WWEC 2015 Jerusalem, Israel26 October, 2015
Arranged for CIGS Seminar on 5 November, 2015

CURRENT STATUS OF JAPANESE OFFSHORE WIND R&D PROJECTS AND ITS ROADMAP

Chuichi Arakawa
The University of Tokyo

・This wind farm withstood Tsunami on 3.11
・7 units of 2MW Wind Turbine
・Extended to 15 units of 2MW and to future Giga-watt farm by private sector

Kamisu, Japan / 2MW x15

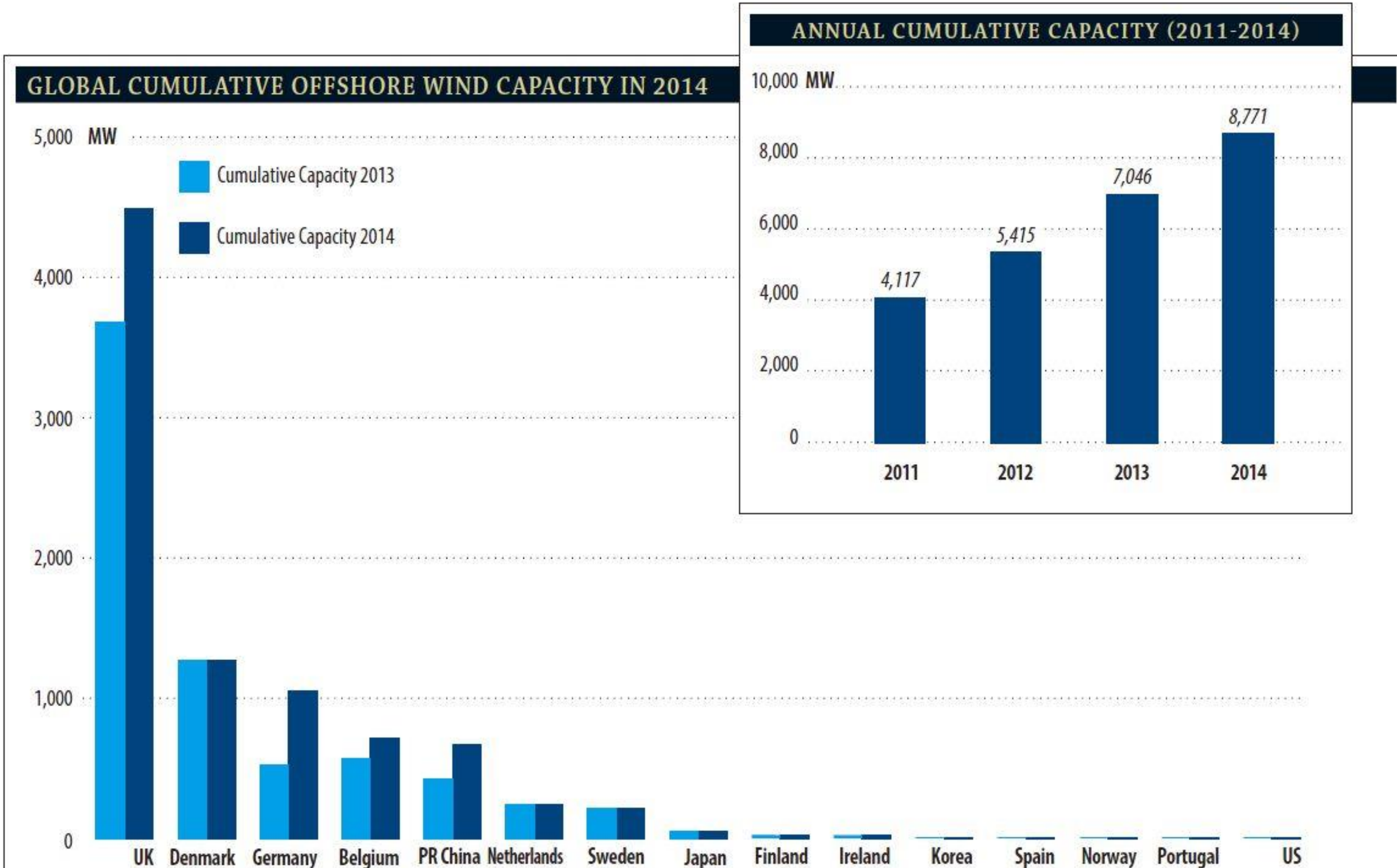
写真提供：株式会社 ウィンド・パワー・いばらき

Total Capacity of Wind Power in the World（2）

WWEA: World Wind Energy Report 2013 - List of Countries and Regions using Wind Power in 2013

Position 2013	Country/Region	Total capacity installed end 2013 [MW]	Added capacity 2013 [MW]	Growth rate 2013 [%]	Installed Capacity per Capita W/person	Installed Capacity per sqkm Kw/sqkm	Total capacity installed end 2012 [MW]	Total capacity installed end 2011 [MW]	Total capacity installed end 2010 [MW]
1	China	91'324,0	16'000,0	21,2	68,3	9,5	75'324,0	62'364,0	44'733,0
2	USA	61'108,0	1'084,0	2,0	195,1	6,2	59'882,0	46'919,0	40'180,0
3	Germany	34'660,0	3'345,0	11,7	425,4	97,1	31'315,0	29'075,0	27'215,0
4	Spain	22'959,0	175,0	0,7	491,1	45,4	22'796,0	21'673,0	20'676,0
5	India	20'150,0	1'829,0	10,0	16,9	6,1	18'321,0	15'880,0	13'065,8
6	United Kingdom	10'531,0	1'883,0	24,7	168,0	43,2	8'445,0	6'018,0	5'203,8
7	Italy	8'551,0	444,0	5,0	140,1	28,4	8'144,0	6'737,0	5'797,0
8	France	8'254,0	631,0	10,1	126,8	12,8	7'499,8	6'607,6	5'628,7
9	Canada	7'698,0	1'497,0	24,1	226,2	0,8	6'201,0	5'265,0	4'008,0
10	Denmark	4'772,0	657,0	14,7	862,9	110,7	4'162,0	3'927,0	3'734,0
11	Portugal	4'724,0	196,0	4,4	439,0	51,3	4'525,0	4'083,0	3'702,0
12	Sweden	4'470,0	724,0	19,4	491,8	9,9	3'745,0	2'798,0	2'052,0
13	Brazil	3'399,0	892,0	35,6	16,7	0,4	2'507,0	1'429,0	930,0
14	Poland	3'390,0	894,0	35,8	88,2	10,8	2'497,0	1'616,4	1'179,0
15	Australia	3'049,0	465,0	18,0	140,1	0,4	2'584,0	2'226,0	1'880,0
16	Turkey	2'959,0	646,0	28,0	37,6	3,8	2'312,0	1'799,0	1'274,0
17	The Netherlands	2'693,0	303,0	12,6	159,9	64,8	2'391,0	2'328,0	2'269,0
18	Japan	2'661,0	50,0	1,8	21,0	7,0	2'614,0	2'501,0	2'304,0
19	Romania	2'599,0	695,0	36,4	118,7	10,9	1'905,0	826,0	591,0
20	Ireland	2'037,0	288,0	17,2	436,1	29,0	1'738,0	1'631,0	1'428,0
21	Mexico	1'992,0	644,0	47,8	17,5	1,0	1'348,0	929,0	521,0
22	Greece	1'865,0	116,0	6,6	173,3	14,1	1'749,0	1'626,5	1'208,0
23	Austria	1'684,0	308,0	22,2	204,9	20,1	1'378,0	1'084,0	1'010,6
24	Belgium	1'651,0	276,0	20,1	158,3	54,1	1'375,0	1'078,0	886,0
25	Norway	768,0	110,0	9,2	163,7	2,4	703,0	520,0	434,6

Total Capacity of Offshore Wind in the World



	UK	Denmark	Germany	Belgium	PR China	Netherlands	Sweden	Japan	Finland	Ireland	Korea	Spain	Norway	Portugal	US	
Total 2013	3,680.9	1,270.6	520.3	571.5	428.6	246.8	211.7	49.7	26.3	25.2	5	5	2.3	2	0.02	**7,046**
New 2014	813.4	0	529	141	241	0	0	0	0	0	0	0	0	0	0	**1,725**
Total 2014	4,494.3	1,270.6	1,049.2	712.5	669.9	246.8	211.7	49.7	26.3	25.2	5	5	2.3	2	0.02	**8,771**

Source: GWEC

Offshore Wind Power in Japan

Black: Early exam.
Green: Founded type
Brown: Floating(small)
Blue: Floating type
____: National Project

Setana
2004
Vestas
600kW
X 2units

Sakata, 2004
Vestas
2MW X 5units

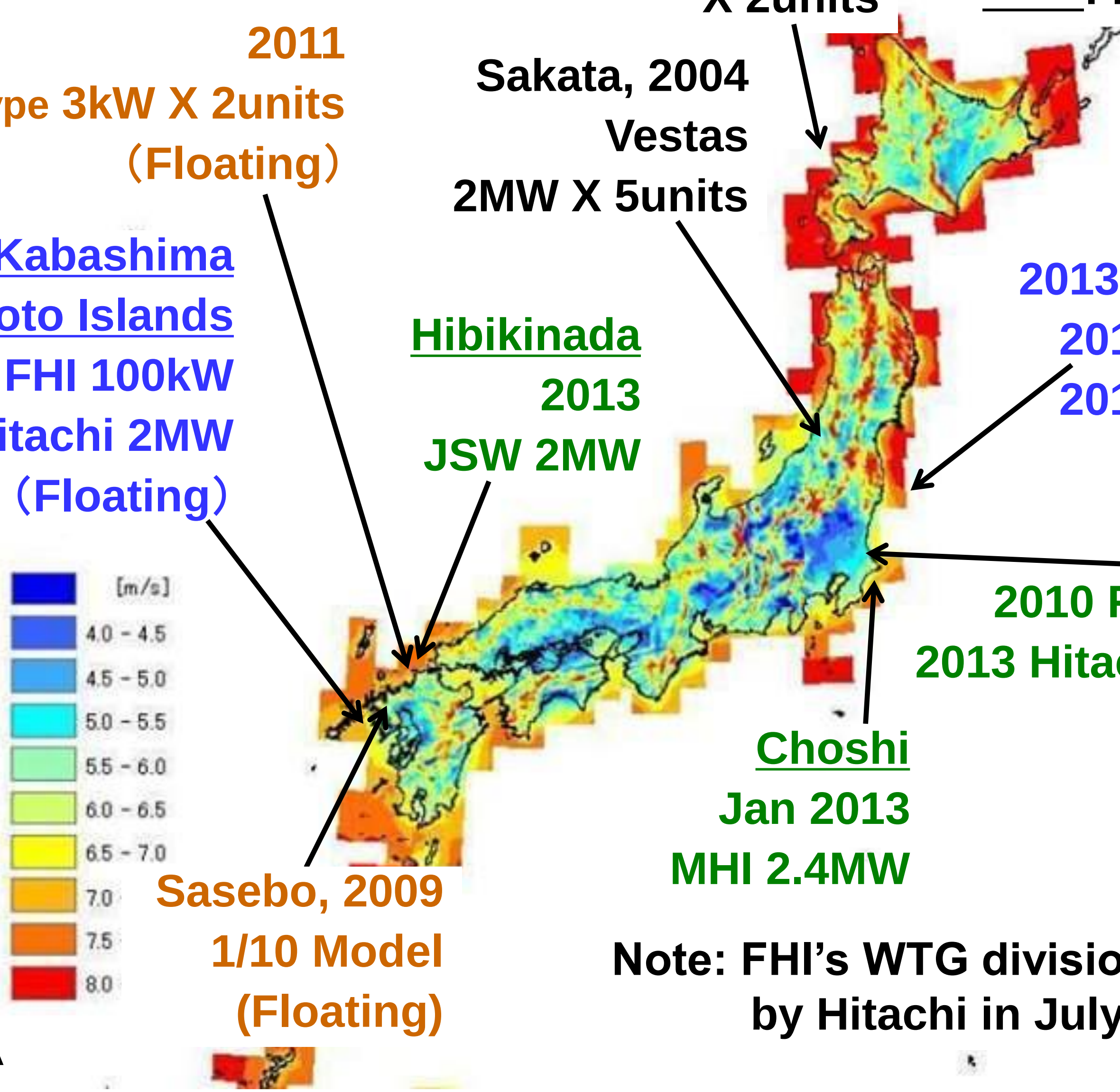
Hakata
2011
Lens type 3kW X 2units
（Floating）

<u>Kabashima</u>
<u>at Goto Islands</u>
2012 FHI 100kW
2013 Hitachi 2MW
（Floating）

<u>Hibikinada</u>
2013
JSW 2MW

<u>Fukushima</u>
2013 Hitachi 2MW
2014 MHI 7MW?
2014 MHI 7MW?
（Floating）

Kamisu
2010 FHI 2MW X 7units
2013 Hitachi 2MW X 8units



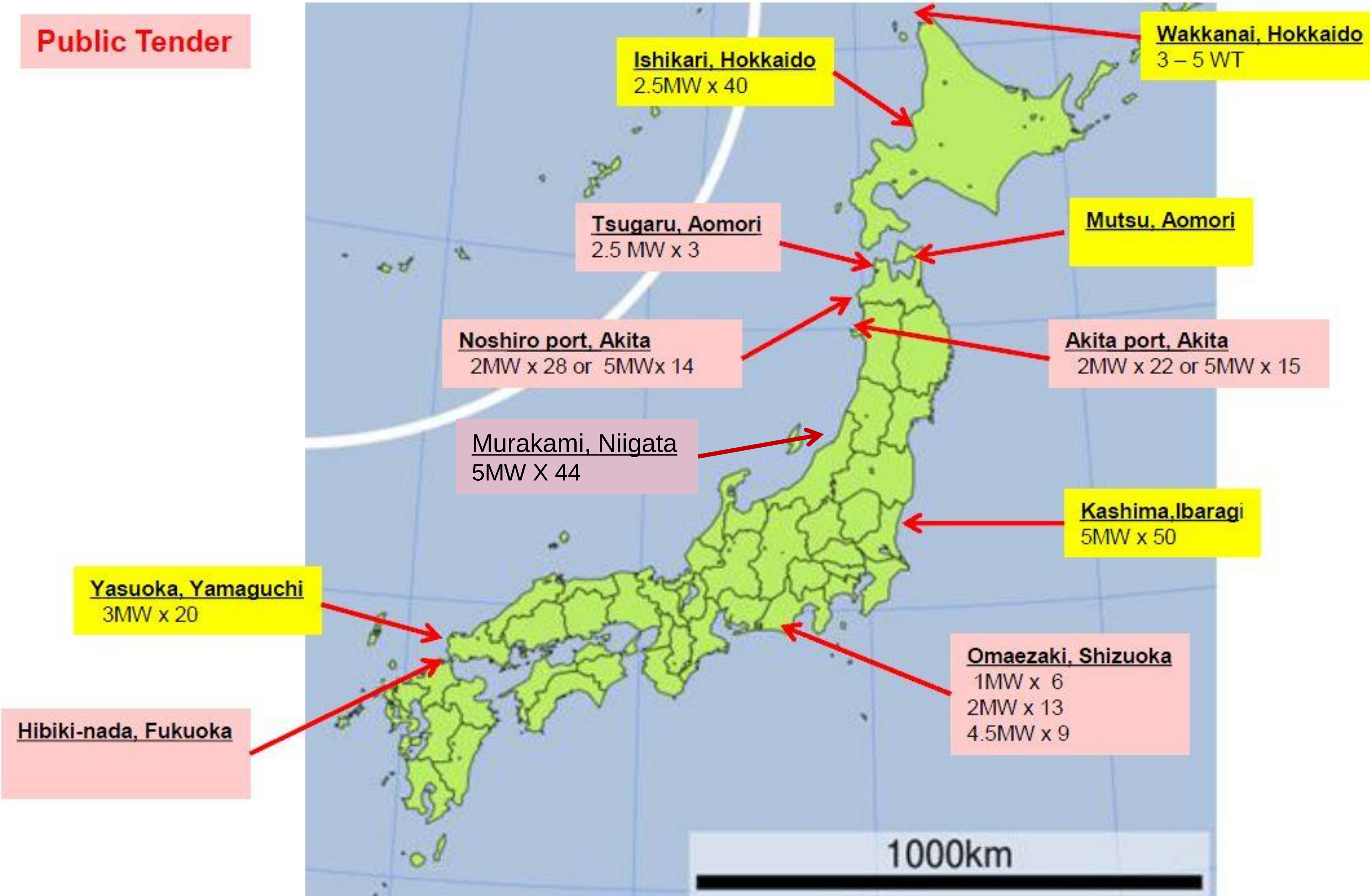
<u>Choshi</u>
Jan 2013
MHI 2.4MW

Sasebo, 2009
1/10 Model
(Floating)

Note: FHI’s WTG division has merged by Hitachi in July 2012.

SOURCE: JWEA&JWPA

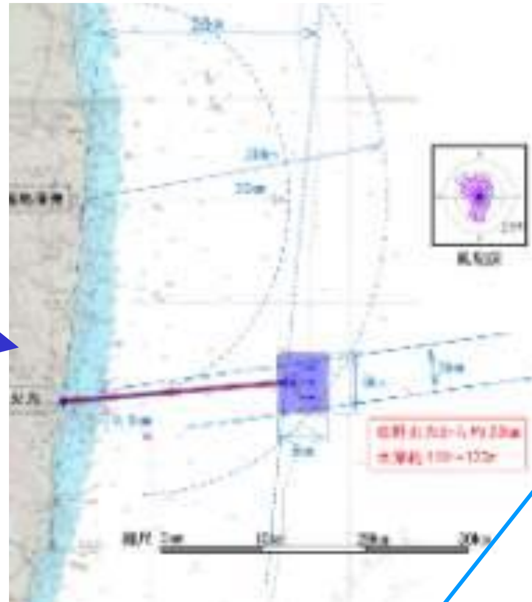
Offshore Wind Projects in Japan
Location Map
Planning up to date

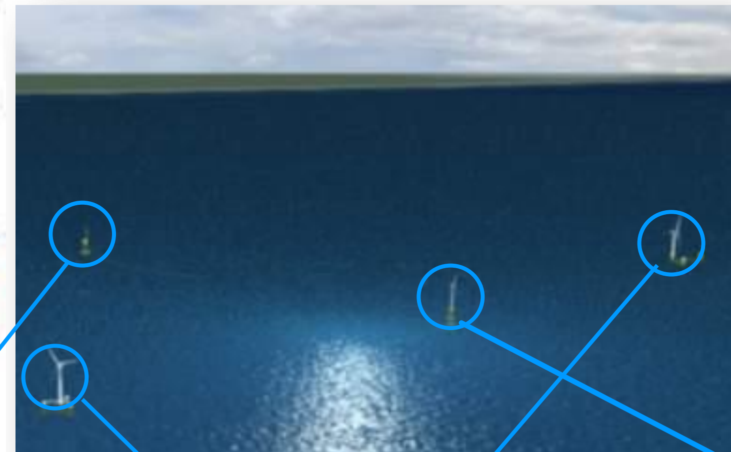


National project of offshore wind in Cho-shi area
By NEDO in October, 2012

National project of offshore wind in Kita-Kyushu area By NEDO in May, 2013

METI's Fukushima Recovery, Experimental Offshore Floating Wind Farm Project

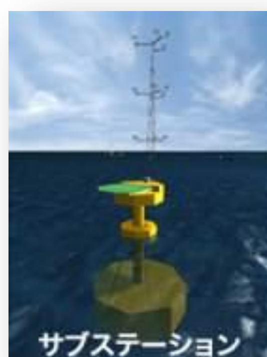




Project Consortium:11 members

Marubeni (Project integrator)
MHI
University of Tokyo
Mitsubishi Corp.
IHI Marine United
MES
Nippon Steel
Hitachi
Furukawa Electric
Shimizu Corp.
Mizuho Information & Research

2013



Hitachi
JMU Spar

2013

Hitachi 2MW
Mitsui semi-sub

2014

MHI 7MW
MHI semi-sub

2014

MHI 7MW
JMU Spar

Source; Fukushima offshore wind consortium

MOE Floating WTG Project at Kabashima Islands, in Goto Nagasaki Pref. (1)

PC Hybrid Spar, Catenary Mooring,

100kW in 2012   Source; MOE Project consortium   2MW in 2013

MOE Floating WTG Project at Kabashima Islands (3)

Up to completion of the wind turbine

Source; MOE Project consortium

1. Steel upper floating body, which was manufactured in the plant, is connected with the concrete made lower floating body at the quay, resulting in completion of the hybrid spar-type floating body.

2. The (hybrid spar-type) floating body is loaded on a salvage barge and transported to the assembly site in the north sea of Kabashima.

3. The floating body is lifted and raised by a large floating crane and is floated on the sea.

4. The tower, nacelle and rotor are assembled to the floating body, then, the wind turbine is completed.

5. After completion of the wind turbine, it is towed from the assembly site in the north sea of Kabashima to the demonstration site.

6. Mooring chains and submarine cables are connected to the turbine at the demonstration site and installation is completed.

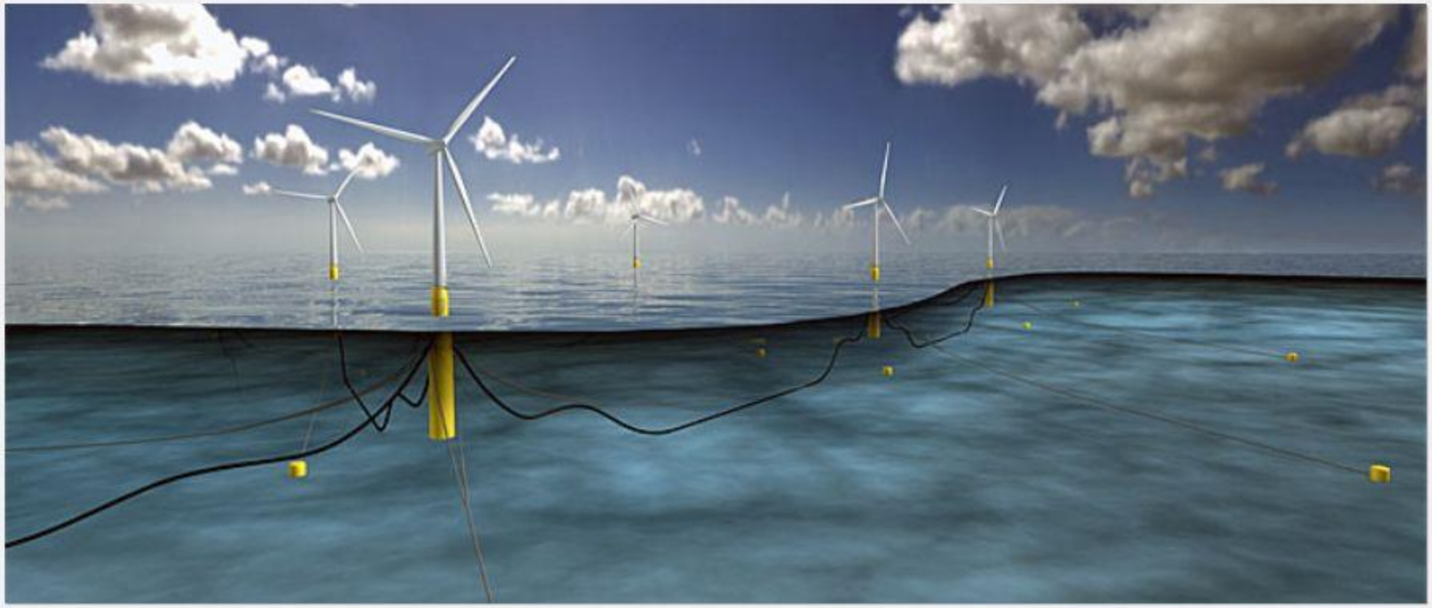
Comments of MOE Project

- The first grid-connected FOWT in Japan (100kW half-scale model) was attacked by severe typhoons, but it survived with no damage.
  - The survivability of the spar type FOWT against typhoon attack has been proven.
- The full scale FOWT (2MW model) has successfully been installed and now in power generation stage. No major technical barrier has not been identified.
- Further cost reduction and experience are required for commercial realization of the floating wind turbine system.

Source: STATOIL Website

Hywind Scotland Pilot Park

Statoil plan to build the first floating wind farm off the Scottish coast. The park will be located near Buchan Deep, approx. 25-30 km off the coast of Peterhead in Aberdeenshire.



The 30 MW pilot project will consist of five, 6 MW floating turbines operating in waters exceeding 100m of depth. The Pilot Park objectives is to demonstrate cost efficient and low risk solutions for commercial scale parks.

The technology that will be used in the pilot project has been tested with excellent results in a demonstration project off the coast of Norway.

Floating wind represents a new and significant renewable energy source that will complement an existing and expanding array of alternative energy projects in Scotland.

This pilot project is expected to demonstrate the feasibility of multiple floating wind turbines in a region that has optimal wind conditions, a strong supply chain within oil and gas and supportive public policies such as enhanced support for floating offshore wind pilot parks under the Renewables Obligation (Scotland).

Offshore Wind Turbine System (Structures for each water depth)

One Example of Future Offshore Wind in Floating Type

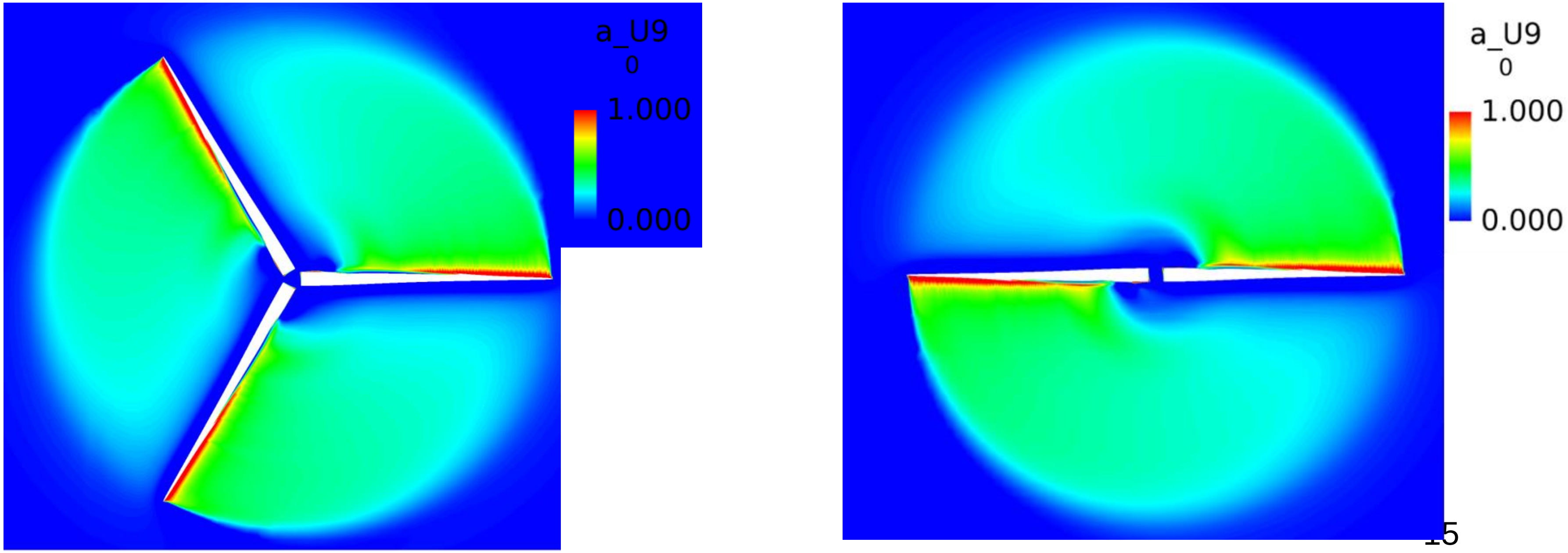
SCD® nezzy 8.0 MW

Source: Aerodyn HP

Future Technology of Giant Wind Turbine for Offshore Wind (1)

Two-Blades Turbine
1) Comparatively low cost
2) Easy maintenance in offshore
3) Teetered hub or traditional one?

Source: AIST

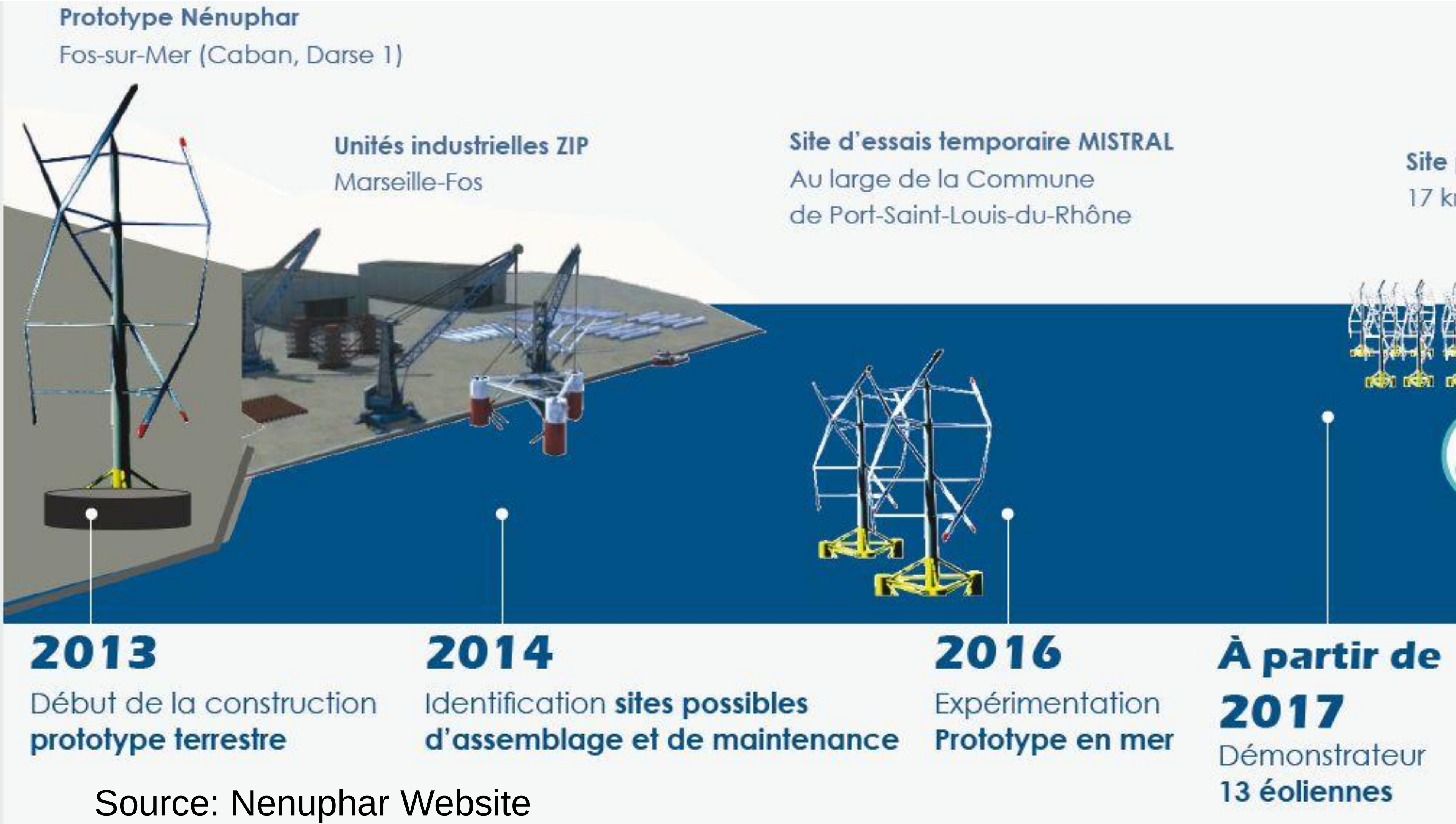


Distributions of Induced Coefficient on Surface of Rotated Blade

Future Technology of Giant Wind Turbine for Offshore Wind (2)

Vertical Axis Wind Turbine of Darius Type

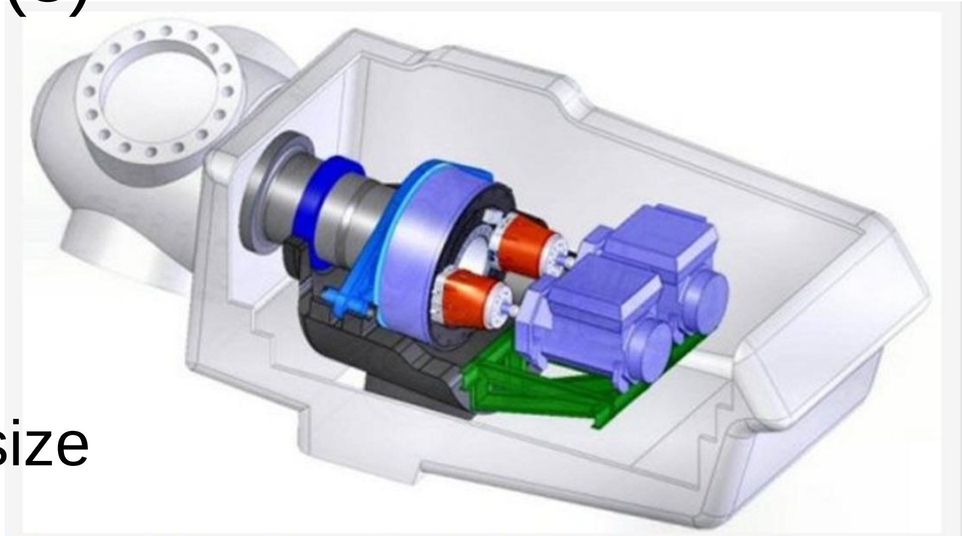
1) Low center of gravity in turbines, 2) Easy transport ?

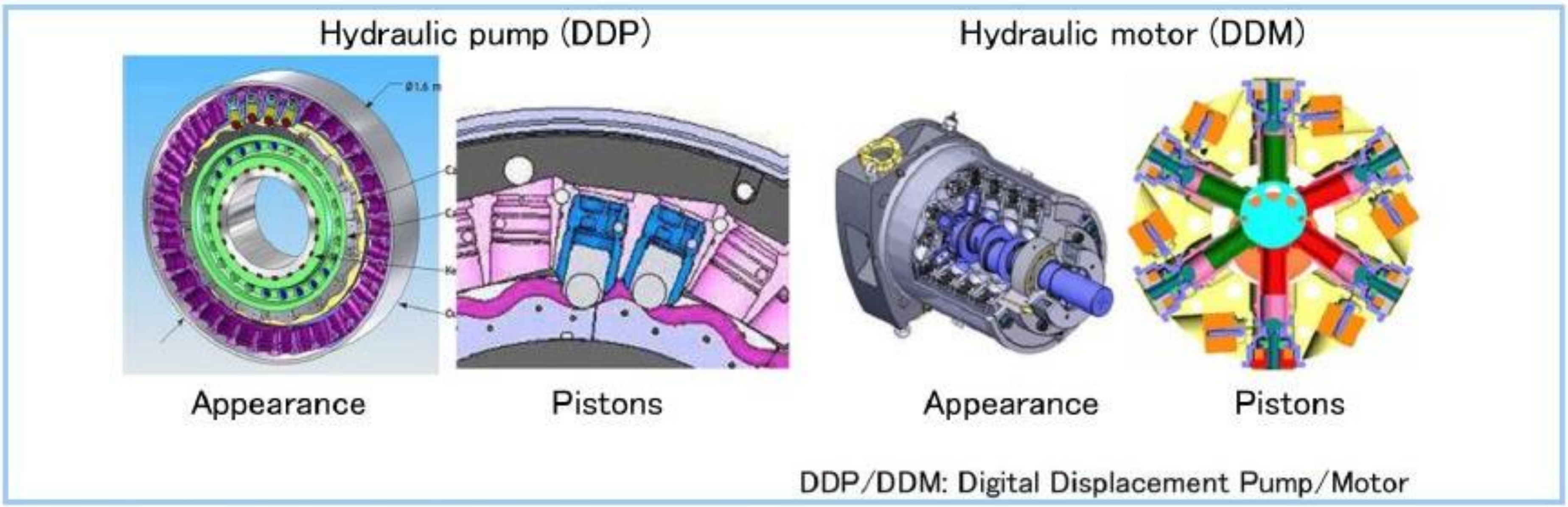


Source: Nenuphar Website

Future Technology of Giant Wind Turbine for Offshore Wind (3)

New Drive-train of Hydraulics
1) Gearless
2) Small size of generators
is available.
3) Easy development to larger size

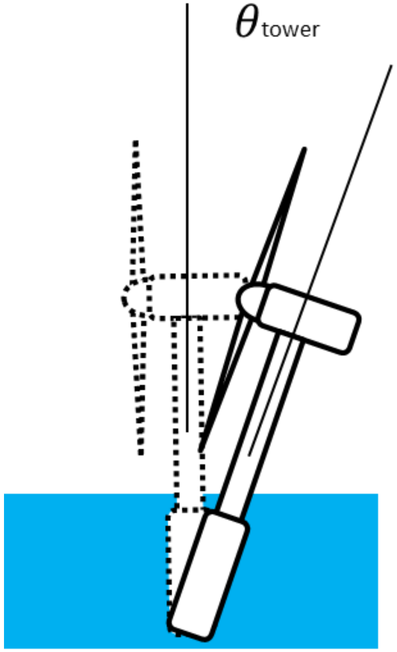


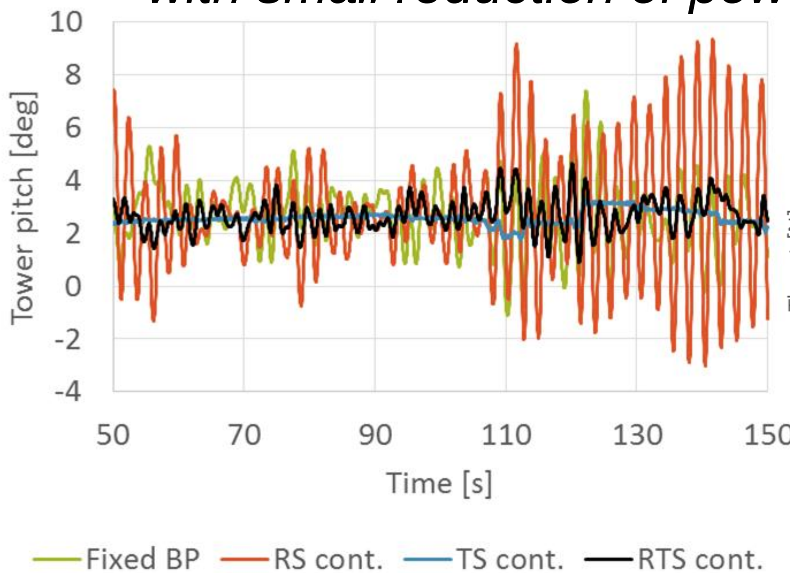


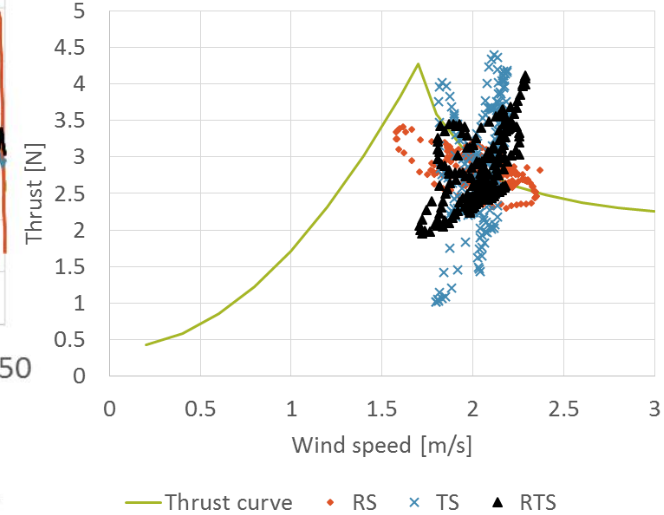
Mitsubishi Heavy Industries Technical Review Vol. 50 No. 3 (September 2013) より

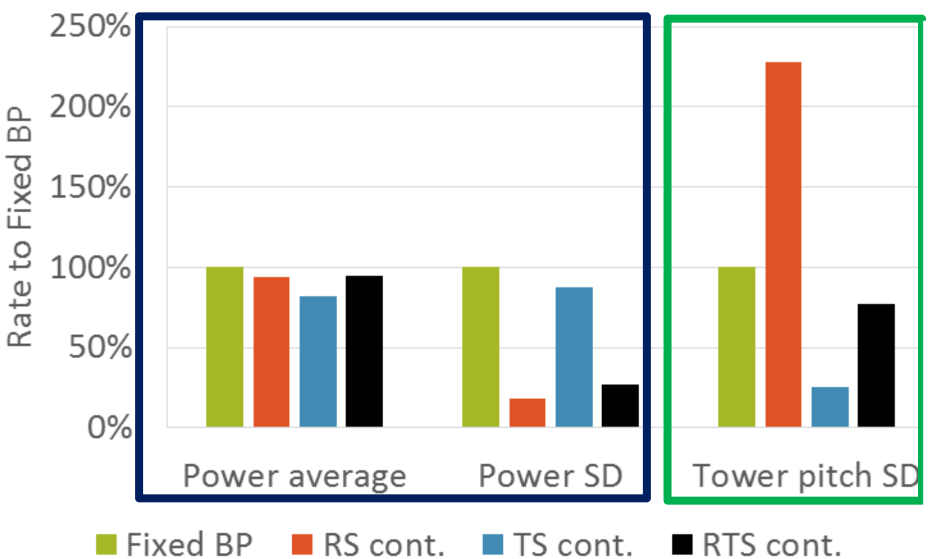
Negative Damping Analysis for Spar-Type Offshore Wind

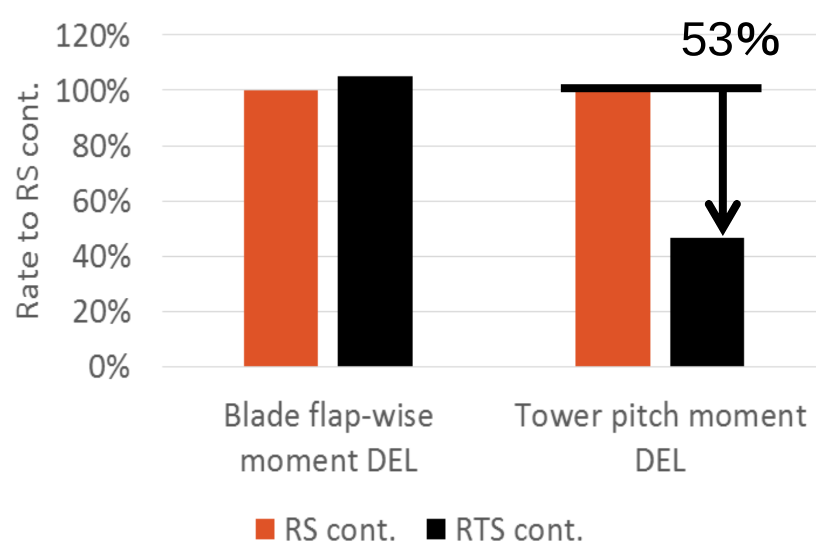
RTS control in order to make variation of power and tower movement smaller with small reduction of power









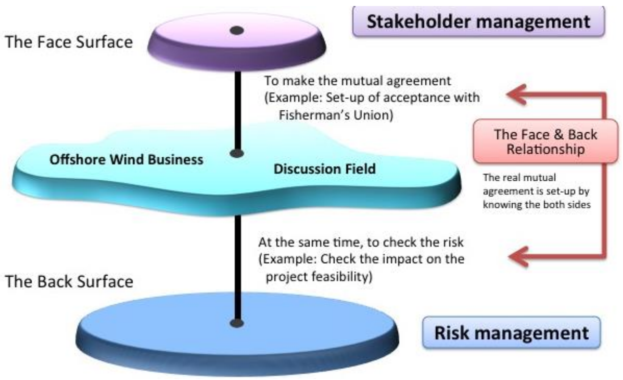


Stakeholder Management Research in Nagoya University

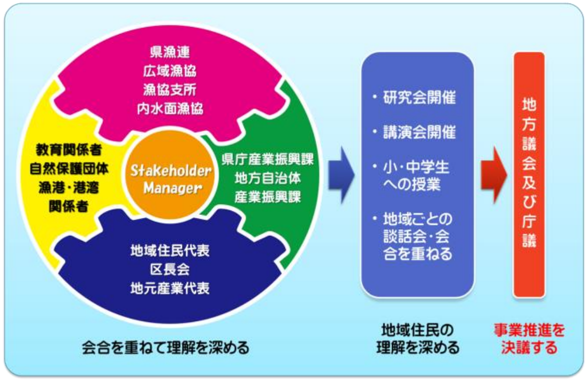
Set up of offshore wind projects in Japan

- Communication with local stakeholders
  - To identify local stakeholders and to coordinate their interests
  - To support local offshore wind energy policy
  - To create local benefits through an offshore wind project
  - To give lectures and workshops to local people
- Communication with governments and private companies
  - To discuss the laws to use general sea areas
  - To discuss risk analysis

Source: Nagoya Univ.



Relationship of stakeholder management and risk management



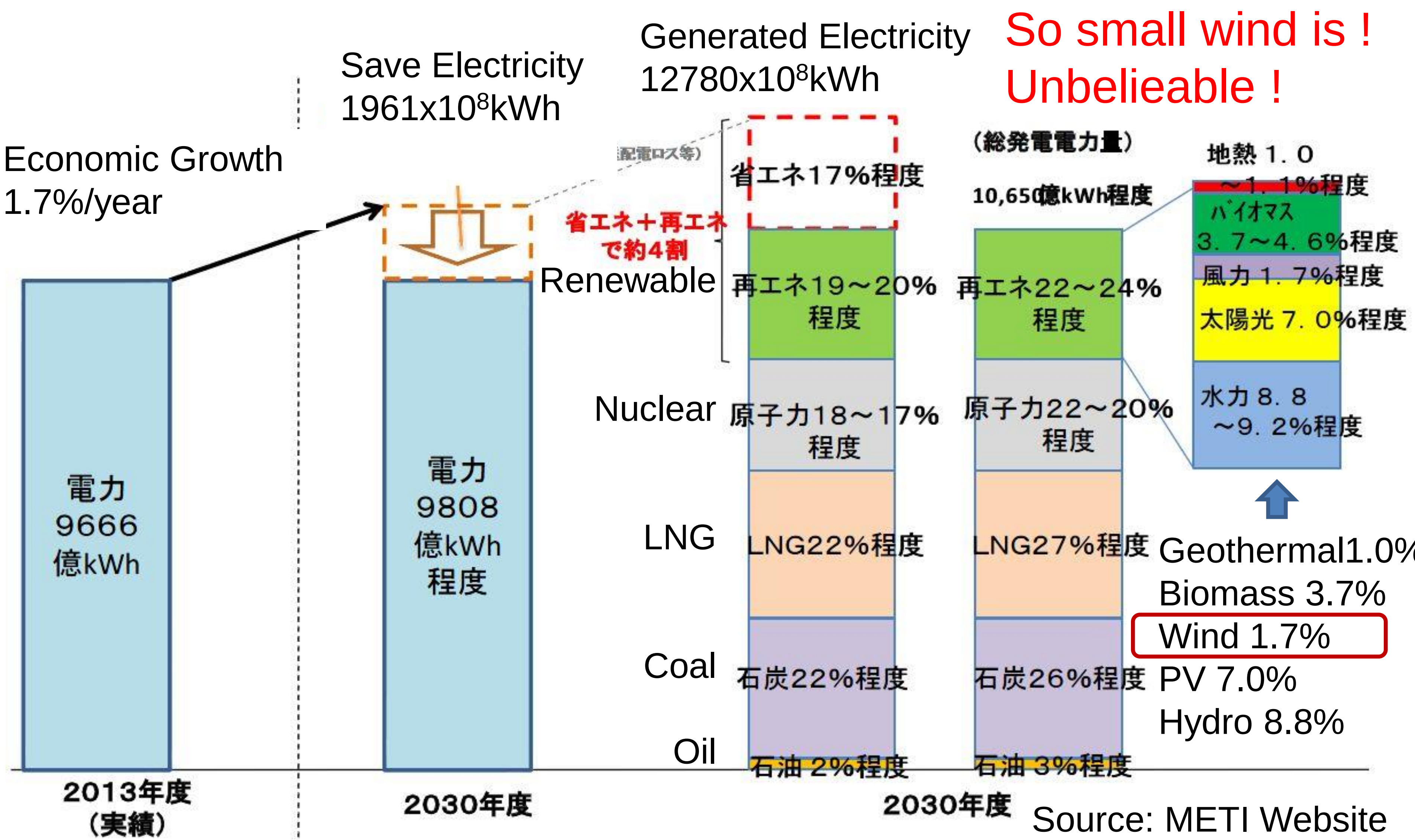
Consensus building process in a general sea area

Workshop at a elementary school

Roadmap of Electricity for 2030 by JP Government

Electricity Demand

Electricity Constitution



Source: METI Website

ROAD MAP of Offshore Wind proposed to government by councellors in Office of Cabinet Secretariat

H26 2014 | H27 | H28 | H29 | H30 2018 | H31 | H32 2020 | H33 | H34 | H35 | H36 2024 | H37 | H38 | H39 | H40 | H41 | H42 2030

Cumulative Installed Capacity Target

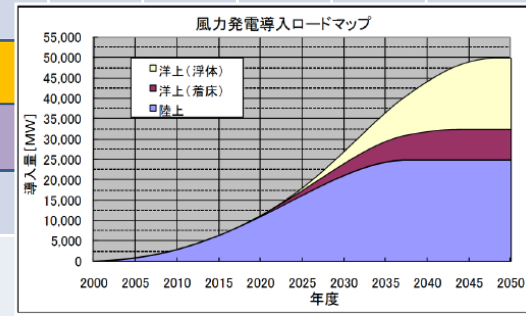
- Before project
- Decision of plan
- 0.2 GW
- Construction of system for promotion
- 2 GW
- 10 GW
- 20 GW

Cabinet Secretariat, Government of Japan

- First stage of PJ (2GW) Decision of project area
- Wind/Wave measurements in candidate area
- Public participation & selection
- Second stage of PJ (8GW) Decision of project area
- Wind/Wave measurements in candidate area
- Public participation & selection
- Third stage of PJ (10GW) Decision of project area
- Wind/Wave measurements in candidate area
- Public participation & selection

METI (Ministry of Economy, Trade and Industry)

- Decision of primary connections to electrical grid
- Extension of grid for offshore wind
- FIT for offshore wind
- Reconsideration of FIT for offshore wind
- Raising of related industries (marine engineering, construction and wind turbine)



MLIT (Ministry of Land, Infrastructure and Transport)

- Certification and new laws for floating offshore wind
- Selection of project area in the port and general sea

MAFF (Ministry of Agriculture, Forestry and Fisheries)

- Selection of fix-structured offshore wind taking fishermen into account
- Selection of floating offshore wind taking fishermen into account
- Stake folder managements, Investigation of sea area for fisheries

MOE (Ministry of the Environment)

- First stage of Environmental assessment
- Second stage of environmental assessament

Project of Power Generation

- First stage of project applications
- Decision of PJ
- First stage of constructions
- Second stage of project applications
- Decision of PJ
- Second stage of constructions
- Third stage o[f] project applications
- Generation and transmission of electricity
- Generation and transmission of electricity

FIT for Offshore Wind in Japan

Newly started from April 2014

- FIT has started in Japan from October 2011.
- FIT for Offshore Wind has firstly been introduced from April 2014.
- It was based on BOT cost but it shall be applied to FOW as well unless separate FIT for FOW will be introduced.

		2013FY	2014FY	Duration
Wind	Onshore Wind	Yen 22	Yen 22	20 years
	Offshore Wind	---	Yen 36	20 years
Solar PV	less than 10kW (house)	Yen 38	Yen 37	10Years
	more than 10kW	Yen 36	Yen 32	20Years
Geothermal	15MW or more	Yen26	Yen 26	15 years
	less than 15MW	Yen40	Yen 40	15 years
Biomass	Biogas	Yen39	Yen 39	20Years

(Tax exclusive, Price per kWh)

平成 26 年 1 月 7 日
資源エネルギー庁

FIT for OFFSHORE

洋上風力の調達価格に係る研究会の取りまとめを行いました

経済産業省は、平成 25 年 11 月より、陸上風力のポテンシャルが限定的な我が国において、再生可能エネルギーの導入拡大を図る上で鍵となる、洋上風力の調達価格の設定に向けて、洋上風力のコスト等について検討を行ってまいりました。今般、検討内容を取りまとめましたので、その結果を別紙のとおり公表します。

3. 取りまとめのポイント

本研究会では、実証事業により得られた実績等を踏まえ、我が国において、洋上風力発電を効率的に実施した場合に必要となる費用の検証を行いました。

NEDO PJ

実証事業では、風車 1 基でしたが、これを 20～50 基のウィンドファームに拡張した場合の費用について試算したところ、資本費 107 万円、112 万円/kW、運転維持費 2.3 万円、3.1 万円/kW/年となりました。

- CAPEX 1.07MYen, 1.12MYen

経済産業省HPより　http://www.meti.go.jp/press/2013/01/20140107001/20140107001.html

- CAPEX 450KYen

①事業検討段階にある一部事業者の報告

- 資本費 45 万円/kW、運転維持費 2.1 万円/kW/年。
- 委員から以下の指摘があった。
  - 利害関係者の特定が容易な港湾内の開発案件で調整コストが安価
  - 事業リスクや設備利用率の見通しなどに不十分

②比較的条件が良い海域(注)において、国内外で商用化実績を有する相対的に安価な基礎構造を想定するケース

- CAPEX 540-590KYen

- 資本費 54～59 万円/kW、運転維持費 1.5～3.0 万円/kW/年。

(注) 海底条件が良く、比較的高い設備利用率が期待できる

③沖合で大型風車を設置する際に採用が見込まれる、相対的に高価な基礎構造を想定するケース

- CAPEX 750-790KYen

- 資本費 75 万円、79 万円/kW、運転維持費 2.1 万円、2.3 万円/kW/年。
- 一部の委員からは、本ケースのような、欧州でも展開が始まっている沖合での大型風車も見据えた調達価格の設定が必要との意見があった。

専門家の間では、特に、②から③の間が有望とされましたが、実際に導入が想定される地理的環境や、どのような風車・基礎を念頭に置くかによって、適切なコスト水準の評価も分かれうるとの見解となりました。

経済産業省HPより　http://www.meti.go.jp/press/2013/01/20140107001/20140107001.html

平成26年度調達価格及び調達期間についての委員長案

③洋上風力注1）：FIT for OFFSHORE

		平成26年度（案）	
調達価格（税抜）	FIT without tax	36円/kWh	36Yen/kWh
資本費	CAPEX	56.5万円/kW	565 KYen
運転維持費	OPEX	2.25万円/kW/年	22.5KYen
設備利用率	Capacity Factor	30%	30%
IRR（税引前）	IRR	10%	10%
調達期間	Period	20年	20Years

（注1）建設及び運転保守のいずれの場合にも船舶等によるアクセスを必要とするもの

Source: METI

Japanese Typhoon Experience and etc.

New Guideline for Wind Turbines in Japan and Asian Area

Typhoon attack

Miyako Island was hit by huge Typhoon #14 on 11.Sep.2003 and all 7 WT were destroyed; 3 fallen down, 3 lost blades, 1 lost nacelle roof

High level of turbulence in wind due to complex terrain

Strong Lightning