Fukushima Floating Offshore Wind Farm Demonstration Project
（Fukushima FORWARD）

Fukushima Offshore Wind Consortium

Fukushima FORWARD

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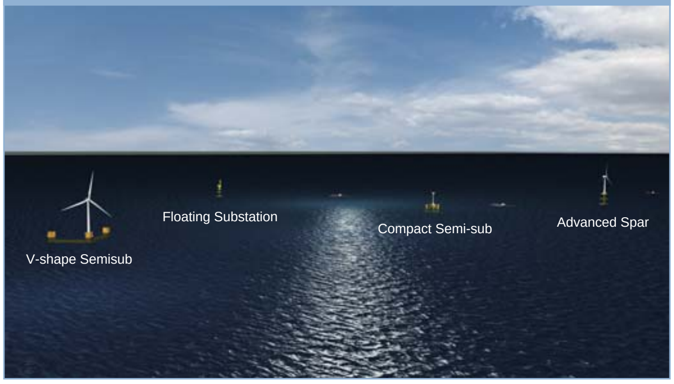
Fukushima offshore wind consortium, which consists of Marubeni Corporation (Project integrator), the University of Tokyo(Technical advisor), Mitsubishi Corporation, Mitsubishi Heavy Industries, Japan Marine United Corporation, Mitsui Engineering & Shipbuilding, Nippon Steel & Sumitomo Metal Corporation, Ltd., Hitachi Ltd., Furukawa Electric Co., Ltd., Shimizu Corporation and Mizuho information & Research, is proceeding with Fukushima floating offshore wind farm demonstration project (Fukushima FORWARD) funded by the Ministry of Economy, Trade and Industry.

In this project, three floating wind turbines and one floating power sub-station will be installed off the coast of Fukushima. The first phase of the project consists of one 2MW floating wind turbine, the world first 25MVA floating substation and undersea cable, and will be completed in 2013. In the second phase two world largest 7MW wind turbines will be installed before 2015.

This project will establish the business-model of the floating wind farm and contribute to future commercial projects. The consortium members are also expected to learn know-how of floating offshore wind farm, which will be one of the major export industries in Japan.

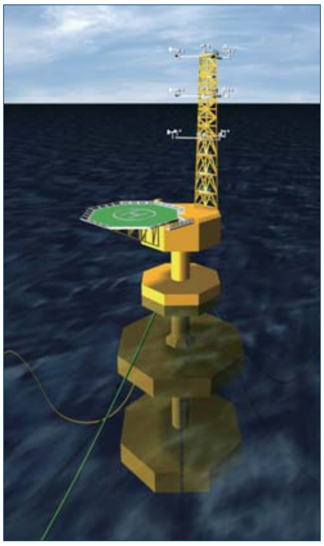
The Fukushima FORWARD project believes to help Fukushima to become the center of new industry which will create new employment in this region to recover from the damage of the Great East Japan Earthquake in 2011.

Field view of FORWARD



Scope of FORWARD

Phase Ⅰ (2011～2013)		Phase Ⅱ (2014～2015)	
Floating Substation	Compact Semi-Sub (2MW)	Advanced Spar (7MW)	V-shape Semi-Sub (7MW)



Three key factors for success

Technical Challenge ／ Social Acceptance ／ Recovery of Fukushima

Design ／Test ／ Optimization

Cost efficiency ／ Standardization ／ Industrialization

Vision of Fukushima Floating Offshore Wind Farm

Two decades have passed since the first bottom-mounted offshore wind turbine was installed in Europe and many large scale commercial projects are in operation now. On the other hand, a few floating offshore wind turbine(FOWT) has been installed as a pilot project in Norway and Portugal. Several technical questions such as floater optimization and transmission system need to be solved for future large scale projects.

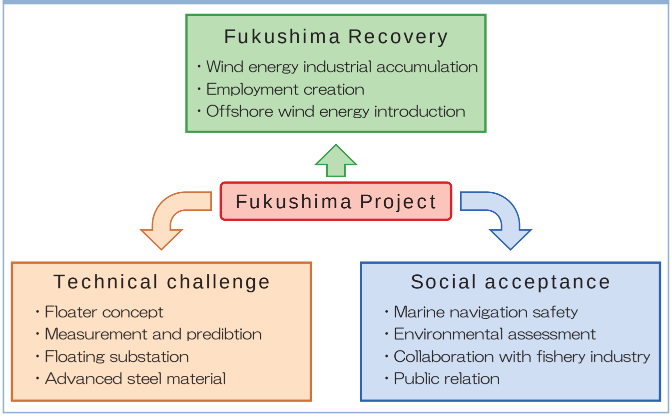
A V-Shape semi-sub floater with the world largest 7MW turbine, the world first 25MVA floating substation and the 66kV undersea cable will be implemented in Fukushima project and the economical feasibility will be studied.

A metocean measurement system considering the floater motion compensation will be developed in order to evaluate the performance and the motion of FOWT. Furthermore, the characteristics of each floater and the wind turbine, and the effect of control system on floater motion will be investigated.

In addition, the advanced steel material against corrosion and fatigue and construction technology under severe weather condition will be developed.

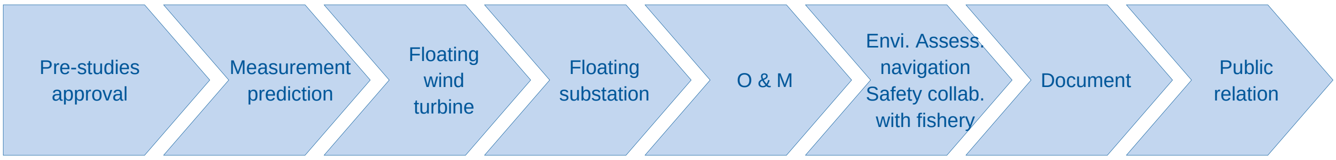
The project will not only focus on technical challenges but also on collaboration with fishery industry, marine navigation safety and environmental assessment, which are needed for the future large offshore floating wind farm. Public relations work will be carried out so that the status and results of this project will be open to public.

Vision of FORWARD



FORWARD member and Main role

FORWARD member	Main role
Marubeni Corporation [Project integrator]	Feasibility study, Approval and licensing, O & M, Collaboration with fishery industry
The University of Tokyo [Technical adviser]	Metocean measurement and prediction Technology, Marine navigation safety, Public relation
Mitsubishi Corporation	Coordination for grid integration, Environmental impact assessment
Mitsubishi Heavy industries, Ltd.	V-shape semi-sub(7MW)
Japan Marine United Corporation	Advanced Spar, Floating Substation
Mitsui Engineering & Shipbuilding Co., Ltd.	Compact Semi-sub(2MW)
Nippon Steel & Sumitomo Metal	Advanced steel material
Hitachi Ltd.	Floating Substation
Furukawa Electric Co., Ltd.	Large capacity undersea cable
Shimizu Corporation	Pre-survey of ocean area, Construction technology
Mizuho Information & Research institute, Inc	Documentation, Committee Operation



Metocean Measurement and Floater Motion Prediction

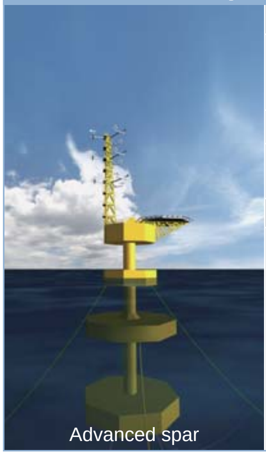
A metocean measurement system is developed by considering the floater motion compensation. Wind speed profile and wind direction are measured by anemometers on a met mast and a lider on the floater and are compared each othes. The motion of the floater is measured by using gyro, compass, accelerometer and GPS, and used for the motion compensation.

Also, in this project a dynamic analysis model of FOWT is developed. The model is improved by comparing the model results with water tank test and measurement data at the site.

1 Metocean and floater motion measurement

Items	Scopes
Metocean measurement	・Development of a metocean measurement system considering the floater motion compensation.
Floater motion measurement	・Development of accurate floater motion measurement system by combining gyro, compass, accelerometer and GPS.

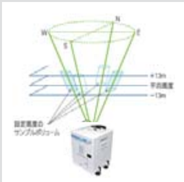
Measurement system on the floating substation


Advanced spar

●Measurement system

meteorology	cup anemometer, wind vane,thermometer, barometer, lider
oceanography	wave buoy, ADCP
motion	accelerometer, GPS, gyro, compass

●Lider

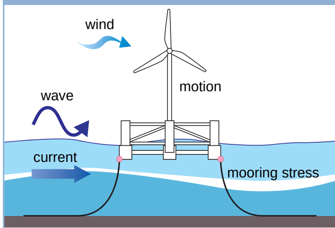


- Able to measure wind speed up to 200m above sea level.
- Ceonveenient and economical than conventional tower measurement.

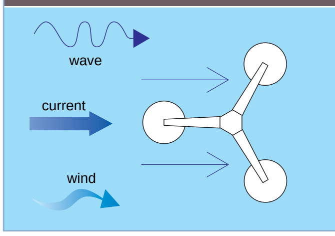
2 Prediction of floater motion

Items	Scopes
Dynamic analysis model	・Development of a coupled analysis model of wind turbine, floater and mooring. ・Development of the wind turbine control model which takes the floater motion into account.
Refinement of the model	・Improvement of the analysis model by comparing with water tank test and on site measurements.

Water tank test



case	current	wave	wind
1	○		
2		○	
3	○	○	○




Water tank test

Floating Wind Turbine Technology

In the first phase of this project, minimization of floater motion, safety and power generation efficiency are attempted by using a compact semi-submersible floater with 2MW downwind wind turbine.

In the second phase, optimization and verification of the design is attempted by using V-Shape semi-submersible floater with the world largest 7MW wind turbine. These studies will establish technologies for a future large scale offshore floating wind farm.

1 Compact semi-sub floater with 2MW down wind turbine

Items	Scopes
Turbine	・Verification of 2MW down wind turbine.
Floating	・Development of compact semi-sub floater. ・Minimization of floater motion and optimization of power generation by turbine control. ・Minimization of floater motion by optimization of ballast
Mooring	・6 pieces catenary.

- Rotor diameter 80m
- Hub height 65m (ASL)
- Height of the floater 32m

2 V-Shape semi-sub floater with 7MW turbine

Items	Scopes
Turbine	・Verification of 7MW hydraulic turbine.
Floating	・Development of V-shape semi-sub floating. ・Development of the reduction of floating motion by turbine control and O&M program.
Mooring	・8 pieces catenary.

- Rotor diameter 164m
- Hub height 105m (ASL)
- Height of the floater 32m

Floating Grid Integration System

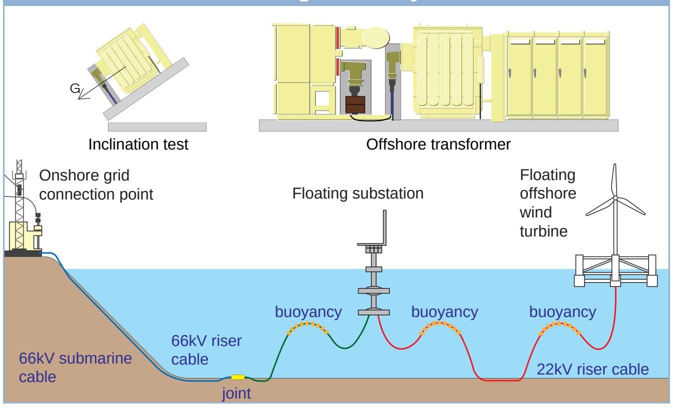
An offshore floating transformer system which is both durable and unsusceptible to motion is developed by evaluating its performance against vibration and inclination through the shaking table tests.

Furthermore, a large capacity water proof riser cable superior to fatigue is developed and optimized by motion analysis. The goal of these studies is to establish the world first floating offshore transformer system against severe metocean conditions.

1 Transmission system for floating offshore wind farm

Items	Scopes
Design and test	・Establishment of design criteria under motion. ・Vibration test, inclination test.
Verification of GIS	・Comparison of two type. (GIS and Vacuum circuit breaker)
O & M	・Periodical cut on & off of equipment and continuous observation.

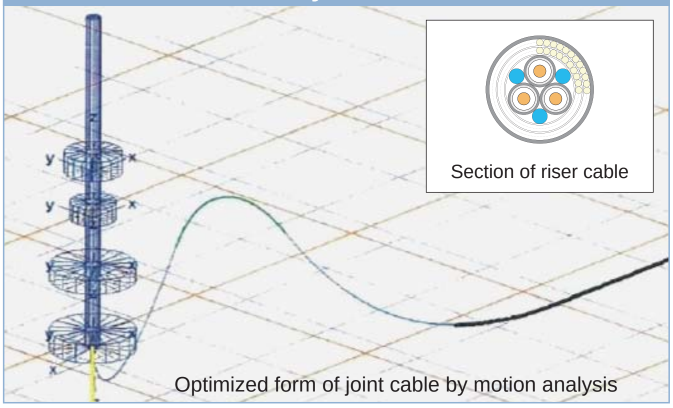
Grid integration system



2 Riser cable, cable joint and motion analysis

Items	Scopes
Riser cable	・Development of water proof cable superior to fatigue under high voltage(22/66kv) condition. ・Design and optimization of dynamic cable by cable motion analysis.
Joint device for riser cable	・Development of joint device between different materials and development of anchor device. ・Design of sub system (intermediate buoy, teminal reinforcement) by motion analysis.

Behavior analysis of riser cable



Pre-survey and Construction Technology for Floating Offshore Wind Farm

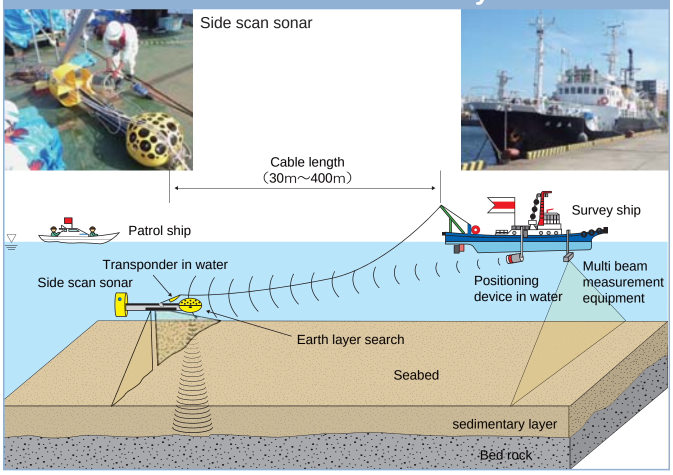
Optimal construction method which can be conducted under severe weather and minimize the impact on fishery environment is developed based on preliminary survey and estimation of meteocean condition.

Furthermore, optimal construction method for windfarm which consists of multiple floating wind turbines will be established.

1 Pre-survey and environmental evaluation

Items		Scopes
Marine survey	Nearshore area	・Sounding survey. ・Diving survey.
	Offshore area	・Sounding, seabed surface, core sampling.
Environmental condition for construction		・Estimation of wind velocity and wave height.

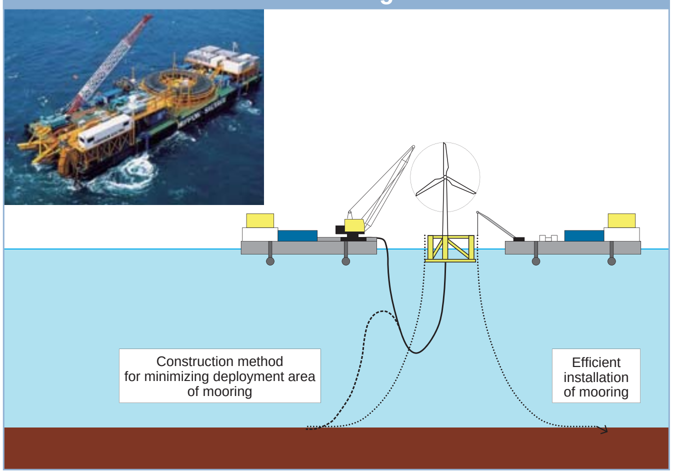
Offshore seabed survey



2 Development of construction technology

Items	Scopes
Construction technology for offshore floating wind turbine	・Optimization of construction method, workfleet and construction equipment. ・Development of construction method minimizing deployment area of mooring for large scale of floating offshore wind farm.

Construction method of floating offshore wind turbine



Advanced Steel Material

The TMCP and UIT developed in Japan are applied into steel material for the world first FOWT and the welding efficiency, corrosion resistance and fatigue for the long operation under the severe metocean condition are verified.

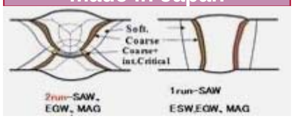
These studies will achieve shortening of the construction time and reduction of the construction cost.

1 Advanced steel material for floating offshore wind turbine

Items	Scopes
High tension steel for offshore wind turbine	・Application of TMCP to floating offshore wind turbine steel material and clarification of improvement of welding efficiency. TMCP（Thermo-mechanical Control Process） High heat input welding to be utilized for high tension steel among ship building and construction field and featured to be as high efficiency welding and easy construction control.
Fatigue solution	・Application of UIT technology into ultrasonic blow wave treatment and clarification. UIT（Ultrasonic Impact Treatment）: Promising technology which improve dramatically fatigue feature of welding joint.
Catenary chain	・Development of steel material for catenary superior to durability and corrosion.

Advanced steel material for tower, floater and catenary

Steel for floating wind turbine made in Japan



TMCP

・Preheated free
・Better weld ability
・Better base material

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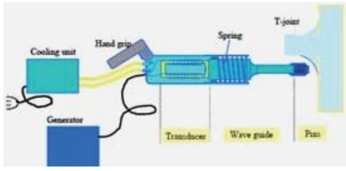
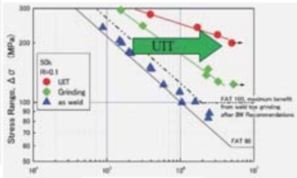
High heat input welding

・Better welding efficiency
・Reduction of welding risk
・Better joint performance

Improvement of fatigue performance by UIT





Improvement of fatigue feature by UIT
（cross welding connection）

Marine Navigation Safety

For floating offshore wind turbines, collisions between ships or collisions between ships and turbines might occur. Development of a collision risk model is carried out and the quantitative collision risk is assessed. Actual traffic data in the coast area along Fukushima are collected. The collision risk assessment makes it possible to take appropriate safety measures.

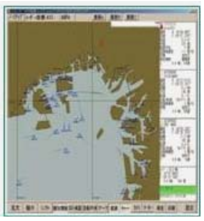
If mooring is failed by severe storms or accidents, drifting floaters may collide with other wind turbines and ships. A simulation method based on actual response of floating turbines is developed and the consequences of drifting of floating turbines is confirmed.

1 Assessment of collision risk

Items	Scopes
Collision risk analysis and risk control option	・Quantitative risk analysis for collision based on risk model and traffic data ・Adoption of appropriate risk controloption (safety measures)
Collection of traffic data in the coast area	・Analysis of oceangoing vessels' traffic by AIS data. (past and daily data) ・Observation for domestic and fishing vessels' traffic by Rader.

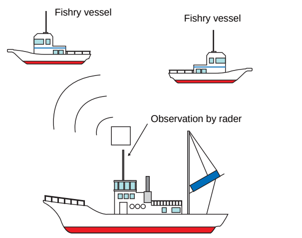
Observation of navigation

Oceangoing vessels' traffic



View of recorded data
by Automatic identification system

Domestic and fishing wessels' traffic

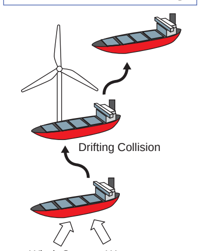


2 Assessment of drifting risk

Items	Scopes
Response of moored floating offshore wind turbine	・Development of analysis method of low frequency, wave frequency and high frequency motion of moored floating offshore wind turbine.
Analysis method of drifting risk of floating wind turbine	・Development of a simulator for risk analysis of drifting floating offshore wind turbines considering coupled response of a floater, a wind turbine and a mooring system.

Safety verification by drifting risk

Concurrent drifting



Drifting test

Environmental Impact Assessment

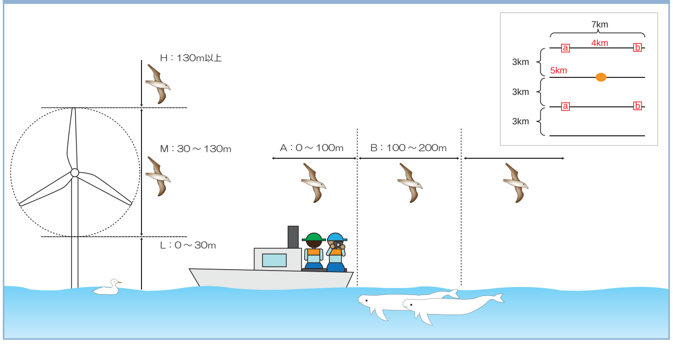
The environmental impact assessment is implemented around the sea where FOWT and seabed cable are installed.

The habits for seabirds, marine mammal and fish in addition to noise, scenery and radio disturbance will be surveyed and the environmental impact from the installation of the turbine and seabed cable will be clarified.

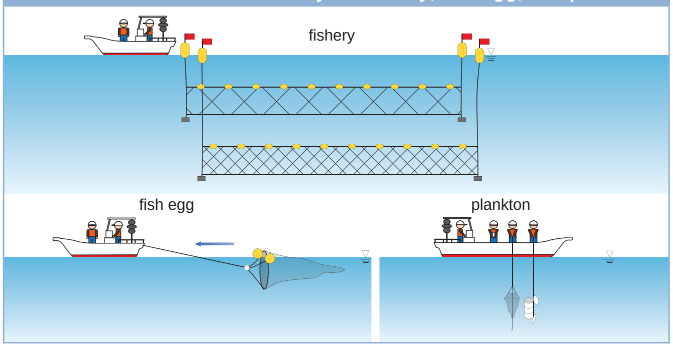
1 Survey area and item

Items	Detail (in habiting situation)	Survey area	
		turbine	cable
Bird	・Feedings, migrant of bird	●	
Marine mamma	・Whale, Dolphine	●	
Underwater sound	・Background noise and horizontal component in normal condition water	●	
Fish	・Fish, prawn/crab, squid octopus	●	●
Fish egg larval	・Fish, egg, young fish	●	●
Plankton	・Zooplankton & phytoplankton	●	●
Intertidal organism	・Attached organism and benthic living from seashore to 3m deep water.		●
Marine plant	・Brown algae such as sea grape and Ecklonia stolonifera.		●
Macrobentos	・Benthic activity such as bivalve, univalveshee and shell fish.		●
Attached Organism Megabenth.	・Benthic activity such as sea chestnut, sea cucumber and sand star.		●
Others	・Sediment made of seawater, earth and sand.		●

Survey for seabird and marine mammal around the floating offshore wind turbine



Around the seabed cable survey for fishery, fish egg, and plankton



Collaboration with Fishery Industry

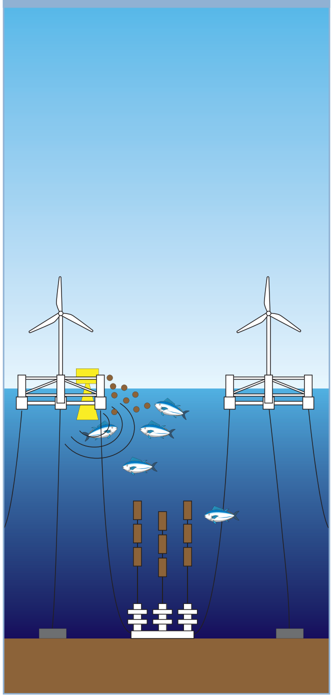
A committee formed by the government, Fukushima prefecture, local public entity and fishermen's union is organized. The impact on the sea and fishery operation around the project after installation of FOWT and a new fishing method are investigated working together with the special consultant of fishery industry.

After that, a proposal for fish gathering effect by marine farm, marine fertilization and culture raft and providing sea information will be discussed.

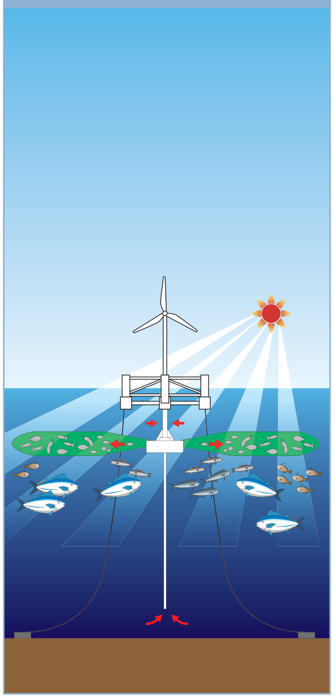
1 Proposal for new fishing method

Items	Scopes
Marine farm	・Construction of new fishery farm by automatic feeder, sound and fishing bank using floater and mooring
Marine fertilization and culture raft	・Cultivation of shellfish and seaweed by marine fertilization through water pumping of deep sea by density diffusion equipment and marine fertilizer
Fish gathering effect	・Observation of fish gathering around floater by ROV
Sea information	・Providing of real time sea information through observation equipment on floater to fisherman and disaster control center

Marine farm



Marine fertilization



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