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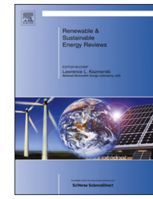

Overview of wind energy policy and development in Japan

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ABSTRACT

This article reviews the history and current issues of wind energy development in Japan and considers the role of policy and future direction of wind energy. Past policy with its weak market focus did not increase wind energy share in Japan. The situation surrounding wind and other renewable energy changed dramatically after the Great East Earthquake and Tsunami and the subsequent Fukushima Nuclear Plant Accident in early 2011. The new Feed-in Tariff regime was introduced and the Electricity Sector Reform is slowly progressing. Although wind energy has much larger potential than other renewables in Japan, the FIT has not increased wind installation to date, and the number of bottlenecks has hindered large-scale market deployment of wind. The limited grid capacity, the current electricity market structure, and grid operating practices by the existing Electricity Power Companies have constrained the grid access of wind projects. A layer of regulations related to development permits increases lead-time, project uncertainty, and risk premiums. Difficulty in terms of social acceptance is also high due to some of the past mistakes which did not address local community concerns. Cost of wind energy is also high, compared with other countries, due to lack of economies of scale and other reasons. Japan needs to implement a more comprehensive policy package to address numerous bottlenecks and risks to increase wind energy share in its energy mix.

Contents

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1. Introduction

The purpose of the research is to review the history and current issues of wind energy and to consider the role of policy and future direction of wind energy in Japan. The article is composed as follows. Following the introduction, a brief history of wind energy policy and development in Japan is presented. Then, the influences of the 3.11 Great East Japan Earthquake and Tsunami and the subsequent Fukushima Nuclear Accident on the current energy policy debates are discussed. The fourth section focuses on the recent progress made in wind energy policy, which is considered critical for increasing renewable energy share. The fifth section discusses the current issues and agenda for wind energy utilization. The final section concludes the review by examining the relationships between the issues discussed and the directions which policy should take to increase the role of wind energy in Japan.

2. History of wind energy in Japan

As in many other countries, Japanese renewable energy support started after the First Oil Crisis of 1973. Before the oil crisis, Japan mainly relied on coal for energy needs during the recovery period post World War II and oil during the subsequent high economic growth period as the main energy source. Approximately 77.4% of the country's primary energy supply was from oil in 1973. In particular, the reliance on the Middle East was significant, as 77.5% of oil was imported from the region each year [1]. The oil crisis created the urgent need for the reduction of Middle East oil dependence by securing oil supply from other regions of the world and advancing energy saving as well as diversifying energy sources by developing new energy technology. For the latter purpose, the Sunshine Program was initiated by the Ministry of International Trade and Industry (MITI) in 1974. The Sunshine Program focused on four particular technologies, namely, solar, geothermal, coal and hydrogen. In 1979, the MITI also started the Moonlight Program, which supported the advancement of energy saving technology. The MITI created the New Energy and Industrial Technology Development Organization (NEDO) in 1980 to manage public RD&D of new energy and energy conservation technologies and to promote the market introduction of such technologies. In 1989, the MITI started another RD&D program called the Earth Environmental Technology Development Program, and integrated it, with the Sunshine and Moonlight Programs, into the New Sunshine Program in 1993.

2.1. Wind energy technology policy up to 2011

Fig. 1 shows government RD&D funding for wind energy in Japan. Wind energy was not chosen as a principal technology of the Sunshine Program, meaning that RD&D support for wind, which began in 1978, had much smaller total budget than solar or geothermal. Also, the wind RD&D support has been uneven over the years as seen in Fig. 1. Most of the RD&D support from the 1990s to the mid-2000s consisted of wind resource database establishment and grid stabilization technology development such as Japan Wind Atlas Development (FY1993),[1] field testing and data gathering projects (FY1995-FY2006), Local Area Wind Energy Prediction System (LAWEPS) development (FY1999-FY2002), wind database based on LAWEPS (FY2003-), energy storage development for large-scale wind farming (FY2003-FY2007), and weather forecasting system development (FY2005-FY2007).

This situation changed in the late 2000s. The Ministry of Economy, Trade, and Industry (METI, the successor of the MITI)[2] published three energy technology roadmaps in 2007, 2008, and 2009. The roadmaps included wind energy as a focus of technology development. For onshore wind, they targeted turbine upscaling, composite materials development, cost reduction, power quality improvement, power system control, wind power generation forecasting, grid connection control, grid stabilization, and high-quality low-wind turbine development. For offshore wind, the roadmaps listed the exploration of both seabed fixed foundation and floating foundation concepts, wind power generation forecasting, grid connection control, grid stabilization, energy conversion and storage system development as focus areas of RD&D [2]. The renewed interests in wind energy by the METI were the result of increased wind energy installation all over the world. The METI included wind energy RD&D as part of its Energy Innovation Program in 2008. This made the dramatic total budget increase from 2009 for the three multiyear programs, as seen in Fig. 1.

The Energy Innovation Program for Wind has three parts. The first was implemented from FY 2008 to FY2012, focusing on developing technology solutions for Japanese-specific weather and climatic conditions such as severe lightening and typhoon. The second program entirely focuses on offshore wind energy technology (FY2008–FY2014), consisting of three types of project: large-scale offshore wind system development; offshore wind demonstration for both fixed and floating foundation; and offshore wind resource measurement projects. The program is now extended to FY 2017. The third program actually started in FY 2007, emphasizing grid stabilization technologies such as storage and power control system development, and necessary data collection (FY 2007–2011) [4]. The NEDO implements most of these projects.

2.2. Market development policy for wind energy up to 2011

In Japan, the major energy policy is technology development policy and market policy has been very weak, and wind was no exception. The two main market policies for wind were capital subsidies and Renewable Portfolio Standards (RPS), based on "Special Measures Law Concerning the Use of New Energy by Electric Utilities".

[1] Japanese fiscal year starts April 1st and ends on March 31st of the next calendar year.

[2] Japan implemented the administrative reform of national government agencies in 2001. The MITI became the Ministry of Economy, Trade, and Industry. In terms of these two agencies, however, the roles and contents have not been changed dramatically by this reform.

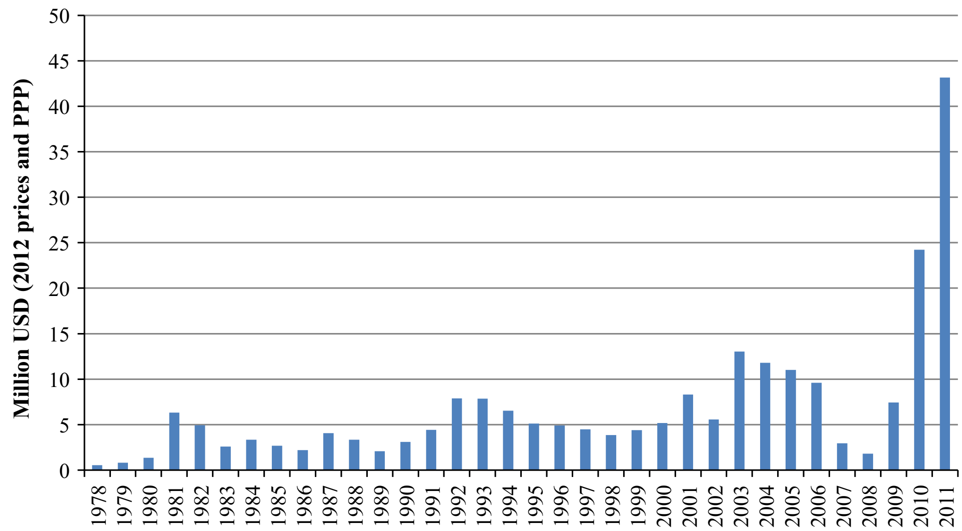


Fig. 1. Government RD&D funding for wind energy in Japan (1974–2011) [3].

Table 1
RPS Targets of Japan (FY2003–FY2014) [6].

FY	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Annual Target (TWh)	7.32	7.66	8.00	8.34	8.67	9.27	10.33	12.20	13.15	14.10	15.05	16.00
Obligation Amount (TWh)	3.28	3.60	3.83	4.55	6.12	7.56	9.46	12.20	13.15	14.10	15.05	16.00
Usage Target Rate (%)	0.87	0.91	0.92	0.93	0.96	0.99	1.11	1.26	1.19	–	–	–

Notes: Obligation amount=supply volume of the electricity retailer (for previous year)*usage target rate*adjustment rate
Where
Usage target rate=national usage target (for corresponding year)/national volume of electricity supply (for previous year)
Adjustment rate=rate accounting for the situation of voltage variation that necessarily accompanies the installation of new energy generation facilities (value 1–0.9).

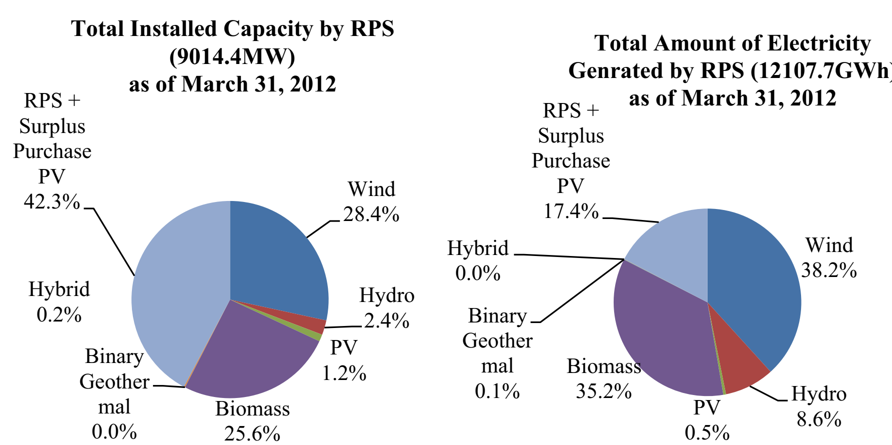


Fig. 2. Installed capacity and power generated by source under the RPS regime as of March 31, 2012 (end of FY 2011). *Note*: "RPS+Surplus Purchase PV" indicates PV installation after the implementation of Surplus Purchase program started on November 1, 2009. "PV" indicates the PV installation before the Surplus Purchase program implementation in 2009 [7].

Capital subsidies started in FY 1998 and lasted until FY2010. One was for private sector development, covering up to one third of capital cost. The other specifically targeted non-profit sector and municipality wind projects, covering up to a half of capital cost. The latter program was not officially terminated in FY 2011, but there were no open recruitments for wind projects in that year [5]. The other main scheme was RPS, which started in April 1, 2003 and lasted until June 30, 2012. The RPS system covered solar power generation, wind power generation, biomass, small- and medium-sized hydro power generation (up to 1 MWcapacity), and binary geothermal power generation. In order to meet its obligation, an electricity retailer could itself generate electricity, purchase new energy electricity from another party, or purchase a "New Energy Certificate" from another party. Table 1 shows the annual targets of utilization of electricity from new energy by electric retailers established by the METI.

As seen in Table 1, the Usage Target Rates were always very low, around 1% of the total volume of electricity supply. Fig. 2 shows installed capacity and power generated by source under the RPS regime, as of March 31, 2012 [7]. Wind energy installation accounts for 28.4% (2559.3 MW) of the total installed capacity under the RPS regime, but generated 38.2% (4630.58 GWh) of electricity, which was 0.4% of the total amount of electricity generated in Japan in 2011 (1107 829 GWh) [8].

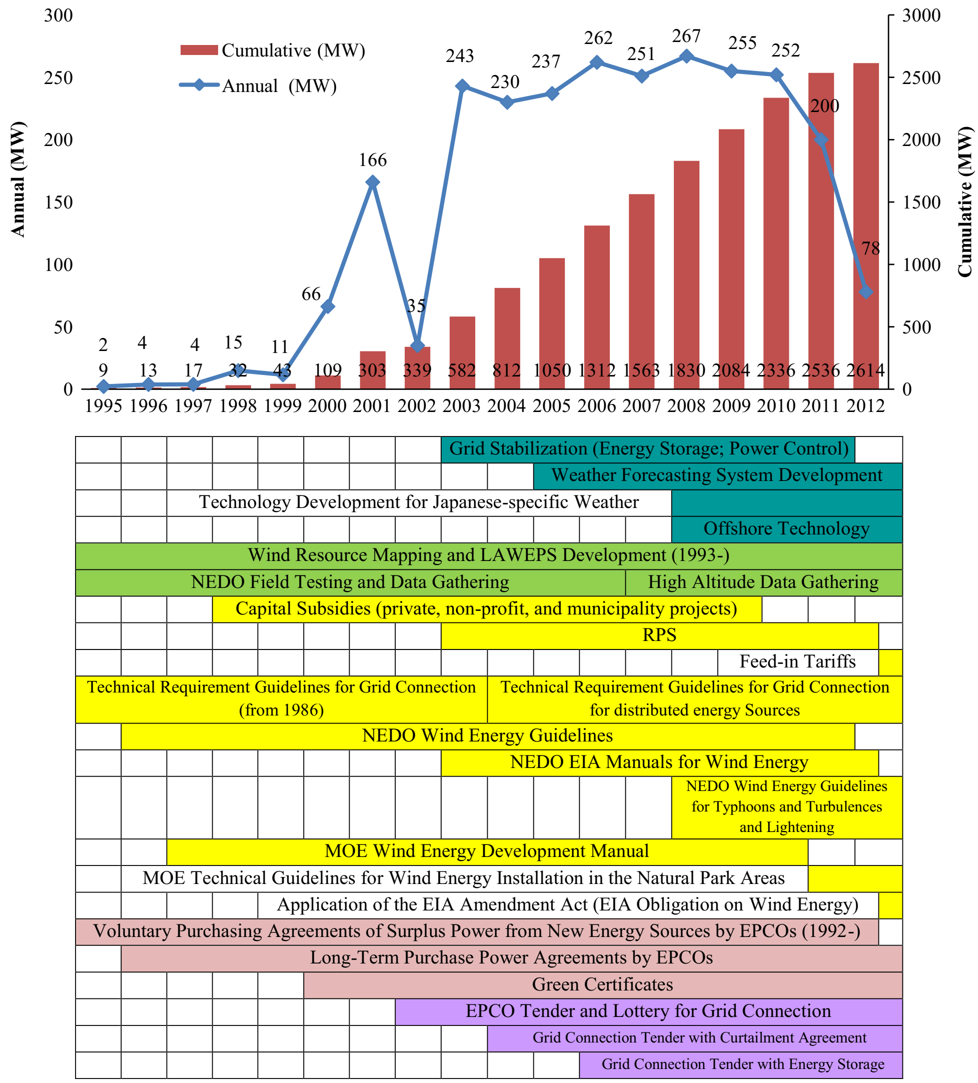


Fig. 3. Annual and cumulative wind energy installation and policy in Japan (1990–2012) [12].

In addition to the direct market deployment supports mentioned above, the NEDO and the Ministry of Environment (MOE) have published several guidelines and manuals to support wind power producers. They are: the NEDO Wind Energy Guidelines (1st edition in FY 1996, 9th edition in FY 2008); the Wind Energy Development Manual by the MOE (FY 1997); the NEDO Environmental Impact Assessment Manuals for Wind Energy (FY2003); the NEDO Wind Energy Guidelines for Typhoons and Turbulences (FY2008), the NEDO Wind Energy Guidelines for Lightening (FY2008), and the MOE Technical Guidelines for Wind Energy Installation in the Natural Park Areas (FY 2011) [9]. As for grid connection, the METI amended the Technical Requirement Guidelines for Grid Connection in order to accommodate more distributed power sources such as wind in October 2004.

Besides the above public policies, there have been several voluntary activities to promote wind energy by electric utilities. First, regional Electric Power Companies (EPCOs) started the voluntary purchasing of surplus power from new energy sources including wind in 1992. Although the focus of the agreement was solar power rather than wind, the EPCOs purchased solar and wind power at retail prices. In 1996, the EPCOs also started long-term purchase power agreements on solar and wind. This had a stronger focus on wind power projects. The Tokyo Electric Power Company (TEPCO), for example, purchased wind power JPY 11.2 (2.5–3 times of fossil fuel generated power purchasing prices) for 15 years from wind power producers. The Green Certificate program of Wind Energy was introduced in November 2000 [10].

2.3. Wind energy policy and development in Japan

Fig. 3 shows the installed capacity of wind energy in Japan with various policy implementations up to 2012 [11].

Wind energy installation started increasing in late 1998 with capital subsidies. The first boost came with the green certificate program in 2000. Although the installation in 2002 dropped with the anticipation of the RPS system introduction in 2003, the combination of RPS and capital subsidies supported annual installation of about 250 MW between 2003 and 2010. However, Japan missed its wind energy target of 3 GW in 2010. Because of the halt of the NEDO capital subsidies to wind projects in FY 2010 due to the anticipated FIT introduction, wind energy installation decreased by 20% between 2010 and 2011. The past two years saw the reduction of installation due to the increasing difficulties in finding suitable onshore projects sites and the application of the national Environmental Impact Assessment (EIA) on wind energy projects (from October 2012) in addition to the ending of capital subsidies, despite the introduction of the Feed-in Tariff (FIT) system on July 1, 2012.

As shown in Fig. 4, in FY 2010, wind energy supplied only 0.01% of the total electricity in Japan [13]. At the end of 2011, the total installation of wind energy worldwide was 238.35 GW, meaning that Japan had only 1% of the global total, far behind China, the Unites States, Germany, Spain, and many other countries [14].

3. Influences of the Great East Japan Earthquake, Tsunami, and Fukushima Nuclear Plant Accident on energy policy in Japan

Japan experienced the Great East Japan Earthquake and Tsunami on March 11, 2011. The Tsunami subsequently caused the Fukushima Nuclear Plant Accident. This changed the energy situation dramatically in Japan, as the Nuclear Plant Accident revealed various problems in the electricity sector.

3.1. Electricity sector reform

The first issue was the lack of a flexible system to transmit electricity beyond regions. The Great East Japan Earthquake, Tsunami, and the Fukushima Nuclear Plant Accident created a large shortage of electricity for subsequent days and months of March 20011 in the eastern part of Japan. At that time, the insufficient nationwide electricity transmitting capacity prevented the Tokyo and Tohoku regions, which were experiencing massive shortage of electricity, from receiving electricity from western Japan with its abundant electricity supply. In addition, the non-liberalized market hindered opportunities for customers to explore cheaper alternatives. Many customers were frustrated by the strong price control, planned blackouts, and inability to choose electricity suppliers freely during the crisis, but could not do anything about it. These problems of early 2011 triggered the movement toward Electricity Sector Reform.

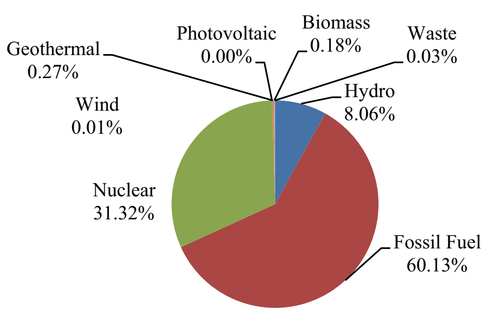


Fig. 4. Electricity mix of Japan (Total 918.239 TWh, FY 2010) [13]. *Note*: The numbers show the supply by large-scale power generations by utilities (above 1 MW) only, excluding non-utility small-scale power generations such as residential PV.

- Electricity is supplied by the regional monopoly of 10 vertically integrated Electricity Power Companies (EPCOs) and the market of the four main islands is segregated into nine regions with very weak transmission capabilities across regional borders (Fig. 5).
- There are two frequency systems. Eastern Japan (Hokkaido, Tohoku, and Tokyo EPCOs) uses 50 HZ frequency, but western Japan (the rest of six EPCOs) uses 60 Hz frequency. At the time of the Great East Japan Earthquake, the frequency conversion capacity of these two areas was only 1.035 GW, which was increased to 1.2 GW in February 2013.
- There is basically only one interconnection between adjacent EPCO control areas. The configuration is longitudinal. Angle stability, voltage stability, and frequency as well as thermal capacity under $n-1$ contingency determine the transfer capacity of interconnection. Due to the limited transfer capacity between areas, there is a necessity to match supply and demand in each control area.

These features create a quite inflexible grid system in Japan. The situation after the Great East Japan Earthquake triggered the debates about the Electricity Sector Reform. Although the METI has implemented partial sector reform since 1995, comprehensive reform has not materialized due to the fierce opposition of 10 EPCOs (Table 2). Unbundling was only implemented in the form of accounting separation, and the retail market for business customers such as factories and office buildings was liberalized, but that for residential customers is still fully regulated. With the very limited

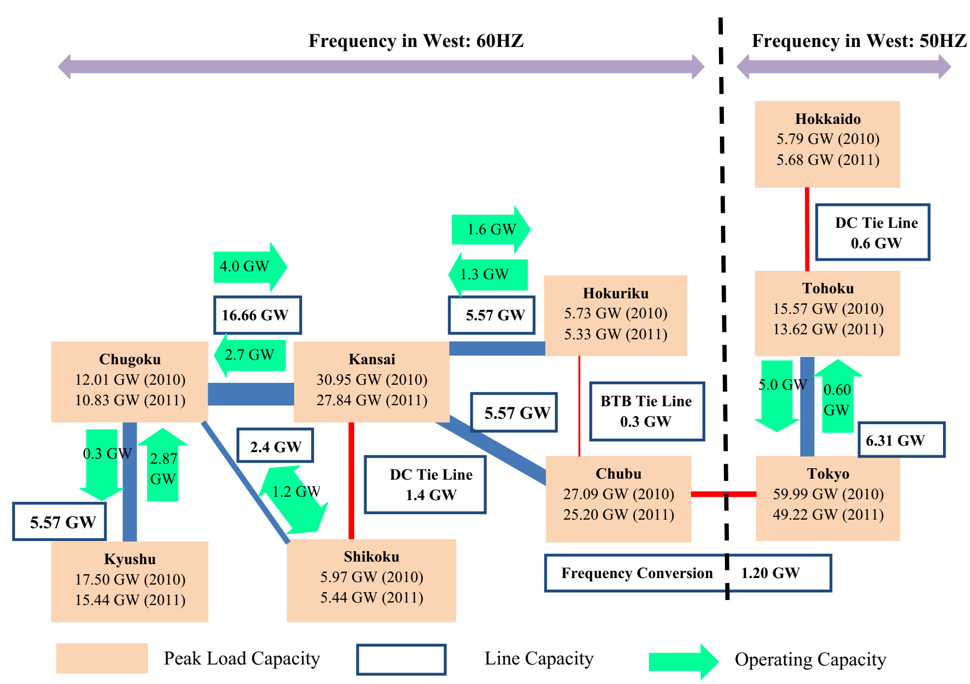


Fig. 5. Generation capacity of nine regional electric power companies (The Okinawa Electric Power Company, with these nine companies, consists of 10 general electric utilities in Japan. The Okinawa EPCO is not connected to any other utilities due to its remote location.). and transmission capacity among them.
Source: drawn by the author based on [15].

Table 2
Summary of the Past Electricity System Reform in Japan [15].

Phase	Year enforced	Overviews
1	1995	• Establishment of the IPP market • Allow specified-scaled and vertically integrated power generator participation to the wholesale market
2	March 2000	• Introduction of partial competition to the retail market • Accounting separation of transmission and distribution sector
3	April 2005	• Expansion of retail competition to high voltage power users such as industrial customers • Establishment of the wholesale power exchange (JEPX) and its supporting body for transmission in wider areas
4	2008	Modification of the rule of wheeling rates

power supply capacity of non-EPCOs (3.6%), transactions at the wholesale power exchange (Japan Electric Power Exchange, JEPX) remains only 0.6% of the total retail market sales, meaning virtually both the electricity wholesale and retail markets are still not liberalized at all [15].

However, this time, things were different. With the weakened political and economic status of the 10 EPCOs following the Fukushima Accident and the subsequent suspended nuclear plant operation along with supportive public opinion, the Expert Committee on the Electricity Systems Reform, summoned by the METI, published their final recommendations to the government on February 15, 2013, including the means and roadmap for unbundling and full-scale market liberalization. The committee had discussed the sector reform for about a year, focusing on how to stabilize the power supply without nuclear power generation and achieving large-scale deployment of renewables. The recommendations by the Committee mention three phases of the Reform plan, which were accepted by the Cabinet on April 2, 2013. The main features of the recommendations are:

1. Establishing Nationwide Transmission System Operator (TSO) to operate the grid system nationwide and a New Regulatory Authority by 2015 to create the fair rules of the grid facility utilization. The objective is to improve planning for inter-regional transmission use and the adjustment of power supply and demand and to prepare for a new regulatory system and unbundling.
2. Full-scale Liberalization of the Retail Market. The contents and target dates are:
   - Full electricity supplier choice for consumers/free business entry to power generation (2016).
   - Elimination of wholesale regulation (2016).
   - Establishment of one-hour ahead market (2016).
   - Elimination of regulated retail tariffs (2018–2020).
3. Legal Unbundling between 2018–2020, to separate transmission and distribution divisions of the existing EPCOs.

Based on the above recommendations, a bill was submitted to the Lower House of the Diet in May 2013. This bill is considered the first in a series of amendments of the Electric Utility Industry Act, and seeks to establish legal basis for the establishment of national TSO by 2015, the first of the three recommendations described above. The bill also mentioned that once the first bill becomes law, the two separate bills will follow in the Diet Sessions in 2014 and 2015, respectively, to implement the rest of the Committee's recommendations. However, the bill failed to pass and was abandoned on because the Diet session run out time June 26, 2013. This makes the future of the Sector Reform very uncertain again as the details of the Reform can be modified significantly by any kind of political changes in the future. However, currently, the Liberal Democratic Party (LDP) and METI are aiming to submit a new bill in the next Diet Session in October 2013 and it is expected to become law by January 2014.

3.2. Changes in energy mix, lack of diversity of energy sources, and future energy plan

The inflexible electricity sector also leads to an inability to transform the energy mix more flexibly and competitively. As seen in Fig. 4, approximately 30% of electricity in FY 2010 was supplied by nuclear energy and 60% by fossil fuels. Within the fossil fuel category, the share of Liquefied Natural Gas (LNG) was 32%. This situation dramatically changed following the Great East Japan Earthquake and Fukushima Accident. The power generation capacity of nine EPCOs in 2011 was lower than those of 2010 due to the suspended operation of 50 nuclear power plants.[3] As Japan reduced the nuclear plant operation one by one in 2011 and 2012, electricity supply was heavily dependent on fossil fuels, almost 90% of the supply, in September 2012, as seen in Fig. 6. This situation increased the share of imported LNG to about 50%. Japan experienced JPY 6.9 trillion trade deficit in 2012, the largest in its history, and the largest contributing factor was the increased LNG import [16].[4] Japan is very vulnerable as regards energy security with the 4% self-sufficiency ratio of energy in 2012.

Figs. 4 and 6 illustrate that renewable energy shares in electricity mix are quite small. These figures do not include non-utility power generation under 1 MW. However, even with those included, renewables without large-scale hydro are estimated to supply less than 4% of the country's electricity. Many have begun questioning such lack of diversity of energy sources as contributing to political and economic vulnerability and a matter of national security from a risk management perspective.

The Great East Japan Earthquake, Fukushima Nuclear Plant Accident, and the subsequent energy crisis triggered fierce debates regarding the future national energy plan and policy. The METI summoned a new Investigation Committee for General Resources and Energy in the spring of 2011, in order to consider various issues raised by the Great East Japan Earthquake and Fukushima Accident and to revise the 2010 Energy Basic Plan. The Committee members were largely divided into two groups: one for keeping nuclear energy options and the other against. Based on various

[3] The total number of nuclear power plants in Japan was 54 before the Fukushima Accident. The total power generation capacity of nuclear in February 2011 was 48.847 GW. As four Fukushima Daiichi nuclear power plants are already closed permanently, the total nuclear power capacity became 46.149 GW in April 2013. 48 out of the 50 nuclear plants did not operate in 2012 [17].

[4] From 2010 to 2012, Japanese import increased 3.8% in monetary basis. LNG import contributed to approximately 1.8% of this total increase [18].

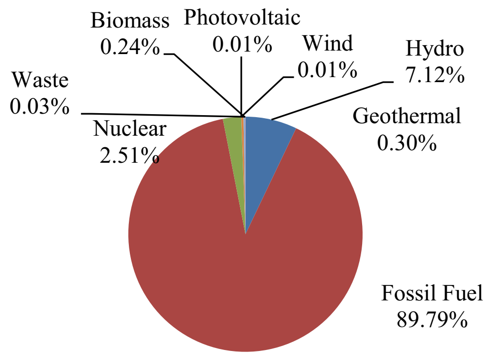


Fig. 6. Electricity mix of Japan in September 2012 (Total 68.242 TWh) [17]. *Note*: The numbers show the supply by large-scale power generations by utilities (above 1 MW) only, excluding non-utility small-scale power generations such as residential PV.

debates, in summer 2012, the Democratic Party of Japan (DPJ) government presented the three future energy scenarios to the public to form national consensus on energy mix by 2030 (Table 3). While the government gathered public opinion, and conducted public hearings and polls, consensus was not reached, and the snap election of the Lower House and the subsequent establishment of the Liberal Democratic Party (LDP) as the leading political party in the Diet in December 2012, left the national future energy plan and energy targets yet to be determined. With the new administration, the METI again summoned a new Investigation Committee for General Resources and Energy and the discussions started in March 2013 with new members. The METI and the Committee target to set the new energy basic plan by the end of 2013, but it is expected that the energy mix and renewable targets will not be set by this plan. This is because that many nuclear power plants are waiting for restarting permit under the revised and stricter nuclear power plant safety standards, and nobody knows how many plants will pass the standards. Without this decision, it is difficult to set a clear energy mix, as Japan has not completely abandoned nuclear option in the future.

3.3. Introduction of Feed-in Tariffs in 2012

Although future energy planning and related discussions have been quite chaotic, the necessity to diversify Japan's energy mix and increase the role of renewable energy has been recognized by many. While it is uncertain how much of renewables should be introduced and by when, i.e. the mid-term and long-term national targets for renewables, Japan repealed the RPS system and introduced the Feed-in Tariff system instead to accelerate renewable energy market growth. In August 26, 2011, the Diet passed the Act on Special Measures concerning the Procurement of Renewable Electric Energy by Operators of Electric Utilities (the FIT Act). Under this new FIT Act, the EPCOs are obligated to purchase solar, wind, hydro, geothermal, and biomass generated electricity at prices to be set by the METI. The act took effect on July 1, 2012.

The FIT Act requires the EPCOs to enter into power purchase agreements with suppliers of renewable electricity certified as Specified Suppliers by the METI.[5] The EPCOs must also interconnect power generation plants of the Specified Suppliers and their electric transmission and other electricity facilities. Table 3 shows the terms of power purchase agreements under the FIT Act for FY 2012 and FY 2013. The tariff levels and purchasing period vary by type, installation mode, scale, and other factors. The METI fixes these terms for one fiscal year. Every year, the METI can modify the terms, after listening to the opinions of other relevant governmental ministries and the Procurement Price Calculation Committee.[6] These power purchase agreements must be executed and the electricity tariffs must be paid by the EPCOs. The existing plants can switch from the RPS payment scheme to the FIT scheme if they submitted an application to the METI by November 1, 2012. This measure was implemented, in particular, to save existing wind power plants experiencing financial difficulty [19]. The implementation of the FIT Act, however, does not change the existing surplus power purchase program for residential PV power producers.

For the purpose of expanding renewables more intensively, the FIT Act requires the METI to set higher purchase tariffs during the period of three years (July 1, 2012 to June 30, 2015) and incentivize electricity suppliers who choose to enter the market early. The costs incurred by the EPCOs for the purchase of renewable electricity are recovered by invoicing end users for a surcharge in addition to the amount usually charged for the supply of electricity. The basis for calculating the surcharge amount will be determined by METI on an annual basis.[7] The EPCOs are excused from their obligation to enter into power purchase agreements and make related interconnections, if there is: (1) a likelihood of unjust harm to the benefit of operators of electric utilities; (2) a likelihood of damage to securing the smooth supply of electricity; or (3) a just reason as set forth in the Implementing Regulations.

4. Wind energy progress after 3.11 – current issues and future agenda

4.1. Renewable potential studies

Before March 11, 2011, both the METI and the Ministry of Environment (MOE) had investigated the installation potentials of renewables. They published the results just after the Great East Japan Earthquake and Fukushima Accident in 2011. These two ministries indicated that onshore as well as offshore wind energy had far greater potential compared with other renewable energy sources (Table 4).

4.2. FIT and wind energy market

With the introduction of the FIT in July 2012, renewable energy installation has grown dramatically. However, as seen in Table 5, more than 95% of facilities that started operation were PV; there are huge discrepancies among renewable resources installed under the FIT program. As for wind, 66 MW wind energy plants started operation during the first 12 months of the FIT program, but the capacity is less than 1.9% of PV. Also, 805 MW of wind energy facilities were certified by the METI as Specified Suppliers and waiting for start of operation, but the number was only 3.8% of PV certified as of the end of June 2013. Approximately 84% of FIT-certified renewable power plants had yet to be operated at the end of June 2013.

This is very unusual compared with renewable installation in other countries, because wind is often a more favorable choice due to its lower cost. The biggest reasons for this discrepancy and the

[5] The Specified Suppliers status can be obtained from the METI by complying with criteria for the power generating facilities and methods for generating Renewable Electricity that are to be set forth in the Implementing Regulations of the FIT Act.

[6] This is a third party independent committee, consisting of five members appointed by the METI with the approval of the Diet.

[7] For business facilities whose annual electricity usage exceeds the amount to be set forth in the Implementing Regulations, a reduction in the surcharge of 80% or more is provided.

Table 3
Terms of Power Purchase Agreements under the Feed-in Tariffs Act in Japan for FY 2012 and FY 2013 [20].

	Plant type	FIT w/tax	
		JPY	Purchase period (years)
PV	**10 kW ≤**	42 (FY 2012) 38 (FY2013)	20
	< 10 kW	42 (FY 2012) 37.8 (FY2013)	10
Wind	**onshore**	23.1	20
	offshore	–	–
Small and medium scale hydro	**1 MW ≤ < 30 MW**	25.2	20
	200 kW ≤ < 1 MW	30.45	
	< 200 kW	35.7	
Geothermal	**15 MW ≤**	27.3	15
	< 15 MW	42	
Woody biomass	**Recycled**	13.65	20
	General	25.2	
	Unused	33.6	

Note: Tariff levels for FY 2013 are not changed from FY 2012, except for PV.
The purchase tariffs are determined by taking into consideration the following:
- the costs recognized as being generally incurred by the Specified Suppliers where the supply of renewable electricity is carried out efficiently;
- the estimated amount of renewable electricity to be supplied; and,
- the profit that Specified Suppliers should make and other factors.

Table 4
Onshore and offshore wind energy potentials in Japan [21].

	Onshore potentials		Offshore potentials	
MOE	Eliminating undevelopable and/or unsuitable land for wind energy*1	280,000 MW 290,000 MW	Eliminating undevelopable and/or unsuitable land for wind energy*2	1,600,000 MW 1,500,000 MW
METI	Excluding Category II and III and Ordinary Zones of Natural Parks and National Forests	150,000 MW	Excluding the areas without established Fishery Rights	400,000 MW

Note *1: The following conditions concern undevelopable and/or unsuitable lands for onshore wind energy.
Natural Condition: wind speed below 5.5 m/s; altitude above 1000 m; maximum angle of inclination 20°.
Legal condition: natural parks; wild life conservation areas; nature conservation areas; special wildlife protection areas within wildlife sanctuary; world natural heritage site; and forest reserve
Land use condition: area designated for urbanization, rice fields, buildings, and highways; river/lakes/ponds; coastal area; golf course; and 500 m from residences. In addition, for the METI scenario, the areas are more than 40 km away from transmission grids
Note *2: the following conditions concern undevelopable and/or unsuitable areas for offshore wind energy.
Natural condition: wind speed below 6.5 m/s; more than 30 km away from coast; water depth of more than 200 m
Legal condition: for the MOE estimates, national and quasi-national parks (underwater parks);
For the METI estimates, wild life conservation areas; nature conservation areas; special wildlife protection areas within wildlife sanctuary; world natural heritage site; and fishing ground for demarcated fishery.
Water use condition: For METI, areas more than 40 km away from transmission grids.

Table 5
Renewables capacity before and after FIT [22].

	Installed before June 30, 2012 (MW)	Installed and start operating between July 1, 2012 and June 30, 2013 (MW)	FIT-certified capacity by the METI by June 2013 (MW)	FIT-certified but yet to be installed and operated (MW)
PV(residential)	4700	1379	1633	254
PV (non-residential)	900	2,120	19,755	17,635
Wind	2600	66	805	739
Small and medium sized Hydro (≥ 1 MW)	9400	0	65	65
Small and medium sized Hydro (< 1 MW)	200	2	14	12
Biomass	2300	98	639	541
Geothermal	500	1	4	3
Total	20,600	3666	22,915	19,249

strong surge of PV are not the tariff levels nor resource potentials, but the difference in lead-time. Wind and geothermal have much longer lead-time than PV due to various bottlenecks including a layer of regulations for development permits; PV is much easier to install with only a few regulatory permits in Japan. The following sections explore those bottlenecks that hinder wind energy expansion.

4.3. Wind resource locations and grid connection issues in Japan

Geographical distribution of wind resources is quite uneven across Japan. Fig. 7 shows wind energy potentials examined by the MOE (2011) and the existing power generation capacity for each EPCO area, illustrating that wind energy resources are concentrated in Hokkaido, Tohoku, and Kyushu EPCO regions, but

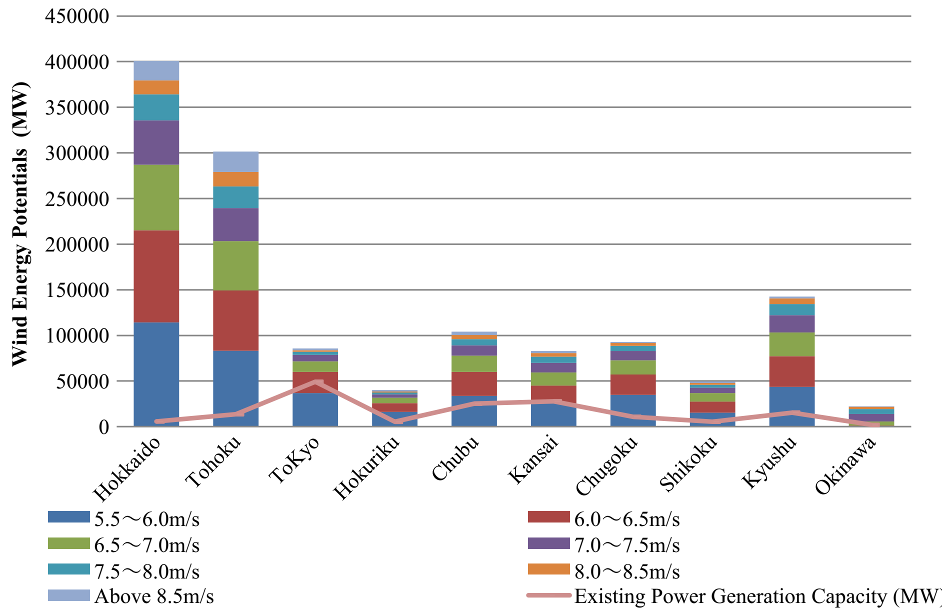


Fig. 7. Wind energy potentials and existing power generation capacity by EPCO [23].

Table 6
Grid connection capacity ceilings posed by EPCOs [24].

EPCO	Grid connection limits as of (MW)				Connected as of March 31, 2013 (MW)
	March 31, 2013	July 31, 2012	September 30, 2011	December 31, 2007	
Hokkaido	560	560	560	310	289
Tohoku	2000	1580	1580	850	542
Tokyo	No Ceiling Set				371
Chubu	No Ceiling Set				224
Hokuriku	450	450	250	150	146
Kansai	No Ceiling Set				78
Chugoku	1000	620	620	420	299
Shikoku	450	450	250	200	166
Kyushu	1000	1000	1000	700	361
Okinawa	25	25	25	25	14
Total	5485	4085	4285	2655	2490

the demand centers indicated by the existing power generation capacity are in the areas supplied by the Tokyo, Kansai, and Chubu EPCOs. Thus, the regions with good wind resources do not have strong demands. Also, good wind resources are remotely located areas with no transmission lines or very small capacity lines, making it very difficult to connect large-scale wind energy projects without fortification of transmission line capacity within each region. This regional discrepancy of market demand and wind energy supply also creates the necessity for a strong transmission grid between regions in order to transmit wind-generated electricity from Hokkaido, Tohoku, and Kyushu to the demand centers such as Tokyo, Kansai, and Chubu regions. However, the weak transmission line capacity between regional EPCOs illustrated by Fig. 5 had limited grid connection of wind power plants in Japan. In addition to the basic features of the grid system described previously, the Japanese power generation mix is inflexible with high penetration of base load power plants such as nuclear, run-of-river hydro, and must-run thermals, creating less flexible power during nighttime.

Due to these circumstances, traditionally, 10 EPCOs have posed a physical ceiling on the grid connection of distributed energy generation. Table 6 shows the grid connection ceilings posed by each regional EPCO, although the Tokyo, Kansai, and Chubu EPCOs do not set the limits, as they refuse to provide clear technical information to distributed power producers regarding their grid. The EPCOs generally justify the grid connection ceilings on the grounds of possible voltage fluctuation, difficulty in maintaining proper frequency, and handling of surplus electricity caused by intermitted wind and PV power generations. Due to the segregation of regional markets without strong regional interconnection, each EPCO must strictly match supply and demand within each area; wind intermittency can cause the difficulty of balancing supply–demand. The actual problems of wind energy grid integration vary across regional EPCOs. The Tohoku, Chugoku, Shikoku, and Kyushu EPCOs lack flexibly controllable power generation capacity and suffer from shortage of downward reserve in case of low demands with high wind supply. This can increase the frequency of the grid. Okinawa EPCO does not have enough control capacity for short-term (several minutes to 20 min) frequency fluctuation and balancing. All EPCOs suffer from the lack of control capacity of long-term (from 20 min to six hours) fluctuation and steep ramp caused by wind power during the period with rapid demand change [25]. With these justifications, there were sudden wind power curtailments by the EPCOs whenever they considered wind power generation threatened their grid stabilization. When the curtailment was executed by the EPCOs for these grid-related reasons, they needed to pay power generation income to wind power producers for curtailment hours if they exceeded 8% of annual power generation hours.

Since 2002, the Hokkaido, Tohoku, and Kyushu EPCOs have let wind power producers apply (bid) for grid access within their ceilings. Grid access winners have been selected by lottery, but the bidding and lottery process have usually taken between six months and one year. In some cases, it has taken approximately two years. Since 2004, these EPCOs have also offered a different type of gird access bidding and lottery options to wind power producers if they agree to curtailment whenever the EPCOs want to stop wind power being fed to their grid. Such curtailment usually occurs when wind power causes oversupply of electricity such as during nighttime, weekends, and holidays, in order to keep the minimum operational capacity of fossil fuel power plants. The EPCOs explain that if they can curtail wind power from the grid during these oversupply periods, they can offer additional grid access to wind power producers. However, the curtailment reduces the earnings from wind power generation and the uncertainty hinders wind power producers' business prospects

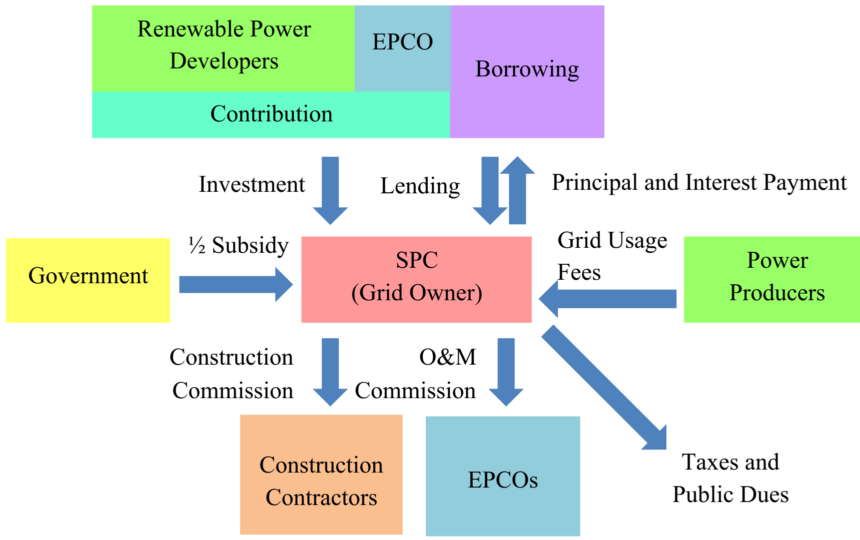


Fig. 8. Proposed grid fortification SPC scheme.
Source: drawn by the author based on [27].

greatly. Similar grid access offers have been made to wind power producers by the EPCOs if they agree to build large energy storage to absorb excess wind supply to the grid as a part of wind projects. This is not an attractive option for power producers either due to high storage capital cost.

These grid-related issues have been considered as the largest bottlenecks for wind in Japan. In the past, wind power producers often had to abandon their projects when the EPCOs refused to provide grid access without providing clear reasons. Obviously, in some cases, the EPCOs did not refuse the grid connection, but instead, they required extremely high cost of building new transmission facilities to remotely located wind energy projects. There have been very few independent, third-party cost verification companies to confirm the costs imposed by the EPCOS for grid connection capacity building. Such lack of clarity and transparency has been rampant, but wind power producers needed to persevere in the face of the strong political and economic power of the EPCOs.

In order to mitigate these grid-related issues, currently, several policy schemes and projects are simultaneously progressing. Firstly, the grid connection rules have become slightly clearer, compared with the pre-FIT period. The FIT Act of 2012 began requiring the EPCOs to provide grid access to renewable developers and pay for any curtailments beyond 30 days a year and explain the reasons for curtailment to wind and PV power producers with 500 kW or more project capacity. However, because the EPCOs can still refuse access on the grounds of grid capacity limitation, in December 2012, the METI published the rules of data and information disclosure related to renewable grid connection, which includes streamlining of administrative process for gird access applications, and notified the Electric Power System Council of Japan (ESCJ) to reflect the rules in its operation. The ESCJ is the current body responsible for making transmission and distribution rules and resolving disputes, coordinating load-dispatching operations, and providing power system information, but its members are 10 regional EPCOs. Therefore, it is still very uncertain that such rules, which were noted by the METI, are applied in an open and fair manner from renewable developer perspective. The planned Electricity Sector Reform is expected to alleviate the grid connection issues by creating an independent transmission system operator by 2015, at least providing fair grid access and relevant necessary data, which does not necessarily come with priority access guarantee under the current FIT. However, there have been some setbacks; along with the failure of the first Reform Bill, the METI changed the curtailment rules in May 2013. Because a large volume of FIT-certified PV projects were concentrated in Hokkaido in the first eight months of the FIT program, the grid capacity which can absorb wind and PV in Hokkaido was quickly reaching the limit. The METI decided to create an exception to the grid connection and priority access rule by removing the payment guarantee requirement beyond 30 days of curtailment a year from the Hokkaido EPCO. Additionally, both PV and wind project developers have no ideas so far how the EPCO or METI will decide which projects will be curtailed first and which region will be next to apply such exemption rules. From their perspective, this change has simply added new uncertainty to old and continuing grid access issues [26].

The second scheme to solve the grid issues concerns technology development; RD&D projects by the METI and NEDO have been in progress since 2008 to support the development of large-scale energy storage system at substation, power control systems, and weather and wind forecasting systems 18. However, these technical means needs to be combined with wider-area grid operation to absorb intermittency of wind. The Electricity Sector Reform discussed above holds an important key here again.

Lastly, the METI has created a scheme to fortify the grid capacity physically to absorb more distributed and intermitted power sources. The METI estimates that such a nationwide grid system project will cost JPY 310 billion, and this involves the establishment of a Special Purpose Company (SPC) to engage in transmission business in a region. Half of the capital is going to be financed by the EPCO of the region and several renewable power producers, and the other half by the METI. The SPC owns the grid system and charges usage fees to users of the grid, mainly wind power generators (Fig. 8). As a start, a budget of JPY 25.3 billion was approved in April 2013 for FY 2013 to reinforce the grid of northern region of Hokkaido, and two SPCs (a SPC funded by Eurusenergy Corporation, and a SPC funded by Mitsui, Marubeni and SB Energy) are selected to start the project in October 2013 [27].

Although there has been certainly some progress with these measures, many practical problems remain. In particular, the establishment of rules regarding information and data disclosure and clear explanation of reasons for grid access refusal or limitation from EPCOs is the most important in the short term.

4.4. Long lead-time and regulatory aspects

Another important issue is the layer of regulations. Before applying grid access to a relevant EPCO, wind project developers

Table 7
Major deregulations concerning wind project development [29].

Relevant laws	Legal content	Current conditions, issues, and demands from wind industry
Environmental Impact Assessment (EIA) Act	The recent EIA amendment requires the full EIA process for wind projects above 10 MW (projects above 7.5 MW and below 10 MW are decided case-by-case) from October 2012, adding one to two additional years to project lead time. Long administrative time and lack of environmental data and consensus on EIA items, methodologies, and procedures are issues.	Streamlining of the EIA administrative process to halve the processing time is underway (currently about 570 days). The lack of basic nationwide environmental data requires developers to gather a large amount of data over a long period of time. Simplifying environmental survey by developers while guaranteeing EIA quality is an issue.
Agricultural Land Act	The new rule of no siting permit for wind development on first-class agricultural land was applied after 2010.	As wind development can coexist agricultural land uses and there are good examples in Japan before 2010, wind turbine siting in the first-class agricultural land should be permitted again.
		Progress Made
Natural Park Act	The technical guidelines for siting wind turbines in natural park areas were set in March 2012, but they do not consider wind technology characteristics well and overlap some of the EIA process.	The landscape guidelines should consider wind technology characteristics, and the guidelines and related EIA process need to be streamlined in order to increase wind development in some of the nature park areas which have good wind resources. The revised technical guidelines were published on March 29, 2013.
Forest Act	Siting permits in protected forest areas included various conditions and were extremely difficult to obtain. Also, the decision-making rules that were applied at prefectural level were very unclear.	Permission for wind turbine siting in protected forest areas with easing conditions and clearer operational decision-making rules was given to prefectural governments on June 29, 2012.
Accounts Law/ National Forest Act	Wind projects in national forest land by non-EPCO developers were not permitted.	Permission to rent national forest lands from the government for wind projects certified by the FIT became possible on June 29, 2012.
Building Codes/ Electric Utility Industry Law	The METI examines the power system/nacelle, but Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) examines the tower.	Unified permit process for entire wind turbine examination was decided on March 28, 2013. The earliest application will be in January 2014.
Grid Access Rules	No explanation of grid access refusal was made to wind developers and the contents and calculation methods of necessary payments regarding grid connected fees for regional EPCOs were made.	In December 2012, the METI published the rules of data and information disclosure related to renewable grid connection, which includes streamlining of administrative process for gird access applications, and notified the Electric Power System Council of Japan (ESCJ) to reflect the rules in its operation.
Electric Utility Business Act	The act requires each wind farm to have a full-time electrical chief engineer regardless of size or location.	Multiple wind farms can be considered as a unified wind farm site (a cluster) and share a full-time electrical chief engineer, creating economies of scale and reducing cost.

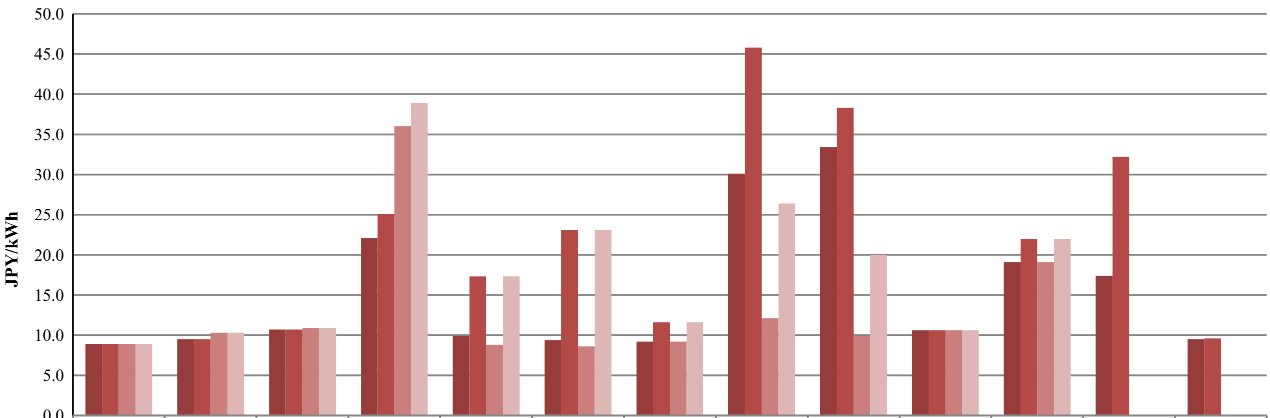
have to clear more than 50 laws, regulations, guidelines, and related operational rules. Lack of Basic Law, development principles in Japan, and clear land use regulations and/or zoning governing renewable and other resource management have created a complicated regulatory picture. This has often made decisions by regulatory authorities at prefectural level vary across regions and left wind projects without nationally unified and established operational rules and guidelines. There is no one regulatory agency overseeing the entire project application process. Thus, going through the complex regulatory process raises uncertainty, increases lead-time, and hence raises risk premium and project cost greatly for wind project developers.

After the Great East Japan Earthquake and Fukushima Nuclear Plant Accident, the necessity to increase renewables and diversify energy sources has accelerated the deregulation process in many fronts for all renewables. Table 7 shows important deregulations already made and those in progress regarding wind energy, indicating good results in the past two years and a half.

However, there are still several outstanding issues. One is the application and streamlining of the Environmental Impact Assessment (EIA) procedures. Before October 2012, the EIA was not obligated to any wind energy project. The recent EIA Amendment changed this, mandating the full EIA process for wind projects above 10 MW capacity. For projects between 7.5 MW and 10 MW, whether the full process will be applied or not will be decided on a case-by-case basis. The second phase of the amendment began in April 2013, adding the so-called Project Strategic Environment Assessment (SEA) to all EIA applicable projects. Since Japan does not have clear land use laws or zoning governing renewables, the usual SEA, which is imposed on “Policy, Planning, and Program”, is not possible. Instead, the EIA Amendment and the MOE require every renewable project developer to submit several alternative locations and explain which location fits best for environmental, social, and economic reasons, shifting the public-sector obligation of SEA to developers and making decisions on a case-by-case basis without articulating integrated development principles to anyone.

In addition, as the full EIA process is very new to wind project developers, the MOE, and the METI, it is still in a process of forming consensus on items, methodologies, and processes regarding research, evaluation, and monitoring. Moreover, currently, the administration procedure alone in various phases of the EIA takes 570 days in Japan. This is recognized as a big burden for developers, and the efforts to halve the processing time is underway; the administrative time can be reduced by a half by processing an application at national and prefectural levels simultaneously. Thus, the implementation of the EIA amendment has increased wind development lead time in Japan to at least five to six years, from three to four years before October 2012 [28]. This is one of the reasons which did not increase wind project certification under the FIT, but did so for the more costly PV, as the EIA is not required for the latter at all. Proper EIA is a critical process to form consensus among all related parties, including local communities. The wind industry and EIA-related regulatory authorities must work harder to establish a firm procedure of the EIA and balance simplification of the process and environmental protection to advance wind energy deployment.

Another regulatory issue is closely related to national park conservation. Since higher wind locations are often found in mountainous conservation areas, the MOE published the Technical Guidelines for Wind Energy Installation in the Natural Park Areas with particular emphasis on landscape consideration in March 2012. This guideline was perceived as being very strict by the wind industry as regards the siting of wind turbines, essentially prohibiting wind turbines on ridges



	Nuclear	Coal	LNG	Oil	Wind: Onshore	Wind: Offshore (fixed foundation)	Geothermal	Photovoltaics: Megasolar	Photovoltaics: Residential	Hydorpower: Large scale	Hydorpower: Small and Medium scale	Biomass: Biomass Only Combustion	Biomass: Mixed Combustion
2010 Lower Limit	8.9	9.5	10.7	22.1	9.9	9.4	9.2	30.1	33.4	10.6	19.1	17.4	9.5
2010 Upper Limit	8.9	9.5	10.7	25.1	17.3	23.1	11.6	45.8	38.3	10.6	22.0	32.2	9.6
2030 Lower Limit	8.9	10.3	10.9	36.0	8.8	8.6	9.2	12.1	9.9	10.6	19.1		
2030 Upper Limit	8.9	10.3	10.9	38.9	17.3	23.1	11.6	26.4	20.0	10.6	22.0		

Fig. 9. Levelized cost of energy by the Cost Examination Committee [34].

which naturally benefit from better wind resources. However, as the EIA was newly introduced to wind projects, the amendment of the Technical Guidelines for Wind Energy Installation in the Natural Park Areas was issued in March 2013 in order to streamline the National Park Act, the technical guidelines, and the EIA procedure. With this latest guideline, the wind industry considers the siting issues in nature conservation areas mostly settled [30].

The outstanding remaining deregulation issue is the removal of restriction of wind development on first-class agricultural lands posed by the Agricultural Land Act. Before 2010, wind projects could be built on first-class agricultural lands, creating the finest examples of coexistence of renewables and agriculture and some of the best tourist attractions, in particular pasturing areas. However, suddenly, the practice was prohibited by the Ministry of Agriculture, Forestry, and Fishery (MAFF), which wants to maintain agricultural lands intact. The Japan Wind Power Association (JWPA) keeps talking to the regulatory authority that wind projects can co-exist with agricultural practices [30].

4.5. Social acceptance issues

Social acceptance of wind projects is another serious bottleneck. In particular, the issues related to noise/low frequency noise, development within national parks and other conservation areas, and landscape preferences are considered most important for local community and stakeholder relationship building. In the early years of wind development, most notably in the late 1990s, these issues were not so much bottlenecks, because the general public perceived wind as environmentally friendly. However, some private wind developers and municipalities built wind projects without proper consideration of these issues, and the opposition against wind grew gradually throughout the 2000s.

With increased resentment from local communities against wind energy, the NEDO published voluntary EIA guidelines for wind projects in 2003. However, these issues did not go away completely and led to the Amendment of EIA Act, which enforced a fully-fledged EIA process on wind projects from October 2012. As for national park conservation, the MOE published the Technical Guidelines for Wind Energy Installation in the Natural Park Areas mentioned above. These regulations are absolutely necessary to create stakeholder consensus. Therefore, the wind industry needs to explore good ways to utilize these regulatory procedures as consensus building process with local communities.

Another reason which makes social acceptance of wind energy difficult in Japan is the lack of community involvement. The past wind projects, which are mostly owned and managed by large private developers, do not bring local communities any benefits but nuisance such as noise and landscape disturbance. In recent months, however, more aggressive involvement from local communities has become evident as many are moving toward developing their own renewable projects with some help from the MOE subsidies and the FIT.

4.6. Cost

In December 2011, the Cost Examination Committee established by the National Policy Unit in the Cabinet Office published a report regarding Levelized Cost of Energy (LCOE) from various energy sources in Japan. The purpose of the report was to examine real LCOE of nuclear and renewable power generations.[8] The examination was done by assuming a typical model plant in 2010 and 2030 and utilizing published financial securities data. Fig. 9 shows the results of the cost examination. The report mentions that wind LCOE is expected to become competitive in 2030 in lower boundary with coal, LNG, and nuclear, if only mass production effects take place with a much larger domestic market enabled by a series of deregulations and grid connection capacity expansion.

Consensus regarding capital cost of onshore wind farms in Japan is around JPY 300,000/kW [31]. This figure was submitted to the Procurement Price Calculation Committee of FIT in 2012 and 2013, and the FIT was determined with this figure. Fig. 10 shows historical capital cost composition of onshore wind built between FY 2005 and FY 2012 [32].[9] From this data, historically, the average

[8] This was the first comprehensive effort by the government to compare LCOE across different energy sources. In particular, the cost of renewable energy was not important before 3.11, as the Japanese government did not have strong intention to deploy renewables, as it was considering nuclear as the most important energy source to combat climate change and other environmental issues and renewables were just a niche. Thus, the report was the first official cost examination result of its kind.

[9] This compiled data consisted of 91 NEDO subsidized projects sites with the average installed capacity of 14.733 MW (average eight wind turbines capacity). The average capital cost was JPY 263,000/kW.

58% of the total capital cost is spent for wind turbine, but the report states that capital cost decreased as more turbines were installed.

Comparing this capital cost (JPY 300,000/kW) with the figures of other countries published by the IEA Wind and the IRENA [33] reveals that wind capital cost in Japan is almost 1.5 to 2 times higher in 2010. The JWPA attributes the following reasons for this higher capital cost [31].

- Small volume of order due to the small domestic market in Japan reduces scaling merit of large volume orders seen in Europe and elsewhere;
- Small individual project sizes and dispersed mountainous locations of those projects also increase installation and transportation costs as well as make it difficult to materialize economies of scale;
- A large portion of wind turbines are imported, which adds transportation fees to wind turbine costs;
- Japanese construction cost in general is much higher than other developed countries; and
- The application of the strict Building Codes (applying the same seismic standards as skyscraper buildings higher than 60 m) and Technical Codes on wind turbines adds costs to engineering, turbines, and installation, in addition to IEC61400-1, which are applied in Europe and elsewhere.

Although it is difficult to prove these points raised by the JWPA, as reliable cost data are so far not available for analysis, Fig. 11 shows that individual project scale has been very small in terms of typical projects in other countries, suggesting achieving economies of scale is very difficult in Japan. In terms of the import of turbines, Fig. 12 shows that the market shares of three Japanese manufacturers (Mitsubishi Heavy Industries, Hitachi-Fuji, and Japan Steel Works (JSW)) are 23% of the cumulative installed capacity of Japan, suggesting additional transporting fees and exchange rate risks and variations.

Table 8 shows typical annual operation cost (20 year average) of a 20 MW wind farm [36]. There are no good data available for O&M cost comparison with other countries. However, the JWPA considered that the Japanese O&M costs are generally higher than other countries for the following reasons [31].

- Japan has more complex wind regime with frequent turbulence, typhoons, and severe lightning strikes, and this causes more parts failures and accidents, raising maintenance and insurance fees compared with Europe.
- While there are specialized firms which oversee O&M of several wind farms with lower costs and higher operational efficiency in Europe, the small wind energy market in Japan does not offer such a business environment and mostly wind project developers or manufacturers themselves engage in O&M with lower operational efficiency.

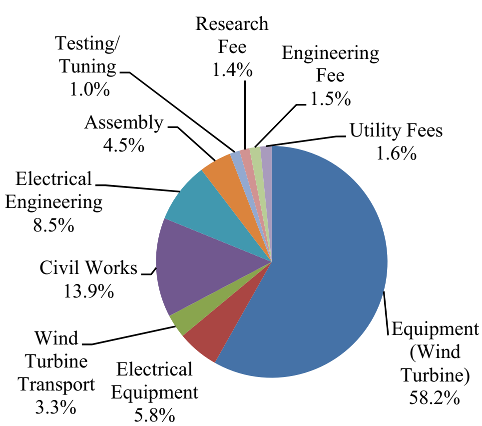


Fig. 10. Historical distribution of onshore wind capital cost (built between FY 2005 and FY 2012) [32].

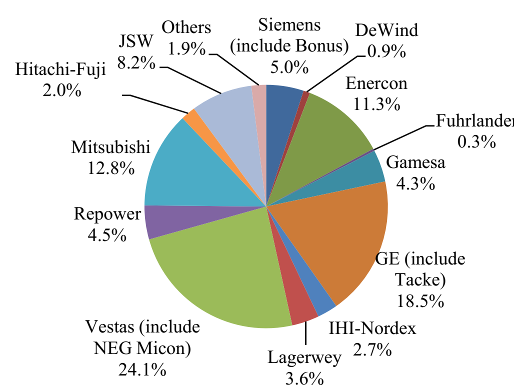
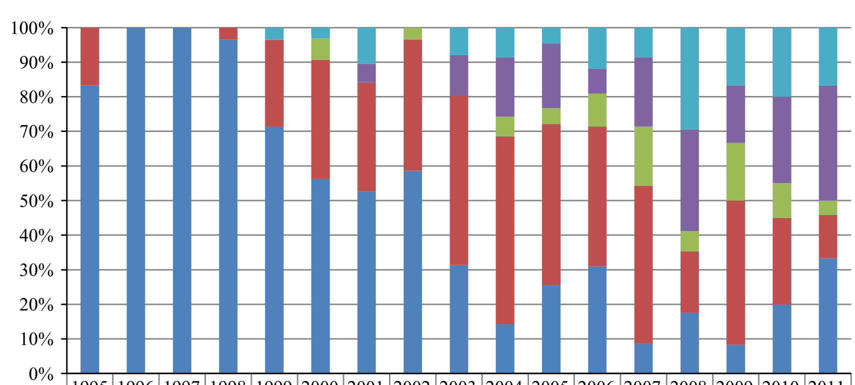


Fig. 12. Domestic market share (by Capacity) (NEDO subsidized projects using wind turbine above 50 kW capacity, cumulative capacity of 2578 MW between 1995 and 2011) [35].



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
20MW ≤	0	0	0	0	1	1	4	0	4	3	2	5	3	5	4	4	4
10MW ≤ < 20MW	0	0	0	0	0	0	2	0	6	6	8	3	7	5	4	5	8
5MW ≤ < 10MW	0	0	0	0	0	2	0	1	0	2	2	4	6	1	4	2	1
1MW ≤ < 5MW	1	0	0	1	7	11	12	11	25	19	20	17	16	3	10	5	3
Below 1MW	5	9	12	29	20	18	20	17	16	5	11	13	3	3	2	4	8

Fig. 11. Individual Project Scale of the NEDO Subsided Project between 1995 and 2011 [35].

Table 8
Typical annual operation cost (average over 20 years) of a 20 MW wind farm [37].

Item	Million JPY	%	
O&M cost	**71.2**	**51.0**	Annual inflation ratio of 1%
General administrative cost	**11.0**	**7.9**	
Insurance fees	**4.2**	**3.0**	
Land leasing	**5.7**	**4.1**	
Fixed asset tax	**32.1**	**23.0**	Fixed asset tax ratio of 1.4%
Business tax	**1.0**	**0.7**	
Maintenance cost	**6.6**	**4.7**	5% reduction every five years
Reserve fund	**7.9**	**5.7**	10% of (O&M cost+Spare Parts) annual inflation ratio of 1%
Total	**139.7** 6985 JPY/kW	**100**	

O&M cost: regular inspection, manufacturer's warranty, electricity charge for receiving power, aircraft warning lights, etc.
General administrative cost: cost of hiring electric chief engineer, power generation data monitoring, recording, etc.
Insurance fees: fire insurance, machine insurance, loss of profit insurance, weather derivative, etc.maintenance costs: spare parts exchange cost, etc.
Reserved fund: fund reserved for use in case there is shortage for other items.

Table 9
Causes of failures and accident of wind turbines in Japan (observation between FY2004 and FY2011) [37].

Causes	Number of incidents	Percentage
Natural phenomenon		
Storm	35	2.9
Lightning strikes	267	22.2
Turbulence	18	1.5
Icing	2	0.2
Flood	23	1.9
Others	21	1.7
Accidents in wind turbines		
Design defect	101	8.4
Manufacturing defect	96	8.0
Loosening of parts	31	2.6
Human causes		
Maintenance defect	54	4.5
Grid caused		
Grid failures	7	0.6
Causes unknown		
Under investigation	139	11.6
Not identified	279	23.2
Others	129	10.7
Total	1202	100.0

- It is difficult to create scale merit in O&M in Japan, as scale of development is small and developments are scattered.

Again, although it is also difficult to prove these points due to data deficiency, the percentage of wind turbine failures triggered by natural causes, in particular, by lightning strikes, is certainly much higher, compared with the German data, as seen in Tables 9 and 10. The NEDO reports [37] mentioned that the accidents and failures caused by lightning strikes have much longer downtime than other causes, affecting project feasibility greatly.

The high capital cost is considered one of the important bottlenecks of wind energy utilization in Japan. It is important to analyze factors behind the high cost and determine what can be done by policy as well as business efforts to reduce it.

4.7. New technology projects – offshore

While onshore wind projects have struggled to expand the market, Japan has set its sights on offshore development in order to utilize the resource potential, which accounts for more than 80% of the country's wind resources. Three near shore projects are already commercialized: Setana Offshore Project in Hokkaido (commenced April 2004, 1.2 MW); Sakata Offshore project in Yamagata Prefecture (commenced January 2004, 10 MW), and Kashima Offshore project in Ibaragi prefecture (commenced June 2010, 30 MW). In addition, four more genuine offshore demonstration projects are currently underway, supported by the METI, NEDO, and MOE. Both Choshi Seabed Foundation Offshore Demonstration project in Chiba Prefecture and Kitakyushu Seabed Foundation Demonstration project in Fukuoka Prefecture by the NEDO started observation in 2012 with one 2 MW turbine and an observation tower for each project. The METI and NEDO spent 5.2 billion JPY in FY 2012 and another 3 billion JPY in FY 2013 for these projects [39]. Another seabed foundation demonstration project is supported by the MOE off the coast of Goshima Island in Nagasaki Prefecture. The purpose of this project is to test the nation's first offshore grid connection: the first 100 kW turbine was set up in June 2012 and another 2 MW turbine started operation in 2013. The MOE budgets for this project was 3 billion JPY in FY 2012 and 1.6 billion JPY for FY 2013 [40].

Table 10
Causes of failures and accidents of wind turbines in Germany (1989–2006) [38].

Causes	Percentage
Natural phenomenon	
Storm	5.16
Lightning strike	3.66
Icing	3.22
Accidents in wind turbines/human causes	
Defect of parts	36.68
Loosening of parts	3.38
Plant control	22.79
Grid failure	6.54
Cause unknown	7.55
Different causes	11.02
Total	100.0

The program which gathered the most attention both domestically and internationally is a deep water offshore floating concept RD&D off the coast of Fukushima by the METI. The project aims to: (1) test three foundation types with three turbine concepts, one floating power substation, component technologies, and system technology, and establish O&M techniques for floating offshore wind (Table 11); (2) develop common standards for floating offshore wind; (3) find a way to balance the existing fishery industry's interests, navigational safety, and environmental protection through proper EIA method; and (4) eventually develop the world's largest floating offshore park and develop a new renewable energy industry and employment opportunities for Fukushima. An industry-academia consortium was formed for 11 partners to proceed with this project, including Marubeni

Table 11
Facility specification and companies in charge of the Fukushima floating offshore demonstration project [41].

Facility/wind turbine type	Floating structure type	Scale	Project term
Substation(Hitachi)	Advanced Spar (IHI-MU)	25 MVA, 66 kV	First phase
Downwind type (Fuji Heavy Industries-Hitachi)	Four-Column Semi-Submersible Platform (Mitsui)	2 MW	First phase
Hydraulic (Mitsubishi)	Three Column Semi-Submersible Platform (Mitsubishi)	7 MW	Second phase
Hydraulic (Mitsubishi) or downwind type	Advanced Spar (IHI-MU)	7 MW	Second phase

Table 12
Main roles of Fukushima consortium members [41].

Consortium member	Main role
Marubeni Corporation	[Project Integrator] Feasibility Study, Approval and Licensing, Environment, Fishery Industry, O&M, etc.
The University of Tokyo	[Technical Advisor] Floating Observation, Technical Developing
Mitsubishi Corporation	Feasibility Study, Approval and Licensing, Environment, Fishery Industry, O&M, etc.
Mitsubishi Heavy Industries, Ltd.	Floating Wind Turbine
IHI Marin United Inc.	Floating Wind Turbine, Floating Body for Substation
Mitsui Engineering & Shipbuilding Co., Ltd.	Floating Wind Turbine
Nippon Steel Corporation	Steel supply
Hitachi, Ltd.	Floating Electric Power Substation
Furukawa Electric Co., Ltd.	Undersea Cable
Shimizu Corporation	Construction Technology
Mizuho Information & Research Institute, Inc.	Documentation, Committee Operations

Corporation as the project integrator (Table 12). The project is divided into two phases: the first phase began in FY 2011 and a 2 MW downwind wind turbine, a 66 kV sub-station, and subsea cable will be installed in 2013. The second phase, between 2013 and 2015, will add two floating platforms each with a 7 MW wind turbine. The characteristics of the demonstration project area, which is 20 km to 40 km from the nearest shore, are considered quite challenging; the average wind speed is 7 m/s, but the depth of the sea is between 100 m and 150 m, and the maximum significant wave height can be 10 to 15 m. The METI budget for the Fukushima Floating Wind Projects was 9.5 billion JPY in FY 2013 and the METI is requesting 31 billion JPY for FY 2014 [39].

In addition to these challenges, social acceptance issues, in particular with the local fishery industry, formed another daunting challenge from the beginning. Negotiations involved the METI, Fukushima Prefecture, the industry consortium, and representatives from the local fishery community. The key was to persuade fishermen to relinquish some of their legally protected fishing rights. After one year of negotiations, the breakthrough came on March 29, 2013, as the fishermen agreed to relinquish their rights. For this, the government agreed to a condition posed by the local Fishermen Association that all the offshore facilities installed by the demonstration project will be removed if a new agreement between the concerned parties will not be reached after three years regarding further expansion of offshore facilities. Following this agreement, the government decided to upgrade the functions and infrastructure of the port of Onahama in Fukushima Prefecture to serve the center of installation for the Demonstration Project [42]. With the removal of this largest concern, the consortium started building the facilities in summer 2013. The Fukushima Prefecture simulated employment effects of such a large offshore wind park with 1 GW capacity to be 22,000 people [43].

4.8. Domestic industry

Because of the existence of a small-scale domestic market, the Japanese wind energy industry is also small. Japan has three medium- to large-size wind turbine manufacturers, namely Mitsubishi Heavy Industries (MHI), Hitachi-Fuji, and Japan Steel Works (JSW). MHI is the largest among the three. Hitachi acquired the wind turbine manufacturing division of Fuji Heavy Industries in July 2012. These three manufacturers' cumulative domestic market share between 1995 and 2011 was about 23%, and all other wind turbines are imported, mostly from Europe (Fig. 12). However, Fig. 13 shows that the market shares vary greatly year by year. The market share of the three Japanese firms was 18.8% in 2006, 9.5% in 2007, 24.5% in 2008, 19.4% in 2009, and 33.3% in 2010, but increased to 61.9% in 2012 [44]. In terms of their presence on the world market, though, it is miniscule. Only MHI is a global player, placing onshore wind turbines in North America for a number of years and plans to introduce 7 MW offshore wind turbines to the UK offshore market soon.

Table 13 shows the names of firms which engage in wind-related component and turbine manufacturing in Japan. The Japan Society of Industrial Machinery Manufacturers (JSIMM) conducted a survey of the wind turbine industry [45].[10] According to the survey result, 72 firms engaged in wind energy-related manufacturing activities, and between them had 2460 employees. The monetary value of wind-related domestic manufacturing was approximately JPY 154 billion and two thirds of the figure (approximate JPY 97 billion) came from export. Also, these firms reported that they engaged in approximately JPY 54 billion of overseas manufacturing in FY2010. About one fifth of the total sales value was used for import of components and materials from overseas. The result indicates that many manufacturing firms, both turbine and component suppliers, earned more in the overseas market than in Japan. These Japanese suppliers and manufacturers supply 1 GW of wind turbines per year on the world market with annual installation capacity of 40 GW (JPY 5.6 trillion in 2010), although the Japanese wind energy market is less than 1% of the world total. The manufacturing presence of Japanese firms is, therefore, strong, compared with the size of the domestic market size. Approximately 80% consider that the domestic market will grow in the future (Table 14), and hope they can expand the market and sales within Japan too.

In addition, some of the international firms in Japan began strengthening their offshore-related technologies and functions, in

[10] The survey was answered by 183 firms, 42.7% response rate, conducted from October to December 2011.

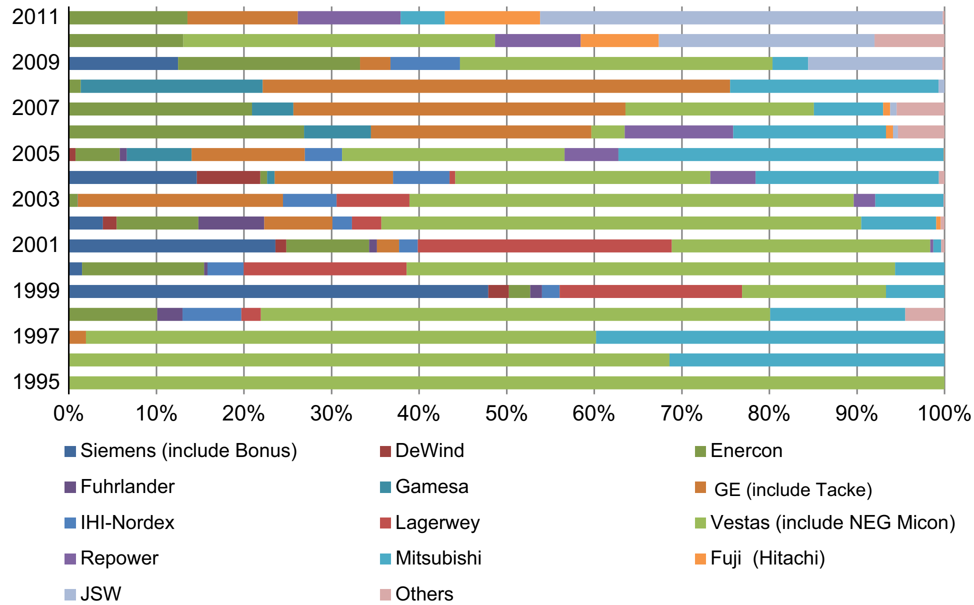


Fig. 13. Domestic market share change between 1995 and 2011 (by capacity) (NEDO subsidized projects using wind turbine above 50 kW capacity, total capacity of 2578 MW) [35].

Table 13
Wind-related component suppliers and turbine manufactures [45].

Item	Manufacturer
Small wind turbine	Komaihaltec; Symphonia Technology; ZEPHYR; Daiwa Energy; Kikukawa; F-tec; Nikko; NKC; Nasudenki; MECARGO; GH Craft; Loopwing
Large wind turbine	Mitsubishi Heavy Industries; Hitachi (Fuji Heavy Industrials); Japan Steel Works (JSW); Komaihaltec
Blade	JSW; GH Craft
Blade materials	Carbon Fiber: Toray; Mitsubishi Rayon; TEIJIN FRP: Japan U-Pica; SHOWA HIGHPOLYMER CO., LTD; DIC; Nippon Reinetsu; Asahi Glass Company (AGC); Nippon Electric Glass; Toray
Gear	Ishibashi Manuffacturing; Seisa; Komatsu; Onex; K-netsuren
Converter	Fuji Electric; Risho
Bearing	Jtekt; NTN; NSK
Electric equipment	Hitachi; Mitsubishi Electric; Toshiba; TMEC; Fuji Electric; Yasukawa Electric; Meidensha; Fujikura
Generator	Hitachi; Meidensha; Yasukawa Electric; TMEIC
Hydraulic	Kawasaki heavy Industries; Moog Japan
Machine equipment	Nabtesco; Sumitomo Heavy Industries; Komatsu; Akebono Brake; Nippon Roballo; Toyooki
Steel casting	JSW; Nippon Chuzo

particular those engaged in the Fukushima Offshore Demonstration Project mentioned above. In March 2012, Marubeni Corporation, together with the Innovation Network Corporation of Japan,[11] acquired Seajacks International Ltd in the United Kingdom, which specializes in offshore wind project installation. In December 2010, MHI acquired Artemis Intelligent Power, Ltd. of Scotland to obtain necessary hydraulic technology to develop 7 MW offshore wind turbines for the Fukushima Demonstration Project as well as the offshore market around the world.

However, in order to make stable the business domestically, each supplier and manufacturer needs a larger domestic market. For example, MHI, a relatively large player, has large domestic wind manufacturing expenses due to only two-digit wind turbine annual manufacturing in Japan, compared with large global players such as Vestas and Siemens, which have four-digit annual production. As a result, MHI has a very weak business basis with large expenses, making it disadvantageous for manufacturing to create a strong industry in a small domestic market.

[11] The Innovation Network Corporation of Japan (INCJ) was established in July 2009 to promote innovation and enhance the value of businesses in Japan with JPY 280 billion as a public-private partnership corporation.

5. Discussion and conclusion

Fig. 14 illustrates the risks and bottlenecks that prevent large-scale deployment of onshore wind energy in Japan by showing a typical wind power generation project flow/value chain on horizontal axis, locations of risks and bottlenecks in terms of resource characteristics, policy and regulations, data/technologies/infrastructures, business practices, cost, market, and stakeholder relationship on vertical axis, and relationships between them.

Multiple bottlenecks exist in every value chain activity, creating uncertainty and high risks, increasing project lead-time, and driving up risk premiums and costs in all phases of projects. Although it is impossible to change natural wind resource characteristics, most bottlenecks are man-made. A layer of regulation creates one of the largest bottlenecks by complicating the project process and increasing uncertainties. Although the deregulation of various laws and regulatory procedures is in progress, it still takes time to sort out the issues related to the newly introduced EIA

Table 14
Result of Survey of Wind-related Manufacturing in Japan [45].

Item	Number of firms which answered	Employment		Number of domestic factories	Domestic manufacturing		Overseas manufacturing (JPY million)	Conversion factor used
		Total of firms	Wind-related employment		Total sales (JPY million)	Sales in overseas markets (JPY million)		
Wind Turbine (WT)								
Micro (< 1 kW)	11	4713	114	8	337	3	0	–
Small (1 kw ≤ < 50 kW)	8	7140	106	10	783	15	79	JPY 9 million/MW
Medium (50 kW ≤ < 1000 kW)	4	43,373	52	4	0	0	0	–
Large (1000 kW ≤)	5*	11,522	650	7	79,900	59,694	0	JPY 1.7 million/MW
Sub Total	**23**	**132,174**	**838**	**26**	**81,020**	**59,711**	**79**	–
Components								
Blade/Nacelle Cover	5	42,040	503	5	503	0	15,171	Nacelle Cover: 1.6 tone /MW
Blade Materials	6	1885	126	10	1340	1337	3124	9.6 tone/MW 22.2% of Large WT JPY 1.6 million/MW
Rotor Hub/Shaft/Gear	4	294	125	7	5413	5305	0	12.9% of Large WT
Control Panel/Converter/ Transformer	9	50,559	377	11	26,652	4648	20,000	Converter: 5% of Large WT, Transformer: 3.59% of large WT
Bearing	3	82,281	800	7	15,900	15,286	0	20 pieces/MW JPY 0.15 million/piece
Generator	5	44,925	220	6	19,042	8545	10,000	5.1% of Large WT
Yaw/Brake/Hydraulic	6	37,923	80	5	1609	1338	0	1.25% of large WT
Tower/Nacelle Plate	5	7195	124	4	850	0	3025	–
Grid Stabilization (Storage/Power Converter)	4	35,935	49	3	930	683	0	–
Others	15	46,544	220	15	736	353	2910	–
Sub Total	**52**	**310,316**	**2244**	**68**	**72,975**	**37,494**	**54,249**	–
Total	**72**	**375,187**	**2460**	**89**	**153,996**	**97,205**	**54,328**	–

* Among five, the wind turbine division of Fuji Heavy Industries was acquired by Hitachi in July 2012. Komaihaltec does not have a strong record in large-scale wind turbine manufacturing.

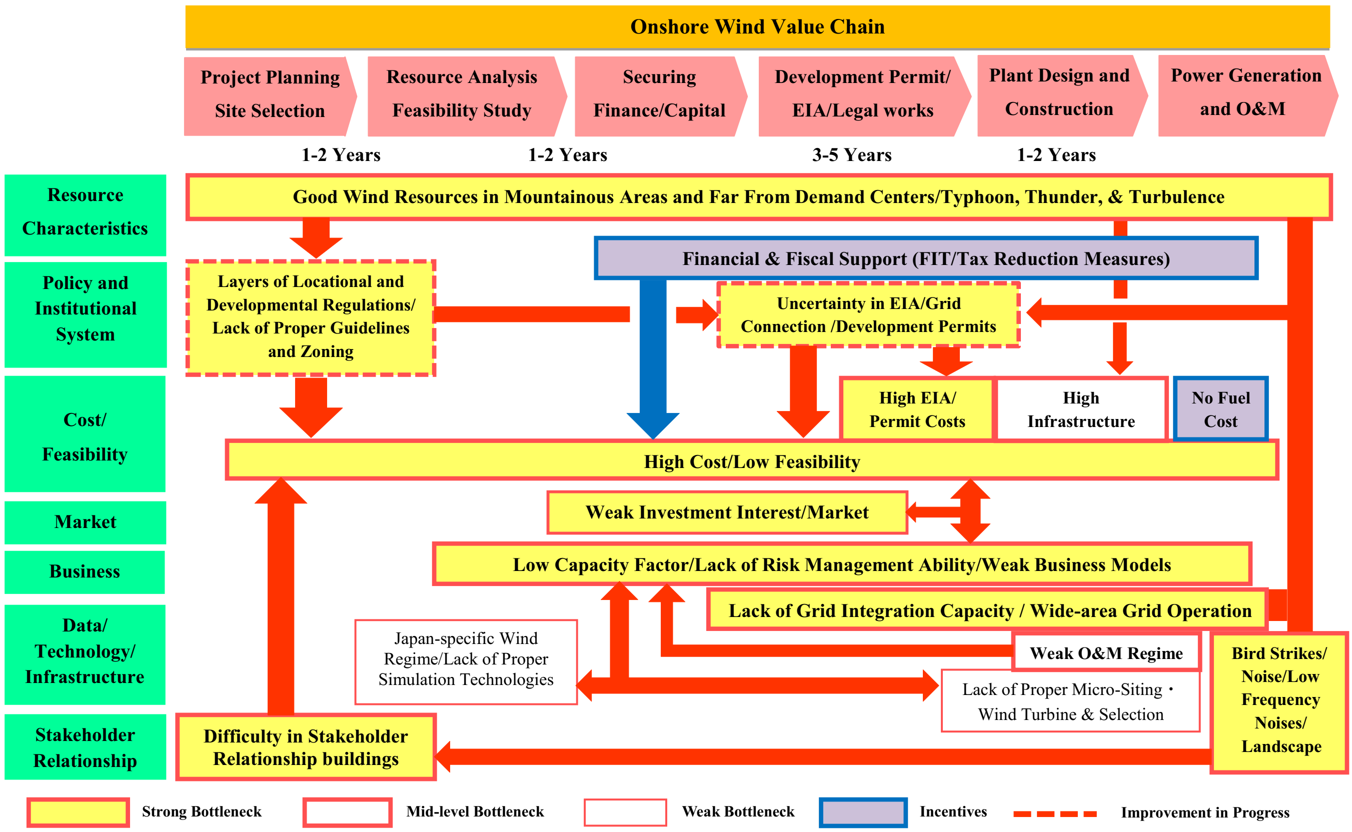


Fig. 14. Current bottlenecks and risks of onshore wind energy development in Japan.

process and establish a simplified but firm development process, which satisfies all of the regulatory authorities, local communities, and the wind industry.

The lack of grid capacity, clear rules, and operational procedures which integrate wind power projects into the existing grid is the cause of another large bottleneck. They contribute to high development and grid connection uncertainties and add up to high development costs. Although the integration of a large amount of wind and solar energy into the grid is currently a strong interest of countries which want to increase intermittent renewables in their energy mix, the dimension of the Japanese problem is quite different from those in countries with already strong wind energy deployment records such as Germany and Spain. The current vertically integrated and regionally segregated and small electricity market structures as well as the lack of transparent grid connection rules require significant institutional changes, which depend on the existence and exercise of strong and continuous political will, as such changes need long-term commitment and effort for transformation. Investment in physical grid capacity expansion is also essential to enable wider area grid operation to absorb the intermittency of wind more easily. This must come with the structural reform of the electricity sector and market. Current timing may be a small window of opportunity as the political and economic powers of the EPCO have been weakened with the halting of nuclear power plants and strong public opposition toward their past business practices, particularly in relation to nuclear power.

Social acceptance issue is another very critical matter. With some past project failures and poor community engagement records, the wind industry must engage in better and sincere communication practices with local communities. The new EIA procedure should be perceived as an important opportunity, as seriously engaging in this procedure is an excellent way of communicating with local communities to ensure environmental protection and community satisfaction.

These issues have meant that the domestic market has remained quite small, depriving opportunities to create economies of scale in cost reduction, wind turbine manufacturing, and O&M practices. In addition, the NEDO capital subsidies which lasted for more than 15 years until the FIT introduction in 2012, contributed to the industry's weak business models with lack of risk management ability and cost reduction efforts.

As shown in Fig. 14, due to these large and small bottlenecks, the market interests and responses to wind power projects have been very weak. Moreover, although wind energy development costs remain high and feasibility is low with numerous bottlenecks and risks, the FIT is the only measures to alleviate the risks and bottlenecks so far. This is apparently not an efficient policy, as the FIT alone has to compensate high risk premiums derived from the lack of other proper regulatory measures and grid integration capacity. Japan has to offer a comprehensive package of policy measures to reduce risks and uncertainties and to promote cost reduction efforts from the business side through efficiency and innovation.

To advance wind energy deployment further in Japan, the following recommendations are made.

5.1. Market policy: streamlining of development permit procedure

A layer of regulations removed or alleviated in the past two years has to be replaced with cohesive and streamlined development permit procedure. In the short term, clear operational rules of administrative procedure of development regulations need to be agreed and applied to regulatory bodies and the wind energy industry. In the longer-term, the establishment of a database which can be used for wind development plan and/or local zoning should be created. The database should have not only wind resource data and infrastructure but also the environmental data and cultural and social data of each local area. In addition, the further amendment of the EIA Act should be within this scope: SEA of local wind zoning and/or local wind development policy and plan which fully aligns international SEA can reduce the uncertainty and time of wind developers perceived in current project-based SEA. Assigning overseeing responsibility of administrative procedure of development permit application to one agency, for example, to the METI, also helps reduce the current complexity of navigating the process for developers. Technology and project certificates which consider Japan-specific wind resource characteristics, financial feasibility, and social acceptance can be included into the streamlined development permit procedure, and help deter low-quality technologies and developers from the market.

5.2. Market policy: more detailed categorization of Feed-in Tariffs

The current FIT has only one category for all onshore wind energy, which does not fit the reality of cost difference. LCOE of wind energy vary across project ownership, size, and location in Japan. In particular, capital and O&M costs in mountainous and remote locations are higher than in already developed flat sites, but capacity factors are higher due to better wind resources. To promote the utilization of more of these better wind resources, FIT categories which differentiate various location-specific characteristics and project scale should be created, for example, with FIT premium or higher FITs for mountainous and remote location projects considering higher infrastructure and O&M costs. Also, community-based and municipality projects tend to be smaller scale with difficulty of making economies of scale in wind turbine purchase, installation and O&M. These projects should be treated differently from other large-scale private developer projects in FIT. To promote offshore, a separate FIT category should be created for offshore as well. All of these require good cost database and independent analysis. Currently, the METI does not disclose the cost data gathered by projects developer under the FIT regime and the previous NEDO-subsidies projects. Such data should be public to promote independent research, transparent discussion, and cost reduction efforts by the industry.

5.3. Market policy: establish a better investment environment

The investment environment needs to be fortified by policy incentives other than FIT. Project finance schemes utilizing a wide range of private investors have to replace the current corporate finance method of wind energy in Japan in order to widen the investment base as well as increase the investment efficiency and returns. This also helps fortify industry competitiveness. Policy to incentivize wind energy investment such as tax incentives to private project investment and private fund initiatives as well as government-led soft loan will be quite effective.

5.4. Market policy: electricity sector reform and fortification of grid infrastructure

Fortification of the grid capacity and wider-area operation of the grid is the key to increasing wind grid connection to the grid and to solving the regional unbalance of wind energy supply and demand. This has to be done in conjunction with the electricity sector reform and long-term wind energy target setting. The complete market liberalization will also help promote wind energy by actualizing hidden market demand for wind energy. Also, the reform needs to allocate clear responsibility of grid management and investment.

5.5. Technology policy

Technology-side policy for onshore wind should focus on more social benefit aspects, because onshore energy technology is relatively mature. This includes environmental and social database building and technologies which enhance grid integration of wind energy. Technology standards and certifications also become important to encourage the use of advanced technologies to reduce and mitigate the effects of accidents/failures caused by natural phenomenon.

5.6. Industrial policy

Building industrial clusters of wind energy-related manufacturing and ancillary services including finance and project execution and fortifying infrastructure become critical to reducing cost and increasing social benefits through creating employment opportunities. This needs to be part of a comprehensive wind energy policy and development plan, along with domestic market expansion, local wind zoning, export opportunity enhancement, human capacity building, and local economic development. In this respect, onshore and offshore should be considered together, as regions with high wind for onshore tend to have good wind resources for offshore.

5.7. Establishment of wind energy market target and roadmaps with strong wind energy development principles

Last but not least, the basis of all policies mentioned above is the establishment of a strong and clear wind energy development principle including clarifying what kind of role wind energy should take in the future energy mix in Japan. Then, the target of wind energy and the roadmap to reach the target should be created based on the principle. Without it, policies lose cohesiveness and cannot send clear market and social signals. Currently, in Japan, this part is quite ambiguous, contributing to the difficulty of social acceptance and agreement. The wind industry players have to work harder with national and local regulatory agencies, local communities, and other stakeholders to form the wind energy development principle.

Disclaimer

The views expressed in this paper are a personal opinion of the author, and not the official position of the corporation to which she belongs.

References

[1] Energy Data and Modeling Center (EDMC). Handbook of energy and economic statistics in Japan. Tokyo: Institute of Energy Economics of Japan; 2011; 2011.
[2] Ministry of Economy, Trade and Industry (METI). Strategic technology roadmap, 〈http://www.,eti.gpo.jp/policy.economy.gijutsdu_kakushin/kenkyu_kaihatsu/str-top.html〉 2007, 2008 and 2009 [accessed 20.12.12].
[3] International Energy Agency (IEA), RD&D statistics, 〈http://www.iea.org/stats/rd.asp〉; 2013 [accessed 24.06.13].
[4] New Energy and Industrial Technology Development Organization (NEDO), project activities for wind and ocean energy technologies, 〈http://www.nedo.go.jp/activities/introduction8_01_02.html〉, 〈http://www.nedo.go.jp/activities/FF_00223.html〉 〈http://www.nedo.go.jp/activities/FF_00383.html〉 〈http://www.nedo.go.jp/activities/FF_00372.html〉, 2012 [accessed 16.04.12].
[5] NEDO, New energy developer supporting projects, 〈http://www.nedo.go.jp/activities/DA_00254.html〉, new energy deployment supporting projects, 〈http://www.nedo.go.jp/activities/ZZ_00321.html〉; 2012 [accessed 16.04.12; and NEPC, new energy developer supporting projects, 〈http://www.nepc.or.jp/topics/2011/0527_2.html〉, new energy deployment supporting projects, 〈http://www.nepc.or.jp/topics/2011/0527_1.html〉; 2011 [accessed 16.04.12].
[6] E-Gov., 〈http://law.e-gov.go.jp/htmldata/H14/H14HO062.html〉; 2012 [accessed 20.04.12]; and; METI/Agency for Natural Resources and Energy (ANRE), outline of RPS system 〈http://www.rps.go.jp/RPS/new-contents/top/toplink-english.

html〉, accredited facilities, 〈http://www.rps.go.jp/RPS/new-contents/top/toplink-5.html〉; 2012 [both accessed 15.03.13].
[7] METI/ANRE, RPS system and accredited facilities in FY 2011, 〈http://www.rps.go.jp/RPS/new-contents/pdf/rps_H23.pdf〉; 2012 [accessed 15.03.13].
[8] EDMC. Handbook of energy and economic statistics in Japan 2013. Tokyo: Institute of Energy Economics of Japan; 2013.
[9] Ministry of the Environment (MOE), Wind Energy Development Manual, 1997; MOE, Technical Guidelines for Wind Energy Installation in the Natural Park Areas, 〈http://www.env.go.jp/press/press.php?serial=13643〉; 2012 [accessed 18.04.12]; NEDO, NEDO wind energy guidelines, 〈http://www.nedo.go.jp/library/fuuryoku/guidebook.html〉; 2008 [accessed 20.03.12]; NEDO, NEDO wind energy guidelines for Japan: Typhoons and Turbulences, 〈http://www.nedo.go.jp/content/100107254.pdf〉; 2008 [accessed 20.03.12]; and NEDO, NEDO wind energy guidelines for Japan: lightening, 〈http://www.nedo.go.jp/content/100107252.pdf, 2008〉 [accessed 20.03.12].
[10] METI/ANRE. General electric utility voluntary agreements on new energy deployment, 〈http://www.meti.go.jp/report/downloadfiles/g10919gj.pdf〉; 2001 [accessed 30.06.13]; Tokyo Electric Power Company (TEPCO). General electric power utilities' efforts for new energy deployment. Presentation at the Institute of Energy Economics of Japan (IEEJ); June 30, 2003.
[11] Japan Wind Power Association (JWPA), current issues and agenda of wind energy in Japan. Presentation at the Renewable Energy 2012, exhibition forum; December 5, 2012. Makuhari, Chiba, Japan; JWPA, wind energy statistics, 〈http://jwpa.jp/pdf/30-12dounyuujisseki2012graph.pdf〉; 2013 [accessed 20.01.13]; and, NEDO, statistics of NEDO supported wind energy projects, 〈http://www.nedo.go.jp/library/fuuryoku/index.html〉, 〈http://www.nedo.go.jp/library/fuuryoku/pdf/01_dounyuu_ichiran.pdf〉; 2012 [accessed December 15.12.12].
[12] JWPA, current issues and agenda of wind energy in Japan. Presentation at the renewable energy 2012, exhibition forum, December 5, 2012. Makuhari, Chiba, Japan; JWPA, wind energy statistics, 〈http://jwpa.jp/pdf/30-12dounyuujisseki2012graph.pdf〉; 2013 [accessed 20.01.13]; and; New Energy Foundation of Japan (NEF). 2012. Textbook for FY 2012 wind energy human resource development workshop, Tokyo.
[13] METI/ANRE, electricity survey statistics for FY 2010, 〈http://www.enecho.meti.go.jp/info/statistics/denryoku/result-2.htm〉; 2011 [accessed 13.03.13].
[14] Global Wind Energy Council (GWEC). Global wind statistics 2011; 2012.
[15] Yamazaki T. Electricity sector reform in Japan, presentation at the US–Japan renewable business RT, 〈http://www.enecho.meti.go.jp/info/event/121203event/3-1_METI_Yamazaki.pdf〉; December 3, 2012 [accessed 27.02.13]; METI/ANRE, interim report by the committee for electricity grid fortification master planning among regions. 〈http://www.meti.go.jp/committee/sougouenergy/sougou/chiikikanrenkeisen/pdf/report01_02_00.pdf〉; 2012 [accessed 12.08.12]; METI/ANRE, wind energy potentials and accelerating its deployment, 〈http://www.meti.go.jp/committee/sougouenergy/sougou/chiikikanrenkeisen/001_11_00.pdf〉 Committee for electricity grid fortification master planning among regions, materials #2 for the First meeting; February 16, 2012 [accessed 15.04.12].
[16] METI/ANRE, "regarding changes of fossil fuel procurement environment," presentation at the Investigation Committee for General Resources and Energy, 〈http://www.enecho.meti.go.jp/info/committee/sougoubukai/2nd/2nd-2.pdf〉; 2013 [accessed 25.04.13].
[17] METI/ANRE, electricity survey statistics for FY 2011, 〈http://www.enecho.meti.go.jp/info/statistics/denryoku/result-2.htm〉; 2012 [accessed on 13.03.13].
[18] METI/ANRE, The future of renewable energy in Japan and wind energy; February 26, 2013, 〈http://www.japan.ahk.de/fileadmin/ahk_japan/Dokumente/02_Murakami_METI_.pdf〉 [accessed 05.05.13].
[19] METI/ANRE, FIT certification for the existing renewable power plants, 〈http://www.rps.go.jp/RPS/new-contents/top/toplink-3.html〉, and 〈http://www.rps.go.jp/RPS/new-contents/pdf/120702exist_plant_fit_nintei_proc.pdf〉; 2012 [accessed 10.04.13].
[20] METI/ANRE, FY 2012 Feed-in Tariff levels and terms, 〈http://www.enecho.meti.go.jp/saiene/kaitori/kakaku.html#h25〉, 2-12. [accessed 06.04.12]; METI/ANRE, FY 2013 Feed-in Tariff levels and terms, 〈http://www.enecho.meti.go.jp/saiene/kaitori/kakaku.html#h25〉; 2013 [accessed 03.04.13]; 2013.
[21] METI/ANRE, report of the survey of wind energy potentials (FY 2010 basic survey project for accelerating new energy deployment), 〈www.meti.go.jp/meti_lib/report/2011fy/E001771.pdf〉; 2011 [accessed 20.06.12]; Ministry of the Environment (MOE), FY2010 report of the survey of renewable energy introduction potentials, 〈http://www.env.go.jp/earth/report/h23-03/www.env.go.jp/earth/report/h23-03/chpt4.pdf〉; 2011 [accessed 20.05.11]; and National Policy Unit (NPU), 2011. Renewable energy potentials by various ministries, 〈www.npu.go.jp/policy/policy09/pdf/…/hokoku_sankou3.pdf〉; 2011 [accessed 15.01.12].
[22] METI/ANRE, renewable energy installation records by the end of May 2013, 〈http://www.enecho.meti.go.jp/saiene/kaitori/dl/setsubi/201305setsubi.pdf〉; 2013 [accessed 25.08.13].
[23] METI/ANRE, interim report by the committee for electricity grid fortification master planning among regions; (MOE), FY2010 report of the survey of renewable energy introduction potentials, 〈http://www.env.go.jp/earth/report/h23-03/ www.env.go.jp/earth/report/h23-03/chpt4.pdf〉; 2011 [accessed 20.05.11]; Yamazaki, T. Electricity sector reform in Japan, presentation at the US–Japan renewable business RT, 2012. December 3, 2012, 〈http://www.enecho.meti.go.jp/info/event/121203event/3-1_METI_Yamazaki.pdf〉; 2012 [accessed 27.02.13].
[24] Federation of electric power companies of Japan, Grid connection capacity for PV and wind power, 〈http://www.fepc.or.jp/environment/new_energy/renkei/〉; 2013 [accessed 21.07.13].
[25] JWPA, smoothing effect of wide-area grid operation and strategies for grid connection capacity enlargement, a collaboration project with Ogimoto Laboratory of the University of Tokyo. Presentation at the FY 2012 JWPA activities reporting event. Tokyo; May 30, 2013.
[26] METI/ANRE, measures for grid access of large-scale PV projects in Hokkaido; April 17, 2013, 〈http://www.meti.go.jp/press/2013/04/20130417003/20130417003.html〉, and 〈http://www.meti.go.jp/press/2013/04/20130417003/20130417003.pdf〉; 2013 [accessed 17.04.13].
[27] METI/ANRE, FY 2013 budget for energy and resources, 〈http://www.meti.go.jp/main/yosan2013/130129_energy2.pdf〉; 2013. [accessed 05.05.13]. METI/ANRE, Press release: SPCs were selected for demonstration project of grid infrastructure buikding for wind power generation in Hokkaido, 〈http://www.meti.go.jp/press/2013/10/20131021002/20131021002.pdf〉 accessed 21.10.13].
[28] JWPA, current issues and agenda of wind energy in Japan and proposals from the JWPA for deregulations, presentation material 1 for the third meeting of the Green Working Group, the Committee on Deregulation and Sector Reform, 〈http://www.cao.go.jp/sasshin/kisei-seido/meeting/2012/green/121108/item1-1-1.pdf〉; 2012 [accessed 25.11.12]; and JWPA, JWPA presentation on social acceptance of wind energy projects, IEA Wind Task 28 meeting in Tokyo; May 31, 2013.
[29] METI/ANRE, the future of renewable energy in Japan and wind energy, 〈http://www.japan.ahk.de/fileadmin/ahk_japan/Dokumente/02_Murakami_METI_.pdf〉; February 26, 2013 [accessed on 05.05.13]; and JWPA, JWPA presentation on social acceptance of wind energy projects, IEA Wind Task 28 meeting in Tokyo; May 31, 2013.
[30] JWPA, current issues and agenda of wind energy in Japan. Presentation at the Renewable Energy 2012 exhibition forum. Makuhari, Chiba, Japan; December 5, 2012.
[31] JWPA, wind energy cost comparison between Europe and Japan. Presentation materials for the Autonomous Study Group for the 10th Basic Energy Issue Committee; May 2012.
[32] NEDO, FY 2010 report of survey of accident and failures in wind power generation. Report to the NEDO Committee on survey of accident and failures in wind power generation; 2011.
[33] International Energy Agency Wind Implementing Agreement (IEA Wind), IEA Wind: 2010 Annual report, IEA wind energy systems, 〈http://www.ieawind.org/index_page_postings/IEA%20Wind%202010%20AR_cover.pdf〉; 2011 [accessed 11.11.12]; and International Renewable Energy Agency. Renewable energy technologies: cost analysis series, vol. 1: power sector: wind power; June 2012, 〈http://www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis-WIND_POWER.pdf〉; 2012 [accessed 20.11.12].
[34] Cabinet Office (CAO). Report of power generation cost comparison by the Cost Examination Committee, a report submitted to the Energy and Environmental Council in the National Policy Unit; December 19, 2011.
[35] NEDO, Statistics of NEDO Supported Wind Energy Projects, 〈http://www.nedo.go.jp/library/fuuryoku/index.html〉, 〈http://www.nedo.go.jp/library/fuuryoku/pdf/01_dounyuu_ichiran.pdf〉; 2012 [accessed 15.12.12].
[36] NEF. Textbook for FY 2012 wind energy human resource development workshop, Tokyo; 2012.
[37] NEDO, FY 2010 report of survey of accident and failures in wind power generation. Report to the NEDO Committee on survey of accident and failures in wind power generation, 2011; and NEDO, FY 2011 report of survey of accident and failures in wind power generation. Report to the NEDO Committee on survey of accident and failures in wind power generation; 2012.
[38] Fraunhofer IWES. 2013. Reliability: climatic causes for failures, windmonitor, 〈http://windmonitor.iwes.fraunhofer.de/windwebdad/www_reisi_page_new.show_page?page_nr=278&lang=en〉 [accessed 15.04.13].
[39] METI 2013. Budget request for FY 2014, 〈http://www.meti.go.jp/main/yosangaisan/fy2013/pr/pdf/ene_enecho_05.pdf〉 [accessed 22.09.13].
[40] MOE, Offhsore wind energy demonstration project, 〈http://www.env.go.jp/guide/budget/spv_eff/review_h23/sheets1109/sheets/n23_017.pdf〉 [accessed 22.09.13]; 2013.
[41] Marubeni Corporation/Mitsubishi Corporation, Fukushima Recovery, experimental offshore floating wind farm project, Press Release; March 6, 2012, 〈http://www.marubeni.co.jp/dbps_data/_material_/maruco_jp/120306a.pdf2011〉 and 〈http://www.mitsubishicorp.com/jp/en/pr/archive/2012/html/0000014308.html〉 [accessed 20.06.13].
[42] Nikkei, An agreement reached among the government, the Prefecture and the local Fishery Association on the Fukushima offshore project; March 29, 2013, 〈http://www.nikkei.com/article/DGXNASDG29056_Z20C13A3CR8000/〉 [accessed 29.03.13].
[43] Nikkei, Fortification of port functions of Onahama for the Fukushima offshore demonstration project; March 30, 2013, 〈http://www.nikkei.com/article/DGXNASFB2900P_Z20C13A3L01000/〉 [accessed 30.03.13].
[44] Navigant Research A BTM Wind Report: World Market Update 2012, Copenhagen; 2013; and NEDO, statistics of NEDO supported wind energy projects, 〈http://www.nedo.go.jp/library/fuuryoku/index.html〉, 〈http://www.nedo.go.jp/library/fuuryoku/pdf/01_dounyuu_ichiran.pdf〉; 2012 [accessed 15.12.12].
[45] Japan Society of Industrial Machinery Manufacturers (JSIMM). Survey report on wind power-related equipment industry. Tokyo; 2012.