The challenge to the world's first floating wind farm

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Marubeni CORPORATION　東京大学 THE UNIVERSITY OF TOKYO　Mitsubishi Corporation　三菱重工　JMU　MES 三井造船株式会社

新日鐵住金　HITACHI Inspire the Next　FURUKAWA ELECTRIC　子どもたちに誇れるしごとを。 SHIMIZU CORPORATION 清水建設　MIZUHO

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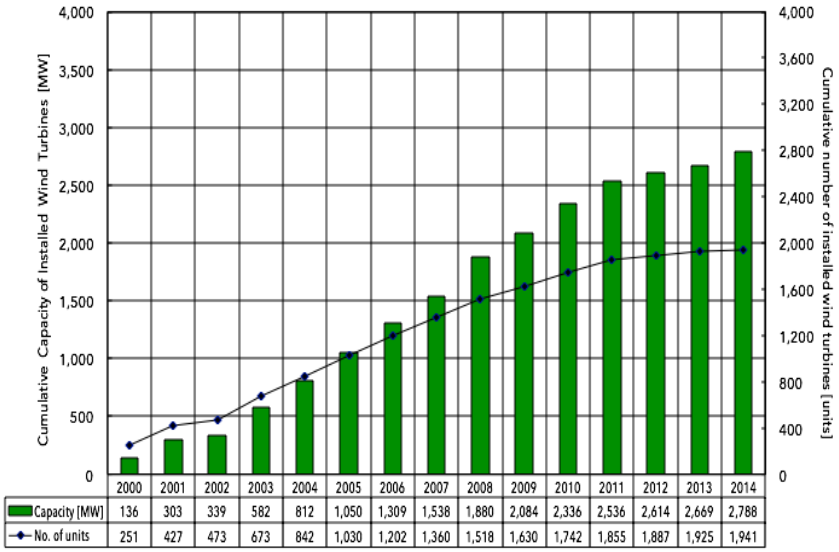
Overview

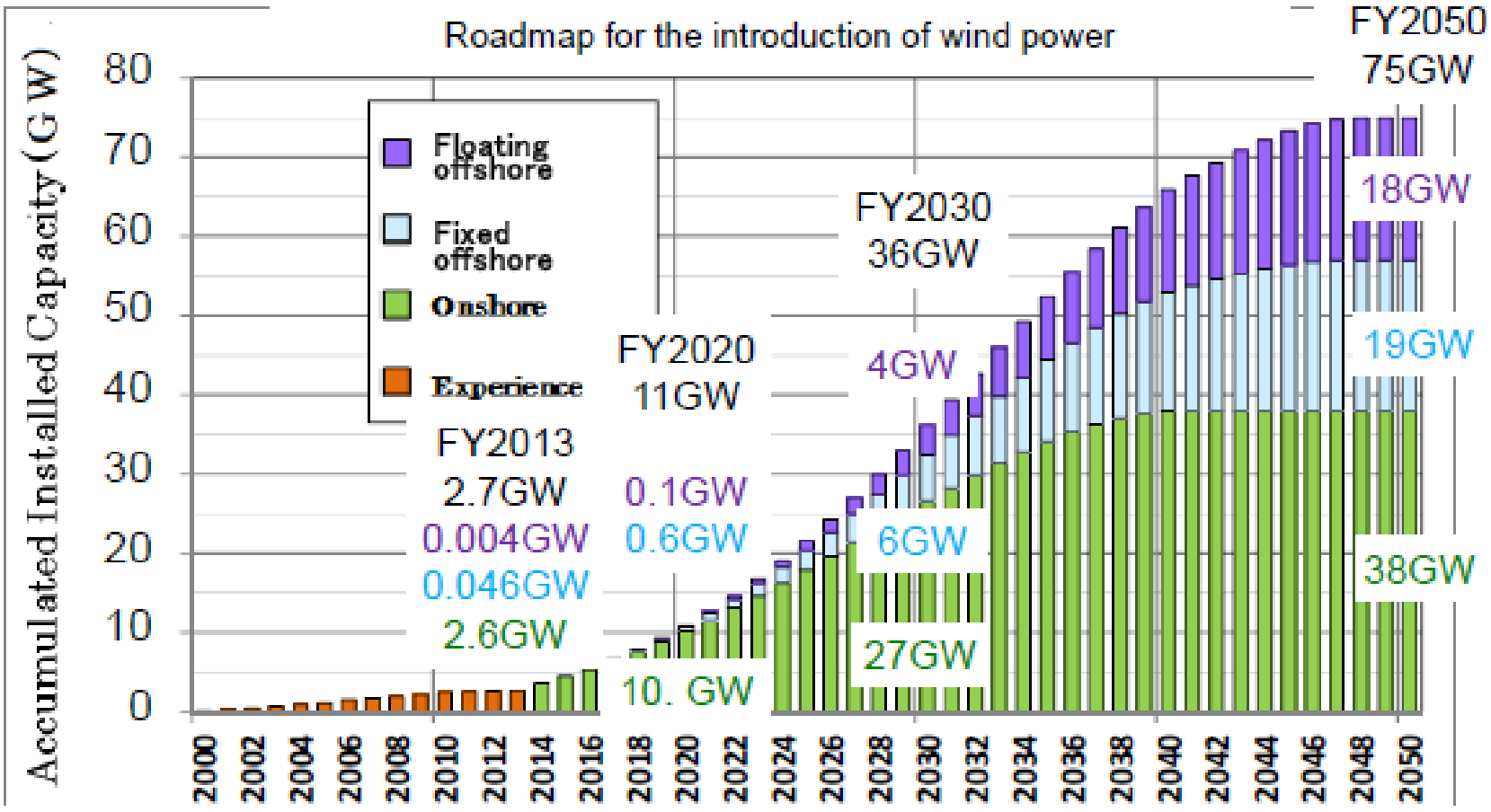
- In 2014, the total installed wind capacity in Japan reached 2,788 MW with 1,941 turbines, including 49.6 MW from 26 offshore wind turbines.
- The annual net increase was 119 MW. Total energy produced from wind turbines during 2014 was about 5.1 TWh
- This corresponds to 0.5% of national electric demand (965.2 TWh).



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Capacity [MW]	136	303	339	582	812	1,050	1,309	1,538	1,880	2,084	2,336	2,536	2,614	2,669	2,788
No. of units	251	427	473	673	842	1,030	1,202	1,360	1,518	1,630	1,742	1,855	1,887	1,925	1,941

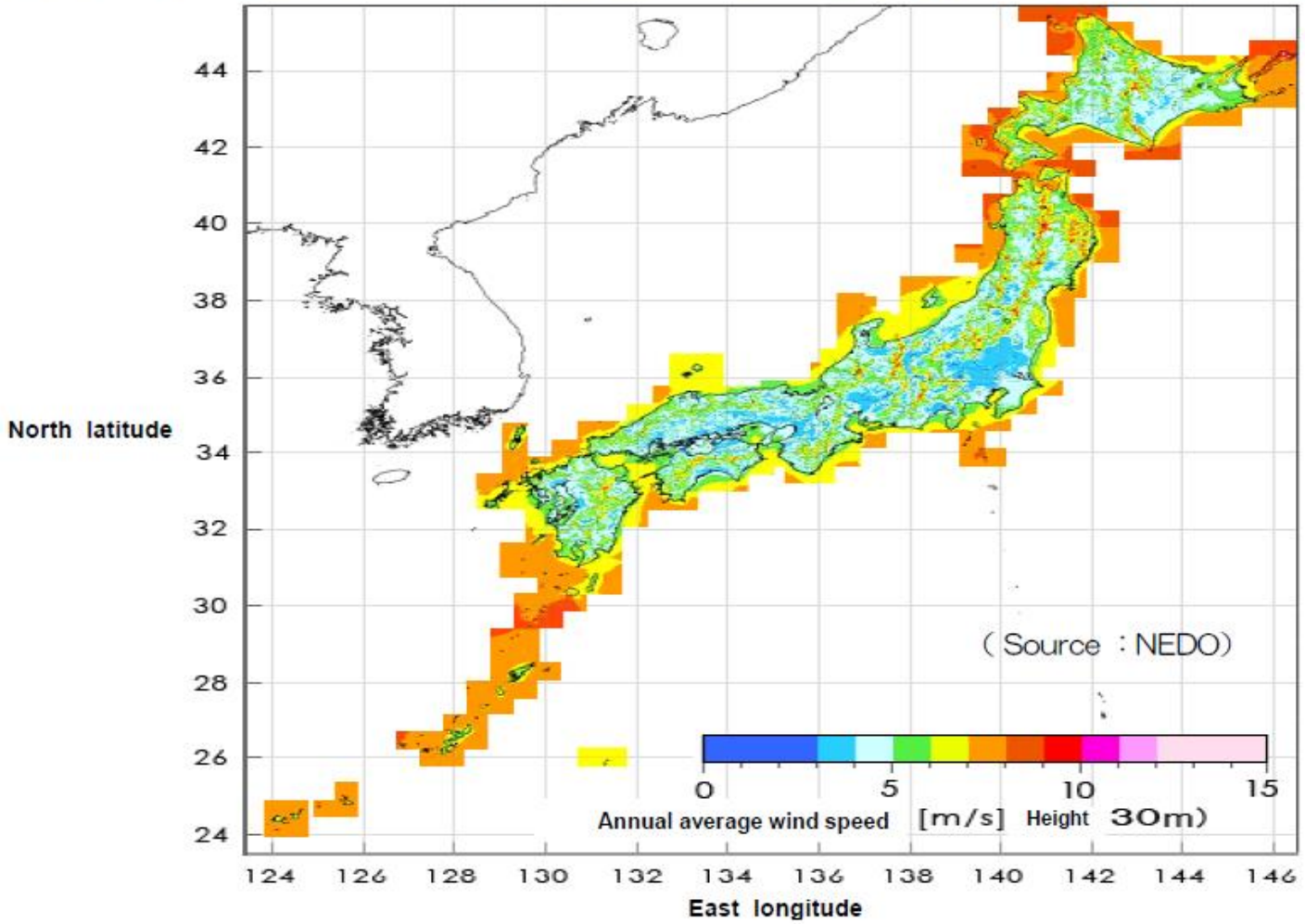
Roadmap for wind power development by JWPA

- Wind power will supply 20% of Japanese electricity by 2050
- In 2013, the ratios to total power supply by wind are 33% in Denmark, 27% in Portugal, 21% in Spain, 12% in Germany, 8% in UK, respectively.



Wind power potential in Japan

- Report of investigation for renewable energy in Ministry of Environment in 2011
- 280 GW for onshore, 1600 GW for offshore as potential value
- 273 GW for onshore , 141 GW for offshore under some scenario such as half-price



The world's 6th largest marine EEZ

- Japan has the world's 6th largest marine Exclusive Economic Zone and has a strong maritime industry.
- This makes offshore wind an attractive option, and Japan currently has 57 MW of offshore capacity, including 11 MW of floating turbines.
- At the moment, there are four offshore projects totaling 254 MW which are under the Environmental Impact Assessment procedure.
- Onshore wind will lead industry at early years and floating offshore will be applied for deep water.

National incentive programs

- The incentive program in Japan, was changed from investment subsidies and Renewable Portfolio Standards (RPS) to the feed-in-tariff (FIT) scheme starting in July 2012.

- The new FIT scheme covers all practical renewable energy sources such as PV, wind power, small- and medium-scale hydropower, geothermal, and biomass.

- At the initiation of the FIT system, the tariff are
  - ✓ 22 JPY/kWh for wind power greater than or equal to 20 kW of capacity .
  - ✓ 36 JPY/kWh for offshore wind from 2014.

Industry status

- There are four Japanese wind turbine manufacturers producing turbines larger than 2 MW: Mitsubishi Heavy Industries (MHI), Japan Steel Works (JSW), Hitachi and Toshiba.
- They have kept more than 60% domestic market share for several years.

New wind turbines developed by Japanese manufacturers

Company	Model	Rated output	Start of operation	Type
MHI	MWT167/7.0	7.0 MW	2015	Digital hydraulic drive
Hitachi	HTW5.0-126 HTW2.0-86	5,0 MW 2.0 MW	2015 2014	Downwind Downwind
JSW	J100-2.7/3.0	2.7/3.0 MW	2013	Gearless PMSG
Toshiba	U88/93	2.0 MW	2012	Medium speed gear with PMSG

Bigger wind turbines

- MHI developed a 7-MW turbine and have been installed at the Fukushima floating offshore wind farm demonstration project in September 2015.
- Hitachi developed a 5-MW, downwind wind turbine. The first machine have been installed in March 2015 in Kamisu city, Ibaraki prefecture and will be installed at the Fukushima FORWARD Phase II.


MHI's MWT167/7.0

HTW5.0-126

Offshore wind demonstration projects in Japan

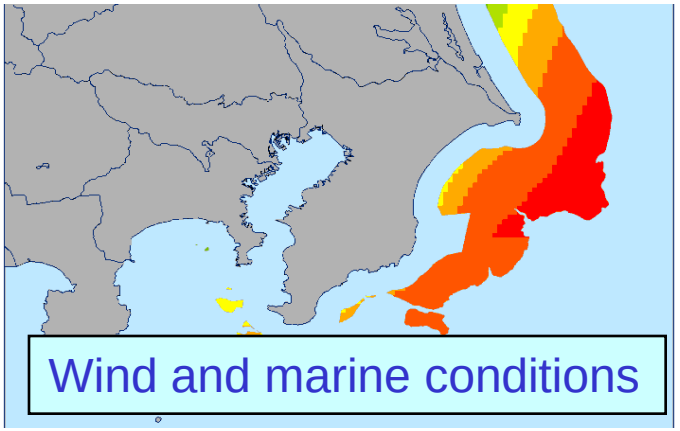
- A number of projects are under way around Japan's coast Two wind power platforms at Choshi and Kitakyusyu are located in shallow waters and are bottom-mounted. This type of platform has a long been used in Europe.
- Floating wind turbines can be positioned in deeper waters. Japan has developed advanced platforms at Goto and Fukushima. It expects will create demand in the rest of the world.

Near the Goto Islands demonstrations of offshore wind power facilities are being carried out.

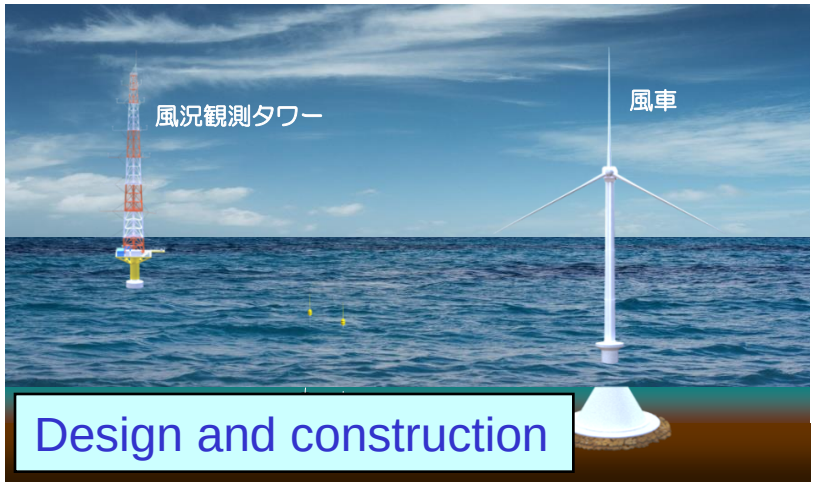
Bottom-mounted wind power facilities have been constructed off the coasts of Choshi and Kitakyushu.

What is the challenge of offshore wind power in Japan

Natural environmental conditions in Japan, such as strong winds during typhoon, high waves, and earthquakes are severer than Europe.



Wind and marine conditions



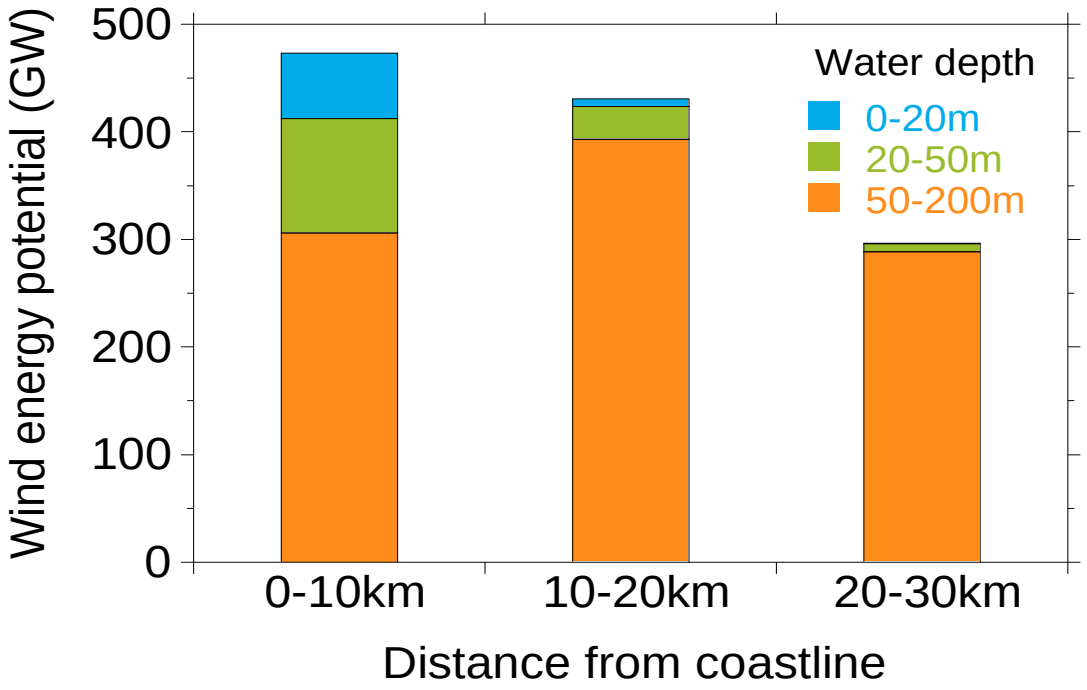
Design and construction

Environmental issue

New methods should be developed and proposed to the next edition of international standards for the environmental conditions such as Japan

Deep water in Japan

- Offshore wind energy potential along Japan is about 1600GW.
- More than 80% of them in Japan are located at deep water.



Generally speaking, when depths are deeper than 50m, the best choice is the floating type of platform. It can be built in a port or dock, tow them to open waters and install them on site. The benefit is it significantly reduces the amount of offshore work.

Benefits of Deepwater Wind

Utilisation of floating support structures has a number of important benefits, principally:

- greater choice of sites & countries
  - Mediterranean (France, Spain, Italy), Norway, US (east and West coast), East Asia (China, Japan, Korea)…
- greater choice of concepts
  - as evidence view the wide variety of technology solutions proposed
- cost probably similar to fixed structures in medium depths
  - Loads are dissipated into the water rather than being transferred rigidly to the ground
- greater flexibility of construction & installation procedures
- easier removal / decommissioning

Ref. A.R. Henderson: Floating support structures enabling new markets for offshore wind energy, EWEC2009

Challenges of Deepwater Wind

However the dynamics foundation introduces a number of new challenges, including:

- minimising turbine and wave induced motion
- additional complexity for the design process
  - understanding and modelling the coupling between the support structure and the wind turbine (moorings & control)
- the electrical infrastructure; flexible cable
- the construction, installation and O & M procedures

Ref. A.R. Henderson: Floating support structures enabling new markets for offshore wind energy, EWEC2009

2. Fukushima Floating Offshore Wind Farm Demonstration Project (FORWARD)

Introduction of project

- Since the Great East Japan Earthquake in 2011, efforts have been under way in many regions of Japan to develop offshore wind power. Fukushima floating offshore wind farm demonstration project is a major project.
- This project, generating the power from a floating offshore wind farm, gathers attention from all over the world as a future technology to solve the environment, economics and energy issues at the same time.

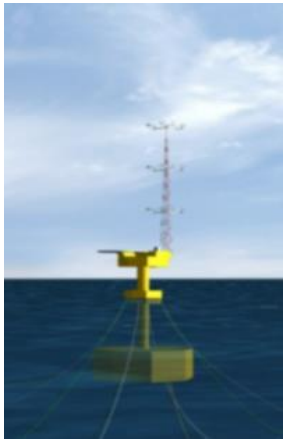
Outline of Project

- Fukushima offshore wind consortium is proceeding with Fukushima project funded by the Ministry of Economy, Trade and Industry.
- The first phase of the project consists of 2MW downwind floating wind turbine, the world first floating substation and submarine cable have been completed in 2013.
- In the second phase, one 7MW wind turbines and one 5MW downwind will be installed before 2016.

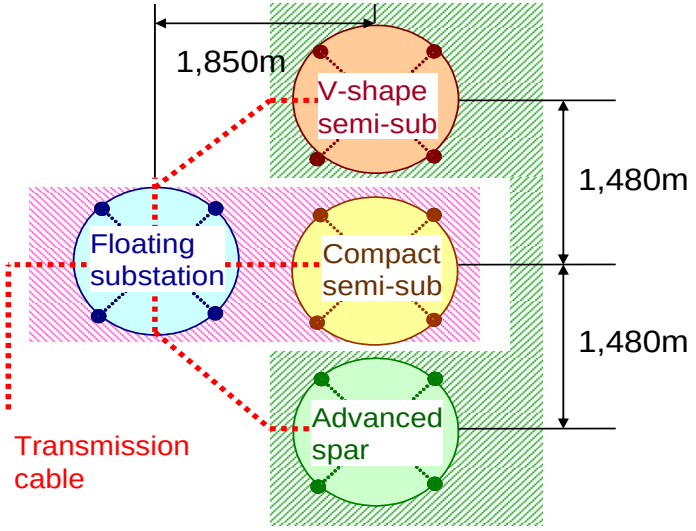
Phase I (2011~2013) → **Phase II (2014~2016)**

Phase I

Floating substation



Compact semi-sub



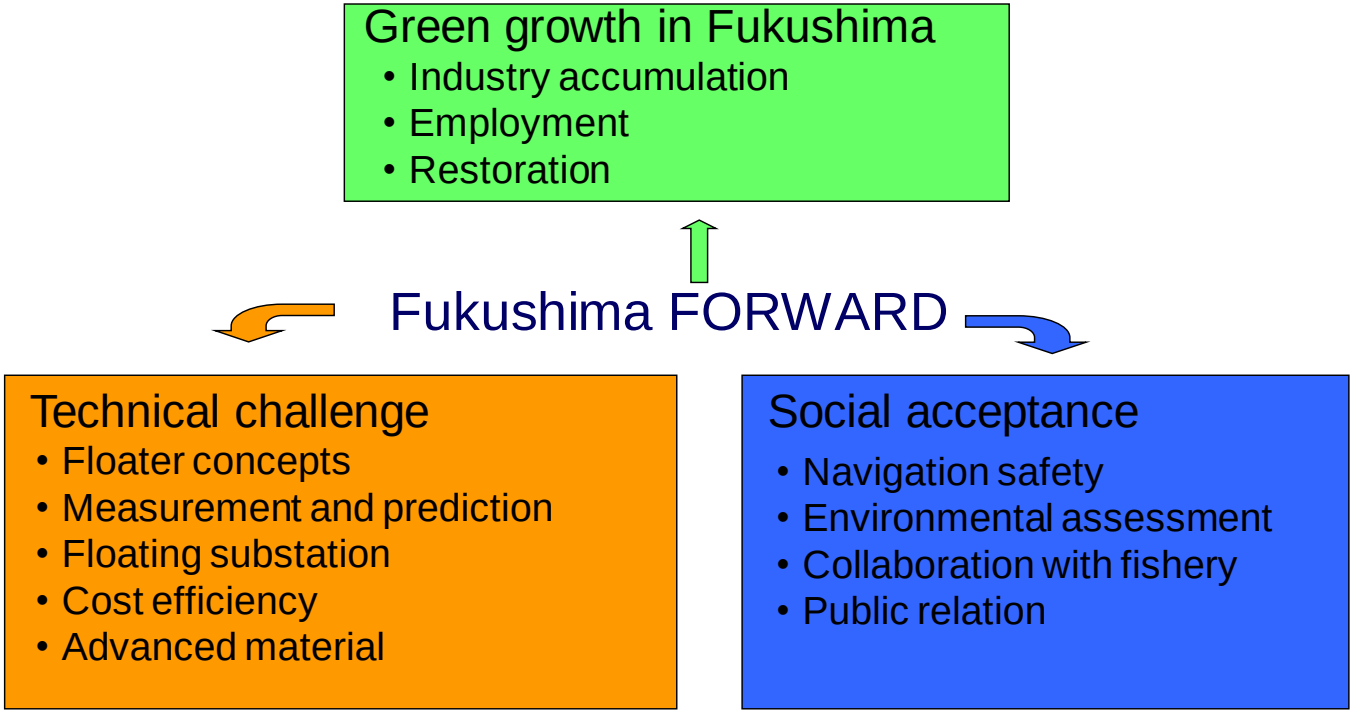
Phase II

Advanced spar

V-shape semi-sub

Fukushima FORWARD vision

- The Fukushima FORWARD project believes to help Fukushima to become the center of new industry which will create new employment in this region to recover from the damage of the Great East Japan Earthquake in 2011.
- This project is also expected to establish the business-model of the floating wind farm and contribute to future commercial projects. The consortium members are expected to learn know-how of floating offshore wind farm.



Presentation of consortium members

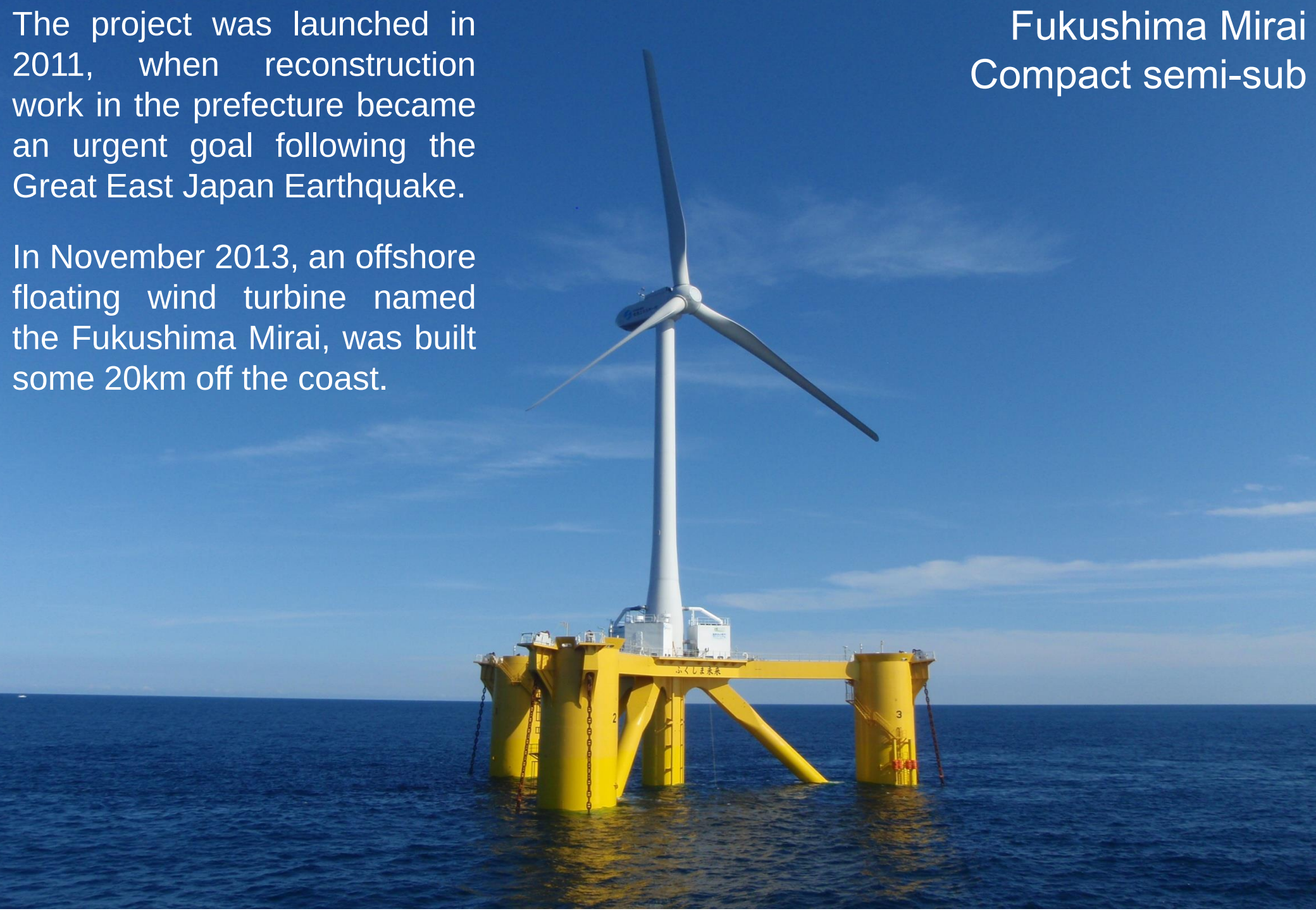
- This project is run by the Fukushima Offshore Wind Consortium. It consists of ten corporations and the University of Tokyo, and makes use of members' latest advances in shipbuilding, electric power infrastructure, steelmaking and undersea cable technology.

Consortium Member	Main Role
Marubeni Corporation (Project Integrator)	Pre-Studies, Approval and Licensing, Operation and Maintenance, Collaboration with Fishery Industry
The University of Tokyo (Technical Advisor)	Measurement and Prediction Technology, Navigation Safety, Public relation
Mitsubishi Corporation	Pre-Studies, Approval and Licensing, Environmental Assessment
Mitsubishi Heavy Industries, Ltd.	V-Shape Semi-Sub Type Floater
Japan Marine United Inc.	Advanced Spar Type Floater and Floating Substation
Mitsui Engineering & Shipbuilding Co., Ltd.	Compact Semi-Sub Type Floater
Nippon Steel & Sumitomo Metal Corporation	Advanced Steel
Hitachi, Ltd.	Floating Electric Power Substation
Furukawa Electric Co., Ltd.	Undersea and Dynamic Cables
Shimizu Corporation	Pre-Studies, Construction and Installation Technology
Mizuho Information & Research Institute, Inc.	Documentation, Committee Operations

Fukushima Mirai
Compact semi-sub

The project was launched in 2011, when reconstruction work in the prefecture became an urgent goal following the Great East Japan Earthquake.

In November 2013, an offshore floating wind turbine named the Fukushima Mirai, was built some 20km off the coast.



Compact semi-sub floater for 2MW

コンパクトセミサブ全体像

フーティングバラストタンクとボンツーンビーム

- The compact semi-sub floater has advantages for construction and installation due to its shallow drought.
- The drought of the floater can be controlled by using the ballast tank located at the bottom of the side columns.

The 2MW downwind offshore wind turbine was installed in June, 2013. At first the 48.5m tower divided into three sections and the nacelle were assembled and then 39m blades were installed. Commissioning test was carried out after towing to Onahama port.

This huge floater was towed from Chiba to Onahama and then to the installation site, offshore 20km of Fukushima. Three front tugboats and one rear boat were used. There were four boats for towing in total.

Fukushima Kizuna Advanced Spar

For a project like this, a critical challenge is efficiently transmitting the wind-generated electricity to land.

The consortium overcame this hurdle by building the “Fukushima Kizuna,” the world’s first offshore substation.

If we can transform wind-generated power into high voltage current on site, it cuts transmission costs and minimizes losses.

Power transformers, however, are immersed in an insulating liquid. So measures had to be taken to counter the transformers rolling caused by ocean waves.

Test for the transformer

- To achieve this, anti-rolling knowhow from shipbuilding to anti-quake measures were utilized.
- An offshore floating transformer system is developed and the performance against vibration and inclination was evaluated through shaking table tests.
- Based on these technology, the world first floating offshore transformer system was established against severe metocean conditions.

Construction of the floating substations

- The construction of the floating substations on the advanced spar floater was completed in June, 2013.
- On the main deck of the upper hull, a met mast and a helicopter deck are installed. Inside the upper hull, the world first floating substation is located.
- The bottom hull is filled with concrete to lower the center of gravity. The floater motion is controlled by using the cob under the upper hull, and the middle hull

On the 11th of July, 2013, the advanced spar floater for floating substation left Isogo dock of JMU and ferried to the installation site directly.

In Tokyo Bay, where many ships were sailing in and out frequently, It was towed carefully to ensure safety.

The anchor and mooring chain installation

- In May, 2013, the anchor and mooring chain for both compact semi-sub and substation floaters were installed and the holding power test was conducted. In this test, the severe wave situations such as typhoon were considered.

World largest riser cable

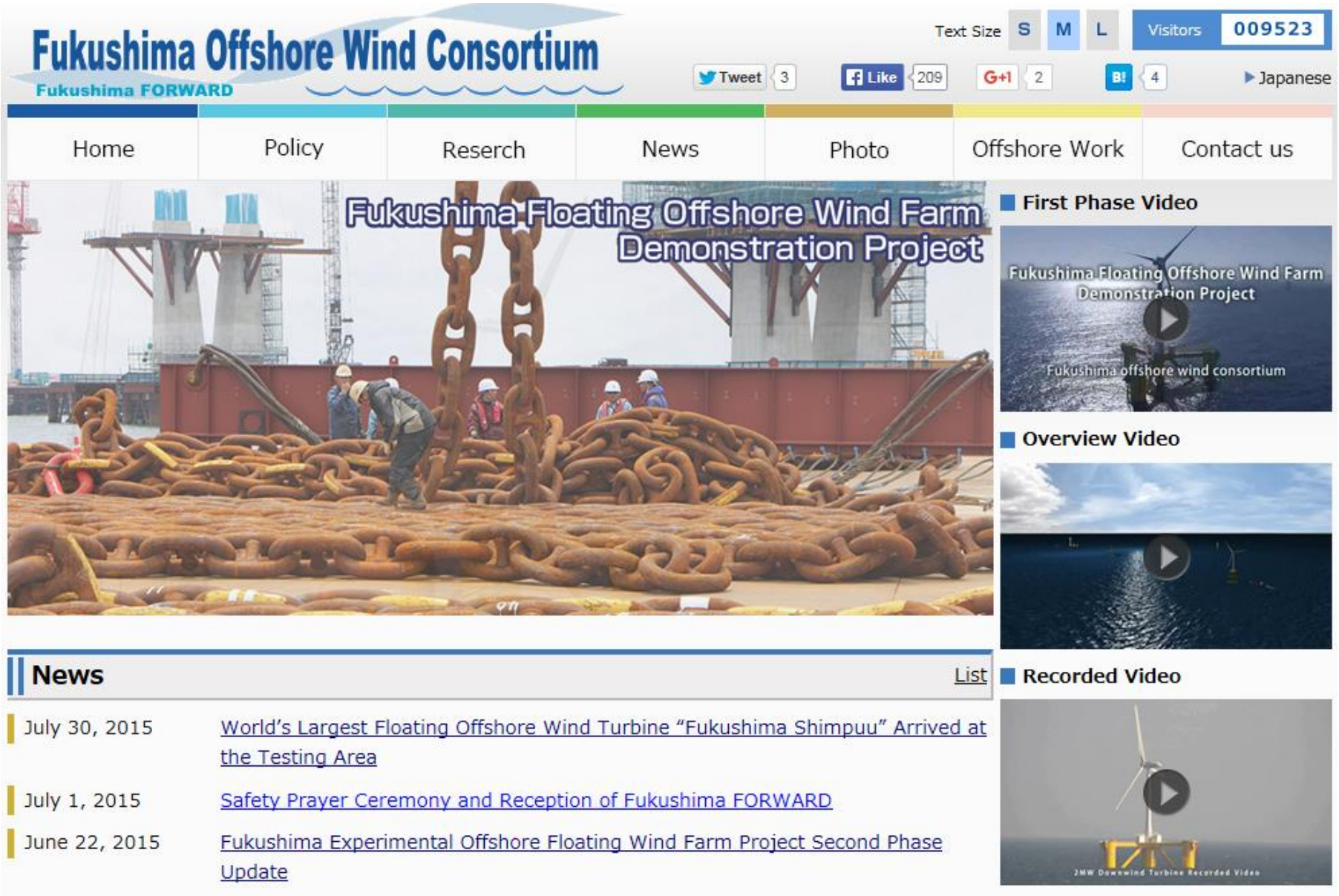
- A water proof riser cable with the world largest capacity at 66,000V is developed. The safety is verified by motion analysis and tension test.
- Connection between the floating bodies with the riser cable is the first time in the world. A riser cable was drawn into each floating body by a cable installation ship while being watched by ROV.

- In June 2013, the installation of the submarine cable between the offshore cable layer ship and the coastline was carried out. Then the ship installed the cable to the installation site of the substations.

World’s Largest Floating Offshore Wind Turbine “Fukushima Shimpuu” has installed at the Testing Area. The height from the sea surface to the rotor center is 105 meters. The wind turbine reaches 188.5 meter at the highest.

Facilities have connected to the mooring system and marine cables have connected to the substation “Fukushima Kizuna”, It will generate electricity soon.

Website for Fukushima Project



Fukushima Floating Offshore Wind Farm Demonstration Project
（Fukushima FORWARD）

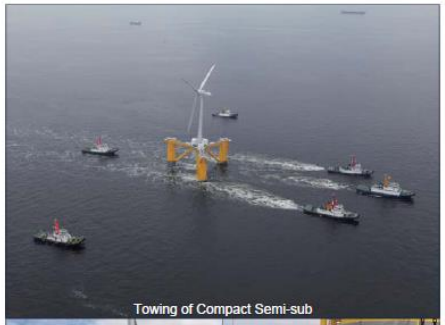
- Construction of Phase I -

Fukushima Offshore Wind Consortium

Fukushima FORWARD

Installation of the compact semi-sub and advanced spar

The compact semi-sub floater with 2MW downwind turbine left Chiba dock of Mitsui Engineering & Shipbuidling on 27th of June, 2013. After testing at Onahama Port, it was towed to the site and installed. On 11th of June, 2013, the advanced spar floater for floating substation left Isogo dock of JMU and towed to the installation site directly. From the 16th of June, 2013, the anchoring for the substation began and finished in October.



Towing of Compact Semi-sub

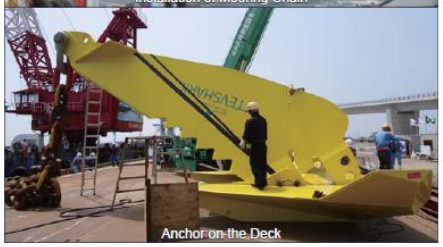
Leaving Dock of Compact Semi-sub

Towing of Substation

Installation of anchor, chain and submarine cable

In May, 2013, the anchor and mooring chain for both compact semi-sub and substation floaters were installed. In June, at the coast of Hirono, where onshore substation is located, the installation of the submarine cable began by the cable layer ship. The grid connection of the floating offshore wind turbine and substation was completed on 31st of October.

Installation of Mooring Chain



Anchor on the Deck

Submarine Cable on the Cable Layer Ship

Installation of Submarine Cable

Learnt from the project

The first phase of the project can be summarized as follows.

1. Although several typhoons were observed around the project site during construction, the technical problems were solved and the installation has finished successfully.
2. Ten months have passed since the installation and the floating substation and 2MW downwind turbine have been operating without any problems. The capacity factor of 43.2% were achieved in December, 2013.
3. Metocean and floater motion measurements on the substation and 2 MW turbine started. All the collected data are under analysis and will compare with simulations for advanced design and optimization of future floating wind turbines.

Thank you for your attention

Acknowledgement: This project is funded by Ministry of Economy, Trade and Industry, Japan. I wish to express my deepest gratitude to the concerned parties for their assistance and contribution in this project.