore wind is needed. Offshore wind farms can also provide clean electricity to local steel manufacturers using electric arc furnaces, which can process recycled steel scraps from both onshore and offshore wind power plants, thus contributing to the local circular economy.

End users such as data centers or industrial users can purchase electricity or hydrogen directly from local offshore wind power generation developers. Round 2 of offshore wind power tenders which was held in December 2023 adopted the Feed-in-Premium (FIP) scheme[82] offshore wind power generation developers chose to sign Power Purchase Agreements (PPA) with end users.

Amid the race to decarbonize industry and the entire energy demand, locations with an abundant supply of low-cost clean energy can be more attractive to industries. Provided that the cost of offshore wind power can be significantly reduced in Japan in the long term, shifting existing industrial energy demand to and siting new industrial energy demand in regions with large offshore wind power potential but limited transmission capacity is a solution for efficient energy use. Industrial relocation will be accompanied by a population shift of workers and their families, and thus can lead to the revitalization of local economy. Relocating energy demand requires the consideration of various aspects from a long-term perspective. Now as we stand at the starting point of the energy transition, we should begin with discussion on a comprehensive vision of future energy, local economy, and industry.

Contact: report@tky.ieej.or.jp

---

[79] Microsoft (July 28, 2022, press release), “Hydrogen fuel cells could provide emission free backup power at datacenters, Microsoft says”, https://news.microsoft.com/source/features/sustainability/hydrogen-fuel-cells-could-provide-emission-free-backup-power-at-datacenters-microsoft-says/

[80] Hydrogen Europe (2020), *Green Hydrogen Investment and Support Report*, p. 19 https://h2fcp.org/system/files/cafcp_members/2%20Hydrogen-Europe_Green-Hydrogen-Recovery-Report_final.pdf, (cited from Hybrit, Fossil free Steel, summary of findings from HYBRIT pre-feasibility study 2016-2017 Assessment of hydrogen direct reduction for fossil-free steelmaking, Valentin Vogl, Max Åhman, Lars J. *Nilsson Journal of Cleaner Production* 203 (2018) 736-745)

[81] IEA (2019), “Offshore Wind Outlook 2019”, page 56, https://iea.blob.core.windows.net/assets/495ab264-4ddf-4b68-b9c0-514295ff40a7/Offshore_Wind_Outlook_2019.pdf

[82] ANRE (November 2023), “Guidelines on call for proposals based on Marine Renewable Energy Act” (Document delivered at the 89th meeting of the Procurement Price Calculation Committee), https://www.meti.go.jp/shingikai/santeii/pdf/089_01_00.pdf