February 3rd, 2022

Sumitomo Corporation Global Metals Co., Ltd.

Expectation and Foresight of Floating Offshore Wind in Japan

Sumitomo Corporation Global Metals has collaboratively created “Expectation and Foresight of FOW in Japan”.

In recent years, the adoption of renewable energy generation has accelerated globally as a way to address climate change. In October 2021, the Cabinet of Japan approved the Sixth Basic Energy Plan, which aims to address the action against climate change and solve challenges facing Japan's energy supply and demand structure. Expectations are rising for renewable energy as the major power source to achieve carbon neutrality by 2050.

“Expectation and Foresight of FOW in Japan” has summarized the expectations, prospects, and proposals for floating offshore wind power generation as a key for decarbonization in Japan. Sumitomo Corporation Global Metals has contributed to the formulate this document from the standpoint and perspective of supply chain, utilizing the knowledge we have accumulated through our historical business activities.

Sumitomo Corporation Global Metals will contribute broadly to the realization of a sustainable society by creating new value through our future-oriented initiatives and business activities.

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Expectation and Foresight of FOW in Japan

Key for decarbonization in Japan

September 2021

Japan's Floating Offshore Wind Group

Japan’s Floating Offshore Wind Group

Japan’s Floating Offshore Wind Group is launched by 6 companies, which are actively promoting floating wind power in Japan.

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Key Messages

FOW[1] technology is a proven and mature technology and large-scale FOW projects can be in operation by 2030

- FOW is a proven and mature technology, based on the oil & gas industry, and at the stage of optimization for cost reduction.
- With 1.5℃ target of Paris Agreement in mind, FOW has increasing importance, and areas like Europe, US, South Korea announced ambitious 2030 targets and development plans.
- With higher predictability, private investments are accelerated, and many companies are to enter the market. The project capacity is also increasing, spanning from several hundred MW to GW scale.

FOW is a key for Japan to achieve decarbonization

- By developing FOW concurrently with BFOW, the 2030 target to reduce greenhouse gas emissions by 46-50% and carbon neutrality by 2050 can be achieved.
- The seabed surrounding Japan can be very steep. FOW unlocks the potential of these areas by allowing a cost efficient installation of offshore farms in deep waters and harness promising wind resources. Further potential is expected in the EEZ.
- To install sizable capacity of FOW, it is important to establish a steady industry for FOW as early as possible by 2030.

FOW harmonizes with the local communities and contributes to the domestic economy and sustainable economic growth

- Japan, which has FOW related industries such as construction, shipbuilding, steel and chemical industry, has potential for domestic industrial development.
- The development of FOW supply chain will contribute to the domestic economy revitalization with the creation of new jobs, and sustainable economic growth will be achieved.
- We will deepen our understanding through close dialogue with local communities and fisheries, and work together to create new value through harmonized measures.

Industrialization and Maturation are the key factors for cost reduction

- FOW can become a cost competitive power resource by cost optimization and developing in wide areas with strong wind resources, such as EEZ.
- The key factors to realize the reduction of LCOE are the Industrialization and Maturation of FOW to enable sizable capacity of installation.
- To realize these factors, it is necessary to create attractive business environment by forming a large, long-term, stable market that enables large-scale investment decisions by the industry, and prompt clarification of systems concerning FOW such as development in EEZ.

Proposals for FOW Market Development

1. Set FOW target of 2-3GW by 2030, mid and long-term targets

- We propose to set a 2030 target of 2-3GW, and to set mid and long-term targets.
- The industry is preparing and large-scale FOW projects can be operational by 2030, thus contributing to Japan's decarbonization.

2. Promote strategic development plans for large-scale and domestic industrial development

- We propose that development plans for projects spanning from several hundred to GW scale by 2030 are necessary in order to industrialize, mature, and reduce FOW costs.
- By showing clear paths for leveraging the domestic industry, reducing costs, and taking strategic action, domestic FOW supply chain can be competitive internationally.

3. Accelerate discussion to create an attractive FOW business environment

- We propose to set committees dedicated to discussing FOW matters, and outline a clear path towards building a business environment. This includes setting mid and long-term targets, plans for large-scale FOW farms, and working towards developing in the EEZ.

[1] In this document, "FOW" refers to "Floating Offshore Wind", and "BFOW" refers to "Bottom-Fixed Offshore Wind". Please refer to the glossary and abbreviation at the end of this document.

1. Introduction: What is FOW?

1.1 Types of Offshore Wind - Bottom-fixed and Floating -

Offshore wind can be distinguished into two types, the bottom-fixed offshore wind (BFOW) and floating offshore wind (FOW). In BFOW, the wind turbines are installed on a foundation fixed to the seabed. On the other hand, FOW is installed on a substructure floating in the sea.

In general, BFOW is suited to sea areas with water depth up to 60m. Therefore, the BFOW is installed in the sea areas relatively close to the shore. When the water depth exceeds 60m, FOW is considered to have a cost advantage. FOW enables offshore wind to be installed in deeper waters.

1.2 Types of substructure

The FOW farm mainly consists of wind turbines, substructures, mooring lines and anchors, cables, and substation.

Substructures can be distinguished into 4 types: Semi-Submersible, Barge, Spar and Tension-Leg Platform (Figure 1).

Suitable substructure depends on the depth of water and natural conditions at the location, social conditions such as fishing, and characteristics of the port. The most economical choice is made on a site basis.

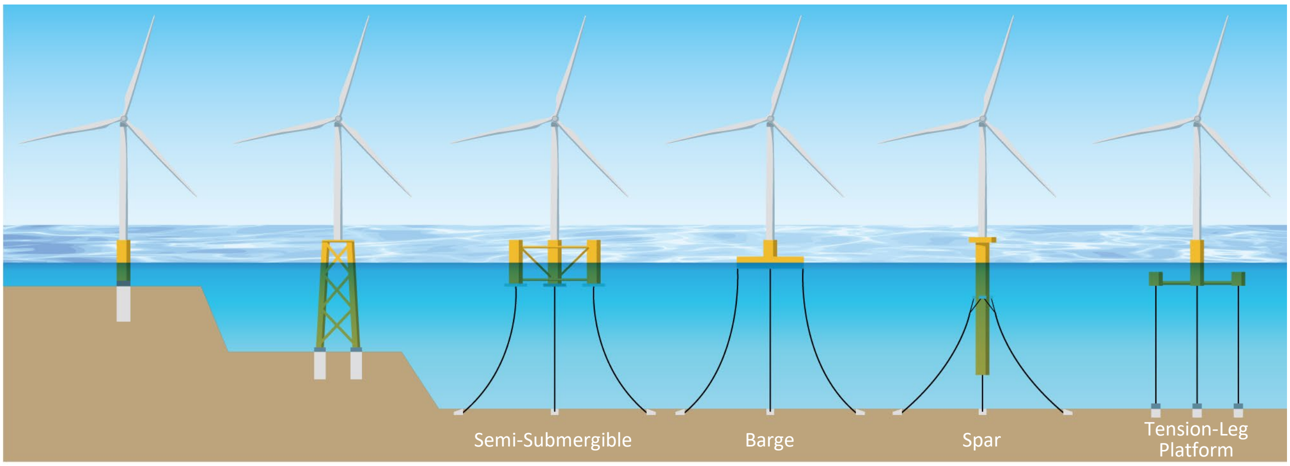
1.3 Advantages of FOW

FOW has many advantages in terms of installation requirement, technology and infrastructure (Table 1). [2]

Table 1 Advantages of FOW

Installation Environment	• Can be installed further offshore with strong winds • Minimal effects by an earthquake • Can be installed in deep waters
Technology Infrastructure	• Possible to install without jack-up vessels • Substructures of the same design can be applied to various seabed conditions, enabling large-scale production

Figure 1 Types of Substructures



Semi-Submersible	Semi-submerged floating body
Barge	Barge-style floating body
Spar	Cylindrical floating body with a low center of gravity
Tension-Leg Platform	Semi-submersible floating body fixed by tension mooring

[2] For details, see Section 6.2.

2. Accelerating Global Development of FOW by Setting National Targets

2.1 FOW Targets and Development plans announced in countries around the world

Growing importance of FOW in achieving decarbonization

Amid the urgent need to address climate change, it is necessary to further expand the use of offshore wind globally, in order to reduce global greenhouse gases emissions by 45% from 2010 levels by 2030 to limit the temperature increase to 1.5°C based on the Paris Agreement, and to achieve carbon neutrality by 2050.

WindEurope, European wind industry association, released a target of 450GW by 2050, of which 100 to 150GW would be achieved with FOW.[3]

It is necessary to expand the installation of FOW in addition to BFOW, and many governments have announced their targets for the installation of FOW and their bidding plans.

Targets and Development plans of GW scale with aim to start operations by 2030

In Europe, the UK, Spain, Ireland, France, Scotland and Norway are showing developments.

Governments in the US and Asia also started recognizing the importance of introducing FOW as a means to realize a decarbonized society.

The UK has set 2030 FOW target of 1GW, and Spain has set 2030 FOW target of 1-3GW. Ireland also announced a plan to produce a long-term vision for FOW in the Atlantic waters.

FOW bidding processes are underway in France, Scotland and Norway. France leads the way, and the auction for 3 sites, each with 250MW class farm is scheduled for 2021-2022, and bidding plans for an additional 500MW class farm are being considered.

In the US, the Biden Administration and the California State Government announced that they would develop 4.6GW of

[3] WindEurope (26)

FOW off the coast of California. Furthermore, Oregon State Government aims to plan for the development of up to 3GW of FOW by 2030.

The government of South Korea also announced a large-scale FOW construction project off the coast of Ulsan, aiming to start operation of 6GW of FOW by 2030.

2.2 Accelerated private investment towards large-scale FOW farms

Increased market attractiveness accelerates private investments

In response to the announcement of the targets and development plans by the governments of various countries, the interest of companies to invest has increased rapidly.

In the UK, where a 2030 target of 1GW was set, concrete plans for the development of FOW farms have been launched, and the UK industry expects 2GW of installations by 2030.[4]

In addition, the ScotWind Leasing round off the coast of Scotland earned broad developers' attention as suitable areas for the development of FOW farms because many of the candidate sea areas are in deep waters.

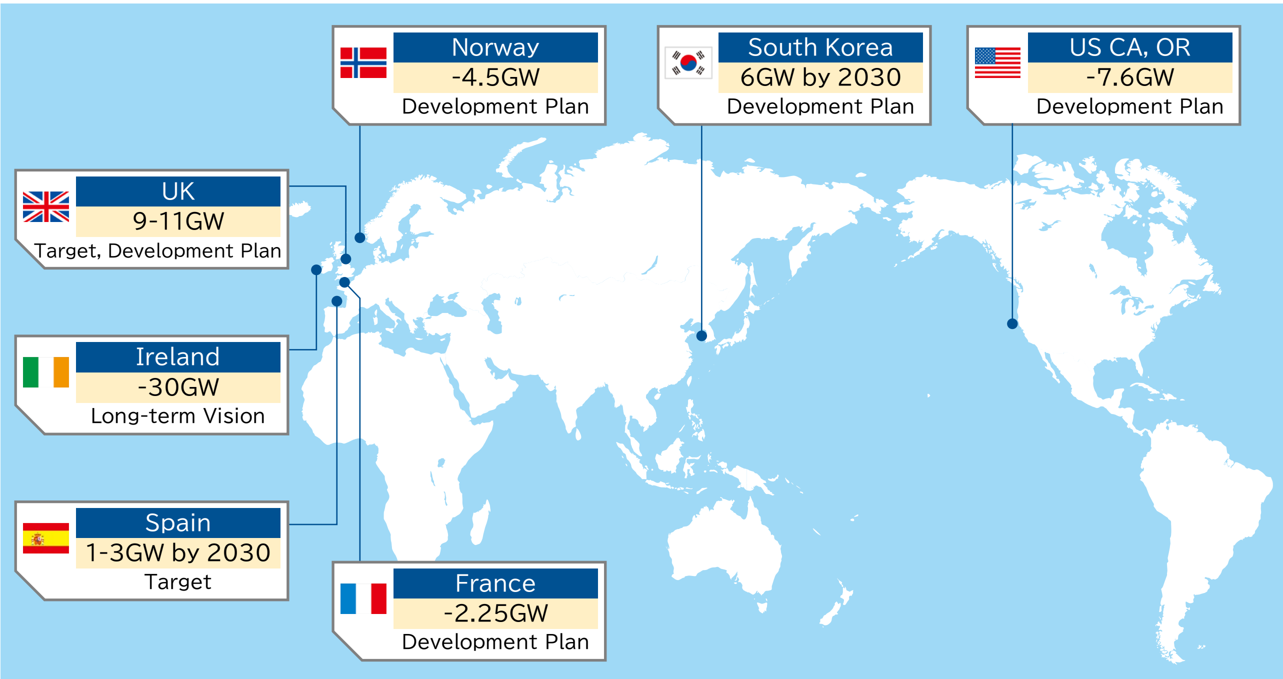
In South Korea, the announcement of an ambitious 6GW development plan by 2030 has attracted considerable interest from around the world, and a number of corporate consortiums are working to flesh out the plan.

Development expanding to several hundred MW to several GW scale projects

The plans of the government and the industry in each country have shifted from small-scale projects of several wind turbines to large-scale projects with a large number of wind turbines, and have expanded to several hundred MW to GW scale.

This development indicates that clarification by the government of targets and specific development plans (size and schedule) will increase market predictability and lead to the promotion of private sector investment and acceleration of development speed.

Figure 2 FOW Government Targets and Development plans



*Norway: Maximum capacity including BFOW
*France: Total announced and planned bids as of 2021
*Scotland: Most of the 15 sites are located in sea areas with a water depth of 60m or more, and the installation of FOW is expected.

Source:UK Government (1), Ireland Government (2), GWEC (3), Norwegian Government (4), Ministère de laTransition écologique et Solidair (5), Commission Nationale du Débat Public (6) (7), Offshore Wind Scotland (8), Korea.net (9), Ministry for the Ecological Transition and the Demographic Challenge (10), The White House (11), Oregon State Legislature (12)

[4] GWEC (27)

3. Proven and Mature Technology, Ready for Optimization

3.1 FOW has reached the stage of technology to provide stable power generation

Technology established in the offshore oil and gas industry

Many of the technologies used in FOW, such as substructures and mooring systems, are converted from the offshore oil and gas industry with a history of more than half a century.

There are already small-scale FOW farms with high capacity factor and long operation times, and large-scale projects are under development, proving that the technical infrastructure of FOW is already established.

We are at the stage of stepping up to cost-competitive power generation by further optimizing technologies and scaling up to reduce costs while utilizing the existing ones.

Steady operation of FOW farms proven

In Europe, where the offshore oil and gas industry has developed, the experience in the development and operation of offshore plants have been utilized in the development of FOW farms in the tens of MW class since the mid-2010s. It has proven that stable power supply is possible even under harsh weather and sea conditions.

In 2017, Hywind Scotland (30MW, Equinor), off the coast of Peterhead, Scotland, became the world's first FOW farm with a capacity of several tens of MW, and consistenly achieved an average capacity factor above 54% since its start of operation.

The WindFloat Atlantic (25MW, Ocean Winds), which began operating off Portugal in 2020, consists of 3 wind turbines of 8.4MW each.

Kincardine (50MW) in Scotland, and Hywind Tampen (88MW) in Norway are currently under construction and scheduled to commence operations in 2021 and 2022, respectively.

In Japan, a 17MW FOW project has been awarded by METI and MLIT off the coast of Goto City, Nagasaki Prefecture.

Technology reliability at bankable level

In Europe, bankable FOW farms that meet the lending standards of financial institution are emerging.

WindFloat Atlantic signed a EUR 60 million project financing agreement with European Investment Bank in October 2018.[5]

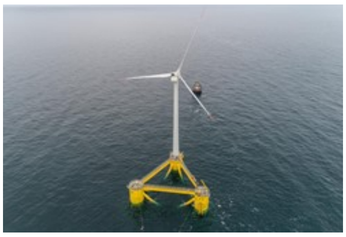
This is the result of appropriate site selection, the selection of reliable technology, and the expertise of the developers and construction firms involved. This proves that the FOW system is at the technological level where stable power generation is possible.

Figure 3 Operational and under construction FOW farms

Sakiyama 2MW FOW farm
(2MW, Operational from 2013)

Hywind Scotland
(30MW, Operational from 2017)

WindFloat Atlantic
(25MW, Operational from 2020)



Kincardine
(50MW, Operational from 2021)

Hywind Tampen
(88MW, Operational from 2022)

Source: Toda Corporation (13), Equinor (14), Ocean Winds (15), Cobra Group (16), Equinor (17)

[5] European Commission (28)

3.2 Key points for technology optimization

Integrated design of substructure and wind turbine

While the optimization of the substructure itself is important, in order to minimize the motion of the substructure, an integrated design and development of the substructure and the wind turbine combined is also crucial.

An optimum design of the entire system is also needed, which should take into account the behavior and load of wind turbines, substructures, mooring systems, dynamic cables, etc., as well as the workability, maintainability, and overall cost.[6]

Large-scale production of substructures

Substructures of the same design can be used in various sea areas because they are not affected by water depth or seabed features. For this reason, substructures are suitable for large-scale production and are expected to have a significant cost reduction effect.

For industrial production of substructures, design and procedures shall be optimized to enable continuous production, automation of suitable manufacturing processes (automatic welding, etc.), and optimal selection of materials and relevant technologies (welding, painting, anticorrosion, etc.).

Improvement of mooring and anchoring technology

The foundation of mooring technology has been established for the floating platforms in the offshore oil and gas industry. It is effective to improve the following technologies to further reduce the costs.[6]

- Development of lightweight mooring lines (synthetic fibers, etc.) with high durability and tensile properties
- Design and manufacture of hybrid mooring lines using synthetic fibers and steel chains
- Improvement of construction efficiency by integral design of substructure, anchor and mooring lines

Long-distance, high-voltage dynamic cables

FOW may require dynamic cables that float in the sea. Long-distance, high-voltage dynamic cables technology is well-established and they have already been used in relation to offshore oil and gas platforms.

In the future, cost reductions are expected through the development of ultra-high voltage cables for large-scale GW farms and technological improvements such as countermeasures for biofouling.

[6] Carbon Trust (29) NEDO (30)

4. The Role of FOW in Japanese Energy Policy

4.1 Evolution of Energy Policies and Growing Expectations for Offshore Wind

Urgent Climate Measures and Expectations for Offshore Wind

Climate change is an urgent issue, and as efforts towards decarbonization are accelerating worldwide, Japan has set targets to reduce greenhouse gas emissions by 46% from 2013 levels by 2030 (aiming for 50%) and achieve carbon neutrality by 2050. To limit the temperature increase to 1.5°C, it is necessary to achieve the target soonest and to set further ambitious targets.

In order to achieve these targets and more, it is essential to decarbonize the power sector as soon as possible, and it is necessary to introduce sizable capacity of renewable energy.

Forests cover 2/3 of Japan's land area, and there is little flatland. Therefore, it is essential to advance into the ocean, and there are rising expectations for offshore wind.

Setting Targets for Japan's first Offshore Wind

To make offshore wind a major power source, it is necessary to promote private investment in the Japanese market, foster industries, and establish cost competitiveness. To accelerate this process, the Public-Private Council on Enhancement of Industrial Competitiveness for Offshore Wind Power Generation (Public-Private Council) was established in July 2020.

Ambitious and specific targets for the installation of offshore wind by the Japanese government were recognized as essential, and the 2nd Meeting of Public-Private Council set a specific target of "Forming 10GW by 2030 and 30-45GW by 2040, including FOW".[7]

Figure 4 Three Targets by the Public-Private Council

National target	10 GW by 2030 and 30 - 45 GW by 2040, including FOW
Domestic procurement ratio	Achieve 60% of total lifetime domestic procurement ratio by 2040
Cost reduction	Reduce the cost of BFOW to 8-9 yen/kWh by 2030 - 2035

Source: Public-Private Council on Enhancement of Industrial Competitiveness for Offshore Wind Power Generation (18)

4.2 Meeting the target through acceleration and sizable capacity of installation of offshore wind

Need for accelerated installation based on 2030 greenhouse gas reduction targets

The targets announced at the Public-Private Council represent a milestone for the government and industry. On the other hand, in order to achieve the greenhouse gas emissions reduction target, it is necessary to increase the share of electricity generated by renewable energy generation to 36-38%. This is much higher than the current target share of renewable energy (22-24%) that was given in the Fifth Basic Energy Plan. Offshore wind has particularly high potential for growth, therefore it is important to accelerate its implementation to ensure the achievement of international commitments.

Further installation necessary for carbon neutrality in 2050

According to calculations by several research institutes, to achieve carbon neutrality by 2050, it is necessary to introduce more than 100GW of offshore wind (Table 2).

This is several times higher than the 2040 target, and accelerating the installation of offshore wind is an urgent task.

Table 2 Required Offshore Wind Capacity to achieve Carbon Neutrality by 2050

Organization	Required Installed Capacity
National Institute for Environmental Studies	Approx. 80-240GW *1
Renewable Energy Institute	63-199GW *2

*1 Calculated power generation is converted into facility capacity assuming an average facility capacity factor of 40%. The figures vary because multiple scenarios are set based on social changes and technological differences in 2050.

*2 Since the scenario is divided into the case of 100% domestic production and the case of 50% import of green hydrogen, the figures vary.

Source: NIES (19), REI (20)

7 It is defined as "certified volume under the Act on Special Measures Concerning Procurement of Electricity from Renewable Energy Sources by Electricity Utilities," and does not specify that the given capacity needs to be in operation in 2030 or 2040.

4.3 Wind Potential Offshore and the Necessity of FOW

Promising potential of FOW

Development of FOW concurrently with BFOW can contribute to the 2030 target to reduce greenhouse gas emissions by 46-50% and carbon neutrality by 2050.

According to Japan Wind Power Association (JWPA), FOW has a large potential because the sea areas around Japan have a steep seabed and FOW can be installed at deep sea depths. Furthermore, the wind speeds are high further offshore and FOW can harness this large potential of wind energy. It is also evident that suitable FOW sites exist in the sea areas relatively close to land within 30 km from shore (Table 3).

Further potential is expected in the Exclusive Economic Zone (EEZ; areas stretching between 12NM and 200NM from the coastal baseline)[8]. According to a survey conducted by the Ministry of the Environment, the offshore potential with a water depth of up to 200m, including EEZ, is estimated to be 3 times greater than the potential in waters within 30km from shore.[9] IEA has analyzed the offshore potential with a water depth of up to 2,000m, and the potential for Japan was estimated to be approximately 9 times the amount of total electricity generated annually[10].

Table 3 Estimated potential by JWPA

Wind speed [m/s]	Potential of FOW [GW] * (100-300m water depth)
7.0-8.0	284
8.0-9.0	128
9.0 or more	12
Total	**425**

* Within 30km from shore, Annual average wind speed: 7.0m/s or more, Water depth: 100-300m for FOW, Minimum capacity per project: 120MW, Required area: 3MW/km² for FOW.

Source: JWPA (21)

FOW required to Achieve Climate Targets

The Central Research Institute of Electric Power Industry estimates the potential to be up to 23GW for the bottom-fixed-type and approximately 90GW for FOW within the territorial waters (12NM, approximately 22 km) excluding the areas where it is difficult to adjust interests of different stakeholders. [11]

Based on this trial calculation, the target of 30-45GW in 2040 can only be achieved by the installation of both BFOW and FOW.

Furthermore, in order to achieve a 100GW level of offshore wind installations for carbon neutrality in 2050, sizable capacity of installation of FOW is necessary.

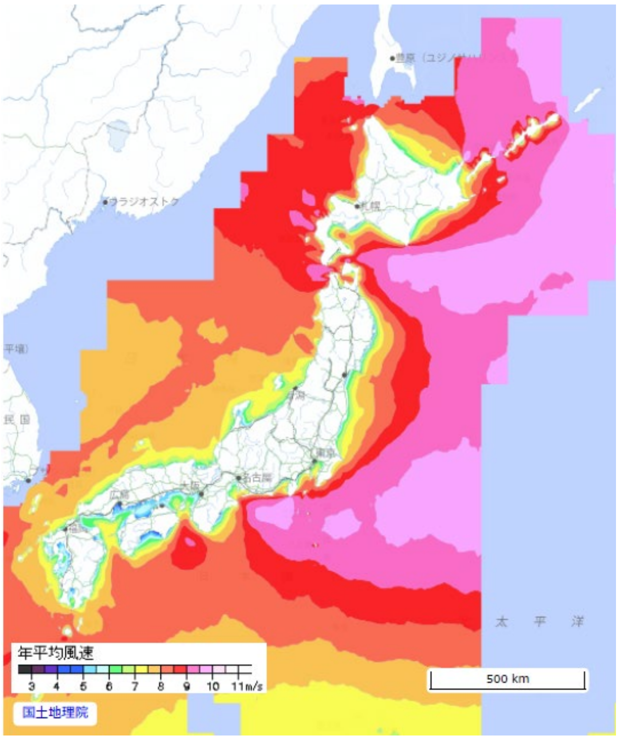
Industrialization of FOW required by 2030

It is also important to establish an industry that will enable the steady development of FOW as early as possible by 2030 in order to achieve the sizable capacity of installation of FOW.

Achieving the target of 30-45GW in 2040 means that more than 2.0-3.5GW/yr of projects need to be created annually from 2030 onwards. This is 2.0-3.5 times faster than the expected rate of 1GW/yr by 2030. To achieve this, it is necessary to start developing and building FOW farms now and develop related industries and necessary infrastructures.

FOW is not a technology of the future, it is needed today, and it is extremely important to start studying the full-scale installation of the system from now.

Figure 5 Wind condition map of sea areas around Japan



Source: NEDO NeoWins (Ocean Wind Conditions Map) (22)

[8] For details, see Glossary and Abbreviation at the back of the document.
[9] Ministry of the Environment (31)
[10] IEA (32)
[11] CRIEPI Estimate of potential for offshore wind in the "installation prioritizing scenario" using GIS evaluation tool. (33)

5. Potential for Developing FOW Industry in Japan

5.1 Strengths and Potential of Domestic Industries

Compatibility of FOW supply chain and Japanese industries

The FOW supply chain consists of a wide range of industries throughout the life cycle of project development, manufacturing, construction and installation, operation and maintenance, and decommissioning.

Japan, which has FOW related industries all over the country, has high compatibility with FOW and has high potential for domestic industrial development.

The construction industry is strong nationwide, and the shipbuilding industry is very active. In addition, there are strong industrial base for industries that can provide materials for substructures, mooring lines and anchors, such as steel, concrete and chemical products.

Demonstration Projects and Knowledge in Japan

Since the 2010s, Japan has been the first country in the world to carry out demonstration tests of FOW using spar, semi-submersible, and barge substructures off the coast of Goto City in Nagasaki Prefecture, Fukushima Prefecture, and Kitakyushu. Experience in various substructures is one of the strengths in Japan compared to other countries.

Through this experience, knowledge and lessons have been accumulated in various industries, including construction, marine engineering, shipbuilding, and steel processing.

In addition, Japanese companies are showing great interest in the FOW market, such as substructure manufacturing and mooring line manufacturing. Japan has sufficient foundation to industrialize domestic supply chain for FOW.

5.2 Effects of FOW

Revitalizing the domestic economy and realizing green growth

FOW uses many materials (steel, concrete, chemical fiber, etc.) for substructures, mooring lines, and anchors. FOW farms of several hundred MW to GW scale use 10,000-100,000 tons of materials.

By procuring and manufacturing related materials domestically, the domestic economy and regional economy will be revitalized over the long term, providing opportunities for new industries and job creation in the region. This is exactly what Japan aims to achieve through its sustainable economic growth policy.[12]

Table 4 FOW Supply Chain and Potential Industries

Major supply chain areas			Major areas and industries with potential of entry
Project development		Environmental survey	Environmental assessment, Metocean measurement
		Design	Engineering and Design consulting
Manufacturing	Substructure	Main body manufacturing	Shipbuilding, Plant engineering, and Construction
		Material manufacturing	Steel processing and concrete fabrication
		Related technology	Welding, Painting and Anticorrosion
	Mooring	Main body manufacturing	Steel products, Mooring lines
		Material manufacturing	Steel processing and Chemical products
	Anchor	Main body manufacturing	Shipbuilding, Steel products, and Machining
		Material manufacturing	Steel processing
	Array and export cable	Manufacturing	Cable manufacturing
Construction and Installation; Decommissioning	Offshore construction and logistics	Civil engineering and marine transport	Marine civil engineering, Construction
		Shipping and Ports	Vessel operators, dredging companies, Port infrastructure and upgrades, Transportation
	Onshore construction and logistics	Civil engineering	Land civil engineering work, Construction work, Transportation, Lifting and other equipment
Operation and Maintenance			Wind power plant maintenance, Vessel operators

[12]An industrial strategy that aims to create a virtuous cycle between the economy and the environment by transforming the industrial structure and socio-economy through environmental measures such as the installation of renewable energy, low-carbon transportation, and energy conservation, by recognizing global warming as an opportunity for growth.

Expectations for Regional Development

FOW is expected to contribute to regional economy.

Concrete substructures are expected to be procured and manufactured in Japan, and local companies are expected to enter the market.

Ideally substructures are constructed and assembled in the port area. Therefore, onshore construction work is needed, for which local companies might contribute to.

In areas under development, locally based service and maintenance companies have been established, contributing to the revitalization of the local economy and job creation.

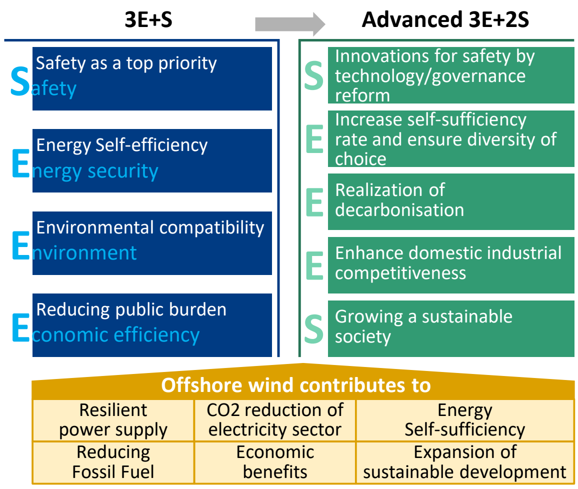
FOW is also expected to have a positive impact on other related service business. In Europe, the activities related to offshore wind farm development, construction and O&M has generated positive ripple effects on a broad range of hospitality industries.

Contribution towards Japanese 3E + 2S

FOW systems provide resilient power supply, reduce CO2 emissions from the power generation sector, improve energy self-sufficiency and distribute disaster-resistant power sources, reduce costs for fossil fuel procurement, have economic ripple effects, and stimulate sustainable development.

These factors are directly linked to Japanese government's energy policy of 3E + S. FOW can also contribute to the global SDGs goal of "Sustainability", making FOW a means to achieve 3E + 2S.

Figure 6 Contribution of Offshore Wind to 3E + 2S



Source: METI (23)

6. Pathways to Reduce LCOE

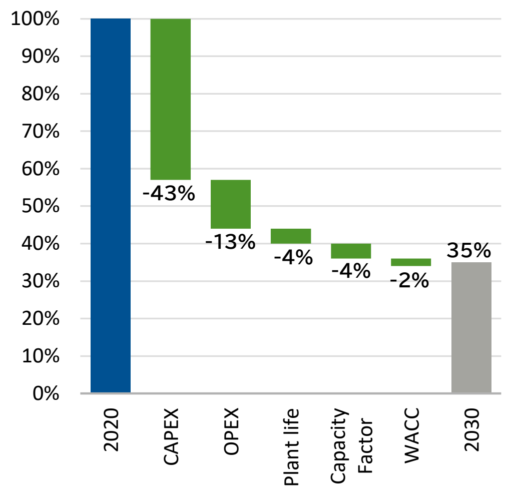
6.1 Industrialization and Maturation are the key factors for cost reduction

Outlook by major European institutions

WindEurope, European wind power industry organization, estimates that the commercialization of FOW could reduce LCOE by 65% by 2030 (Figure 6). In addition, WindEurope cites the following three factors that can reduce LCOE by 65%.

- Industrialization and maturation of FOW to enable large-scale project development
- Utilization of knowledge from offshore oil and gas industries and bottom-fixed-type industries
- Increase in the number and scale of FOW projects

Figure 7 Example of cost reduction potential analysis of FOW



Source: WindEurope (24)

Industrialization and Maturation are the Key Factors

The key factors to realize the reduction of LCOE are the Industrialization and Maturation of FOW to enable sizable capacity of installation.

It is necessary to form a large, long-term, stable market that enables large-scale investment decisions by industry, and prompt clarification of systems concerning FOW such as development in EEZ and create attractive business environment.

Expansion of annual installation and farm size

In order to increase the cost reduction effect, it is effective to increase the number of FOW farms developed in the market as a whole and to expand the scale of farms.

The increase in the number of projects developed each year will make it easier for component manufacturers to establish large-scale production systems. In addition, the expansion of the scale of the farm will increase the number of wind turbines, substructures, and other components generating economies of scale. It will also lead to an increase in the operation rate of infrastructure and personnel during construction and operation and maintenance, which will further reduce the cost.

6.2 Features of the FOW System that enable LCOE reduction

Harnessing good wind resources

For wind power, strong and stable wind is the most important factor to increase power generation. Even with the same wind turbine, the higher the wind speed, the greater the amount of power generated, leading to a reduction in LCOE.

In general, the further we are from the shore, the stronger and more stable the wind becomes. In Japan, where the seabed can be very steep, the ability to receive strong and stable winds far offshore and deep into the sea is a major attractiveness of FOW.

Industrial production of substructures

Since the substructure of the same design can be applied to various depths with little or no influence from the seabed features, large-scale production of the substructure is possible.

The shift to continuous production of substructures is a major factor in reducing installation costs.

Installations without large jack-up vessels possible

For FOW, the substructure and the wind turbine are usually assembled at the port and towed to the installation site at the sea. In this case, large-scale assembly work is not required offshore, meaning crane vessels and tugboats can be used, without the necessity of using large jack-up vessels.

7. Key measures to expand and accelerate development of Japanese Market

7.1 Deepening the vision for offshore wind industry

Need to advance policies to enhance market attractiveness

In December 2020, Japan's offshore wind market took a big step forward with the announcement of the first "Vision for Offshore Wind Power Industry (1st)" at the Public-Private Council.[13]

In addition to targets, this industrial vision presented a comprehensive basic strategy, including the introduction of a new government-led project formation scheme (known as "Japanese centralized system"), the development of electrical and port infrastructure plans, the development of the business environment through inspections of regulations and standards, and human resource development. These factors greatly contribute to the expansion of the offshore wind.

Furthermore, it is crucial to improve the attractiveness of the FOW market with market size and long-term stability.

Key measures under consideration in Public-Private Council

- Achievement of installation targets, domestic procurement ratio, and cost reduction targets
- New government-led project formation scheme (known as "Japanese centralized system")
- Development of grid and port infrastructure plans
- Streamlining regulations and standards
- Strengthening supplier competitiveness
- Human resource development programs
- Development of technologies especially FOW
- International standardization and intergovernmental discussions

7.2 Setting large-scale, mid and long-term targets for FOW

To accelerate the development of the FOW industry, it is important to have concrete targets for FOW within the offshore wind target of 10GW by 2030 and 30-45GW by 2040, and clearly show the vision of the country and industry.

By specifying the large-scale market in the future, it is expected that private companies interested in FOW will be encouraged to enter the market and that investment in product and technology development and supply chain development will be promoted.

It is also important that there are defined medium and long term targets. In addition to the targets for 2030 and 2040, setting a target for FOW to achieve carbon neutrality by 2050 will clarify long-term stable market formation.

7.3 Identifying regulation-related issues and necessary measures specific to FOW

Acceleration of EEZ development and solutions to related issues

It is effective to start a discussion between the government and the industry at an early stage and take concrete action on the systems and regulations including EEZ development.

Japan has EEZ that is approximately 12 times the size of its land area, and it is necessary to install in EEZ in addition to the territorial waters for the expansion of FOW.

It is important to grasp regulation-related issues related to EEZ development at an early stage, and to facilitate development.

7.4 Development of port infrastructures for FOW

Based on the first "Vision for Offshore Wind Power Industry", a study group has been established to discuss the location and scale of future port infrastructures and harbors, and the development of port infrastructures and harbors is being discussed considering the technological development status of FOW.[14]

In FOW, it is assumed that the substructure and the wind turbine are assembled at the port, then towed to the offshore project site. Depending on the type of substructure, it is necessary to secure enough water depth to tow a substructure at the port.

It is necessary to steadily promote port development suitable for the installation of FOW through close consultations between the public and private sectors.

7.5 Development of human resources

Offshore wind is a new industry full of hopes and challenges. For offshore wind development and operation, various industries are involved such as developers, component suppliers, construction companies, operators, and maintenance companies and financiers and/or institutional investors as well as lenders.

In order to realize the large-scale installation of offshore wind, it is necessary to develop tens of thousands of human resources throughout the supply chain.

It is important to promote education for the young

[13] See also Chapter 4 for details.

[14] MLIT 2050 Carbon Neutrality Forum (34)

generation that will lead the future of offshore wind. It is necessary for the government, academia, and industry to work together for education in high schools, technical colleges, and universities so that the next generation can deepen the understanding and see the attractiveness of FOW.

In addition, it is also important to conduct safety training to raise awareness of health, safety and environment (HSE).

7.6 Harmonization with Local Communities and Fisheries

Maritime space design to build cooperative relationship

The sea is a complex and important space for diverse stakeholders. It is extremely important to discuss and design ways of using the maritime space to build a cooperative relationship through dialogues among relevant stakeholders.

In Europe, Maritime Spatial Planning is a process to identify stakeholders who use these areas and to coordinate their views towards collaborative use.

In Japan as well, it is important to promote maritime space design to build cooperative relationships among the stakeholders.

Harmonized measures and new value creation through dialogue

We will be able to deepen understanding through close dialogue with local communities and fisheries, and work together to create new values through harmonized measures.

In the stakeholder dialogues, it is important to gain a deep understanding of the sea areas where fishing is conducted, the fishing methods used, and the relationship between the local tourism industry and the sea areas, and to pursue harmonized measures and development plans that respect this understanding.

In addition, effective measures and plans will increase fish catch, create job opportunities, revitalize and stimulate growth in local communities.

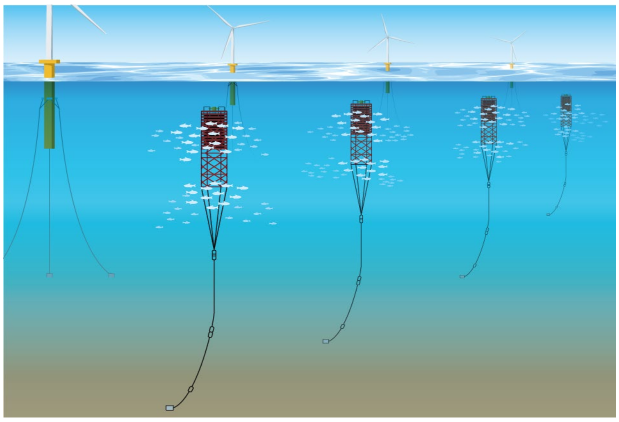
Example of harmonization (1): The reef effect

The "reef effect" is one of the positive effects that FOW is expected to have on fisheries. The reef effect of FOW is studied in each country, and the effects vary depending on the fish species.

The FOW installed off the coast of Goto City, Nagasaki Prefecture has a reef for demersal fishes at the base as well as floating fish reef at the sea surface[15], and its reef effect has been confirmed.[16]

FOW farms off the coast may serve for fish breeding with possible ripple effect to the coastal area.[17]

Figure 8 Image of floating reef installation around FOW



Source: Designed based on RIOE (25)

Example of harmonization (2): Creation of fish farming and aquacultures

It is considered that new types of fish farms and aquacultures can be created in combination with FOW. For example, automatic feeding equipment can be installed on floating structures.[18]

In France and Spain, trials are underway to build floating aquaculture facilities in parallel to FOW.[19] [20]

In Europe, as part of the plans to realize sustainable fisheries, efforts are underway to cultivate fishes in offshore facilities, for which electricity from FOW can be used.

Example of harmonization (3): Collection and utilization of metocean data

One of the possible harmonized measures will be to use floating equipment to collect ocean data and utilize the data for fishing. For example, sensors can be installed in the foundation to measure water temperature, salinity, flow direction and flow velocity, wave height, wave direction, subject to change for each possible project site.[16]

[15] RIOE (35)
[16] RIOE (25)
[17] Tokyo Kyuei (36)
[18] Fukushima-Forward Consortium (37)
[19] MISTRAL (38)
[20] MARIBE (39)

Toward Harmonization with Local Communities and Fisheries

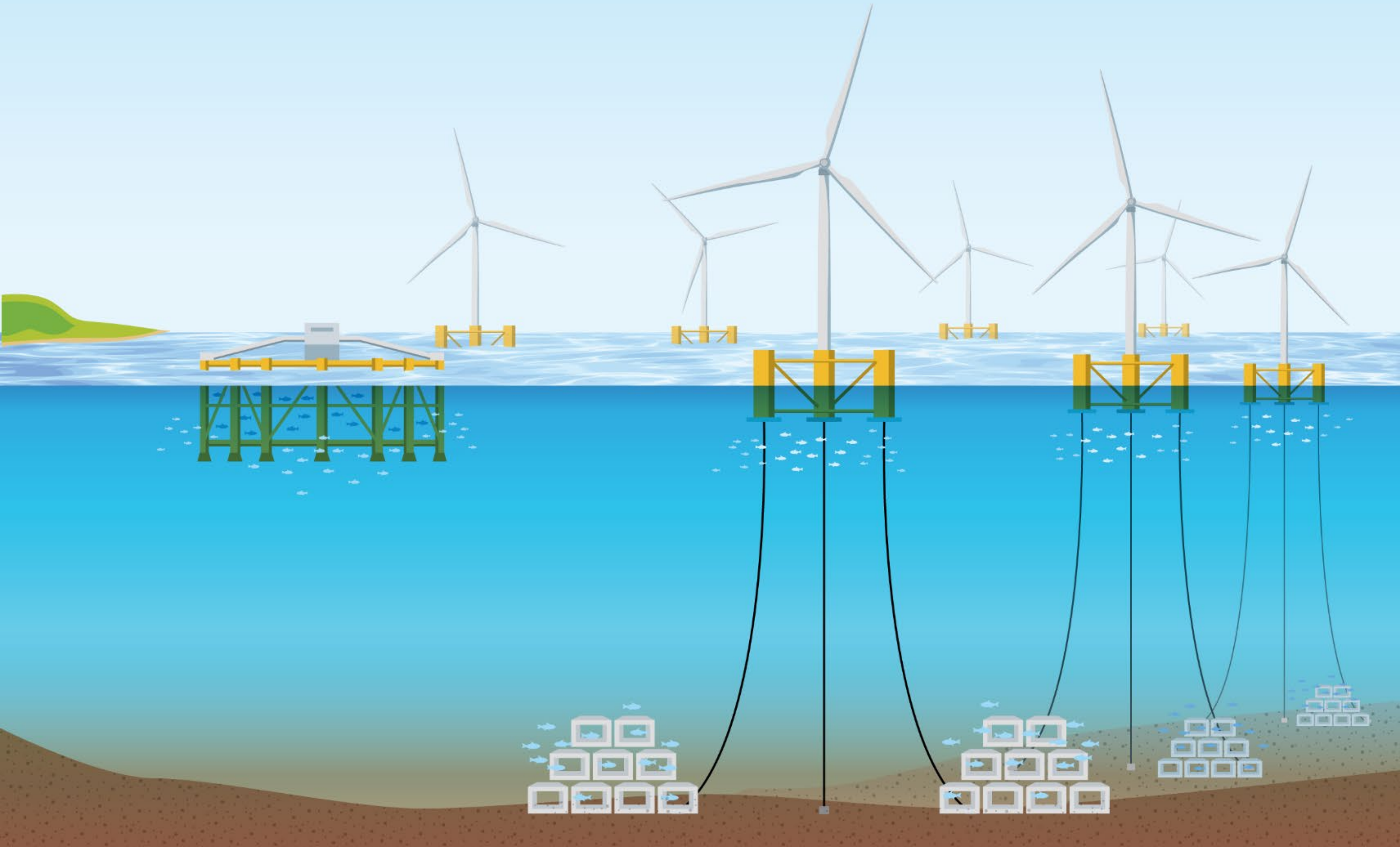
1. Creating dialogue among stakeholders
2. Developing harmonized measures and development plans based on deep understanding and consideration for local communities and fisheries
3. Developing harmonized measures and development plans that create new value for local communities and fisheries

Artificial reef effect and new possibilities for aquaculture

- Artificial reef effect and place of growth for juveniles
- Attracting fishes by installation of automatic feeding equipment
- Sea fertilization by upwelling deep ocean water
- Provision of electricity to aquacultures

Harmonization measures in project development

- Project development based on dialogues
- Avoiding construction on existing fishing ground, Permitting fishing or entering of fishing boats in wind farm areas
- Construction of farms based on environmental impact assessments and scientific data analysis of the effects on fishing



Harmonization measures through data analysis

- Setting sensors on substructures and collecting real-time metocean data(water temperature, salinity, ocean currents, etc.) to be used for local activities such as fishing

Harmonization measures through energy projects

- Investment by local communities and fisheries in energy business
- Local employment opportunities for construction, operation and maintenance

8. Towards the Development of FOW Market

Proposals for FOW Market Development

1. Set FOW target of 2-3GW by 2030, mid and long-term targets
2. Promote strategic development plans for large-scale and domestic industrial development
3. Accelerate discussion to create an attractive FOW business environment

8.1 Set FOW target of 2-3GW by 2030, mid and long-term targets

Set the target of 2-3GW by 2030

We propose to set a 2030 target of 2-3GW, and to set mid and long-term targets.

Deployment of FOW is essential for achieving the 2030 greenhouse gas reduction target and achieving carbon neutrality as early as possible by 2050.

The industry is preparing and large-scale FOW projects can be operational by 2030, contributing to Japan's decarbonization.

Establishment of medium- and long-term targets for 2040 and 2050

It is important to set medium- and long-term targets for early realization of carbon neutrality by 2050.

By specifying the portion of FOW to be operational by 2040 out of the overall OW targeted capacity (30-45GW) and setting a target for 2050, long-term stable market formation on the scale of several GW every year will be clarified and market attractiveness will be further enhanced.

8.2 Promote strategic development plans for large-scale and domestic industrial development

Develop multiple FOW projects of several hundred MW to 1GW by 2030

We propose that development plans for projects spanning from several hundred to GW scale by 2030 are necessary in order to industrialize, mature, and reduce FOW costs.

FOW is realized on proven technology and can provide a stable power supply. Through industrialization and further maturation, costs can be significantly reduced.

Promote strategic development plans to achieve domestic industrial development

In promoting the development of FOW, we propose that the public and private sectors work together to formulate a strategic development plan to realize domestic industrial development.

By making use of the technologies established to date and, identifying further optimization opportunities, environmental factors such as typhoons unique to the Asian region, as well as how to take advantage of the strengths of domestic industries, we can create strategic development plans, enabling domestic industries to become internationally competitive.

8.3 Accelerate dedicated discussion to create an attractive business environment

Early initiation of comprehensive discussions to accelerate FOW

We propose to set committees dedicated to discussing FOW matters, and outline a clear path towards building a business environment. This includes setting mid and long-term targets, plans for large-scale FOW farms, and working towards developing in the EEZ.

By comprehensively discussing issues for the large-scale installation of FOW and implementing effective measures, we will be able to realize the development of large-scale FOW farms by 2030 and its full-scale expansion onwards.

The Industry is highly motivated and well-prepared

The industry is highly motivated and keen to work with the government to develop domestic industries, reduce costs, and contribute to Japan's energy policies and global climate change measures.

Glossary and Abbreviation

Term	Explanation
Anchors	Used for fixing the location of floating substructures via mooring lines.
Array Cables	Cables connecting wind turbines to the substation.
Barge	A type of substructure with barge-style floating body.
Bottom-Fixed Offshore Wind	A type of offshore wind where the foundations are fixed to the seabed. In this document, it is abbreviated as BFOW.
Capacity Factor	Usage rate of power facilities as a percentage of actual power generation to the maximum capacity that the facility can generate. For offshore wind, the power generation depends on the weather and there will be times with no wind, resulting in capacity factor below 100%.
Carbon Neutrality (Japanese definition)	A state where the net emission of greenhouse gas emissions is zero.
Dynamic Cables	Electrical cables that are not fixed to the seabed and move dynamically in the waters.
Exclusive Economic Zone (EEZ)	Areas within 200NM from the coastal baseline. In EEZ, the sovereign country has exclusive rights for fishing and usage of resources and rights to regulate marine contamination.
FIT	Abbreviation of Feed-in Tariff. A government policy in which power companies procure power generated by renewable energies at a fixed cost for a fixed period.
Floating Offshore Wind	A type of offshore wind installation where the wind turbines are set on floating substructures. The substructures are moored to the seabed by mooring lines and anchors. In this document, it is abbreviated as FOW.
Japanese central system	A government-led system for project formation, where the government leads necessary preparations for FOW such as wind resource, metocean, and geographical assessments and grid capacity procurement.
kW/MW/GW	Units of power. 1,000kW=MW. 1,000MW=GW.
Mooring lines	Ropes or chains that is used to fix the location of floating substructures.
Offshore Oil and Gas Industry	An industry that extracts oil and gas from beneath the sea and develops infrastructure for extraction and production of oil and gas.
LCOE	The cost of power generation facilities throughout its lifetime (project development, manufacturing, construction/installment, operation and maintenance, decommissioning) divided by the total power generated in its lifetime.
Project Finance	Financing of specific projects which treats cash flow produced by the projects as resources to return the debts and limits collateral debt protection to project resources.
Reef	Areas underwater where structures such as rocks or artificial structures attract marine species to hide, live or reproduce.
Semi-Submersible	A type of substructure with semi-submerged floating body.
Ship Registration	Certification of ships and related organizations based on technological standards. In Japan, the tower, substructure, mooring components are required to satisfy Ship Safety Act and need to be registered by certification organizations.
Spar	A type of substructure with a cylindrical floating body with a low center of gravity.
Substructures	One of the key components of offshore wind power plants representing the foundation of the wind turbines. In floating, substructures can be classified into semi-submersible, spar, TLP, and barge type.
Tension mooring	Mooring using the tension forces between the substructure and the anchor in the seabed.
Territorial Waters	Area of the sea within 12NM (equivalent to ~ 22.2km) from shore.
Tension Leg Platform	A type of substructure with a semi-submersible floating body fixed by tension mooring.

Sources and References

1. UK Government. New plans to make UK world leader in green energy. [Cited: 9 30, 2021.] https://www.gov.uk/government/news/new-plans-to-make-uk-world-leader-in-green-energy.
2. Ireland Government. Programme for Government Our Shared Future. 2020/5. p. 35.
3. GWEC. GLOBAL OFFSHORE WIND REPORT 2021. 2021/9/9. p. 108.
4. Norwegian Government. Norway opens offshore areas for wind power. [Cited: 9 30, 2021.] https://www.regjeringen.no/en/aktuelt/norway-opens-offshore-areas-for-wind-power/id2705986/.
5. Ministère de la Transition écologique et solidaire. French Strategy for Energy and Climate Multi Annual Energy Plan. 2019. p. 117.
6. Commission nationale du débat public. Compte Rendu du Débat Public Éolinenes Flottantes au sud de la Bretagne. 2020. p. 8.
7. —. PROJET D'ÉOLIENNES FLOTTANTES EN MÉDITERRANÉE ET LEUR RACCORDEMENT: L'essentiel pour comprendre le projet. 2021/7/12. p. 2.
8. Offshore Wind Scotland. Scotland Offshore Wind Market. [Cited: 9 30, 2021.] https://www.offshorewindscotland.org.uk/scottish-offshore-wind-market/.
9. Korea.net. Remarks by President Moon Jae-in at Strategy Presentation for Floating Offshore Wind Farm in Ulsan. [Cited: 9 30, 2021.] https://www.korea.net/Government/Briefing-Room/Presidential-Speeches/view?articleId=198309.
10. Ministry for the Ecological Transition and the Demographic Challenge. El MITECO saca a información pública la propuesta de Hoja de Ruta de la Eólica Marina y las Energías del Maricono barra herramientas. [Cited: 9 30, 2021.] https://www.miteco.gob.es/en/prensa/ultimas-noticias/el-miteco-saca-a-informaci%C3%B3n-p%C3%BAblica-la-propuesta-de-hoja-de-ruta-de-la-e%C3%B3lica-marina-y-las-energ%C3%ADas-del-mar/tcm:38-529100.
11. The White House. FACT SHEET: Biden Administration Opens Pacific Coast to New Jobs and Clean Energy Production with Offshore Wind Development. [Cited: 9 30, 2021.] https://www.whitehouse.gov/briefing-room/statements-releases/2021/05/25/fact-sheet-biden-administration-opens-pacific-coast-to-new-jobs-and-clean-energy-production-with-offshore-wind-development/.
12. Oregon State Legislature. [Cited: 9 30, 2021.] https://olis.oregonlegislature.gov/liz/2021R1/Measures/Overview/HB3375.
13. Toda Corporation. Haenkaze.com. [Cited: 9 30, 2021.] https://haenkaze.com/.
14. Equinor. World's first floating wind farm has started production. [Cited: 9 30, 2021.] https://www.equinor.com/en/news/worlds-first-floating-wind-farm-started-production.html.
15. Ocean Winds. Multimedia Resources. [Cited: 9 30, 2021.] https://www.oceanwinds.com/media/multimedia-resources/.
16. Cobra Group. Kincardine Offshore Floating Wind Farm. [Cited: 9 30, 2021.] https://www.grupocobra.com/en/proyecto/kincardine-offshore-floating-wind-farm/.
17. Equinor. Hywind Tampen. [Cited: 9 30, 2021.] https://www.equinor.com/en/what-we-do/hywind-

tampen.html.

18. Public-Private Council on Enhancement of Industrial Competitiveness for Offshore Wind Power Generation. Vision for Offshore Wind Power Industry (1st). 2020/12/15.
19. National Institute for Environmental Studies. 2050 年脱炭素社会実現の姿に関する一試算. 2020/12/14. p. 39.
20. Renewable Energy Institute. 総合資源エネルギー調査会基本政策分科会第 34 回 資料 3-2 2050 年カーボンニュートラルへの提案－自然エネルギー100%の将来像. 2020/12/14. p. 4.
21. Japan Wind Power Association. 第 1 回洋上風力の産業競争力強化に向けた官民協議会資料 4-1 洋上風力の主力電源化を目指して. 2020/7/17. p. 14.
22. NEDO. NeoWins. [Cited: 9 30, 2021.] https://appwdc1.infoc.nedo.go.jp/Nedo_Webgis/top.html.
23. Ministry of Economy, Trade and Industry. 新しいエネルギー基本計画の概要. [Cited: 9 30, 2021.] https://www.enecho.meti.go.jp/category/others/basic_plan/pdf/180703_01.pdf.
24. WindEurope. Getting fit for 55 and set for 2050 Electrifying Europe with wind energy. 2021/6. p. 18.
25. Research Institute for Ocean Economics. 洋上風力発電等の漁業協調の在り方に関する提言 第 2 版. 2015/6. pp. 11,18,21.
26. WindEurope. Our Energy, Our Future. 2019. p. 69.
27. GWEC. GLOBAL WIND REPORT 2021. 2021/3. p. 30.
28. European Commission. EU loan helps kick-start construction of floating wind farm off the coast of Portugal. [Cited: 9 30, 2021.] https://ec.europa.eu/info/news/eu-loan-helps-kick-start-construction-floating-wind-farm-coast-portugal-2018-oct-19_en.
29. Carbon Trust. Floating Wind Joint Industry Project Phase 2 Summary Report. 2020/07. pp. 38-47.
30. NEDO. 洋上風力の産業競争力強化に向けた技術開発ロードマップ. 2021/4/1. p. 8.
31. Ministry of the Environment,. 令和元年度再生可能エネルギーに関するゾーニング基礎情報等の整備・公開等に関する委託業務報告書. 2020/3. pp. 150, 153.
32. IEA. Offshore Wind Outlook 2019. 2019. p. 51.
33. Central Research Institute of Electric Power Industry. 洋上風力導入量 GIS 評価ツール. [Cited: 9 30, 2021.] https://www.denken-serc.jp/rpg/offshore/.
34. Ministry of Land, Infrastructure, Transport and Tourism. 2050 年カーボンニュートラル実現のための基地港湾のあり方に関する検討会(第 1 回) 資料 3. [Cited: 9 30, 2021.] https://www.mlit.go.jp/kowan/kowan_tk6_000073.html.
35. Research Institute for Ocean Economics. 洋上風力発電と漁業協調・地域振興について. 2018/12. p. p.14.
36. Tokyo Kyuei Co., Ltd. 沿岸生態系を考慮した洋上風力発電施設周辺域における新規漁場の創出案. p. 2.
37. Fukushima FORWARD. 福島復興浮体式洋上ウィンドファーム実証研究事業. [Cited: 9 30, 2021.] http://www.fukushima-forward.jp/pdf/pamphlet.pdf.
38. MISTRAL. THE CASE OF FRANCE - BLUE BUSINESS PLAN COMPETITION. [Cited: 9 30, 2021.] https://mistral.interreg-med.eu/no-cache/news-events/news/detail/actualites/the-case-of-france-blue-business-plan-competition/.
39. MARIBE. UNLOCKING THE POTENTIAL OF MULTI-USE OF SPACE AND MULTI-USE PLATFORMS. 2016. p. 22.

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Report Cooperation

Mitsubishi Research Institute, Inc.

Expectation and Foresight of FOW in Japan

Key for decarbonization in Japan

September 2021

Japan's Floating Offshore Wind Group