IEA WIND
2014 Annual Report

Executive Committee of the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems of the International Energy Agency

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Front cover photo: Tugliq Énergie Enercon 3-MW turbine at Raglan Mine, Quebec, Canada with aurora borealis (Credit: Justin Bulota)

iea wind

Message from the Chair

By the end of 2014, more than 370 gigawatts of wind electricity were in operation worldwide, providing 5% of the world's electricity demand, and IEA Wind member countries are world leaders in this wind deployment. For example, Denmark gets 39.1% of its electricity from wind, China has deployed nearly 115 gigawatts of wind energy, the United Kingdom increased offshore capacity 22% in 2014 and Germany reached half of its 2020 offshore target of 6.5 gigawatts. Over the past decade, great strides in wind energy technology development have enabled these impressive deployment numbers. R&D collaboration amongst the 21 countries of IEA wind has played a major role in addressing the most difficult to solve wind technology challenges; and collaboration will continue to be important as future challenges are identified and addressed.

The IEA Wind Annual Report documents the activities and accomplishments of the IEA Wind member countries in 2014. The report also shows the wide breadth of research being conducted world-wide, as reflected in the thirteen IEA Wind cooperative research tasks. In 2015, IEA Wind plans to add two new research tasks, to improve wind forecasting and to take a systems approach to wind turbine design.

The IEA Wind agreement is strong and increasing in membership and activities. In 2014, the government of France became the newest member and Belgium and Israel plan to become members in 2015. IEA Wind welcomes and encourages the addition of new countries as members. With vast expertise in wind research and deployment, IEA Wind countries can help accelerate wind deployment in countries that are new to wind energy or can benefit from the experience of countries that are successfully operating wind plants as part of their electrical systems.

IEA Wind cooperative efforts advance wind energy's role in the world's energy supply. Continued growth in wind energy deployment will depend on solving the critical technology and deployment challenges of the future. IEA Wind countries will play an important role in developing the solutions to these challenges.

Jim Ahlgrimm
Chair of the Executive Committee, 2013–2015

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1 Executive Summary

1.0 Introduction

Wind generation met close to 5% of the world's electricity demand in 2014 [1]. Worldwide, 371,022 gigawatts (GW) of wind plants were operating at the end of 2014 [2]. Nearly 85% of the world's wind generating capacity resides in the 21 countries participating in the International Energy Agency (IEA) Wind Technology Initiative (IEA Wind), an international co-operation that shares information and research activities to advance wind energy deployment. These IEA Wind member countries added more than 40.68 GW of capacity in 2014, which is 79% of the record-setting worldwide market for the year (51.48 GW). In the IEA Wind countries, the 314.7 GW of wind generating capacity operating in 2014 produced enough electricity to meet 4.1% of the total electrical demand in those countries (Tables 1–4).

This *IEA Wind 2014 Annual Report* contains chapters from each represented country and from the European Wind Energy Association (EWEA) and the European Commission (EC) (the administrative body of the European Union [EU]). The countries report how much wind energy they have deployed, how they benefit from wind energy, and how their policies and research programs will increase wind power's contribution to the world energy supply. This annual report also presents the latest research results and plans of the 13 co-operative research activities (tasks) that address specific issues related to wind energy development.

This Executive Summary presents highlights and trends from the chapters about each member country and research task, as well as compiled statistics for all countries. Data reported in previous IEA Wind documents (IEA Wind 1995–2013), are included as background for discussions of 2014 events. The website (www.ieawind.org) contains archived searchable documents dating back to the very beginning of the IEA Agreement in 1977.

2.0 National Objectives and Progress

IEA's updated *Technology Roadmap for Wind Energy* [3] now targets a goal of 15–18% of global electricity coming from wind power by 2050. The previous target of 12% was seen as too conservative based on industry accomplishments to date and the need to reduce greenhouse gas (GHG) emissions. Significant investments will be required to reach the new goal. In 2014, wind energy supplied 5% of global electricity.

IEA Wind member governments and industries establish national targets for

Twelve of the IEA Wind member countries installed more wind capacity in 2014 than in 2013; six of these countries installed record amounts of wind in 2014.

Table 1. Key Statistics of IEA Wind Member Countries 2014	
Total installed capacity (land-based and offshore)	314.72 GW
Total offshore wind capacity[a]	9.25 GW
Total new wind capacity installed	40.68 GW
Total annual output from wind	598.8 TWh
Wind generation as a percent of IEA Wind members' national electric demand	4.1%

[a] In the International Electrotechnical Commission (IEC) Standard Document, IEC 61400-3 (Offshore Wind Turbines), *offshore wind turbine* is defined as a "wind turbine with a support structure which is subject to hydrodynamic loading." For this report, wind turbines standing in lakes, rivers, and shallow and deep waters are considered offshore.

Table 2. National Statistics of the IEA Wind Member Countries 2014

Country	Total Installed Wind Capacity	Annual Net Increase in Capacity[a]	Wind-Generated Electricity	National Electricity Demand	National Electricity Demand Met by Wind[b]
	(megawatts [MW])	(MW)	(terawatt-hours [TWh]/yr)	(TWh/yr)	(%)
Austria	2,095	411	4.5	62.5	7.2
Canada	9,691	1,871	***22.1***	***580.0***	***3.8***
China	114,599	23,186	153.4	5,523	2.8
Denmark	4,896	77	13.1	33.9	39.1
Finland	627	178	1.1	83.0	1.3
France	9,278	1,071	17.0	465.0	3.6
Germany	39,153	4,914	55.9	578.5	9.6
Greece[c]	1,980	114	***3.3***	***49.3***	***6.1***
Ireland	2,211	270	5.1	28.2	18.3
Italy	8,663	105	15.0	309.0	4.9
Japan[d]	2,788	119	***5.1***	***965.2***	***0.5***
Korea	643	89	***1.2***	556.0	0.2
México[c]	2,381	522	***5.7***	***275.0***	***2.0***
Netherlands	2,753	45	5.8	***120.9***	***4.8***
Norway	856	45	2.2	127.0	1.7
Portugal	4,953	222	12.1	50.3	24.0
Spain	***22,986***	***28***	***51.1***	***243.5***	***20.4***
Sweden	5,425	956	11.6	145.0	8.0
Switzerland	60	0	***0.1***	***63.8***	***0.2***
United Kingdom	12,808	1,599	31.6	335.0	9.0
United States	65,877	4,854	181.8	4,093.0	4.4
Totals	**314,723**	**40,676**	**598.8**	**14,687.1**	**4.1**

Bold italic indicates estimates
[a] Net increase in capacity = capacity installed minus capacity decommissioned
[b] Percent of national electricity demand from wind = (wind generated electricity / national electricity demand) × 100
[c] Global Wind Energy Council [2], and ENTSO-E [7]
[d] April 2013 to March 2014 (Only "fiscal year data" is available in Japan)

Table 3. Worldwide Installed Wind Capacity for 2014

IEA Wind Members[a]

Country	Total installed wind capacity (MW)
China	114,599
United States	65,877
Germany	39,153
Spain	***22,986***
United Kingdom	12,808
Canada	9,691
France	9,278
Italy	8,663
Sweden	5,425
Portugal	4,953
Denmark	4,896
Japan	2,788
Netherlands	2,753
Ireland	2,211
Austria	2,095
México[b]	2,381
Greece[b]	1,980
Norway	856
Korea	643
Finland	627
Switzerland	60
Totals IEA Wind Countries	**314,723**
European Union	128,751

Bold italic indicates estimates
[a] Numbers reported by IEA Wind member countries
[b] Numbers from GWEC [2]

Rest of World[b]

Country	Total installed wind capacity (MW)
India	22,465
Brazil	5,939
Rest of Europe	5,856
Poland	3,834
Australia	3,806
Turkey	3,763
Romania	2,954
Chile	836
Morocco	787
Other countries[c]	748
Taiwan	633
New Zealand	623
Egypt	610
South Africa	570
Uruguay	464
Chile	335
Argentina	271
Pakistan	256
Tunisia	255
Thailand	223
Philippines	216
Costa Rica	198
Nicaragua	186
Ethiopia	171
Honduras	152
Peru	148
Total Rest of World	**56,299**
Grand Total	**371,022**

[b] Numbers reported by GWEC [2]
[c] Countries not in IEA Wind and with less than 100 MW capacity

renewable energy and wind energy (Table 4), design incentive programs (Table 11), and conduct focused research and development (R&D) programs to help reach these targets (Table 18). Their reasons for supporting wind energy include increasing employment and economic development, building a domestic industry, contributing to domestic energy supply, reducing GHG emissions and other pollutants, and replacing nuclear energy.

2.1 National targets

Most IEA Wind member countries have targets for increasing the amount of renewable energy or low-carbon energy in the electrical generation mix. These targets are embedded in legislation, appear in roadmap documents, or have been announced by elected officials. Some countries have specific goals or targets for renewable energy generally and wind energy in particular. Table 4 shows the 2014 values compared to the wind targets for each country: generation capacity (MW), contributions to electricity supply (TWh), or contribution to electricity demand (%).

Other kinds of targets are affecting planning in some countries. Canada set the goal to reduce GHG emissions by 30% below 2005 levels by 2030. The *Chinese Plan of Action for Prevention and Control of Atmospheric Pollution* proposed a 13% increase in non-fossil energy consumption by 2017.

Although the U.S. government has no official targets for wind energy, a new *Wind Vision* analysis has quantified the benefits and economic impacts of current and potential future wind energy deployment levels. Scheduled to be published in early 2015, the study examines a scenario in which wind would provide 35% of the nation's end-use electricity by 2050. In addition to the detailed modeling of the U.S. electric generation system with and without added wind generation, the study has also developed a roadmap with a portfolio of actions for achieving the scenario.

2.2 Progress

2.2.1 Capacity increases

A record 40.68 GW of net wind capacity was added in 2014 by the IEA Wind member countries; 39% more than the 29.20 GW added in 2013 (Table 5). This added capacity was 79% of the global wind market for 2014, which was also a record at 51.48 GW [2].

- Six countries installed record amounts of wind energy in 2014: Austria, Canada, China, Germany, Ireland, and Sweden.
- Six countries increased capacity by more than 20% in 2014: Finland (40%), México (34%), China (25%), Canada (24%), Austria (24%), and Sweden (21%) (Table 6).
- Twelve countries installed more capacity in 2014 than in 2013: Austria, Canada, China, Germany, Ireland, Japan, Korea, México, Norway, Portugal, Sweden, and the United States (IEA Wind, 2013and 2014).
- Six countries installed more than 1 GW: China (23.19 GW), Germany

Table 4. Targets Reported for IEA Wind Countries: Renewable Energy Sources (RES) and Wind			
Country	Official Target RES	Official Target Wind	2014 Total Wind Capacity (MW), Annual Contribution to demand (%), or Annual Production (TWh)
Austria	Plus 4,400 MW from 2010–2020	Plus 2,000 MW from 2010–2020	2,095 MW
Canada	---	---	9,691 MW
China	15% of the primary energy consumption from non-fossil energy by 2020	200,000 MW (30,000 MW offshore) by 2020	114,599 MW
Denmark	100% by 2050; more than 35% renewable by 2020	50% of electricity by 2020	39.1%
European Union	20% of final energy by 2020	207,663 MW by 2020	128,751 MW 8.0% of demand
Finland	38% of final energy consumption by 2020	6 TWh/yr (2,500 MW) in 2020	627 MW 1.1 TWh
France	23% of final energy consumption in 2020; 32% in 2030	19,000 MW land-based wind in 2020; 6,000 MW offshore wind in 2020	9,278 MW
Germany	40–45% of gross electricity consumption by 2025 and 55 to 60% by 2035	Land-based: 2,500 MW net/yr; Offshore: 6,500 MW (in total by 2020) resp. 15,000 MW (by 2030)	39,153 MW 9.6%
Greece	40% of electricity by 2020	---	1,980 MW
Ireland	16% RES (40% renewable energy sources for electricity [RES-E])	None (Indicative 35% RES-E = 3,500 MW)	2,211 MW
Italy	17% by 2020	12,000 MW land-based, 680 MW offshore by 2020	8,663 MW
Japan	22 to 24% in 2030	Not specified	2,788 MW
Korea, Republic of	3.0% (2014)	0.9% by 2020	0.2%
México	35% by 2024	12,000 MW by 2024	2,381 MW
Netherlands	14% by 2020; 16% by 2023; 20% reduction of CO_2 in 2020 as compared to 1990 level	6,000 MW land-based installed by 2020 3,450 MW offshore installed by 2020 4,450 MW offshore installed by 2023	2,753 MW
Norway	---	---	856 MW
Portugal	31% of gross energy consumption by 2020	5,273 MW land-based, 27 MW offshore by 2020	4,953 MW
Spain	20% of overall energy consumption by 2020	25,000 MW land-based; 750 MW offshore by 2020	22,986 MW
Sweden	50% of overall energy consumption by 2020.	Planning framework of 30 TWh by 2020: 20 TWh land-based, 10 TWh offshore	11.6 TWh
Switzerland	Increase generation by 22 TWh by 2050	4.0 TWh/yr by 2050 (0.6 TWh by 2020, 1.5 TWh by 2035)	0.1 TWh
United Kingdom	15% of energy supply by 2020	---	12,808 MW
United States	No official targets; goal to double wind and solar generation by 2025	No official targets	65,877 MW
--- = No official target available			

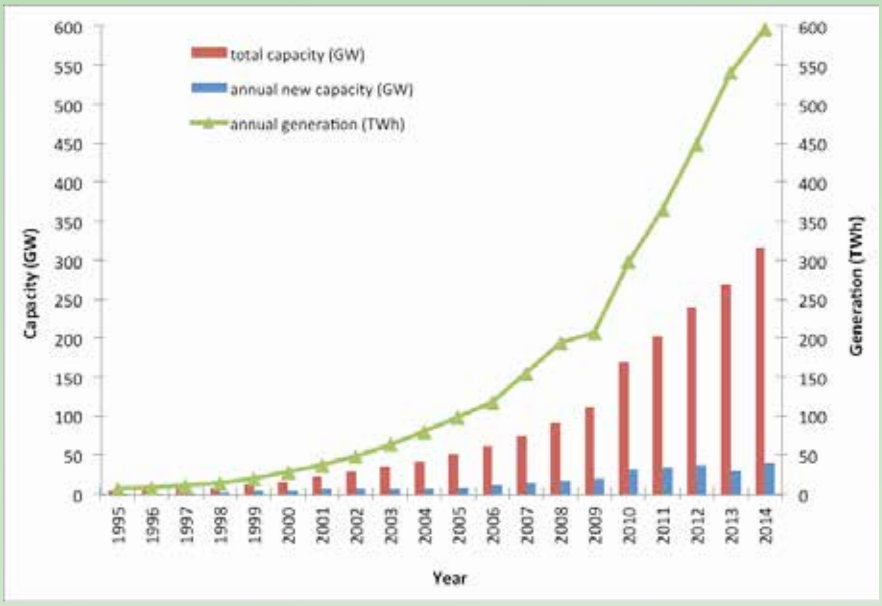

Figure 1. Annual new capacity (net), cumulative capacity, and electricity generation for IEA Wind member countries, 1995–2014 (Note: China is first represented in 2010; France in 2014)

(4.91 GW), the United States (4.85 GW), Canada (1.80 GW), the United Kingdom (1.60 GW), and France (1,071) (Table 2).

• Austria, México, and Sweden added more than 400 MW each.

• In all, 15 countries added more than 100 MW of new capacity.

• France installed the most wind capacity since 2010.

The added capacity in twelve countries offset the dramatic *decline* in new installations in Denmark, Italy, the Netherlands, Norway, Spain, and Switzerland. As a whole, capacity has increased in the IEA Wind member countries from less than 5 GW in 1995 to more than 314.72 GW in 2014 (Figure 1).

Repowering—the replacing of smaller, older turbines with larger-capacity machines—is a way to increase land-based capacity without significantly increasing the land area used. In Denmark, where overall capacity did not increase significantly compared to previous years, 105 MW (93 new turbines) were installed on land, while 29 MW (69 turbines) were dismantled. At one wind plant, 35 old 600-kilowatt (kW) turbines were dismantled in 2014 to make room for a new wind plant with 22 new 3.2-MW turbines in 2015.

Wind generating capacity is mostly represented by large turbines of 1 MW or greater. However, installation of individual, small wind turbines continues in most countries at homes, farms, and small industrial users. For example, in the United States, this is referred to as distributed wind—wind power plants or turbines that are connected either physically or virtually on the customer side of the meter. In the United States, distributed capacity of 64 MW was installed in 2014, bringing total of such capacity there to 906 MW from nearly 74,000 wind turbines.

In the EU, the power sector is installing smaller amounts of fuel oil, coal, nuclear, and gas generation, while increasing its total installed generating capacity with wind and solar photovoltaics (PV). In 2014, wind power installations represented 43.7% of all new power capacity installations in the EU.

2.2.2 Electrical production

Electrical production from national wind capacity is influenced by the quality of the wind resource for the year, the operating availability of the wind plants, and the availability of the transmission grid. In the IEA Wind countries, wind generation *capacity* increased 15% in 2014 and electrical *production* from wind increased by 57.1 TWh or nearly 11% over 2013. Production from wind could have been greater, according to the countries reporting. Many new wind plants were put on line near the end of the year, so their production will begin in 2015. In addition, some countries with large generating capacity experienced a lower-than-average wind year in 2014 (Table 7). Other countries have reported increased productivity due to better grid connection (reduced curtailment), as well as improved hardware and better wind plant siting and design.

The wind resource for a given year plays a major role in the resulting electrical production statistics. For this reason, considering wind indexes along with production numbers is becoming more common. These indexes are based on a five-year or ten-year average wind resource. Table 7 compares the wind resource levels reported by some IEA Wind member countries in 2014.

In 2014, combined wind energy generation met 4.10% of the combined national

Table 5. History of Wind Capacity and Generation in IEA Wind Member Countries

Year	Number of member countries	Total wind capacity (GW)	Annual new wind capacity (GW)	Annual generation From wind (TWh)	National electricity demand (TWh)	Electricity demand from wind (%)
2005	20	51.36	8.92	98.73	8,294	1.19
2006	20	61.85	10.46	117.88	8,280	1.42
2007	20	74.84	13.31	154.95	9,428	1.64
2008	20	91.77	17.00	193.99	8,521	2.28
2009	20	111.53	20.39	206.67	8,370	2.47
2010	21	169.61	31.83	298.53	12,950	2.31
2011	21	202.97	37.00	365.20	13,144	2.78
2012	21	239.59	36.95	449.39	13,719	3.28
2013	21	268.84	29.20	541.30	14,038	3.86
2014	21	314.72	40.68	598.80	14,687	4.10

electrical demand of the IEA Wind countries, compared to 3.86% in 2013. The percent contribution of wind generation to total electrical demand, also known as *penetration level*, depends on installed wind generation relative to total national electrical demand. Wind generation is affected by the wind resource and curtailment, while national electrical demand is affected by economic growth, weather, and energy conservation policies.

The penetration level increased in 2014 in all countries except in four countries where it remained constant: Japan, Korea, Spain, and Switzerland. Some countries set records in 2014 for wind penetration (Table 8). Denmark set the new world record by meeting 39.1% of annual national electric demand from wind energy in 2014. Wind energy met nearly 24% of Portuguese electricity demand in 2014. In Spain, wind energy was the largest single contributor to electricity generation for the entire year, surpassing nuclear, coal, and hydropower. In the EU, it is estimated that wind power capacity installed at the end of 2014 would, in a normal wind year, produce 265 TWh of electricity, enough to cover 9.5% of the EU's electricity consumption—up from 8% in 2013. About 1% of this EU production is from offshore wind.

Table 9 shows wind penetration and national electrical demand for 2014 in the IEA Wind countries. National electrical output from wind energy in 2014 increased over 2013 levels [4] in all member countries except Spain, which had a lower-wind-speed year than in 2013 and a small increase in wind capacity (28 MW). Meanwhile, total national electrical demand in the IEA Wind countries rose by 690.1 TWh in 2014. Total national electrical demand *increased* in Austria, Canada, China, Ireland, Japan, Korea, México, Sweden, and the United States; stayed the same in the Netherlands, Portugal, Switzerland; and *decreased* in Denmark, Finland, France, Germany, Greece, Italy, Norway, Spain, and the United Kingdom.

Table 6. Wind Capacity Increases

	2012 capacity (MW)	2013 new capacity (MW)	Increase (%)[a]
Country	Cumulative capacity end of 2013 (MW)	2014 added capacity (MW)	Increase
Finland	448	178	40
México[b]	1,551	522	34
China	91,413	23,186	25
Austria	1,684	411	24
Canada	7,803	1,871	24
Sweden	4,469	956	21
Korea	561	89	16
United Kingdom	10,861	1,599	15
Germany	34,660	4,914	14
Ireland	1,896	270	14
France	8,207	1,071	13
United States	61,110	4,854	8
Greece[b]	1,865	114	6
Norway	811	45	6
Portugal	4,709	222	5
Japan	2,670	119	4
Denmark	4,808	77	2
Netherlands	2,709	45	2
Italy	8,554	105	1
Spain	22,959	***28***	0.1
Switzerland	60	0	0

Bold italic indicates estimates
[a] % increase = (added capacity 2014/ capacity in 2013) x 100
[b] Numbers reported by GWEC [2]

Table 7. Reported Wind Resource for 2014 Compared to Average

High wind Country (index %)	**Average wind** Country (index %)	**Low wind** Country (index %)
Finland (104%) Norway (103%)	Denmark (99.7%) Portugal Spain United Kingdom United States[a]	China Germany Ireland Italy (97%) Netherlands (89%)

The average wind year = 100%
[a] Regional resources vary across the continent in any year

2.2.3 Offshore wind progress and plans

Among the IEA Wind member countries, offshore wind systems totaling about 9,327 MW were operating in 13 countries at the close of 2014 (Table 10). In 2014, the IEA Wind countries added 2,525 MW of offshore wind.

Several countries have set targets for offshore wind deployment (Table 4) and are making good progress. For example, by the end of 2014, Germany had met half of its offshore wind target (6.5 GW by 2020), counting 3,263 MW of turbines installed, erected but not yet grid-connected, and under construction. Offshore capacity of around 800 MW/yr is planned by the German federal government.

In Finland, by the beginning of 2015, nearly 2,300 MW of offshore projects had been announced, but investment subsidy to enable building phase has so far been

Table 8. Percent Contribution of Wind to National Electricity Demand 2010–2014[a]

Country	2010	2011	2012	2013	2014
Denmark	21.9	28.0	29.9	32.7	39.1
Portugal	17.0	18.0	***20.0***	23.5	24.0
Spain	16.4	16.3	17.8	20.9	***20.4***
Ireland	10.5	15.6	***14.5***	***16.3***	18.3
Germany	6.1	8.1	8.3	8.7	9.6
United Kingdom	2.6	4.2	5.0	5.0	9.0
Sweden	2.6	4.4	5.0	7.0	8.0
Austria	3.0	3.6	5.0	5.8	7.2
Greece[b]	4.0	5.8	***5.8***	***5.8***	***6.1***
Italy	***2.6***	***3.0***	***4.0***	***4.7***	***4.9***
Netherlands	4.0	4.2	4.1	4.7	4.8
United States	***2.3***	***2.9***	***3.5***	***4.1***	***4.4***
Canada	***1.8***	***2.3***	***2.8***	***3.1***	***3.8***
France	---	2.2	3.1	3.3	3.6
China	1.2	1.6	2.0	2.6	2.8
México	***0.6***	***0.6***	***1.2***	***1.5***	***2.0***
Norway	0.7	1.0	1.1	1.4	1.7
Finland	0.3	0.6	0.6	0.9	1.3
Japan	0.4	0.5	0.5	0.5	***0.5***
Korea	0.2	0.2	***0.2***	***0.2***	***0.2***
Switzerland	0.05	0.1	***0.1***	***0.2***	***0.2***
Overall of IEA Wind Countries	***2.3***	***2.8***	***3.3***	***3.8***	***4.1***

Bold italic indicates estimates
[a] Percent of national electricity demand from wind = (wind generated electricity / national electricity demand) × 100
[b] [2] and [7]

granted to only one demonstration project (about 50 MW). In France floating wind is a very active research sector. In Korea, construction is underway for the 100-MW first phase of a 2.5-GW offshore demonstration wind plant. In the United States, 18 offshore wind projects in 10 states are under various stages of development.

Offshore wind is seen as the next area for expansion of wind development in most countries with coastlines or active wind turbine and wind plant supply chains. National and co-operative R&D efforts are being focused on technology for this application (Section 4 and Table 18).

2.3 National incentive programs

All IEA Wind member countries have government or market structures designed to encourage renewable energy development. Most of these incentives also apply to wind energy (Table 11). The EU Emissions Trading System (EU ETS) cap on carbon dioxide (CO_2) emissions will encourage the move to renewables, including wind energy [5]. Feed-in tariffs (FIT) were used by 14 of the IEA Wind member countries to encourage wind development. In order to better integrate large amounts of variable renewables in the electricity markets and system, the EU recently started to phase out FIT schemes in favor of tender systems (solicit offers to undertake wind projects or supply electricity).

Also popular with the IEA Wind member countries are programs that mandate utilities to supply a portion of electricity from renewables. Nine countries use these utility obligations, renewable obligations, or renewable portfolio standards.

2.4 Issues affecting growth

At the end of 2014, more than 57 GW of new wind plants were planned and/or under construction in the reporting IEA Wind member countries (Table 12). The actual increases in capacity for 2015 and beyond will depend on resolution of the issues in the following paragraphs, reported by the IEA Wind member countries as affecting growth. Many of these issues are being addressed through national research projects, incentive programs, and

Table 9. National Electricity Demand and Percent Contribution from Wind in 2014[a]

Country	National electricity demand from wind (%)	National electricity demand (TWh/yr)
China	2.8	5,523.0
United States	4.4	4,093.0
Japan	***0.5***	965.2
Canada	***3.8***	***580.0***
Germany	9.6	578.5
Korea	***0.2***	556.0
France	3.6	465.0
United Kingdom	9.0	335.0
Italy	4.9	309.0
México	***2.0***	***275.0***
Spain	***20.4***	***243.5***
Sweden	8.0	145.0
Norway	1.7	127.0
Netherlands	***4.8***	***120.9***
Finland	1.3	83.0
Switzerland	***0.2***	***63.8***
Austria	7.2	62.5
Greece[b]	6.1	49.3
Portugal	24.0	50.3
Denmark	39.1	33.9
Ireland	18.3	28.2
Total IEA Wind	***4.1***	***14,687.1***

Bold italic indicates estimates
[a] Percent of national electricity demand from wind = (wind generated electricity / national electricity demand) × 100
[b] [2] and [7]

co-operative research projects of IEA Wind and other groups.

Policy:
Changing policies increase risk for project developers, reducing the number of new projects proposed. Government programs to increase access to financing, provide larger and longer-term FITs, increase tax benefits, and provide targeted grants are mentioned as ways to reduce the effects of policy uncertainty. Announcements of policy changes to take place in a specific year can increase deployment.

Better incentives may delay project starts to take advantage of better returns. Less favorable incentives can increase project starts in the short term before they take effect. For example, in Germany starting in 2017, the payment for electricity from renewable energy sources will be based on tendering auctions, yet to be designed. The prospect of this change in Germany is expected to stimulate the growth of annual added land-based wind energy capacity in 2015 and 2016 that will still fall under the old regulations.

In Austria, adoption of the law known as GEA 2012 means that the determining factor for wind power growth will be the amount of the FIT. Some stability is guaranteed because the tariffs are fixed for two years.

In the United States, short-term extensions (one year at a time) of the Production Tax Credit have not been sufficient for sustaining the long-term growth of the wind industry. This is partly because the planning and permitting process for a wind plant in the United States can take up to two years or longer to complete.

Costs:
As shown in Figure 2, installed costs are rising in some countries and falling in others. In Austria, the growing demands from grid providers and rising installation costs are constraining growth. On the other hand, in Ireland, recent wind turbine price decreases have left the industry with good economic underpinnings and there is a strong appetite to build out permitted projects.

Economic climate:
Reduced national electrical demand as a result of the economic slowdown (and possibly energy conservation) has resulted in overcapacity or at least lack of pressure to increase generation capacity. Reduced electrical demand has also created financing and subsidy policy challenges slowing down the progress (especially offshore) as reported by some countries.

Shortage of sites on land:
A shortage of onshore wind sites was cited in some countries—Denmark, Germany, Japan, Korea, the Netherlands, and the United Kingdom —as a reason to develop offshore wind projects.

Grid integration and capacity issues:
In many countries, the electrical grids are adapted to the needs of centralized, large-scale power plants. Their capacity has been limited to existing generation and demand. Some of these systems must now absorb large amounts of wind power. When grid operators need to balance supply and demand, they sometimes shut down or curtail production from wind plants. Improved forecasting and grid upgrades are addressing this problem. Additionally, requirements imposed by grid operators are reported to increase project costs.

Permitting delays:
Delays due to permitting requirements have limited wind development in several countries. In Finland, developers consider the planning and permitting process with the environmental impact assessment to be lengthy and there are also regionally-different processes.

Environmental impacts:
Concerns about environmental impacts were also mentioned as issues affecting the permitting of new wind projects. Research projects on environmental impacts are underway in most countries. The IEA Wind Task 34 Working Together to Resolve Environmental Effects of Wind Energy (WREN) will leverage the findings of these projects for the task participants. One of the positive effects of wind generation is displacing fossil fuel consumption by the power sector and the related economic and environmental costs. Some countries calculate the avoided emissions attributable to wind energy (Table 13) and the number of households supplied with electricity generated by wind turbines. These calculations are based on the national generation mix and usage patterns of each country reporting.

In November 2014, Health Canada released the summary results of its major "Wind Turbine Noise and Health Study." The study concludes that there is no evidence of a causal relationship between

Table 10. Offshore Wind Energy Capacity in IEA Wind Member Countries 2011–2014

Country	2011 Capacity (MW)	2012 Capacity (MW)	2013 Capacity (MW)	2014 Capacity (MW)
United Kingdom	1,838	2,679	3,653	4,502
Germany	203	308	903	2,340
Denmark	871	920	1,271	1,271
China	263	390	428	658
Netherlands	228	228	228	228
Sweden	163	163	211	211
Japan	25	25	50	50
Ireland	25	25	25	25
Finland	27	27	27	28
Spain	0	0	0	5
Korea	0	2	2	5
Norway	2	2	2	2
Portugal	2	2	2	2
Total	**3,647**	**4,771**	**6,802**	**9,327**

Table 11. Incentive Programs in IEA Wind Member Countries for 2014 into 2015		
Type of program	Description	Countries implementing
Carbon tax	A tax on carbon that encourages a move to renewables and provides investment dollars for renewable projects.	The EU ETS - international system for trading GHG emission allowances covers more than 11,000 power stations, industrial plants, and airlines in **31 European countries**; Canada has carbon taxes in 3 provinces with more provinces considering it.
Feed-in tariff	An explicit monetary reward for wind-generated electricity that is paid (usually by the electricity utility) at a guaranteed rate per kilowatt-hour that may be higher than the wholesale electricity rates paid by the utility. Special definition in Finland and the Netherlands: *Subsidy* is the difference between a guaranteed price and the electricity market price—producers are in the electricity markets.	Austria, Canada, China, Denmark (offshore fixed from project to project and small wind turbines), Finland (special definition), Germany, Ireland, Italy, Japan, Korea, the Netherlands (special definition), Portugal, Switzerland, United Kingdom **(14 countries**)
Renewable portfolio standards (RPS), renewables production obligation (RPO), or renewables obligation (RO)	Mandate that the electricity utility (often the electricity retailer) source a portion of its electricity supplies from renewable energies.	Canada, China, Italy, Korea, México (under development), Norway, Sweden, the United Kingdom, the United States **(9 countries)**
Green electricity schemes	Green electricity based on renewable energy from the electric utility, which can be purchased by customers, usually at a premium price.	Canada, Denmark, Finland, Norway, the Netherlands, Sweden, the United Kingdom, the United States **(8 countries)**
Spatial planning activities	Areas of national interest that are officially considered for wind energy development.	Austria, China, Denmark, Korea, México, the Netherlands, Sweden, the United Kingdom **(8 countries)**
Electric utility activities	Activities include green power schemes, wind plants, various wind generation ownership and financing options with select customers, and wind electricity power purchase models.	Austria, Canada, Denmark, Finland, Sweden, the United Kingdom, the United States **(7 countries)**
Net metering or net billing	The system owner receives retail value for any excess electricity fed into the grid, as recorded by a bi-directional electricity meter and netted over the billing period. Electricity taken from the grid and electricity fed into the grid are tracked separately, and the electricity fed into the grid is valued at a given price.	Canada, Denmark, Italy, the Netherlands (small wind only), Portugal (micro-generation only), the United Kingdom, the United States **(7 countries)**
Green certificates	Approved power plants receive certificates for the amount (MWh) of electricity they generate from renewable sources. They sell electricity and certificates. The price of the certificates is determined in a separate market where demand is set by the obligation of consumers to buy a minimum percentage of their electricity from renewable sources.	Canada, México (under development), Norway, Sweden, the United Kingdom, the United States **(6 countries)**
Special incentives for small wind	Reduced connection costs, conditional planning consent exemptions. Value-added tax (VAT) rebate for small farmers. Accelerated capital allowances for corporations. Can include microFIT.	Canada, Denmark, Italy, Portugal, the United Kingdom, the United States **(6 countries)**
Income tax credits	Some or all expenses associated with wind installation that may be deducted from taxable income streams.	Canada, China, Ireland, Norway, the Netherlands, the United States **(6 countries)**
Investment funds for wind energy	Share offerings in private wind investment funds are provided, plus schemes that focus on wealth creation and business success using wind energy as a vehicle to achieve these ends.	Canada, Ireland, the Netherlands, the United Kingdom **(4 countries)**

Type of program	Description	Countries implementing
Sustainable building requirements	The requirements of new building developments (residential and commercial) to generate a prescribed portion of their heat and/or electricity needs from on site renewable sources (e.g., wind, solar, biomass, and geothermal). Existing buildings can qualify for financial incentives to retrofit renewable technologies.	Denmark (solar), Korea, Portugal, the United States **(4 countries)**
Capital subsidies	Direct financial subsidies aimed at the up-front cost barrier, either for specific equipment or the total installed wind system cost.	China, Korea
Commercial bank activities	Includes activities such as preferential home mortgage terms for houses, including wind systems; and preferential green loans for the installation of wind systems.	The Netherlands, the United Kingdom
Relief from import tax	Large wind turbine technology and related components included on lists of imports are exempt from customs and import VAT charges.	China
Special licensing to reduce administrative burden	RES plants are exempt from the obligation to attain certain licenses; on islands, RES plants that are combined with water desalination plants get priority.	Greece
Capital expenditure (Capex) based auctions	A fixed investment incentive such that an auction is based on a Capex reference value and the winner will be subsidized with a fixed price per MW.	Spain

Table 12. Potential Increases to Capacity Beyond 2014 in Reporting IEA Wind Member Countries

Country	Planning approval[a] (MW)	Under construction[b] (MW)	Total planned and/or under construction (MW)
Austria	600	350	700
Canada	1,700	---	1,700
China	---	---	79,540
Denmark	---	---	3,300
Finland	300	100	400
France	2,194	---	(land-based) 6,428 (offshore) 3,123
Germany	(offshore) 8,436	(offshore) 923	(offshore) 9,359
Ireland	1,663	---	1,663
Japan	300	215	5,200
México	600	350	950
Netherlands	(offshore) 600 (land-based) 825	(offshore) 145 (land-based) 865	2,435
Norway	3,470	7	3,477
Spain	40	---	---
Sweden	8,389	761	9,150
Switzerland	0	0	0
United Kingdom	15,436	2,369	17,805
United States	---	12,700	12,700

--- = no data available
[a] Projects have been approved by all planning bodies.
[b] Physical work has begun on the projects.

Table 13. Environmental Benefits of Wind Energy in Reporting IEA Wind Countries			
Country	Reduced CO_2 Emissions (million tons/ year)	Reduced CO_2 Emissions (gram [g]/ kWh)	Additional Benefits
Austria	3.50	---	
China	130	741	
Denmark	9.74	746	
Finland	0.80	700	
Germany	40.52	---	
Ireland	2.33	460	Lowered carbon intensity of electricity generation to a record 457g/CO_2/ kWh
Italy	8.26	551	
Portugal	4.30	---	
Spain	26.10	---	Saved 10.2 million tons of conventional fuels and met the electrical needs of 16.5 million households.
United States	125.00	---	Avoided consumption of 68 billion gallons of water and met the electrical needs of 17 million homes.
--- = no data available			

exposure to wind turbine noise and self-reported medical illnesses and health conditions. The study did identify a relationship between wind turbine noise and annoyance. More detailed analyses will be released through peer-reviewed conference papers and journals in 2015.

Social acceptance:
Social acceptance is becoming an issue in nearly every country that has wind development. IEA Wind Task 28 Social Acceptance of Wind Energy Projects is addressing the process of wind project development.

3.0 Implementation

3.1 Economic impact

Key impacts of wind energy development include providing employment, bringing economic activity to project sites and supply chain entities, stimulating domestic manufacturing, and enhancing the export of wind turbines, components, and consulting expertise. Even countries with no domestic turbine manufacturers have export markets attributed to wind energy as components, materials, and services. Table 14 shows estimated labor and economic turnover effects for 2014 in the reporting IEA Wind member countries.

In several countries employment in the wind sector was reported to have *increased* in 2014 over 2013: Austria, China, Finland, Germany, Ireland, the Netherlands, the United Kingdom, and the United States. Employment was reported to have *decreased* in Japan. Employment *stayed the same* in Italy, Portugal, and Spain. Eight countries—Canada, Denmark, Greece, Korea, México, Norway, Sweden, and Switzerland—did not report an employment number.

Several landmark analyses were performed to estimate the economic benefit of expanding wind or meeting deployment targets. In Ireland, one published analysis suggested that as many as 35,000 jobs in construction, engineering, manufacturing, and information technology could be generated by developing Ireland's wind energy sector further. Another study estimated that from 2012 to 2020 the average annual value of the land-based wind energy supply chain for Ireland would be 330 million EUR/yr (400 million USD/yr). Up to 87% of this onshore supply chain could be captured in Ireland with proper support policies.

The Canadian Wind Energy Association (CanWEA) estimates that, in the province of Québec alone, the wind energy industry has created over 5,000 jobs and generated 10 billion Canadian dollars (CAD) (7.1 billion EUR; 8.6 billion USD) worth of investments over the past decade. The wind industry now contributes 500 million CAD (356 million EUR; 432 million USD) to Québec's gross domestic product (GDP) every year. The wind energy sector in Québec has benefited from a ten-year period of predictable and integrated approaches by successive governments.

A key benefit cited in many countries is the number of workers employed in the wind energy sector. In China, it is estimated that about 15 jobs could be produced by each megawatt of wind installation. Among these jobs, 13–14 are in the manufacturing industry, and about 1.5 jobs are involved in installation and maintenance. In Italy, operations and maintenance (O&M) expenditures overtook the investment for new installations, due to the dramatic decrease in new added capacity in 2014. The decrease in new capacity was due to the 2012 change in the incentive structure. In the United Kingdom, a 2014 study concluded that more than 6,800 people were directly employed in the nation's offshore wind sector. In the United States, the 22,500 new wind sector jobs included 19,200 in manufacturing.

Export markets can grow even if domestic markets are not growing. In Japan, because of the shrinking of the domestic market, Japanese companies intend to expand their business worldwide by merging or collaborating with foreign companies. Some Spanish companies maintain their wind activity despite the poor market in Spain, by selling to other countries. In 2014, the Spanish wind sector exported 2.234 billion EUR (2.705 billion USD) in

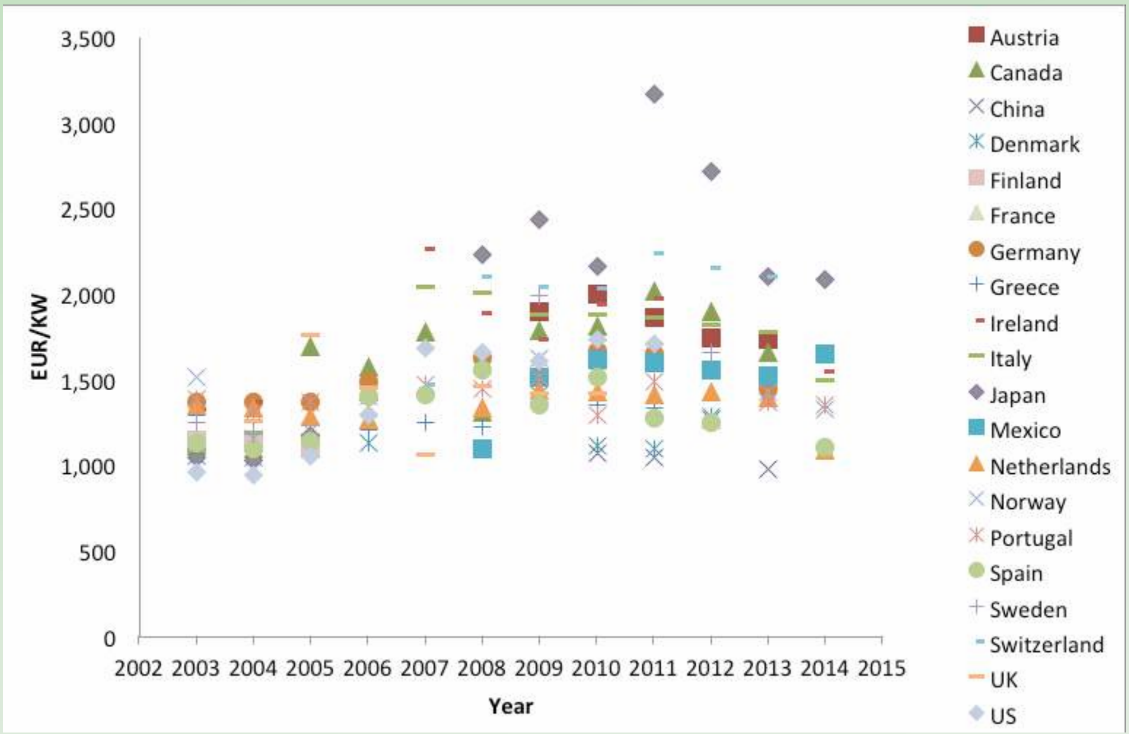

Figure 2. Average project cost of wind turbines *on land* 2003–2014 as reported by IEA Wind member countries. Prior-year costs were adjusted to 2014 values using Harmonised Inflation Europe (HICP) table averages by year. (www.inflation.eu/inflation-rates/europe/historic-inflation/hicp-inflation-europe.aspx)

equipment, an increase of 57.4% compared to the previous year.

3.2 Industry status

Wind projects are owned by utilities, co-operatives, independent power producers (IPPs), private companies (i.e., industries for self-supply), income funds, and communities (including First Nations in Canada and the United States). Table 15 reports the total number of turbines operating in the IEA Wind countries and the average rated capacity of the new turbines installed in 2014. Many details are presented in the country chapters of this report. A few examples are included here.

In Canada, nearly half of the 37 new wind energy projects commissioned in 2014 included significant ownership stakes by First Nations (jurisdictions governed by native peoples), municipal corporations, and local farmers. These projects were contracted under calls for tender or FIT programs that targeted these partnerships. Interesting applications in Ireland included, two 3-MW turbines providing power to the Janssen Biologics and DePuy health-care and pharmaceuticals companies.

In China, 26 manufacturers installed turbines in 2014. Of these, 13 each installed more than 500 megawatts of capacity. In the United States, at the end of 2014, there were more than 500 wind-related manufacturing facilities across 43 states, producing everything from major components like blades, nacelles, and towers down to bearings, fasteners, and sensors. More than 60 non-utility entities have invested in wind energy, including Amazon, Google, IKEA, Mars Foods, Microsoft, Walmart, and Yahoo! among others.

3.3 Operational details

Wind plants, also called *wind farms* or *wind parks* are composed of many individual wind turbines and are becoming more productive by several measures. One of these is *capacity factor.* The annual capacity factor is the amount of energy a generating plant produces over the year divided by the amount of energy that would have been produced if the plant had been running at full capacity during that same time interval. For wind turbines, capacity factor is dependent on the quality of the wind resource, the ability of the machine to generate when there is sufficient wind (i.e., its reliability), and the size of the generator. The capacity factor is reduced if the utility curtails production to meet load management needs. Most wind power plants operate at a capacity factor of 25–40%. Long blades improve the capacity factors especially at low wind sites. Offshore wind turbines generally have higher capacity factors due to large rotors (long blades) and excellent winds. The IEA Wind member countries' estimated average annual capacity factors for 2014 are reported in Table 16.

A related measure reported in some country chapters is full-load hours for the year. A year has 365 days, hence 8,760 hours. Full load hours describe the (calculated) amount of time the generators would have run at full capacity to produce the electricity they actually generated in the year. For perspective on this measure, Figure 3 shows full-load hours calculated for various generation sources in Germany for 2013 (the latest year with data).

The IEA Wind member countries report a trend of installing turbines that have taller towers, longer blades, and comparatively smaller generators. These trends

Table 14. Capacity in Relation to Estimated Jobs and Economic Impact 2014

Country	Capacity	Estimated number of jobs)	Economic impact (million USD[a])
China	114,599	470,000	---
United States	65,877	73,000	8,000
Germany	39,153	140,000	16,954
Spain	***22,986***	17,850	2,335
United Kingdom	12,808	25,819	12,628
Canada	9,691	---	---
France	9,143	10,000	---
Italy	8,663	30,000	3,460
Sweden	5,425	---	---
Portugal	4,953	3,200	---
Denmark	4,896	---	1,380
Japan	2,788	3,000	454
Netherlands	2,753	7,900	3,710
Ireland	2,211	3,400	426
Austria	2,095	5,600	939
México	2,381	----	1,153
Greece	1,980	---	---
Norway	856	---	---
Korea	643	---	---
Finland	627	5,200	1,230
Switzerland	60	---	70
Total	**314,588**		

Bold italic indicates estimates
[a] Applicable conversion rate USD to EUR: 0.826

result in larger capacity factors for the new turbines. These turbines allow wind development in more areas, including those with forests or lower wind speeds, resulting in better performance. For example, in Austria since 2013, more than 80% of new installations are 3-MW turbines or larger. These installations include two 7.5-MW wind turbines and a 3.2-MW test turbine that reaches a total height of 200 m (tower plus blade). In China, the average full-load hours of operating wind plants was 1,893 hours, a decrease of 181 hours compared to 2013. In Denmark, the average capacity factor was 30.8% (average wind index 99.7%) for the turbines that have been in operation the whole year. The 1,271 MW of offshore wind plants alone counted for 40% of the production with an average capacity factor of 46.4%. In Finland, the capacity factor was 30% for the 74 turbines with a hub height of 100 m or more.

The move to offshore deployment, replacing older, smaller machines and developing large wind plants, led to countries installing turbines averaging 1,137 MW in Denmark up to 3,725 MW offshore in Germany. The average power rating of new wind turbines in 2014 was higher compared to 2013 in seven countries: Austria, Canada, Japan, Germany (land-based), the Netherlands, Norway, and the United States. The average power rating of new turbines was lower in 2014 than in 2013 in China, Denmark, Germany (offshore), Italy, Korea, México, and Sweden.

In the United States, 2,500 utility-scale wind turbines were installed in 2014. The average project size was 118 MW (excluding wind projects with a single wind turbine), and the average turbine size was 1.94 MW. The average rotor diameter of the turbines installed in 2014 was 99.7 m and the average hub height was 82.4 m.

3.4 Wind energy costs

The cost of electricity from wind generation is declining, according to the IEA Wind member countries. IEA Wind Task 26 is addressing this key metric, often referred to as the levelized cost of energy or LCOE, by collecting data on system and project costs, assessing methodologies for projecting future wind technology costs, and surveying methods for determining

Table 15. Turbine Details 2014

Country	Total Number of Turbines Operating	Average Capacity of New Turbines (kW)
Austria	1,013	2,900
Canada	5,323	1,997
China	76,241	1,768
Denmark	5,269	1,137
Finland	260	3,100
France	5,200	***2,200***
Germany	25,410	land-based: 2,690 offshore: 3,725
Greece	---	---
Ireland	1,434	---
Italy	6,358	1,920
Japan	1,941	2,038
Korea	368	1,500
México	1,620	1,800
Netherlands	---	***3,173***
Norway	371	3,000
Portugal	2,496	***2,000***
Spain	***20,265***	***1,983***
Sweden	3,048	2,605
Switzerland	***35***	---
United Kingdom	6,031	---
United States	48,544	1,940

Bold italic indicates estimates;
--- = no data available

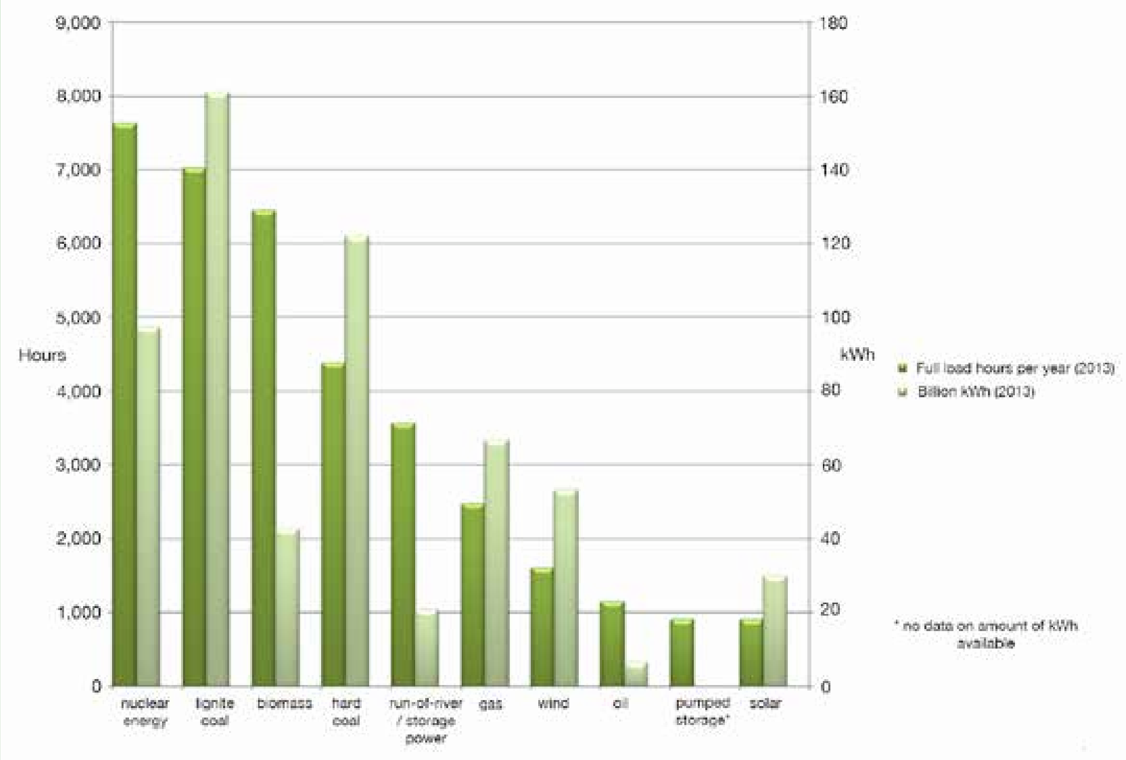

Figure 3. Comparing full load hours of generation sources for Germany in 2013. (Based on data from the Federal Association of the Energy and Wind Industry (BDEW) and data from the German Federal Statistical Office [destatis])

the value of wind energy (Lantz et al. 2012). The individual country chapters include estimated costs of energy based on local conditions.

The trend toward using turbines on taller towers with larger rotors for a given generator capacity is working to reduce the LCOE by extracting more energy from a given site. Ireland reports that the newer large-rotor, low-specific-power models represent the upper end of the cost range for turbines and projects. However, because these turbines yield a higher energy capture per rated kilowatt of the generator, they will allow a continued reduction in the cost of wind energy.

The country chapters also address costs for turbines, development, operation and maintenance in some detail. Table 17 shows reported *turbine* and project costs in 2014 currency. Figure 2 shows trends of *project* costs since 2003 as reported by IEA Wind member countries in those years. Please note that the historic cost numbers (2003–2013) have been adjusted to 2014 euros using Harmonised Inflation Europe (HICP) table averages by year (www.inflation.eu/inflation-rates/europe/historic-inflation/hicp-inflation-europe.aspx).

Canada has demonstrated that electricity generated by wind energy is becoming a cost-competitive option. In 2014, Hydro-Québec issued a call for tenders for 450 MW. Through this process, Hydro-Québec selected three wind projects totaling 446.4 MW, and will pay an average price of 0.063 CAD/kWh (0.045 EUR/kWh; 0.054 USD/kWh) for the energy.

In China, under the current technology, without considering the cost of long-distance transmission or the resource and environmental benefits of wind power, the cost of wind power is higher than that of coal-fired power by 0.20 Yuan/kWh (0.027 EUR/kWh; 0.032 USD/kWh). If resources and environmental benefits are taken into consideration, the cost of wind power was nearly equal to that of coal-fired power generation.

4.0 Research, Development, and Deployment (R, D&D) Activities

A significant benefit to countries that join the IEA Wind agreement is that relevant organizations within the country can participate in the co-operative research tasks. In 2014, 13 active research tasks sponsored by IEA Wind were advancing wind energy technology and deployment. To guide these activities, the Executive Committee of the IEA Wind agreement prepared a new Strategic Plan 2014–2019. This plan is based on the document *Long-Term Research and Development Needs for Wind Energy for the Time Frame 2012 to 2030*, approved by the IEA Wind members in 2012. Figure 4 lists the active task activities and their time frames. Any task may be extended beyond the endpoint in the figure if the participants agree and the Executive Committee approves the work plan. New tasks are added as the member countries agree on new research topics for co-operation. For example, a new task was added in 2013 for ground-based testing. New tasks on forecasting, systems engineering, and noise modulation will be considered in 2015.

4.1 National R&D efforts

The major research areas discussed in the individual country chapters are listed in Table 18. The country chapters contain references to recent reports and databases resulting from this research. One clear trend is that the governments of most countries with shorelines are placing a high priority

Table 16. Reported Average Capacity Factors 2011–2014 (%)[a]

Country	Average capacity factor 2011 (%)	Average capacity factor 2012 (%)	Average capacity factor 2013 (%)	Average capacity factor 2014 (%)
Austria	---	30.0	24.0	***24.0***
Canada	31.0	31.0	31.0	***31.0***
China	---	22.4	23.7	21.6
Denmark	28.4	22.6	27.1	30.8
Finland	28.0	24.0	26.0	27.0
France	21.7	24.0	23.2	***22.6***
Germany	19.0	---	18.5	18.7
Greece	---	---	27.5	***27.5***
Ireland	31.6	28.4	30.5	28.7
Italy	18.0	---	21.0	***20.0***
Japan	19.0	19.9	17.0	***22.0***
Korea	---	---	---	23.7
México	30.0	30.0	30.0	***30.0***
Netherlands	---	Land-based: 20.0 Offshore: 39.5	Land-based: 22.3 Offshore: 38.6	Land-based: 22.0 Offshore: 37.5
Norway	31.3	31.2	29.2	31.0
Portugal	26.0	28.0	29.0	28.0
Spain	---	24.1	26.9	25.4
Sweden	---	26.0	28.3	***26.7***
Switzerland	20.0	<20.0	20.0	20.0
United Kingdom	Land-based: 27.4 Offshore: 36.7	Land-based: 27.4 Offshore: 36.7	---	Land-based: 26.4 Offshore: 37.0
United States	33.0	33.0	32.1	32.3

Bold italic indicates estimates; --- = No data available
[a] The amount of energy the plant produces over the year divided by the amount of energy that would have been produced if the plant had been running at full capacity during that same time interval.

on research to support offshore wind technology (China, Denmark, Finland, Germany, Italy, Japan, Korea, the Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom, and the United States, as well as the European Commission).

Government research support contributes to advancing wind technology and deployment. It is difficult to calculate the total research dollars supporting wind energy technology in many countries. However, Table 19 lists government budgets for wind R&D reported by some countries. Investments from research partners in industry and academia also contribute to advancing wind energy deployment.

A clear trend in Canada, México, the Netherlands, and the United Kingdom is that national R&D is increasingly directed by the business sector, research centers, and universities rather than by political and governmental organizations. Newly-designed programs strive to have the R&D community work more in line with requests from the industrial sector; while the industrial sector is encouraged to make more use of the knowledge available in the research centers and universities.

For more information on test centers and research activities, please refer to the country chapters and the chapter from the European Commission/European Wind Energy Association. A few highlights are presented here.

4.1.1 New test, research, and demonstration facilities

Several important new research centers were opened, under construction, or being planned in 2014.

In Canada, the TechnoCentre éolien inaugurated its Dynamic Smart Microgrid to test and validate wind-solar-diesel-coupling technologies. This infrastructure focuses on the integration of renewable energies into remote micro-grids and distributed grids.

In France, the SEMREV test site became operational to test floating wind turbines off the coast at Le Croisic, on the Atlantic Ocean. Several environmental measurement devices are already present on the site to allow for the evaluation of the local sea and wind conditions.

In Germany, the wind turbine generator system test bench of the Center for Wind Power Drives started its operation in March 2014 at the RWTH Aachen University. This test bench has a high dynamic direct drive with a nominal capacity of 4 MW and a maximum torque of 3.4 meganewton meters (MNm). The dynamic loads on the rotor flange and the power connection can be calculated in real-time using the worldwide unique HiL mode of operation. While the Test Center for Support Structures became fully operational in 2014 at Fraunhofer Institute for Wind Energy and Energy System Technology, the institute's 10-MW test rig, called DyNaLab will be officially inaugurated in autumn 2015.

In Italy, the POLI Wind Group has developed a wind tunnel testing facility, which includes actively controlled and aero-elastically scaled wind turbine models. The facility has been recently expanded for the simulation of wind parks and the study of wake interactions.

In Portugal, the WindFloat offshore prototype is a semi-submersible structure and a 2-MW Vestas V80 wind turbine. The system has survived 16-m waves with only minor maintenance required and it had delivered 12.02 GWh of renewable electricity to the grid by the end of 2014.

4.1.2 Highlights of research

Details of these and other completed projects, references to the resulting publications, and descriptions of planned R&D activities can be found in the country chapters of this report.

In Austria, a two-and-a-half-year study was completed to develop a model to estimate risk zones near wind turbines taking site-specific parameters into account.

Health Canada released summary results of a thorough epidemiological study on noise and health impacts of wind turbines. The study measured health effects on people living in proximity to wind turbines. It used a large sample survey conducted by Statistics Canada, and in a smaller sampling, it measured people's stress hormone indicators and monitored their sleep patterns. It also measured the noise from the wind turbines near the studied populations. The study found no links between exposure to wind turbine noise and any of the self-reported or measured health endpoints examined. The study did demonstrate a relationship between increasing levels of wind turbine noise and annoyance towards several features associated with wind turbines, such as: noise, vibration, shadow flicker and the aircraft warning lights.

In Denmark, the Megavind project published recommendations for policymakers, industry, and research to increase the owners' value of wind power plants in energy systems with large shares of wind energy.

In France, Phase 1 of the VALEF project was carried out to ensure the accuracy of the software used to model the dynamic behavior of floating wind turbines. The work improved methodologies and validation data. This first phase was based on a detailed review of the state-of-the-art and wind tunnel and wave basin testing. It proposed recommendations for specific methodologies for an experimental campaign to be carried out in Phase 2.

In Germany, a state-of-the-art procedure was developed for low-noise installation of offshore foundations in water depths up to 25 m. With the help of big bubble curtains, cofferdams, and hydro sound dampers, the national thresholds of sound emission were met and the disturbance area for marine mammals was reduced by 90%.

Table 17. Estimated Average Turbine Cost and Total Project Cost for 2014 in Reporting IEA Wind Countries

Country	Turbine cost (EUR/kW[a])	Total installed project cost[b] (EUR/kW[a])
Austria	1,181	1,384
China	532	1064
Ireland	909	1,550
Italy	---	1,500
Japan	1,389	2,081
México	1,322	1,652
Netherlands	---	Land-based: 1,087 Offshore: 2,643
Norway	856	1,328
Portugal	1,080	1,351
Spain	700	1,100
United States	900	---

--- = No data available
[a] Applicable conversion rate 2014 EUR to 2014 USD: 1.211
[b] Total Installed Project Cost includes: costs for turbines, roads, electrical equipment, installation, development, and grid connection.

In Ireland, the Sustainable Energy Authority of Ireland (SEAI) is revising the Wind Farm Planning Guidelines on noise and shadow flicker. A final report by the National Economic and Social Council strongly advocated community shareholding or ownership of wind plants.

In Italy, Energy and Sustainable Economic Development (ENEA) has been defining validation methods for in-situ, non-destructive testing of small wind turbine blades so they could be used to perform quantitative analysis of defects inside the component. The analyses are performed using an x-ray, high-resolution computed tomography system in the laboratory.

In Japan, an offshore demonstration wind turbine and an offshore measurement platform survived several severe typhoon attacks from 2013 to 2014. Only minor damage was sustained, such as disconnection of a grounding wire and deflection of the support structure of submarine cables.

In Spain, the first 1:35-scale, test prototype of a floating offshore wind turbine was developed and tested in a wave test tank operated by the Hydraulic Institute of Cantabria.

In the United Kingdom, the Offshore Renewable Energy Catapult managed the delivery of a cost reduction monitoring framework and launched SPARTA (System performance, Availability and Reliability Trend Analysis), which is a secure database of offshore wind farm performance data that will improve wind turbine operational performance by increasing safety, reliability, and availability.

In the United States, four reports published in 2014 analyzed the U.S. offshore wind market, examined the impacts of offshore wind energy on the national transmission system, found that the Western grid could tolerate disturbances resulting from high penetrations of renewable generation (wind and solar), and showed that careful design of the ancillary services markets will result in increased revenue when wind plants provide these services. In other work, the National Oceanic and Atmospheric Administration (NOAA) is using high-tech airplanes equipped with Doppler to drop sensors into developing storms that measure temperature, pressure, wind speed, and direction to understand how storms could affect wind turbines.

4.2 Collaborative research

The collaborative research conducted by organizations in the IEA Wind member countries made significant progress in 2014. IEA Wind Recommended Practices serve as pre-normative guidelines in advance of formal standards. In 2015, new or updated Recommended Practices are under development in Task 19 Wind Energy in Cold Climates, Task 26 Cost of Wind Energy, Task 27 Small Wind Turbines in High Turbulence Sites, Task 33 Standardizing Data Collection for Wind Turbine Reliability Studies, Task 34 Working Together to Resolve Environmental Effects of Wind Energy (WREN), and Task 35 Full-Size Ground Testing of Wind Turbines and their Components.

Task 11 Base Technology Information Exchange held two Topical Expert Meetings: Floating Offshore Wind Plants and Field Test Instrumentation and Measurement Best Practices. Proceedings from these meetings of invited experts will be posted on the IEA Wind website in 2015. These meetings often result in proposals

Table 18. Reported Research Activities in IEA Wind Member Countries

Type of program	Country activities reported	IEA Wind co-operative activities in 2014
Offshore wind	• Technology development and testing of turbines, including turbines up to 10 MW and foundations (fixed and floating) • Design work for turbines up to 20 MW • Drive train advances • Transmission issues • Bigger blades • Innovative materials for blades, towers, and generators • Resource assessment • Reliability of operations and maintenance • Improvement of project development processes • Floating wind technology	Task 30 OC4 Comparison of Dynamic Codes and Models for Offshore Wind Energy (structures)
Wind farm modeling	Data acquisition and model development	Task 31 WAKEBENCH: Benchmarking of Wind Farm Flow Models
Small wind	• Technology development and testing of turbines generating 50 kW or less • Investigation of legal and social issues • Tools for siting in urban settings • Operation and maintenance costs reduction • Noise reduction • Assessing economics and usability	Task 27 Small Wind Turbine Labels for Consumers in conjunction with IEC MT2 standards work; Second term title for Task 27 is Small Wind Turbines at Turbulent Sites
Mid-sized wind	Technology development of turbines between 50 kW and 1 MW	
Hybrid systems	• Wind with hydropower, biomass, diesel, and storage	
Technology improvements	• Two-bladed rotors, upwind and downwind designs, blade materials and design work, control systems • Applying systems engineering to improvements in components	
Resource assessment, mapping, and forecasting	• Measurement programs and model development to assess and map the wind resource • Remote sensing programs and techniques • Wind atlas development • Forecasting techniques • Implementation of predictions for wind energy generation	Task 32 LIDAR: Wind lidar systems for wind energy deployment; Task 11 Base Technology Information Exchange: Topical Expert Meeting on forecasting techniques.
Operations and Maintenance	Condition-based monitoring.	
Environmental issues	• Developing impact assessment procedures • Conducting assessments in sensitive areas • Monitoring procedures • Wildlife impact: birds, bats, aquatic species • Sound propagation • Impact on radar systems.	Task 34 Environmental Assessment and Monitoring of Wind Energy Projects
Social impacts	Developing techniques for assessment and mitigation of negative attitudes toward wind projects to improve permitting and approval processes. Measuring health impacts of wind.	Task 28 Social Acceptance of Wind Energy Projects; Task 27 Small Wind Turbine Labels for Consumers

Cold climate, severe conditions, and complex terrain	• Assessing the effects of cold on production • Mitigating ice formation; • Assessing risks of ice fall; • Design for lightning, turbulence, and high winds	Task 19 Wind Energy in Cold Climates; Task 11 Base Technology Information Exchange: Topical Expert Meeting on wind energy in complex terrain
Building domestic industry	Support for domestic turbine or component developers to optimize, manufacture, and develop supply chain.	
Test centers	Increase or enhance public/ private test centers for design and endurance testing of wind turbines and components including blades, gearboxes, control systems, and wake effects.	Task 29 Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models Task 35 Full-Size, Ground-Testing for Wind Turbines and their Components
Reducing and assessing costs	• Wind turbine research and design to reduce manufacturing, operation and maintenance costs • Improvement of modeling tools used for wind turbine design • Development of condition monitoring systems for efficient operations • Standards for offshore wind • Options of financing offshore wind • Life cycle wind farm management platform	Task 26 Cost of Wind Energy; Task 29 Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models; Task 30 OC4 Comparison of Dynamic Codes and Models for Offshore Wind Energy (structures); Task 31 WAKEBENCH; Task 33: Reliability Data: Standardizing Data Collection for Wind Turbine Reliability and Maintenance Analyses
Integration with electric power systems	• Model and measure impacts of wind generation on the power supply system • Develop strategies to minimize costs • Design and test use of storage (flywheel, battery, and hydrogen) and demand management	Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power
Innovative concepts	Vertical axis, hydraulic drive, kites, and airships.	
Workforce	• Identification of gaps • Mobility of researchers • Shared use of testing centers	
Markets	Innovative electricity market design.	
Performance	Understanding underlying physical processes affecting performance	

to establish multi-year IEA Wind research tasks on the topic of the meeting.

For 2015, four Topical Expert Meetings are scheduled: Wind Energy Systems Engineering, Noise Reduction Technologies, Uncertainty Quantification of Wind Farm Flow Models, and Mitigation of Wind Turbine Impacts on Radar. In addition, the IEA Wind Executive Committee decided to re-establish regular meetings on aerodynamics similar to those formerly known under Task 11 as Joint Action Symposia.

Task 19 Wind Energy in Cold Climates task participants worked on ice throw guidelines and a standardized method to calculate production loss due to icing events. In 2015, these guidelines will be incorporated into the updated Recommended Practices and an update to a previous state-of-the-art report (to be called Available Technologies).

Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power participants presented papers on the following topics during the Wind Integration Workshop in 2014 in Berlin:

- The CO_2-reduction impacts of wind power
- Synergies between wind and solar generation and demand response
- An index for wind power variability
- An objective measure of interconnection usage for high levels of wind integration.

Two papers on stability issues and Recommended Practices were presented during the 2014 IEEE Power & Energy Society (PES) summer conference. In 2014, a four-page fact sheet on integration issues was developed and published on the Task 25 Web page for policy makers. In 2015, detailed topics will be addressed in other fact sheets linked to the first general summary fact sheet. The work of Task 25 was extended by the IEA Wind Executive Committee for a fourth term from 2015–2017.

Task 26 Cost of Wind Energy contributed to publishing the expert workshop proceedings for the "System Approach to Assessing the Value of Wind for the Society" held in November 2013 was in conjunction

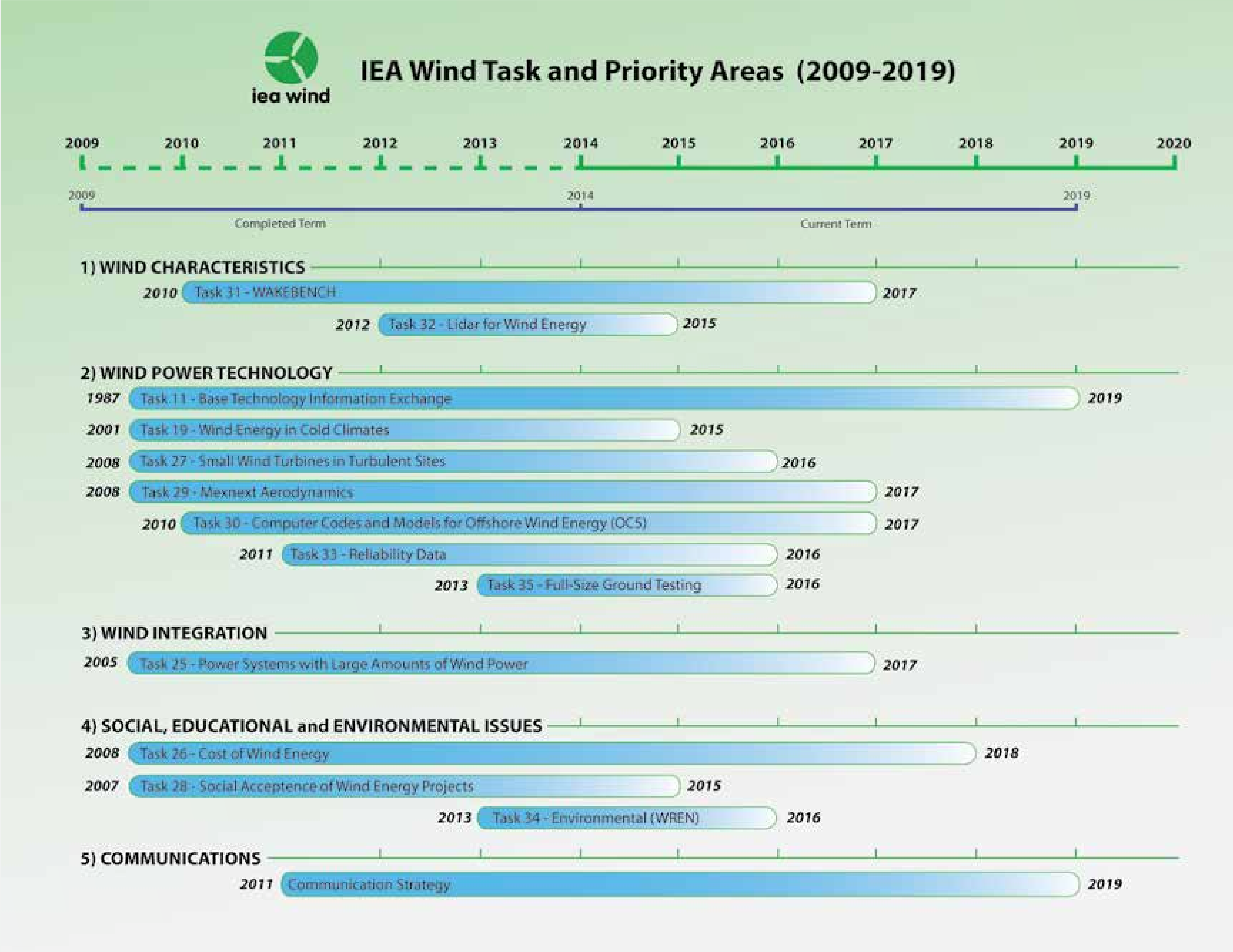

Figure 4. Priority areas from *IEA Wind Strategic Plan* and active research tasks [6]

Table 19. National R&D Budgets 2010–2014 for Reporting Countries

Country	2010[a] Budget million EUR; (million USD)	2011[a] Budget million EUR; (million USD)	2012[a] Budget million EUR; (million USD)	2013[a] Budget million EUR; (million USD)	2014 Budget million EUR; (million USD)
Austria	---	---	---	---	---
Canada	---	6.00; (7.76)	4.23; (5.84)	3.62; (4.99)	***3.89; (4.71)***
China	---	---	---	---	---
Denmark[b]	36.31; (48.80)	24.25; (32.60)	17.13; (22.6)	41.89; (57.70)	---
European Commission	34.97; (47.00)	27.31; (36.71)	61.35; (80.94)	65.67; (90.46)	24.71; (29.92)
Finland	4.00; (5.20)	10.00; (12.90)	2.00; (2.75)	3.12; (4.30)	0.99; (1.20)
France	---	---	---	---	---
Germany	52.96 (71.18)	81.21; (105.09)	78.31; (103.21)	36.75; (50.64)	38.51; (46.64)
Greece	---	---	---	---	---
Ireland	0.30; (0.40)	0.30; (0.40)	0.88; (1.07)	---	---
Italy	3.00; (3.96)	3.00; (3.96)	3.00; (3.89)	3.00; (4.13)	***3.00; (3.63)***
Japan	18.29; (24.58)	31.92; (42.91)	41.89; (55.26)	25.05; (47.50)	52.73; (63.84)
Korea	28.36; (38.12)	29.10; (37.66)	33.91; (44.69)	35.60; (49.06)	---
México	---	---	---	---	1.74; (2.10)
Netherlands	38.00; (51.07)	7.08; (9.15)	8.10; (11.60)	5.07; (7.00)	3.73; (4.51)
Norway	12.60; (16.72)	14.87; (19.69)	17.14; (22.68)	13.20; (18.19)	12.39; (15.00)
Portugal	---	---	---	---	---
Spain	150.00; (115.91)	150.00; (115.91)	120.00; (158.16)	85.50; (117.82)	---
Sweden	10.80; (14.47)	10.80; (14.47)	10.80; (14.23)	10.80; (14.88)	6.45; (7.81)
Switzerland	0.41; (0.53)	0.41; (0.53)	0.41; (0.53)	0.41; (0.53)	0.39; (0.47)
United Kingdom	---	---	---	---	---
United States	59.52; (80.00)	59.52; (80.00)	70.90; (93.50)	49.51; (68.20)	43.12; (52.2)

Bold italic indicates estimates; --- = no data available
[a] Currency is expressed in year of budget. It is not adjusted to present value.
[b] Projects supported by public funds

with the European Commission–Joint Research Centre. A draft survey to obtain valuable, quantifiable information about costs was piloted among a small group of experts in November, 2014 at the National Renewable Energy Laboratory in Golden, Colorado, the United States. The survey design was improved to maximize the value of responses. The survey will be administered online in 2015. An extension of the task through 2018 is under consideration.

Task 27 Small Wind Turbines at Turbulent Sites is an extension of the original Task 27 that developed a label and testing approach for small wind turbines. The current effort conducts research to improve the IEC standards applying to small wind turbines. Work is under way to gain a better understanding of the special, turbulent wind conditions found in areas of complex terrain such as urban environments and develop potential changes to small wind turbine design per IEC 61400-2. Many papers were published in 2014 on the experimental and modeling activities of the task.

Task 28 Social Acceptance of Wind Energy Projects is translating the findings of social scientists into the language of planners and engineers to improve the process of bringing wind energy projects to completion. In 2012, participants developed and IEA Wind approved Recommended Practices 14: Social Acceptance of Wind Energy Projects, a guide to good practices by developers and local authorities. In the second term of the project through 2015 participants have evaluated the role of "positive intermediaries" in reducing conflicts between citizens and developers of wind projects. In 2015, work will continue to develop approaches to measure and monitor social acceptance.

Task 29 Mexnext II: Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models is working with field and wind tunnel data sets to improve aerodynamic models used to design wind turbines. An inventory of unexplored experiments has been assembled. Calculations in comparison with the measurements were performed for four cases in axial flow of the NREL Phase VI (NASA-Ames) experiment. The results were published in 2014. The main activity in 2014 was the New Mexico experiment, in the Large Low-speed Facility (LLF) of German-Dutch Wind Tunnels (DNW) in the Netherlands. The lessons learned from the former Mexico experiment were also used to design experiments aimed at understanding several unexplained phenomena found during the Mexico experiment.

Task 30 Offshore Code Comparison Collaboration Continued, with Correlation (OC5) is coordinating the work of 93 participants from 45 organizations in 15 countries to improve the design of offshore wind turbines using verified and improved codes. Task 30 (OC5) was extended in April 2014 for four years and two phases. Phase I will consider two separate datasets. The first dataset is provided by MARINTEK. A paper summarizing the work will be presented at the International Society of Offshore and Polar Engineers (ISOPE) conference in June 2015. A second dataset of a fixed cylinder provided by DTU/DHI will be completed. A final report on OC4 will be published in 2015.

Task 31 Wakebench: Benchmarking Wind Farm Flow Models has defined a framework for model evaluation activities. Most of the work is organized around benchmark exercises on verification and validation test cases. To manage these exercises, the www.windbench.net web platform has been made available by CENER. This tool is designed such that the test case can be managed by the owner of the data, with standardized procedures on how to define a test case, schedule the benchmark exercise, and administer access to the data. A three-year extension of Task 31 was approved in October 2014. The extension will be called Task 31 WAKEBENCH: Verification, Validation, and Uncertainty Quantification (VV&UQ) of Wind Farm Flow Models.

Task 32 LIDAR: Wind Lidar Systems for Wind Energy Deployment provides an international information exchange on lidar technology. In 2012, participants and an extended group of experts developed *Recommended Practice 15 Ground-Based, Vertically-Profiling Remote Sensing for Wind Resource Assessment*. IEA Wind Task 32 will refine this document based on results of the task work into a second edition and provide input to IEC standards development. The results of two comparative studies were published at the Science of Making Torque from Wind Conference in summer 2014. The first tested the rotor equivalent wind speed method under different shear conditions and with different measurement technics. The second compared the different approaches applied by participants to reconstruct the wind vector from nacelle-based lidar measurements. In 2015, a recommended practice for the use of floating lidar systems will be prepared based on the experience of and data collected by participants in offshore experimental campaigns.

Task 33 Reliability Data: Standardization of Data Collection for Wind Turbine Reliability and Operation & Maintenance Analyses is applying the experience of reliability analyses and failure statistics to determine common terminologies, prepare formats and guidelines for data collection, and set up procedures for analysis and reporting. Internal reports have been assembled from the survey of 28 initiatives collecting reliability data. These and two other state-of-the-art reports from working groups will supply the foundation for developing Recommended Practices for Reliability Data.

Task 34 Environmental Assessment and Monitoring of Wind Energy Projects on Land and Offshore (rebranded in 2014 as Working Together to Resolve Environmental Effects of Wind Energy [WREN]) was approved in 2012 to advance the global understanding of the environmental effects of land-based and offshore wind energy development. In 2014, participants began drafting a white paper on adaptive management, conducted two webinars (one focused on bat interactions with land-based wind energy, the other focused on the attraction and interaction of marine mammals and seabirds to offshore wind), and established the WREN hub as a source of information and scientific literature related to the environmental effects of wind energy development.

Task 35 Full-Size Ground Testing of Wind Turbines and their Components began in 2013. Task 35 is gathering the key stakeholders in the wind industry together to discuss consistency in the development and use of system test benches for wind turbines and their components. During the startup phase, a blade test group and a nacelle assembly test group has been set up. The blade test group work included canvasing and comparing static and fatigue wind turbine test methods and capabilities of worldwide laboratories. The nacelle test group is working to describe nacelle tests, compare test facility capabilities, and to compare test procedures with functionality aspects (wind loads, grid loads, control structure, and environment).

For details on recent activities and published reports, visit www.ieawind.org and select the task number from the home page.

5.0 The Next Term

Wind energy production will continue to supply an increasing percentage of the electricity needs of the world. Increasing performance of the world's wind generation fleet will continue to expand its role in the electricity generation portfolio. In some countries, consistent incentive schemes will be needed to restart growth in deployment. Wind turbines with towers, blades, and generators designed for specific locations will incorporate the latest technology to extract the greatest amount of energy from the wind. On land, improved technology will allow expanded, cost-effective installation of wind turbines in forested and otherwise complex terrain.

Offshore wind applications will greatly expand the generation capacity of many nations.

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[6] IEA Wind. (2013). *Strategic Plan for 2014–2019.*

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[7] European Network of Transmission System Operators (ENTSO-E) https://www.entsoe.eu/data/data-portal/production/Pages/default.aspx

Statistics for IEA Wind member countries have been provided by the authors of the country chapters and represent the best estimates of their sources in March 2015. For the latest information, visit www.ieawind.org.

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2 Implementing Agreement

1.0 Introduction

The overall aim of IEA Wind is to support development of cost-effective wind turbine systems that can be connected to an optimized and efficient grid or be used to supply electricity without being connected to the grid. National governments agree to participate in the IEA Wind Implementing Agreement so that their researchers, utilities, companies, universities, and government departments may benefit from the active research tasks and information exchange of the group. Interested parties in member countries should contact their country representative about ways to benefit from the IEA Wind research tasks. IEA Wind Members are listed at www.ieawind.org.

Under the auspices of the International Energy Agency (IEA*), the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind†) is a collaborative venture among 25 contracting parties from 20 member countries, the Chinese Wind Energy Association (CWEA), the European Commission, and the European Wind Energy Association (EWEA) (Table 1). Since it began in 1977, participants have worked together to develop and deploy wind energy technology through vigorous national programs and through co-operative international efforts. They exchange the latest information on their continuing and planned activities and participate in selected IEA Wind research tasks.

Each year, the IEA Wind agreement issues a report on its activities and those of its Member countries and organizations. This, the thirty-seventh *IEA Wind Annual Report*, lists accomplishments by the close

Table 1. Participants in IEA Wind in 2014	
Country/Organization	Contracting Party to Agreement
Austria	Republic of Austria
Canada	Natural Resources Canada (NRCan)
Denmark	Ministry of Business and Economic Affairs, Danish Energy Authority
European Commission	The European Commission
Finland	The Finnish Funding Agency for Technology and Information (TEKES)
France	Government of France
Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
Greece	Center of Renewable Energy Resources (CRES)
Ireland	Sustainable Energy Authority of Ireland (SEAI)
Italy	Ricerca sul Sistema Energetico (RSE S.p.A.) and Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)
Japan	National Institute of Advanced Industrial Science and Technology (AIST)
Korea	Government of Korea
México	Instituto de Investigaciones Electricas (IIE)
Netherlands	Ministry of Economic Affairs
Norway	Norwegian Water Resources and Energy Directorate (NVE) and Research Council of Norway
Portugal	National Laboratory of Energy and Geology (LNEG)
Spain	Centro de Investigaciónes Energetícas Medioambientales y Tecnológicas (CIEMAT)
Sweden	Swedish Energy Agency
Switzerland	Swiss Federal Office of Energy
United Kingdom	Offshore Renewable Energy Catapult
United States	U.S. Department of Energy
Sponsor Participants	
CWEA	Chinese Wind Energy Association
EWEA	European Wind Energy Association

of 2014. The Executive Summary (Chapter 1) compiles information from all countries and tasks to highlight important statistics and trends. Activities completed in 2014 and planned for 2015 are reported for the overall agreement (Chapter 2) and for the research tasks (Chapters 3 through 15). Member country chapters (Chapters 16 through 37) describe activities in the research, development, and deployment of wind energy in their countries during the year just ended. The *IEA Wind 2014 Annual Report* is published by PWT Communications, LLC in Boulder, Colorado, United States, on behalf of the IEA Wind Executive Committee (ExCo).

2.0 Collaborative Research

Participation in research tasks (Table 2) is open to any organization located in member countries of IEA Wind (Table 1). Member countries choose to participate in tasks that are most relevant to their current national research and development programs. A lead organization in each country must agree to

* The IEA was founded in 1974 within the framework of the Organization for Economic Co-operation and Development (OECD) to collaborate on international energy programs and carry out a comprehensive program about energy among member countries. The 29 OECD member countries, non-member countries, and international organizations may participate. For more information, visit www.iea.org.

† The IEA Wind implementing agreement (also known as the Wind Energy Technology Initiative) functions within a framework created by the International Energy Agency (IEA). Views and findings in this Annual Report do not necessarily represent the views or policies of the IEA Secretariat or of its individual member countries.

Table 2. Active Cooperative Research Tasks (OA indicates operating agent that manages the task)	
Task 11	Base Technology Information Exchange OA: Vattenfall, Sweden (1987–2008) changed to CENER, Spain (2009–2012; 2013–2014; 2015–2016)
Task 19	Wind Energy in Cold Climates OA: Technical Research Centre of Finland - VTT (2012-2015)
Task 25	Design and Operation of Power Systems with Large Amounts of Wind Power OA: Technical Research Centre of Finland – VTT, Finland (2012-2014; 2012–2015)
Task 26	Cost of Wind Energy OA: NREL, United States (2013-2016)
Task 27	Small Wind Turbines in High Turbulence Sites OA: CIEMAT, Spain (2012-2015)
Task 28	Social Acceptance of Wind Energy Projects OA: ENCO Energie-Consulting AG, Switzerland (2012-2014)
Task 29	Mexnext: Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models OA: ECN, the Netherlands (2012-2014; 2015–2017)
Task 30	OC3/OC4/OC5: Offshore Code Comparison Collaborative Continuation with Correlation OA: NREL, the United States and Fraunhofer Institute for Wind Energy and Energy System Technology (IWES), Germany (2010–2013; 2014–2017)
Task 31	WAKEBENCH: Benchmarking of Wind Farm Flow Models OA: CENER, Spain and NREL, United States (2010-2013)
Task 32	Lidar: Wind Lidar Systems for Wind Energy Deployment OA: ForWind Center for Wind Energy Research, Germany (2012–2015)
Task 33	Reliability Data: Standardizing Wind Data Collection for Wind Turbine Reliability and Operation and Maintenance Analyses OA: Fraunhofer Institute For Wind Energy and Energy System Technology (IWES), Germany (2012-2015)
Task 34	Working Together to Resolve Environmental Effects of Wind Energy (WREN) OA: NREL, United States (2013–2016)
Task 35	Full-Size, Ground Testing of Wind Turbines and Components OA: Rheinisch Westfälische Technische Hochschule (RWTH) Aachen University, Germany (2013–2016)

the obligations of task participation (agree to perform specified parts of the work plan and pay a common fee for management of the task). Research tasks are approved by the ExCo as numbered annexes to the Implementing Agreement text. Tasks are referred to by their annex number. The numbers of active tasks are not sequential because some tasks are extended and some have been completed and do not appear as active projects.

In 2014, 13 active tasks were exploring issues of wind energy research, development, and deployment (R, D&D). Additional tasks are planned when new areas for co-operative research are identified by members. In 2014, member countries continued work on 13 tasks and had discussions about two potential new research tasks: Task 36 on forecasting and Task 37 on Systems Engineering. This work and potential work on noise abatement may begin in 2015.

The combined effort devoted to a task is typically the equivalent of several people working full-time for a period of three years. Each participant has access to research results many times greater than could be accomplished in any one country. Some tasks have been extended so that work can continue. Some projects are cost-shared and carried out in a lead country. Other projects are task-shared, in which the participants contribute in-kind effort, usually in their home organizations, to a joint research program coordinated by an operating agent (OA). In most projects, each participating organization agrees to carry out a discrete portion of the work plan. Often a participation fee from participating countries supports the work of the OA to coordinate the work and handle reporting to the ExCo.

Research efforts of each country are returned many times over. Table 3, taken from the End-of-Term report published in 2013, illustrates the added value to countries of active research tasks.

By the close of 2014, 20 IEA Wind research tasks had been successfully completed, two tasks had been deferred indefinitely, and 13 were working on solving issues of wind energy technology and deployment.

For more information about the co-operative research activities, contact the OA representative for each task listed in Appendix B of this report).

Final reports, technical reports, plans, and Recommended Practices produced by tasks are available through the IEA Wind

Table 3. Added Value of IEA Wind Research Tasks (Source: End-of-Term Report of IEA Wind, 2013)				
Task Number and Topic	Annual Fee per Country (EUR)	Total Labor Months from all Countries*	Value of Labor (EUR)**	Value/Cost per Country (EUR)
11 Experts Meetings	3,600	2yrs: 14	151,200	21
25 Integration	3,333	2yrs: 1,037	11,199,600	1,680
26 Cost	5,810	3yrs: 537	5,799,600	499
27 Small Wind	3,400	2yrs: 38	410,000	120
28 Social Acceptance	4,500	2yrs: 54	583,200	65
29 Aerodynamics	10,000	3yrs: 257	2,775,600	93
30 Offshore models	3,790	2yrs: 36	388,800	51

*Labor contributions equal in-kind effort designated in work plan, plus estimated contributing effort from related national projects including PhD work that is shared with the task for making reports and analysis for the effort.
** One labor month (140 hr) valued at 10,800 Euro

Web site: www.ieawind.org. Table 4 shows participation by members in active research tasks in 2014.

3.0 Executive Committee (ExCo)

The ExCo consists of a member and one or more alternate members designated by each participating government or international organization that has signed the IEA Wind Implementing Agreement. Most countries are represented by one contracting party that is a government department or agency. Some countries have more than one contracting party in the country. The contracting party may designate members or alternate members from other organizations in the country. International organizations may join IEA Wind as sponsor members.

The ExCo meets twice each year to exchange information on the R&D programs of the members, to discuss work progress on the research tasks, and to plan future activities. Decisions are reached by majority vote or, when financial matters are decided, by unanimity. Members share the cost of administration for the ExCo through annual contributions to the Common Fund. The Common Fund supports the efforts of the Secretariat and other expenditures approved by the ExCo in the annual budget, such as preparation of this Annual Report and maintenance of the ieawind.org website.

Officers

In 2014, Jim Ahlgrimm (United States) served as chair; Ignacio Marti (United Kingdom), John McCann (Ireland), and Brian Smith (United States) served as Vice Chairs. These officers were re-elected to serve in 2015.

Participants

In 2014, there were several personnel changes among the members and alternate members representing their organizations (See Appendix B IEA Wind Executive Committee 2014). For the latest and most complete ExCo member contact information, please click the IEA Wind Members tab at www.ieawind.org.

France was accepted as a new contracting party during 2014.

Meetings

The ExCo met twice in 2014 to review ongoing tasks, approve publications, plan for new tasks, and report on national wind energy research, development, and deployment activities (R,D&D). The first meeting of the year was devoted to reports on deployment activities in the member countries and in the research tasks. The second meeting was devoted to reports from member countries and tasks about R&D activities.

The 73rd ExCo meeting was hosted by The National Renewable Energy Centre (Narec) which is now known as Offshore Renewable Energy (ORE) Catapult. The meeting was held in Newcastle, United Kingdom, 19–21 May 2014. Forty-one participants included ExCo members or alternates from 17 participating countries and sponsor members. Presentations were given about all 13 active research tasks. The Common Fund audit report for 2013 was approved. The requested withdrawal of Australia from the agreement was approved effective December 31, 2013. The ExCo approved by email ballot on February 20, 2014 a 15% fee increase in 2014 (over 2013 levels) and 2.5% increase in each coming year. The revised budget was also passed in this email ballot. The technical tour included a tour of the Narec facilities, as well as supply chain companies Soil Machine Dynamics Ltd. And Offshore Group Newcastle Ltd. On May 21, IEA Wind and Narec sponsored a workshop *Fostering participation between the UK and IEA Wind* featuring speakers about Offshore Renewable Energy Catapult, the Supergen Wind Consortium, an overview of UK Energy Policy from the Department of Energy & Climate Change, and the Carbon Trust Offshore Wind Accelerator, as well as overviews of IEA Wind Tasks 11 Information, 25 Integration, 26 Cost, 27 Small Wind, 30 Offshore Structure codes, and 34 Environmental.

The 74th ExCo meeting was hosted by the Canadian Government through Natural Resources Canada, CanmetENERGY. The meeting was held at Charlottetown, Prince Edward Island, Canada, October 22 through October 24, 2014. Twenty-seven participants from 15 contracting parties were present at the ExCo meeting. The ExCo welcomed France as the newest member. OA

Table 4. Member Participation in Research Tasks During 2014

Participant *	Research Task Number												
	11	19	25	26	27	28	29	30	31	32	33	34	35
Austria													
Canada													
CWEA, China													
Denmark													
European Commission													
EWEA													
Finland		OA**	OA										
France													
Germany								OA		OA	OA		OA
Greece													
Ireland													
Italy													
Japan													
Korea, Republic of													
México													
Netherlands							OA						
Norway													
Portugal													
Spain	OA				OA				OA				
Sweden													
Switzerland						OA							
United Kingdom													
United States				OA				OA	OA			OA	OA
Totals	16	8	18	7	7	7	9	11	13	8	9	5	4

* For the latest participation data, check the task websites at www.ieawind.org.
** OA indicates operating agent that manages the task.

representatives from all 13of the active tasks gave reports. Budgets were approved for the ongoing tasks and for the Common Fund for 2015. The participants toured the Wind Energy Institute on PEI, and observed the electrical storage facility under test.

4.0 Decisions, Publications, and Outreach

In 2014, IEA Wind approved publication of the Final Technical Report (and management report) for Task 30 Offshore Code Comparison Collaboration Continued (OC5). In addition, Recommended Practices are under development in Task 27 Small Wind Turbines in High Turbulence Sites, Task 31 WAKEBENCH: Benchmarking Wind Farm Flow Models, Task 32 Lidar Systems for Wind Energy Deployment, Task 33 Standardizing Data Collection for Wind Turbine Reliability Studies, and Task 35 Full-Size Ground Testing of Wind Turbines and Their Components.

The ExCo approved extending Task 11 Base Technology Information Exchange through 2016, Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power through 2017, Task 29 Mexnext-III improving aerodynamic models, and Task 31 Wakebench: Benchmarking Wind Farm Flow Models through 2017.

The *IEA Wind 2013 Annual Report* was published in August 2014; 1,200 copies were printed and distributed to member organizations; and press releases were issued with links to the electronic version on the website. The Executive Summary of the 2013 Annual Report was printed as a separate document (1,000) and shipped to members with the Annual Reports. The IEA Wind document *Long-Term R&D Needs for Wind Energy for the Time Frame 2012–2030* was printed and sent with the Annual Reports to the Members.

Table 5. Priority Areas Address Strategic Objectives					
Priority Areas	Strategic Objectives				Active Tasks
	Reduce cost of wind energy use	Increase flexibility of transmission and power systems	Increase social acceptance of wind energy projects	Increase exchange of best practices	Collaborative IEA Wind efforts to address priority area
1: Wind Characteristics	•			•	11, 19, 27, 31, 32
2: Wind Power Technology	•		•	•	11, 19, 26, 27, 29, 30, 33, 35
3: Wind Integration	•	•		•	11, 25
4: Social, Educational, and Environmental Issues	•		•	•	11, 26, 27, 28, 34
5: Communications			•	•	All

The website, www.ieawind.org, continued to expand coverage of IEA Wind activities. Two Task 11 Proceedings of Experts Meetings from 2013 were posted on the public website. The 2013 Annual Report and Executive Summary as well as the *Long-Term R&D Needs for Wind Energy for the Time Frame 2012–2030* were announced through LinkedIn as the first use of social media for the IEA Wind agreement. Increased use of this portal to target audiences is planned for 2015. In addition, countless journal articles, conference presentations, and poster presentations drew upon the work of the IEA Wind research tasks. Many of these are posted on the task websites accessible from the home page of IEA Wind.

A planning committee consisting of the Chair, Vice Chairs, the Secretary, the former Chair, and the OA Representative for Task 11 Base Technology Information Exchange perform communication and outreach activities between ExCo meetings. One of these activities is providing support for IEA Paris initiatives. For example, the Vice-Chair attended the IEA REWP meeting in Paris.

Invitations to attend ExCo meetings were extended to Argentina, Belgium, India, IRENA, and Israel. All countries with active interest in wind energy are welcome to explore participation by contacting the Chair or Secretary by email at ieawind@comcast.net.

5.0 Strategic Planning 2014–2019 and Long-Term R&D Needs through 2030

Conducting activities that are in line with the Strategic Plan were major goals of IEA Wind in 2014[1]. The work concluded that significant cost reductions are possible with R&D in five strategic areas: 1) characterise the wind resource to support reliable and cost-optimised technology, 2) develop wind turbine technology for future applications such as large, highly reliable machines for offshore applications in shallow or deep waters, 3) develop technology that facilitates the integration of this variable energy source into energy systems, 4) improve existing methods to forecast electricity production from wind energy systems and to control wind power plants for optimal production and distribution of electricity, and 5) address challenges related to implementation uncertainties such as physical planning to optimise land use and minimise negative effects to people and nature.

[1] See End-of-Term Report 2009–2013 and Strategic Plan 2014–2019. 2013. www.ieawind.org.

3 Task 11 Base Technology Information Exchange

1.0 Introduction

The objective of Task 11 of the IEA Wind Agreement is to promote and disseminate knowledge through meetings of invited experts for information exchange on R&D topics of common interest to the IEA Wind members. Nearly every country of the agreement participates in this important task. These cooperative activities have been part of the Wind Implementing Agreement since 1978.

Table 1 lists the countries participating in Task 11 in 2014. These countries pay a fee to support the work of the Operating Agent (OA) that manages the Task. The Spanish National Centre of Renewable Energies (CENER) is the current OA.

Task 11 is an important instrument of IEA Wind. It allows members to react quickly to new technical and scientific developments and information needs. Task 11 documents bring the latest knowledge to wind energy experts in the member countries and present collections of information and recommendations for the work of the IEA Wind Agreement. Task 11 is also an important catalyst for starting new IEA Wind tasks.

Immediately following Task 11 meetings, resulting documents are made available to organizations in countries that participate in the Task. After one year, documents can be accessed on the IEA Wind public Web pages (www.ieawind.org) under the Task 11 heading.

2.0 Objectives and Strategy

The objective of Task 11 is to promote wind turbine technology through information exchange among experts on R&D topics of common interest. This exchange is primarily achieved by holding Topical Expert Meetings (TEMs) of invited experts. The meetings are hosted by organizations from the countries participating in the task.

The goal is to hold four meetings on different topics every year. Active researchers and experts from the participating countries are invited to attend these meetings. Meeting topics, selected by the IEA Wind Executive Committee, have covered the most important topics in wind energy for decades. A TEM can also begin the process of organizing new research tasks for the IEA Wind Agreement. Table 2 lists the TEMs held in the last five years (2009–2014). A list of all TEMs and links to their reports can be found on the ieawind.org website on the Task 11 tab.

A second activity of Task 11 is to develop IEA Wind Recommended Practices for wind turbine testing and evaluation. So far, 16 IEA Wind Recommended Practices have been issued. Many of the IEA Wind Recommended Practices documents have served as the basis for both international and national standards (Table 3).

Table 1. Countries and Organizations Participating in Task 11 During 2014		
	Country	Institution(s)
1	Republic of China	Chinese Wind Energy Association (CWEA)
2	Denmark	Danish Technical University (DTU) - Wind Energy
3	Finland	Technical Research Centre of Finland (VTT Energy)
4	Germany	Bundesministerium für Unwelt, Naturschutz und Reaktorsicherheit (BMU)
5	Ireland	Sustainable Energy Authority Ireland (SEAI)
6	Italy	Ricerca sul sistema energetico (RSE S.p.A)
7	Japan	National Institute of Advanced Industrial Science and Technology (AIST)
8	Republic of Korea	Korea Energy Management Corporation (KEMCO)
9	México	Instituto de Investigaciones Electricas (IEE)
10	Netherlands	Rijksdient voor Ondernemend Nederland (RVO) (Netherlands Enterprise Agency).
11	Norway	Norwegian Water Resources and Energy Directorate (NVE)
12	Spain	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)
13	Sweden	Energimyndigheten - Swedish Energy Agency
14	Switzerland	Swiss Federal Office of Energy (SFOE)
15	United Kingdom	Offshore Renewable Energy Catapult
16	United States	U.S. Department of Energy (DOE)

3.0 Progress in 2014

3.1 TEMs

The meetings are of the workshop type, where information is presented and discussed in an open manner. The participants themselves decide what they want to present. Guidance for presentations is given in the Introductory Note that is distributed along with the invitation to the meeting.

Usually the meetings last two days. Oral presentations are expected from all participants. The agenda usually covers the following items:

1. Collection of proposals for presentations
2. Introduction by the host
3. Introduction by the OA, recognition of participants
4. Presentation of the Introductory Note
5. Individual presentations
6. Discussion
7. Summary of the meeting.

Four TEM were organized in 2014, but two were cancelled. The proceedings of the conducted meetings were published on the FTP server for country members. They are available to the public one year after each meeting on www.ieawind.org.

3.1.1 TEM #76: Floating offshore wind plants

The meeting on Floating Offshore Wind Plants (April 29–30, 2014) was hosted by the Oceanic Platform of the Canary Islands (PLOCAN). The meeting had 21 participants from 10 countries (China, Germany, Italy, Japan, Republic of Korea, Netherlands, Norway, Spain, the United Kingdom, and the United States). Nineteen presentations were given.

The primary goal was to give the participants a good overview of the challenges encountered in floating offshore wind plants. Following the presentations, a general discussion took place among the participants. Topics selected for the discussion were:

- Levelized Cost of Energy
- Scale Models For Testing
- Validation Models
- Dedicated Floating Wind Turbine Control
- Advanced Technological Concepts for Wind Turbines.

The participants decided that more development of this technology is needed before a specific IEA Wind Task covering the selected priorities could be launched.

3.1.2 TEM #77: Best practices for wind turbine and plant end of life

The minimum number of registered experts was not met, so the meeting was canceled. The Netherlands Enterprise Agency, a Dutch agency, was the proposed host of this meeting originally scheduled for June 24–25, 2014. However, it was postponed because too few experts registered. The meeting was re-scheduled for September 30 to October 1, but failed to attract enough experts.

3.1.3 TEM #78: Field test instrumentation and measurement best practices

The meeting on field test instrumentation and measurement best practices on October 7–8 was hosted by Texas Tech University in the United States. The meeting was attended by 21 participants from eight countries (Denmark, Germany, Korea, the Netherlands, Norway, Spain, the United Kingdom, and the United States). The two days of presentations and discussions created enthusiasm among the group

Table 2. Topical Expert Meetings (2008–2013)		
No.	Meeting Title	Year
79	Meso-Scale to Micro-Scale Model Coupling (cancelled)	2014
78	Field Test Instrumentation and Measurement Best Practices	2014
77	Best Practices for Wind Turbine and Plant End of Life (cancelled)	2014
76	Floating Offshore Wind Plants	2014
75	Wind Energy in Complex Terrain	2013
74	Operation and Maintenance Challenges (Cancelled)	2013
73	Noise Reduction Technologies (Cancelled)	2013
72	Forecasting Techniques	2013
71	Wind Farm Control Methods	2012
70	Social Acceptance of Wind Energy	2012
69	Operation and Maintenance Challenges (Cancelled)	2012
68	Advances in WT and components testing	2012
67	Long Term R&D Needs on Wind Power	2011
66	Offshore Foundation Technology and Knowledge, for shallow, middle and deep water	2011
65	International Statistical Analysis on Wind Turbine Failures	2011
64	Wind Conditions for Wind Turbine Design	2010
63	High Reliability Solutions and Innovative Concepts for Offshore Wind Turbines	2010
62	Micrometeorology inside Wind Farms and Wakes between Wind Farms	2010
61	Wind Farms in Complex Terrain	2010
60	Radar, Radio Links and Wind Turbines	2009
59	Remote Wind Speed Sensing Techniques using SODAR and LIDAR	2009
58	Sound Propagation Models and Validation	2009
57	Wind Turbine Drivetrain Dynamics & Reliability	2008
56	The Applications of Smart Structures for Large Wind Turbine Rotor Blades	2008
*Meetings are sometimes cancelled if confirmed participants are fewer than five.		

on the various topics related to wind plant integrated R&D. At the end of the workshop, most participants felt that continued discussions and, potentially, an IEA Wind task on the topic would be a good path forward.

For advanced methods in multi-disciplinary design, analysis, and optimization (MDAO), the discussion focused mainly on the need for benchmarking efforts in MDAO at different levels of the system. There was a lot of enthusiasm about the topic but many different perspectives on what the main foci should be. Generally, the thought was that a simple focus (perhaps the rotor, or even just the aerodynamics of the rotor) might be a good place to begin because there are several groups engaged with MDAO work in that area, and the problem is more contained than at higher system levels. The group felt that continued discussion on the topic would be needed as part of an IEA Wind task proposal development.

Finally, the group identified the utility that systems engineering/integrated R&D frameworks could bring to the wind energy community primarily to transfer knowledge across traditional silos. The group felt that the framework should not be tied to a particular software platform, but that a more "pseudocode" type of approach could be very useful for providing a framework guideline that could be implemented by stakeholders in any number of different software platforms. Good examples of existing frameworks were the FAST, FUSED-Wind, and OpenWind platforms presented in the workshop.

More discussion and the development of an IEA Wind Task proposal on the topic was encouraged. All of the groups found some common ground and were very encouraging of the idea of forming an IEA Wind Task on integrated R&D around the themes discussed at the workshop.

3.1.4 TEM #79: Meso-scale to micro-scale model coupling

The next meeting on Meso-Scale to Micro-Scale Model Coupling was scheduled

Table 3. IEA Wind Recommended Practices

No.	Area	Edition	Year	First Ed.	Valid	Status
16	Wind Integration Studies	1	2013		Yes	
15	Remote Sensing for Wind Resource Assessment	1	2013		Yes	
14	Social Acceptance of Wind Energy Projects	1	2013		Yes	
13	Wind Energy Projects in Cold Climates	1	2012		Yes	
12	Consumer Label for Small Wind Turbines	1	2011		Yes	
11	Wind Speed Measurement and use of Cup Anemometers	2	1999			Document will be used by IEC 61400 MT 13, updating power performance measurement standards
10	Noise Emission Measurement	1	1997		yes	
9	Lightning Protection	1	1997		yes	See also IEC TR61400-24, Lightning protection for wind turbines
8	Glossary of Terms	2	1993	1987		See also IEC 60050-415 International Electrotechnical vocabulary: Wind turbine generator systems
7	Quality of Power	1	1984			Superseded by IEC 614000-21, Measurement and assessment of power quality of grid connected wind turbines
6	Structural Safety	1	1988		no	See also IEC 614000-1, ed. 2
5	Electromagnetic Interference	1	1986		yes	Also see CENELEC Draft prEN50373, Wind Turbines - Electromagnetic compatibility
4	Measurement of Noise Emission	3	1994		no	Superseded by IEC 61400-11, Acoustic noise measurement techniques
3	Fatigue Load Characteristics	2	1990	1984	yes	Part of IEC 61400-13 TS, Measurement of mechanical loads
2	Estimation of Cost of Energy from WECS	2	1994	1983	yes	
1	Power Performance Testing	2	1990	1982		Superseded by IEC 61400-12, Wind Power Performance

to be hosted by in Mexico by the Electric Research Institute (IIE). Unfortunately, the host was not able to support the meeting so the meeting was cancelled.

3.2 Future meetings

Planned TEM for 2015 are:

- TEM #80: Wind Energy Systems Engineering. January 12–13, Broomfield (CO), the United States
- TEM #81: Noise Reduction Technologies, April 23–24, Glasgow, the United Kingdom
- TEM #82: Uncertainty Quantification of Wind Farm Flow Models. June 11–12, Gotland, Sweden
- TEM #83: Mitigation of Wind Turbine Impacts on Radar. September 22–23, Germany

In addition, at the IEA Wind Executive Committee meeting in May 2014, the decision was made to re-establish regular meetings on aerodynamics similar to those formerly known under Task 11 as Joint Action Symposia. One of these will be scheduled for 2015.

4.0 Plans for 2015 and Beyond

In addition to organizing and conducting the four Topical Expert Meetings planned for 2015 and conducting a Joint Action Symposium on aerodynamics, the OA of Task 11 will work with the OAs of following tasks to develop additional IEA Wind recommended practices:

- Task 30 Offshore Codes Collaboration Comparison, Continuation with Correlation (OC5)
- Task 31 WAKEBENCH – Benchmarking Wind Farm Flow Models
- Task 32 Wind LIDAR Systems for Wind Energy Deployment
- Task 33 Reliability Data: Standardizing Wind Data Collection for Wind Turbine Reliability and O&M Analyses
- Task 35 Full-Size, Ground Testing for Wind Turbines and their Components.

Photo credit: PLOCAN (The Oceanic Platform of the Canary Islands)

Author: Félix Avia Aranda, National Renewable Energy Center (CENER), Spain.

4 Task 19 Wind Energy in Cold Climates

1.0 Introduction

Deployment of wind energy in cold climate areas is growing rapidly because of favorable wind conditions, increased air density leading to higher energy yields, low population densities, and increasing technological solutions. Wind resources in cold climate areas are typically good, but icing of turbines and low ambient temperatures pose additional challenges for wind energy projects. Icing of wind turbine rotor blades reduces energy yield, mechanical life time of turbines, and noise emissions, while it increases safety risks due to risk of ice throw. Low temperatures can affect turbines' mechanical lifetime if they are not taken into account in turbine design by using appropriate materials. Cold climate areas have gained more focus compared to the earlier years as the wind energy targets have been updated. Also, increased experience, knowledge, and improvements in cold climate technologies have enabled the economics of wind projects to become competitive in relation to standard wind projects.

By the beginning of 2013, the wind capacity in cold climates in Asia, Europe, North America, and Scandinavia was approximately 70 GW, although only a small portion of this wind turbine fleet was designed for icing and low-temperature conditions. The potential for installing new capacity between 2013 and 2017 in cold climate areas, such as in Canada, China, the northern United States, and northern Scandinavia, is vast, summing to a total of 50 GW and representing 20% of total global capacity. This means that the stimulus for further development of wind power projects and technology in cold climates is strong.

Turbine manufacturers have developed technical solutions for low temperatures for their standard turbines. First generation commercial solutions for de- and anti-icing of wind turbine blades have entered in the markets. R&D activities have been conducted in a number of countries to master the difficulties that atmospheric icing and low temperatures create. These activities aim to improve the economics of wind power in new areas around the globe. The coming years will be important for validating the new information and knowledge and analyzing the performance of the adapted technologies arising from on-going wind

Table 1. Countries and Organizations Participating in Task 19 During 2014

	Country	Institution(s)
1	Austria	Energiewerkstatt
2	Canada	Wind Energy TechnoCentre éolien
3	China	Chinese Wind Energy Association (CWEA)
4	Denmark	Technical University of Denmark (DTU) Wind Energy
5	Finland	VTT Technical Research Centre of Finland Ltd
6	Germany	Fraunhofer Institute for Wind Energy and Energy System Technology (IWES)
7	Sweden	Swedish Energy Agency/WindREN/ Meventus
8	Switzerland	Meteotest

energy projects, as well as gathering more information for public availability.

Task 19 Wind Energy in Cold Climates, an expert group under IEA Wind research collaboration, has been working to solve the additional challenges of cold climates since 2002. Table 1 shows the countries and organizations participating in Task 19 during 2014. The group collects, evaluates, and creates information covering all aspects of wind energy in cold climates, for example, assessing sites in icing conditions, clarifying the economics of cold climate wind projects, and improving health and safety issues and procedures.

2.0 Objectives and Strategy

The objectives of Task 19 for 2014 are as follows:

- Review current standards and recommendations from the cold climate point of view and identify possible needs for updates.
- Validate the IEA Ice Classification used for estimating the effects of atmospheric icing on energy production.
- Determine the current state of cold climate solutions for wind turbines, especially anti-icing and de-icing solutions that are available or are entering the market.
- Clarify the significance of extra loading that ice and cold climate induce on wind turbine components.
- Create a new Task 19 Available Technologies report and update the expert group study on guidelines for applying wind energy in cold climates.

The items above have been identified as key topics that are slowing cold-climate wind power development. The ongoing national R&D activities in task-participant countries are contributing to tackling these challenges and providing new information and know-how on the subject. The results of the ongoing national activities will improve the overall economy of wind energy projects in cold climates and, thus, significantly lower the risks of development in areas where low temperatures and atmospheric icing occur. The collaboration actively disseminates results through conferences and seminars, as well as the Task 19 website (http://www.ieawind.org/task_19.html).

3.0 Progress in 2014

In 2014, the Task 19 main activities focused on deriving major updates to the upcoming reports. A previous report, *IEA Wind Task 19 State-of-the-Art of Wind Energy in Cold Climates*, from 2013 will be renamed *Available Technologies for Wind Energy in Cold Climates* (target audience: wind farm developers and financiers) in order to clarify the distinction from the *Recommended Practices 13: Wind Energy Projects in Cold Climates* report (target audience: engineers and scientists). A draft outline for the Available Technologies report exists, and report writing has started.

In 2014, for the updated Recommended Practices, two major focus points were prioritized in order to provide the necessary pre-standards for the cold climate wind community:

1. Ice throw risk mitigation guidelines
2. A standardized method, T19IceLossMethod, for evaluating production losses due to icing, using only supervisory control and data acquisition (SCADA) data.

With the ice-throw guidelines, new, safer wind farms can be planned using the step-by-step approach. The ice throw guidelines are also to be used as a platform for standardizing vocabulary and applicable ice throw risk assessment methodologies. The T19IceLossMethod will enable extensive validation of the widely used IEA Ice Classification table developed in 2012 and boost dissemination of information among data owners (developers) and the scientific community.

During the year 2014, members of Task 19 were invited as speakers and chairs in numerous seminars, conferences, and workshops dealing with cold-climate wind energy. In total, Task 19 held six public presentations and numerous Task 19 references were mentioned, mainly in following events:

- WinterWind Conference, Sundsvall, Sweden [1]
- Quebec Wind Energy Conference, Gaspé, Quebec, Canada [2]
- Windpower Monthly forum: Optimising Wind Farms in Cold Climates, Helsinki, Finland

A journal article "Overview of cold climate wind energy: challenges, solutions, and future needs," by Wallenius and Lehtomäki (doi: 10.1002/wene.170), was published in Wiley WIRES, summarizing the current and future cold climate wind needs.

Two meetings were organized in 2014. The first meeting was held in Gaspé, Quebec, Canada, hosted by Wind Energy TenchnoCenter. The meeting was connected to the sixth Quebec Wind Energy Conference, also hosted in Gaspé, where Task 19 had an official workshop for all interested conference participants (also advertised in the conference program). The Task 19 workshop was a true success, with nearly 40 participants in total, ranging from research to government officials to wind turbine manufacturers.

The goal of the workshop was to listen to what the audience had to say. First, they were asked to identify key topics for wind energy

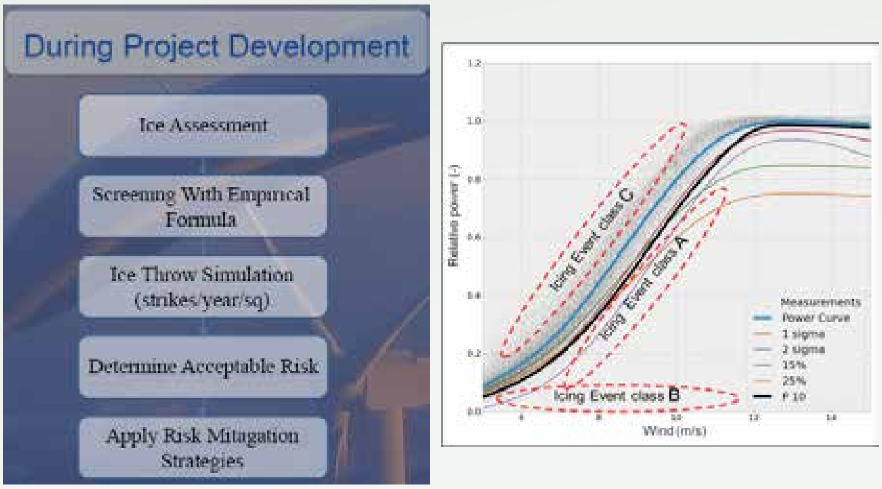


Figure 1. Left: Ice throw guidelines overview, Right: Production loss method from power curve

Figure 2. Task 19 Gaspé workshop (left: participants, right: review of results)

in cold climates. They answered with four main topics: 1) turbine anti- and de-icing, 2) turbine ice throw, 3) ice assessment, and 4) turbine icing loads and dynamics. The group was then split into smaller teams to answer the following questions about each topic within one hour:

1. What are the challenges?
2. What are your needs/requirements with respect to the topic?
3. Propose a list of solutions for challenges to fulfilling the needs. Don't be afraid of crazy ideas.

All groups were facilitated by a Task 19 participant who also documented discussions on paper flip charts. Detailed meeting minutes were made and distributed to all participants. This workshop also served as a great meeting place for Task 19 and the Quebec wind industry, as well as dissemination of Task 19 activities. The overall workshop was such a success that the format will be repeated at the Winterwind 2015 conference. Workshop minutes will be used when planning next Task 19 term for 2016–2018.

The second meeting was held in Aarhus, Denmark, hosted by Vestas, in conjunction with the large Scandinavian project Ice-Wind's final seminar. The SIRRIS/ Offshore Wind Infrastructure Application Lab (OWI-LAB) from Belgium participated in the meeting as an official observer. Based on this meeting, Belgium will participate in Task 19 as a new member.

In order to further boost Task 19 dissemination, Finnish and Swedish Wind Power Associations have posted Task 19 report links on their websites; all Task 19 participant countries plan to do the same. The new Task 19 website can be found at www.ieawind.org/task_19.html.

4.0 Plans for 2015 and Beyond

The main goals of the year 2015 are to:

- Update the fourth-term Recommended Practices with verification of the recommendations, especially the cold-climate site classification, methods for energy yield estimation, and health and safety recommendations to coordinate safety regulations with respect to icing conditions (ice throw).
- Finish the report Available Technologies for Wind Energy in Cold Climates.

Task 19 will hold two meetings in 2015, the first one in Belgium in June, and the second one in Austria in the fall.

References:

Opening photo: Wind energy in cold climate (Credit: A. Vignaroli, Source: VTT 2010)

[1] http://windren.se/WW2014/

[2] Summary of the conference as white paper: http://1.windenergyupdate.com/LP=162?utm_campaign=3500%20 13AUG14%20Con

Author: Ville Lehtomäki, VTT Technical Research Centre of Finland, Ltd, Finland.

5 Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power

1.0 Introduction

Wind power will introduce more uncertainty into operating a power system because it is variable and partially unpredictable. To meet this challenge, there will be a need for more flexibility in the power system. How much extra flexibility is needed depends on the amount of wind power and the existing flexibility of the power system.

The existing targets for wind power anticipate quite a high share of wind power in many countries. Wind integration studies are important measures to make sure the anticipated amounts of wind power can be accommodated in a power system. In addition to studies, there is growing real-life wind integration experience emerging from some countries; e.g., Denmark, Ireland, and the Iberian Peninsula (Spain and Portugal) already show a high penetration of 20–40% of yearly electricity consumption coming from wind power.

Comparisons between integration study results are difficult to make because they use different methodologies, data, and tools, as well as different terminology and metrics, in representing the results. Task 25 has worked on summarizing results from its participating countries, as well as formulating recommendations on best practices for integration studies. Because system impact studies are often the first steps taken towards defining wind penetration targets within each country, it is important to apply commonly accepted standard methodologies in system impact studies.

The Task 25 website is at www.ieawind.org under Task Web Sites. The public portion of the site contains the Task 25 publications, as well as literature bibliography, contact details of participants, and a Task work plan. The members-only section details the meeting presentations and information relevant to task participants.

2.0 Objectives and Strategy

The ultimate objective of IEA Wind Task 25 is to provide information to facilitate the highest economically feasible wind energy penetration in electricity power systems worldwide. Task 25 work supports this objective by analyzing and further developing the methodology to assess the impact of wind power on power systems. Task 25 has established an international forum for the exchange of knowledge and experiences related to power system operation with large amounts of wind power. Transmission system operators (TSOs) also participate in the meetings.

The participants are collecting and sharing information on experience in wind integration and from current and past studies. Their case studies will address different aspects of power system operation and design: reserve requirements, balancing and generation efficiency, capacity credit of wind power, efficient use of existing transmission capacity, requirements for new network investments, bottlenecks, cross-border trade, and system stability issues. The main emphasis is on technical operation. Also, technology that supports enhanced penetration will be addressed, such as wind power plant controls and operating procedures, dynamic line ratings, storage, and demand side management. Assessing costs has resulted in a lot of discussions, as it is hard to find a fully transparent and cost-reflective way of allocating system-wide costs to a single technology.

The task work began with a state-of-the-art report that collected the knowledge and results so far. This report, first published in 2007, was updated and published in 2009 as a final report of the 2006–2008 work. It was updated again in January, 2013, summarizing 2009–2012 work. The next edition is expected to be published in 2015, summarizing work in 2012–2014.

In September 2005, Task 25 of the IEA Wind Implementing Agreement was first approved for three years, 2006–2008, at Executive Committee (ExCo) meeting 56. The work was granted a fourth term from 2015–2017 at ExCo 74 in 2014. Table 1 shows the participants in the task. Since the initial 11 countries plus the European Wind Energy Association (EWEA) joined the first term, Canada, Japan, Italy, and China have joined Task 25 in the second and third phases. France and México joined in the fourth term.

Table 1. Countries and Organizations Participating in Task 25 During 2015–2017

	Country	Institution(s) coordinating work in countries
1	Canada	Hydro Quebec/Hydro Quebec Research Institute (IREQ)
2	Chinese Wind Energy Association (CWEA)	State Grid Energy Research Institute (SGERI)
3	Denmark	DTU Wind; TSO Energinet.dk
4	EWEA	European Wind Energy Association
5	Finland	VTT Technical Research Centre of Finland
6	France	EdF R&D; TSO RTE
7	Germany	Fraunhofer Institute for Wind Energy and Energy System Technology (IWES); TSO Amprion
8	Ireland	University College Dublin (UCD); Sustainable Energy Authority of Ireland (SEAI)
9	Italy	TSO Terna
10	Japan	Tokyo University; Kansai University; Central Research Institute of Electric Power Industry (CRIEPI)
11	México	Instituto de Investigaciones Eléctricas (IIE)
12	Netherlands	TSO TenneT; Delft University of Technology (TUDelft)
13	Norway	SINTEF Energy Research
14	Portugal	National Laboratory on Energy and Geology (LNEG), Institute for Systems and Computer Engineering of Porto (Inesc Porto)
15	Spain	University of Castilla-La Mancha
16	Sweden	Royal Institute of Technology (KTH)
17	United Kingdom	Center for Distributed Generation and Sustainable Electrical Energy (DG&SEE)
18	United States	National Renewable Energy Laboratory (NREL), Utility Variable Generation Integration Group (UVIG), U.S. Department of Energy (DOE)

Note: International Council on Large Electric Systems (CIGRE) Joint Working Group (JWG) C1, 3, 6/18, IEA Secretariat in Paris, and European TSO consortium European Wind Integration study (EWIS) have sent observers to meetings.

3.0 Progress in 2014

The meetings organized by Task 25 have established an international forum for exchange of knowledge and experiences. The spring task meeting in 2014 was organized in the United States in Golden, Colorado, hosted by NREL and DOE. The autumn meeting was hosted by the Research Institute for Energy Economy (FfE) in Munich, Germany.

Coordination with other relevant activities is an important part of the Task 25 effort. The system operators of Denmark, Italy, the Netherlands, and Quebec, Canada have been active in Task 25 work in 2014. Task 25 follows the Institute of Electrical and Electronics Engineers (IEEE) activities in new working groups for flexibility and operation of power systems.

Publication of the work is a key goal of Task 25 cooperative research. Collaborative papers on the following topics were presented during the 13th Wind Integration Workshop on Large-Scale Integration of Wind Power into Power Systems in 2014 in Berlin:

- The CO_2-reduction impacts of wind power
- Synergies between wind and solar generation and demand response
- An index for wind power variability
- An objective measure of interconnection usage for high levels of wind integration.

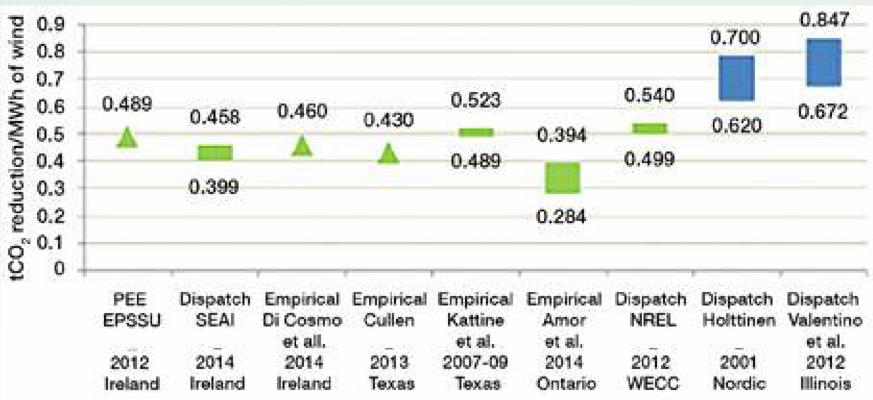
Two papers were presented on stability issues and Recommended Practices during the 2014 IEEE Power & Energy Society

(PES) summer conference. In 2014, general short summaries (fact sheets) of wind integration issues were prepared. The main fact sheet is a four-page document illustrating the main issues document. It is published on the Web. The linked two-page fact sheets for each topic will be finalised in 2015.

3.1 Impact of wind power in reducing CO_2 emissions

Several methods have been used to estimate the CO_2 reductions of wind power. In order to estimate CO_2 reductions caused by wind power, one should isolate the impact of wind power from all other changes in the system and compare the system with wind power to the system if it did not include wind power. There is no fully objective way to establish the comparative cases, and this is one reason for divergent methodologies and results concerning CO_2 reductions from any power source.

Estimates based on historical data have more pitfalls in methodology than estimates based on dispatch simulations. Taking into account exchange of electricity with neighboring regions is challenging for all methods. Results for CO_2 emission reductions from several countries are shown in Figure 1. Wind power reduces emissions for about 0.3–0.4 million tons of CO_2/MWh when replacing mainly gas and up to 0.7 million tons of CO_2/MWh when replacing mainly coal-powered generation. These are estimated CO_2 emissions from the power system operation phase.



Green—Power systems where predominantly gas is replaced
Blue—Power systems where predominantly coal is replaced

Figure 1. Comparison of estimated emission reductions from wind power

3.2 Recommended practices for wind integration studies

The methods of wind integration studies are evolving, building on experience from previous studies, with more data on system-wide wind power production and improved models. Task 25 has made a recommendation report to compile the best practices and instructions on how to perform an integration study. Best practice recommendations have been formulated on how to perform wind integration studies. The IEA Wind recommended practices *RP16 Wind Integration Studies* was published in October, 2013. Participants started by making a flow chart of all the phases of an integration study. A complete integration study includes several parts, which usually means an iterative process. Figure 2 shows this process, with relevant iteration loops from simulations to set-up and portfolio development. Often wind integration studies only cover one or a few parts of a complete study.

A wind integration study usually has as a starting point a set of input data. These data include wind power plant location and output, the configuration of the remaining power system, and the load level for the particular year(s) of interest. The study identifies a wind penetration level of interest to be studied (the blue boxes). At this stage, the scope of the system to be studied should be determined (i.e., the whole synchronous power system or a part of it).

The portfolio development step is needed to set up the details of the system to be studied—the present or future system, assumed generation fleet and transmission network, demand and flexibility options available, and interconnection options to neighboring areas. The basic setup assumptions have a crucial impact on the results of the study. For example, how the wind power is added—replacing something else or with the remaining generation staying the same—makes a difference. For lower penetration levels, the assumption that the remaining system stays the same can be used as a starting point. However, reaching higher penetration levels usually also means the conventional generation portfolio may change in the future system.

Changes in system management may need to be made from the start to accommodate large amounts of wind power. This involves checking the options for flexibility available in the power system through operational measures and through the transmission grid. Allocation, procurement, and use of reserves in a cost effective manner may also have to be changed.

Wind integration studies usually involve investigations of transmission adequacy, simulations of the operation of the power plants in the system and calculations on the capacity adequacy to meet the peak load situations (the green boxes in the flow chart, Figure 2). A more detailed level includes dynamic simulations and a flexibility assessment—these are necessary when studying higher penetration levels of wind power. Reliability constraints from transmission, capacity adequacy, or reserve margins may require iteration on the initial results to change the installed capacity of the remaining power plants, the transmission grid, the operational methods, or the reserves.

Analyzing and interpreting results of wind integration studies is not straightforward. The assumptions made and the setups of the study (such as investments in the remaining system) are crucial to determining the integration impacts. Larger wind shares in the power system usually mean ten to 30 years in the future, and the question is which other investments are to

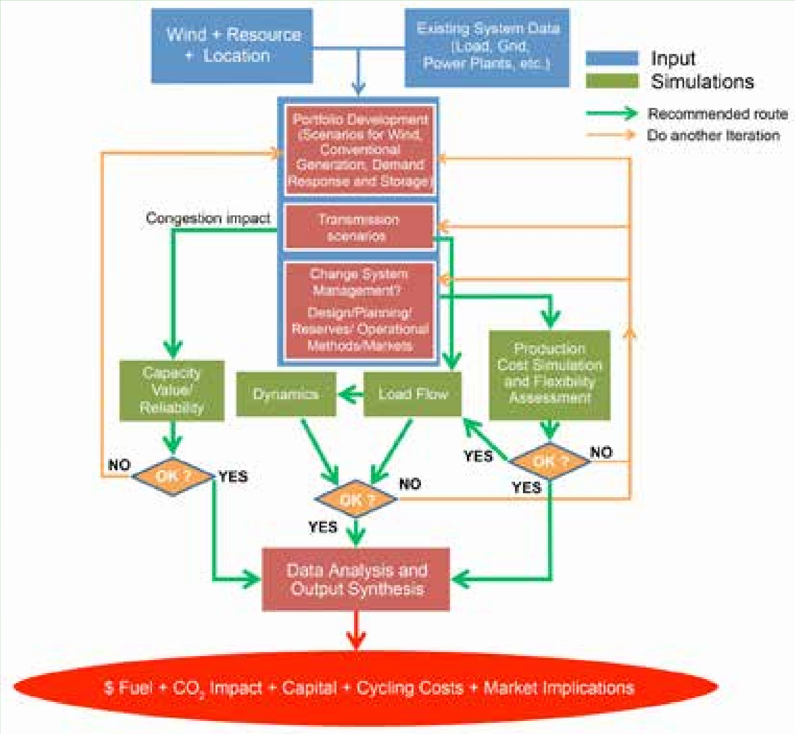


Figure 2. Flow chart of a complete wind integration study, showing relevant iteration loops from simulations to set-up and portfolio development

be performed in the power system during these years.

Integration costs are especially challenging to derive. Because system costs are difficult to allocate to any single plant or technology, wind integration studies aim to quantify the incremental increases in costs for power systems. One issue is grid reinforcement costs, with the allocation challenge that most grid upgrades also benefit other users.

Most studies so far have concentrated on the technical costs of integrating wind into the power system. Another approach is cost-benefit analysis. The benefit to adding wind power to power systems is the reduction of the total operating costs and emissions as wind replaces fossil fuels.

4.0 Plans for 2015 and Beyond

The spring meeting in 2015 will take place in April in Trondheim, Norway, hosted by SINTEF Energy Research. The fall meeting is planned for Paris, hosted by EdF R&D. Task 25 will seek more collaboration with IEA Photovoltaic Power Systems Program (PVPS) Task 14 on grid integration, with a joint meeting planned for the spring of 2016 in Denmark.

The summary report from the 2012–2014 phase will be published in 2015. Task 25 work and results are expected to be presented at several meetings: the IEEE PES summer conference in Denver in July, 2015; Wind Integration Workshop 2015 (WIW15) Brussels in 2015; and in the EWEA conference in 2015.

Journal articles and conference presentations will be drafted about critical modeling issues in wind integration studies, such as integration costs, electricity market design, curtailments, wind-hydro integration, forecast error modeling, and variability. Fact sheets on wind integration issues will be finalized. A database with one year of hourly time series of large scale wind power relevant for integration studies will be made public on the Web in 2015, and the literature list will be updated.

References:

Opening photo: Wind turbines supply electricity to the substation in Japan (Credit: Rick Hinrichs, Boulder, Colorado)

Author: Hannele Holttinen, Operating Agent Representative, VTT Technical Research Centre of Finland, Finland.

6 Task 26 Cost of Wind Energy

1.0 Introduction

Modern wind power generation is experiencing a unique situation. After decades of cost reduction leading to competitive levels with conventional technologies, the investment cost per megawatt began rising for new wind projects. This was associated with increasing commodity prices (mainly raw material such as copper and steel, plus a bottleneck in certain sub-products), tightness in the international market for wind turbines, and other factors. Recent expectations, however, include reductions in investment cost, along with increased performance due to a range of wind turbine options, which may yield historically low cost of wind energy. Figure 1 shows the estimated wind plant cost of energy in the United States for the single-turbine technology prevalent in 2002–2003 compared to the multiple-turbine technology offerings available in 2012–2013 [1].

In addition, natural gas prices have experienced a significant market impact resulting from innovative drilling practices in some parts of the world, particularly the United States. The impact of wind technology advances, market influences, and the relative cost of natural gas will influence the cost competitiveness of wind relative to other generation options.

This is precisely the background that justifies the continuation of Task 26 on the cost of wind energy. As wind is becoming an important source of electricity generation in many markets and competes with other technologies—notably natural gas—in terms of new installed capacity, it is crucial that governments and the wind research community are able to discuss the specific costs of wind systems on the basis of a sound methodology. Without a clear, impartial voice regarding the costs of wind systems, organizations without a clear understanding of wind systems are left to determine and publicize the costs of wind systems, often in error. These issues are exacerbated by the diversity of the wind portfolio and variations in international project development cost assumptions. The work undertaken in Task 26 is also expected to assess methodologies for projecting future wind technology costs. Finally this task aims to survey methods for determining the value of wind energy.

2.0 Objectives and Strategy

The objective of Task 26 is to provide information on the cost of wind energy in order to understand past, present, and anticipated future trends using consistent, transparent methodologies, as well how wind technology compares to other generation options within the broader electric sector. Task 26 will continue to add data and analysis, develop methodologies, and enhance collaboration.

Expected results include:

- Enhanced international collaboration and coordination concerning the cost of wind energy.
- Updated data, analysis, and understanding of land-based wind energy cost trends and comparison among countries.
- Identification of the primary offshore wind energy cost drivers and the variation of these costs among participating countries.
- Collaborative journal articles summarizing and further analyzing work conducted to understand trends in the cost of energy.
- Workshops or experts meetings on methods to value wind energy and methods to evaluate historical and future technology cost trends.

3.0 Progress in 2014

In 2014, efforts were focused in three areas: 1) development of a survey for wind energy experts to elicit perspective on future cost reduction potential for land-based, fixed-bottom offshore, and floating offshore wind technologies; 2) assessing data and methodologies for illustrating technology, cost, and financing trends for land-based wind energy

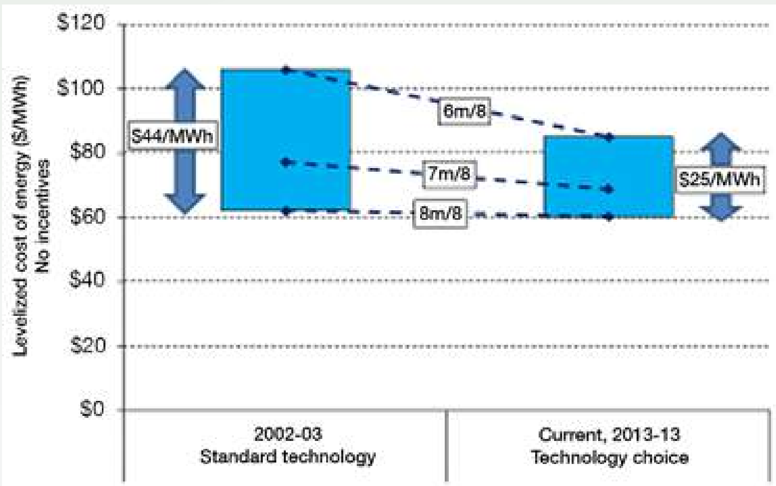


Figure 1. U.S. estimated wind plant cost of energy in 2002–2003 compared to 2012–2013 (in U.S. $)

Table 1. Countries and Organizations Participating in Task 26 During 2014

	Country	Institution(s)
1	Denmark	Denmark Technical University (DTU), EA Energy Analyses
2	EU	European Commission – Joint Research Centre (JRC)
3	Germany	Deutsche WindGuard; Fraunhofer Institute for Wind Energy and Energy System Technology (IWES)
4	Ireland	Dublin Institute of Technology (DIT)
5	Netherlands	Energy Center of the Netherlands (ECN), Top consortium for Knowledge and Innovation Offshore Wind (TKI Wind op Zee)
6	Norway	SINTEF, Norwegian Energy Agency
7	United States	National Renewable Energy Laboratory (NREL), Lawrence Berkeley National Laboratory (LBNL)

systems; and 3) collaboration among participating countries to assess offshore wind data and information needed to estimate the cost of offshore wind energy. In addition to the activities summarized below, a publication of the expert workshop proceedings for the "System Approach to Assessing the Value of Wind for the Society" held in November 2013 was published in conjunction with the European Commission–Joint Research Centre [2].

3.1 Future cost of wind energy perspectives

IEA Wind Task 26 investigates the current state and cost of wind energy technologies, and how costs might evolve in the future. One method for quantifying the potential cost of energy perspectives is expert elicitation, asking structured questions of top experts in the field for their perspectives. Task 26 participants are preparing a survey of top experts in the field that will cover land-based, fixed-bottom offshore, and floating offshore wind systems, aiming to capture insights from experts on three principle topics:

- The level of possible wind technology advancement and cost reduction
- The areas within which advancements and cost reductions are potentially most sizable
- The broad drivers most likely to facilitate wind technology advancements and cost reductions.

Ultimately, this work intends to inform policy and regulatory communities on future cost reduction potential, provide high level input into electric sector modeling assumptions, and highlight R&D opportunities.

A draft survey was created with input from experts in elicitation to obtain valuable, quantifiable information. The draft survey was piloted among a small group of experts in November, 2014 at the U.S. National Renewable Energy Laboratory in Golden, Colorado. This pilot survey was valuable in improving the survey design and questions in order to maximize the value of responses. The revised survey will be administered online in 2015.

3.2 Cost of land-based wind energy

Updated estimates of the cost of wind energy for land-based wind plants will be made based on the work conducted in the first phase of the task [3]. Participants collected and analyzed wind plant data representing projects installed in 2008 for each country, and a comparison was made across the countries to identify drivers and differences among them. This work will be updated by participants continuing in the task and expanded to include the new task participants, Norway and Ireland.

Data is required to represent the four primary elements of cost of energy: 1) total capital investment to bring a wind plant to commercial operation; 2) annual operating expenditures over the life of the wind plant; 3) annual energy production over the life of the wind plant; and 4) cost of financing the wind plant. Accessing such data for each project installed in a participating country is often difficult or incomplete. A variety of sources may be available, and each country's data availability and quality differs. Establishing trends from 2007 to 2012 in order to identify changes in wind technology and its associated impact on the cost of energy is anticipated to be a valuable addition to understanding the cost of wind energy in each country.

For example, Figure 2 illustrates trends in the United States and the European Union related to wind turbine "specific power" and hub height. In the figure, a box and whiskers format is used to represent the projects or turbines that achieved commercial operation in a given year, including the median (horizontal line), average (diamond), 25th to 75th percentile (box), and minimum and maximum (whiskers). The wind turbine specific power is defined as the turbine nameplate capacity rating divided by the rotor swept area (W/m^2). A lower specific power indicates that more wind energy can be extracted for a given generator size, thereby boosting capacity factors, all else being equal. In the United States, there is a trend toward lower specific power while maintaining a relatively consistent hub height from 2007 to 2012. In the European Union, the reduction in specific power is not as dominant, and tower height increases are evident. Both of these trends tend to increase energy capture. The impact these types of trends have on the cost of energy in each of the participating countries is discussed in a report that will be published in 2015.

Semi-annual meetings provide a valuable forum for exchanging ideas among the participants and engaging with other industry or research organizations. For example, a meeting held in Dublin, Ireland, in May 2014, included presentations and discussion from a number of Irish industry, government, and academic perspectives. This informal information exchange is highly valuable to the task overall, as well as for the participating national organizations.

3.3 Cost of offshore wind energy

Because offshore wind cost of energy is very site-specific and currently concentrated in a small number of markets, an approach for consolidating data among participating countries was devised. Data and model estimates for existing and planned offshore wind projects were combined and compared. A baseline representation of the physical characteristics of a typical offshore wind plant was developed. This approach allows for analysis of cost drivers based on information provided from the various participants and will represent offshore wind project costs generically—rather than specifically to those countries where projects are in operation. Using this baseline, each of the participating countries will explore country-specific deviations in market and policy conditions in order to identify and quantify both technical and policy-based cost drivers.

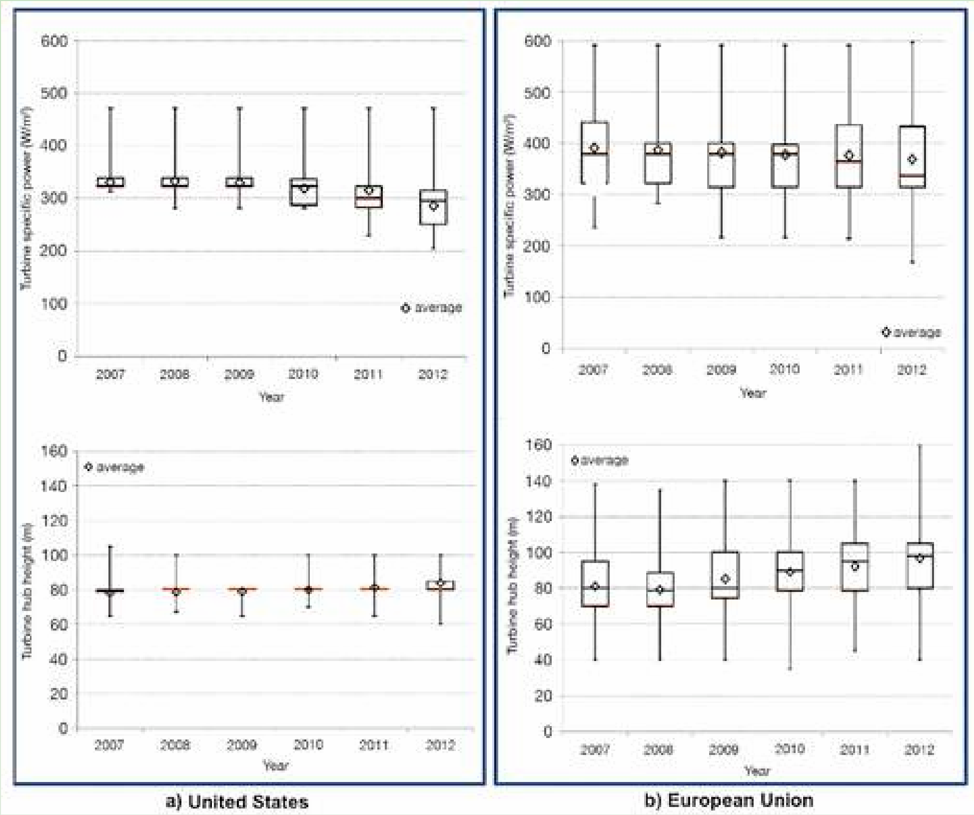


Figure 2. Trends in wind plant specific power and hub height from 2007 to 2012 in the United States and the European Union

4.0 Plans for 2015 and Beyond

In 2012, a task extension proposal was approved by the Executive Committee. The task extension includes the following activities over the subsequent three years (October 2012 through September 2015). An extension of the task through October 2018 is under consideration.

A report discussing trends in wind plant and turbine technology, cost, and performance will be published in 2015. Exploring trends in technology, as well as wind plant resource conditions over this period, enabled the participants to refine cost of energy estimates based on recent and anticipated technology trends. The format devised to present the statistical range of data reflecting projects in a given country is easily updated and will provide a mechanism for more current representation of the basic cost of energy parameters going forward.

Continued exploration of offshore wind cost drivers, both technical and policy-related will occur. Methodologies to compare the impact of these drivers are under consideration. Eventually a publication related to offshore wind cost drivers and country-specific impacts will be written.

The expert survey on future cost of wind energy will be conducted online in 2015. A broad range of wind industry experts from industry, research, and academia have been contacted. Results of the survey will be published in a journal article in a later phase of work.

In addition to these specific work packages, regular meetings will be held to stimulate collaboration among the participants, resulting in additional publications at conferences or in journals. Progress can be followed on our website (www.ieawind.org/task_26).

References:

[1] Lantz, E.; Wiser, R.; Hand, M. (2012). *IEA Wind Task 26—The Past and Future Cost of Wind Energy*; "Work Package 2 Final Report." NREL/TP-6A20-53510.

[2] Lacal-Arantegui, R.; http://setis.ec.europa.eu/publications/jrc-setis-reports/system-based-approach-assesing-value-of-wind-society and ieawind.org/task_26.html

[3] Schwabe, P.; Lensink, S.; Hand, M. (2011). *IEA Wind Task 26—Multi-national Case Study of the Financial Cost of Wind Energy*; "Work Package 1 Final Report." 122 pp.; NREL Report No. TP-6A20-48155.

Author: Maureen Hand, National Renewable Energy Laboratory (NREL), United States.

7 Task 27

Development and Deployment of Small Wind Turbine Labels for Consumers (2008–2011) and Small Wind Turbines in High Turbulence Sites (2012–2016)

1.0 Introduction

Small wind turbines have a great potential to provide electric power in remote and peri-urban windy areas and offer an important potential for distributed applications. The interest in distributed wind generation—the use of small wind turbines to produce clean energy for individual homes, farms, and small businesses—is growing at a rapid pace. With this technology, people are able to generate their own power, reduce their external energy supply, cut their energy bills, and help protect the environment.

Most small wind turbines are not designed for a roof, built environment, or urban setting because anything blocking the wind in the dominant wind direction creates high turbulence—the most difficult wind condition for all wind turbines of all sizes. The main goal of Task 27 is to offer the opportunity to share technical experience on measuring and modeling urban and peri-urban wind resources and gain practical experiences with built-environment wind turbines. IEA Wind Task 27 participants have identified new issues found in this urban and peri-urban environment and its effect on wind resource assessment methodology and trends of impacted turbine performance.

Task 27 work began late in 2013 and is proceeding very successfully within the planned schedule (duration of four years: 2012–2016). Five work packages were defined:

WP 1: Small Wind Association of Testers (SWAT)/Consumer label deployment

WP 2: Analyze and model highly turbulent wind resource

WP 3: Collection of "new" wind resource and turbine power performance data from rooftop /complex terrain test sites

WP 4: Recommended Practice on micro-siting of small turbines in highly turbulent sites

WP 5: Many designs of small wind turbines feature a vertical axis design approach. This work package will prepare for standards by developing a new approach to a simplified load calculation methodology for vertical axis wind turbines, and other multi-year research needed to improve the next, fourth revision of the IEC 61400-2 standard.

2.0 Objectives and Strategy

This work will require analyses of existing data and collection of new measurement data combined with analyses to provide an understanding of the turbine inflow, three-dimensional analysis of turbulence, and directional variability.

The objectives and expected results are:

- Promote the technical exchange of small wind turbine testing approaches and methodologies.
- Deploy the consumer label for small wind turbines based on IEA Wind Recommended Practice and the International Electrotechnical Commission (IEC) 61400-2 third revision, informative annex.
- Provide data and results along with guidance for a new design classification with specific guidance on I15 or similar variables for IEC 61400-2 and new information on external conditions; i.e., the normal turbulence model and extreme direction change found in Section 6 of 61400-2.
- Compare existing power performance test results (typically from accredited power performance test organizations) to power performance results taken in highly turbulent sites.
- Identify software tools that can be used to help understand the complex flow found in an urban environment.
- Validate simple computational fluid dynamics (CFD) models based on test data.
- Identify a common measurement and analysis approach.
- Develop a Recommended Practice that provides guidelines and information on micro-siting of small turbines in highly turbulent sites (urban/peri-urban settings, rooftops, forested areas, etc.) and the possible energy production for these sites.
- Develop a preliminary vertical-axis wind turbine simplified load methodology, which should be validated and used in consideration of the fourth edition of IEC 61400-2 (scheduled to start in 2018).

Table 1. Countries and Organizations Participating in Task 27 During 2014

	Country	Institution(s)
1	China	Chinese Wind Energy Association (CWEA)
2	Denmark	Technical University of Denmark (DTU)
3	Ireland	Dundalk Institute of Technology (DKIT)
4	Japan	National Institute of Advanced Industrial Science and Technology (AIST)
5	Korea, Republic of	Korea Institute of Energy Technology Evaluation and Planning (KETEP)
6	Spain	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)
7	United States	National Renewable Energy Laboratory (NREL)
	Australia (Observer)	Australian National Small Wind Turbine Centre (RISE) Murdoch University
	Austria (New partner in 2015)	University of Applied Sciences, Technikum Wien GmbH
	Argentina (Observer)	Instituto Nacional de Tecnología Industrial (INTI)
	France (Observer)	Scientific and Technical Center for Building (CSBT)

3.0 Progress in 2014

3.1 Meetings

During 2014, the activities of Task 27 were significant. Four meetings of participants were conducted: two virtual meetings and two face-to-face meetings. The first face-to-face meeting was held in Boulder, Colorado (the United States), hosted by NREL on May 7–8. The second was held in Zhang-bei (China), hosted by CWEA. The meetings in China included the Third Annual Conference of SWAT on August 25–27 and two days of IEC meetings on August 28–29. The two virtual meetings were held on February 12–13 (a call with Asia was on following day) and July 12–13.

3.1.1 Virtual meetings

The first virtual meeting was hosted by NREL and attended by 21 experts from Australia (2), China (11), Ireland (1), Spain (3) and the United States (4). The primary focus of this meeting was to define the new Work Package 5 for small wind turbine standardization issues like developing a simplified load methodology for vertical-axis wind turbines and refining the existing simplified load calculation methodology for horizontal-axis wind turbines.

Several important actions have been based on the calculations for the Hi-VAWT turbine using Dr. Su's vertical-axis wind turbine simplified load calculation methodology. NREL is installing a small vertical-axis wind turbine that will be instrumented for loads. It is a helical, 3-bladed design. Also, in China and Japan, universities are developing simplified load calculation methodology, blade design, and modeling vertical-axis wind turbines.

At the first virtual meeting, two presentations were given on urban wind assessment: "CFD Simulation of Wind Flow Over an Isolated Building," developed by Francisco Toja Silva CIEMAT PhD Fellow (Spain); and "Suitability of the Von Karman and Kaimal Spectra for the Structure of the Turbulence in the Built Environment for Small Wind Turbine Rooftop Applications," developed by Amir Tabrizi and Dr. Jonathan Whale from Murdoch University (Australia).

Tabrizi and Whale showed the results of their continued CFD modeling effort for the Bunning warehouse in Australia. Different modeling filters were used to get better correlation with model results. In conclusion, the author noted that the wind resource is unstable on rooftops, and for a neutral condition, the Kaimal model is more accurate for the lateral and vertical components of the wind vector. For the unstable condition, the Kaimal model is still better for the lateral and vertical components, but the Von Karman filter is better for the longitudinal component.

Other presentations addressed length scales and test stations. The need for a new definition of length scale for the built-environment was presented. The use of a common length scale definition of a ratio that is the height of the anemometer above the roof or container divided by the height of the roof was proposed. It would be good to use meteorological masts that can be raised to different heights for assessing the rooftop wind resource. The conclusion was that the rate z/h where z is the height of anemometer above the building and h is the height of the building could be strongly recommended. This approach can be used to compare different measurement sites.

Then construction of new field test stations for small wind turbines in mainland China was presented. This initiative is very important in China given that there are over 100,000 small wind turbines installed in China, and 65% of small wind turbines

Figure 1. Participants in the Third International Conference of SWAT in Zhang-bei (People's Republic of China), 25–27 August 2014

manufactured in China are installed in China. In order to improve the small wind turbines exported to other countries, a new test and certification body will be developed in Inner Mongolia and the southern coastal sites.

The U.S. testing setup at Johnson Space Center was described. NREL will be collecting data for seven to eight months.

New research data were offered to better interpret and understand urban and complex terrain. Analysis of the differences between 2-D and 3-D measurements proposed the following needs: breakdown the V52 data available from Dundalk Institute of Technology (DkIT) wind turbine into further wind sectors; use the Wind Atlas Analysis and Application Program (WAsP) to analyze roughness heights; redo 2011 data using WAsP to better characterize roughness heights; check the influence of these specific conditions on Cl and Cd characteristics for the blades of the Hy-Energy 3-kW turbine that is being offered for common use of a single turbine at multiple test sites.

Other questions and suggestions included: determine how to minimize the wind interference from the anemometer equipment; in measuring ambient conditions, decide how far away the measurements should be made; potentially use Japanese Civil Engineering classifications I-V to get a summary of the site characteristics and to determine whether to also define another qualitative or quantitative way to characterize the site more specifically; and analyze the possibility to use the IEA Wind Task 31 WAKEBENCH best practices.

The second virtual meeting was set up to review the upcoming third International SWAT and IEA Wind Task 27 meetings to be hosted by CWEA, the Chinese Wind Energy Equipment Association (CWEEA), and the National Wind Power Integration Research and Test Center (NWIC) in China. Agendas were revised to allow for significant research summaries presented by Chinese experts, mainly from two universities, the Inner Mongolia University of Technology, and Shandong University (China). Further work to develop a simplified load methodology for vertical-axis wind turbine was presented by Dr. Su (SWTDEL-Institute of Nuclear Energy Research [INER], Taiwan).

3.1.2 Face-to-face meetings

The first face-to-face meeting of IEA Wind Task 27 included participants came from Australia (observer), China, Denmark, Ireland, Japan, Spain, the United Kingdom (observer), and the United States. Participants discussed the new Work Package 5, titled "Preparation for next revision IEC 61400-2" that is being led by experts from China, Japan, and Korea. It involves two different activities, simplified load methodology for horizontal-axis wind turbines and for vertical-axis wind turbines. Existing simplified load methodologies for horizontal-axis wind turbines are open to misinterpretation. It is clear that a refined, simplified load methodology for horizontal-axis wind turbines is required. Data sets that clear up the discrepancies are currently available and will go a long way toward making this refinement for small wind turbine manufacturers. The United Kingdom would be a valuable contributor to this research topic.

Participants concluded that more information is needed on vertical-axis wind turbine energy production, loads, and yaw motion. In Japan, a plan for vertical-axis wind turbines was developed based on a request by Class NK, the Japanese certification body. An aero-elastic dynamic model is also needed for vertical-axis wind turbines to better understand them. Finally, a procedure to check the design of diffuser wind turbines must be established. A draft simplified load methodology for vertical-axis wind turbines is being developed based on horizontal-axis wind turbine models. While yawing load cases do not exist for vertical-axis wind turbines (they accept wind from all directions), revolutions per minute (RPM) issues for dynamics are still significant. Work needs to focus on reviewing and changing wind conditions for the next revision of the standard where there may be a link that influences simplified load methodology for both horizontal-axis and vertical-axis wind turbines

Dr. Julio Melero from Energy Resources & Consumption Research Center (CIRCE) (Spain) described a new European SWIP project (New innovative solutions, components and tools for the integration of wind energy in urban and peri-urban areas). The project shares common activities with WP 2 "Wind Resource Assessment in Urban Areas." Jason Fields (NREL, U.S.) and Dr. Melero discussed their interest using common analysis and data collection methodologies. CIRCE is currently using Open Foam and UrbaWind (large eddy simulation modeling) software tools. Members from UrbaWind are participating in the SWIP effort.

Raymond Byrne (DkIT, Ireland) gave a presentation on the V52 (52-m diameter, 850-kW) turbine installed on the campus at the Dundalk Institute of Technology. This presentation was an expansion of the work presented in previous meetings. There is a mountain that is 7 to 8 km to the north. There is also a high rise hotel that is 200 m southwest of the turbine. One conclusion is that there is no bi-modal distribution at 10 m, based on the V52 anemometer. Another conclusion is that buildings that are low and wide may have more influence on the wind resource than buildings that are tall and thin (high-rise hotel).

Francisco Toja of CIEMAT presented his work with Dr Carlos Peralta of IWES on CFD simulation work and on Reynolds-averaged Navier-Stokes (RANS) turbulence modeling of wind flow around buildings. For the standard k-epsilon (SKE) turbulence model, the turbulent kinetic energy does not match the experimental measurements. This is because the SKE turbulence model does not reproduce the recirculation on the roof well. Toja has developed a new modification of the Durbin model that, using the coefficient proposed by Crespo (School of Industrial Engineering-Technical University of Madrid [ETSII-UPM], Spain), shows better results. With this new configuration he has successfully validated the new turbulence modeling, and the recirculation matches the experimental results.

The meeting also involved several presentations about the small wind turbine market in the countries involved in the Task 27.

The second face-to-face meeting of IEA Wind Task 27 was held in conjunction with the Third International SWAT meeting was hosted by CWEA, Dr. He Dexin, and colleagues. The SWAT meeting was then followed by the final IEC Certification Advisory Committee (CAC) small wind turbine subgroup meetings.

The Task 27 meeting consisted of detailed discussions of turbulence test results for several sites and CFD results for specific Barber-Wind Turbines (BWT) test sites found in Japan (Takaaki Kono from Kanazawa University), China (Shandong University and Inner Mongolia University), and Taiwan. Regarding the implementation of a joint rooftop wind resource measuring strategy, BWT test specifications were defined by participants of China, the United States (NREL), and Taiwan (Ion Pei-Tat from the Metal Industries Research Development Center [MIRDC] and Prof Lee Kung-Yen from National Taiwan University [NTU]). Finally, Professor Hikaru Matsumiya presented comparisons between Japan's and China's simplified load methodology approaches for vertical-axis wind turbines. Virtual participants were also included, such as Francisco Toja (CIEMAT, Spain), and Jonathan Whale (Murdoch University, Australia).

The Third International SWAT Conference, attended by more than 45 experts from China, featured more than 30 presentations on small wind turbines, including: unaccredited testing, accredited testing, the latest in national standards and certification plans, new results from CFD studies of BWT turbines, new approaches to gathering yaw measurements for BWT turbine testing, lessons learned from small wind turbine testing, and progress in vertical-axis small wind turbines. The SWAT meeting used virtual capabilities with participation from Argentina [observer], Canada [observer], Spain, the United Kingdom [observer], and the United States.

It was concluded that a simplified load methodology for vertical-axis wind turbines needs to validate multiple configurations (Savonius type, Darrieus type, Hybrid type, H-type, and Helical type). Japanese and Chinese methodologies are for different configurations, which may explain part of the discrepancy in preliminary comparisons of the two. Japan is working on the H-rotor configuration and the Chinese are working on the hybrid Darrieus/Savonius rotor. This will be an area that requires further contribution, particularly from partners who can contribute helical rotor information.

3.2 Publications, presentations, and agreements

3.2.1 Publications

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Bashirzadeh Tabrizi, A. Whale, J., Lyons, T. Urmee, T. (2014) *Rooftop wind monitoring campaigns for small wind turbine applications: effect of sampling rate and averaging period* (submitted to J. Renewable Energy)

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Use of CFD to gain insight into inflow conditions on the rooftop of the bunnings warehouse in Port Kennedy-WA. Jonathan Whale and Amir Tabrizi (Murdoch University, Australia).

Thoughts on Standardisation of Measurements from Roof-top Wind Monitoring. Jonathan Whale and Amir Tabrizi (Murdoch University, Australia).

Historical Data Analysis. Future data analysis and testing. Ray Byrne. Center for Renewable Energy at Dundalk IT CREDIT, Ireland)

NASA JSC Building 12 Wind Energy. Project Assessment. Jason Fields NREL, the United States

CFD Analysis of Wind Conditions at the Tokyo Observation Site. Takaaki Kono (Kanazawa University, Japan)

Developing BWT Test Plans in Taiwan. Chin-Jen Chang. (INER, Taiwan)

Turbulent Wind Flow. Seokwoo Kim, (Korea Energy Technology Evaluation and Planning [KETEP] Republic of South Korea)

Comparison of V-SLM between CNS and JSWTA. Wei-Nian Su (INER, Taiwan)

3.2.3 Agreements

Proposal of agreement with consortium of SWIP Project *New innovative solutions, components and tools for the integration of wind energy in urban and peri-urban areas* (EU FP7) www.swipproject.eu to exchange data and procedures with Task 27. Proposal of Agreement with the World Wind Energy Association (WWEA) Small Wind to implement the label in the www.small-wind.or web page. Development of a proficiency test for duration test per IEC 61400-2 between the IEC CAC and SWAT (summer 2014). Industry participation: HyEnergy, Zhejiang Huaying Wind Power Generator Co (China); Zephyr Co (Japan); Baiwind, Kliux (Spain); and UGE (United States).

4.0 Plans for 2015 and Beyond

The following are plans for 2015 and beyond:

- Develop a proposal on the methodology of rooftop small wind turbine power performance tests
- Investigate standardizing measurements from roof-top wind monitoring
- Discuss analysis and data collection methodology for rooftop/complex terrain testing and analysis
- Establish an approximate procedure for annual energy prediction of small wind turbines operating at highly turbulent wind sites
- Define a new IEC-2 wind class
- Develop simplified equations for all types of vertical-axis wind turbine rotors (Savonius, Darrieus, Giromill, Hybrid, and Helical)
- Deploy SWAT completely in 2015, along with completion of a status on governance issues and the organization of laboratories relationships.

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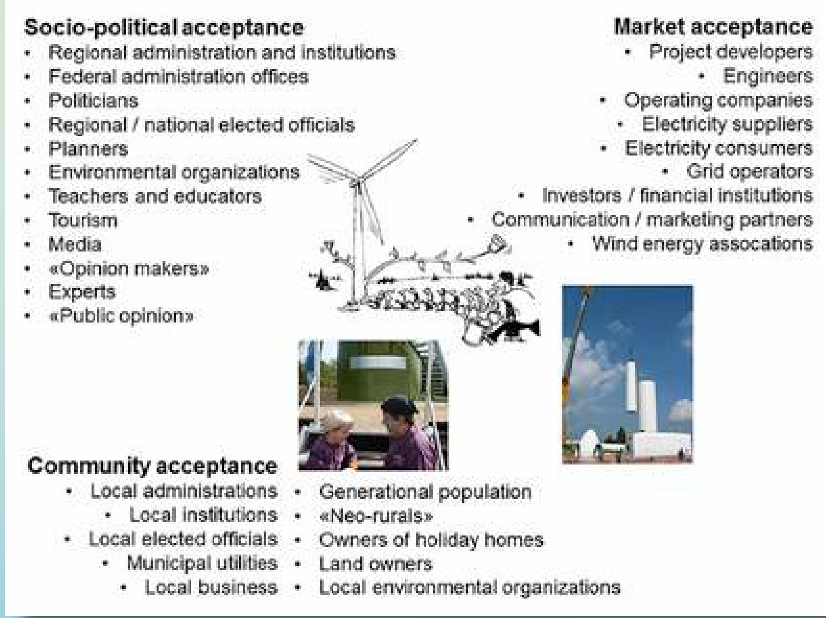
Opening photo: Two UGE VisionAir5 4-kW small vertical axis wind turbines installed on the Eiffel tower in Paris (Photo credit: Société d'Exploitation de la Tour Eiffel [SETE] and UGE International)

Authors: Ignacio Cruz, CIEMAT, Spain; and Trudy Forsyth, Wind Advisors Team, United States.

8 Task 28

Social Acceptance of Wind Energy Projects



1.0 Introduction

Wind power installations are complex technologies in terms of the actors involved in their development and implementation (see opening graphic). To develop wind power installations many authorities, organizations, and people are involved in numerous fields. These include planning grid integration, design and landscape/urban integration, health, safety and environmental issues, communication and participation processes, financing and community benefits. While there is a manager, usually with a technical background, for the general project, who takes care of the procedural issues?

In 2014, IEA Wind Task 28 focused on having intermediaries bring the various actors involved together. Task 28 defined the "positive intermediaries" as those engaged in the arbitration or mediation of the stakeholders involved in the deployment of specific wind energy projects, with the aim of building trust and acceptance of the deployment process. The term "positive" refers to process quality; while the outcome may not necessarily be positive for the promotor or a certain stakeholder, the positive intermediaries are mitigating or avoiding conflicts in a spirit of "Allparteilichkeit," meaning neutrality towards all interests. A range of institutions took on such roles, including governmental agencies (e.g., Agentschap NL in the Netherlands and the Wind Turbine Secretariat in Denmark), non-governmental organizations (NGOs), and businesses, such as consultants or even an individual person; e.g., a locally trusted leader. While some of them intentionally took on the role of intermediary or were even hired or called to do so, others stepped into this role rather accidentally. IEA Wind Task 28 intends to continue work on this issue in 2015 and present the results to the public in reports and publications.

In 2014, seven countries participated in Task 28 (see Table 1).

2.0 Objectives and Strategy

IEA Wind Task 28 supports participating countries and institutions by:

- Providing up to date information on social acceptance of wind energy in each of the participating countries.
- Identifying and documenting successful policy strategies anticipated to be applicable across local contexts.
- Enabling sharing of practical information, learning from each other, complementing each other's approaches.
- Discussing the complex issues around social acceptance and gaining additional insights from the broad transnational and interdisciplinary experience of the Task 28 network.

Table 1. Countries and Organizations Participating in Task 28 During 2014

	Country	Institution(s)
1	Denmark	Danish Energy Agency; Technical University of Denmark (participating since 2014)
2	Germany	Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety; Martin Luther University; University of the Saarland
3	Ireland	Sustainable Energy Authority; Queen's University Belfast
4	Italy	Ricerca Sistema Energetico (RSE)
5	Japan	National Institute of Advanced Industrial Science and Technology; Nagoya University
6	Switzerland	Federal Department of the Environment, Transport, Energy and Communications, Swiss Federal Office of Energy; ENCO Energie-Consulting AG
7	United States	U.S. Department of Energy; National Renewable Energy Laboratory, Wind Technology Center; Lawrence Berkeley Lab

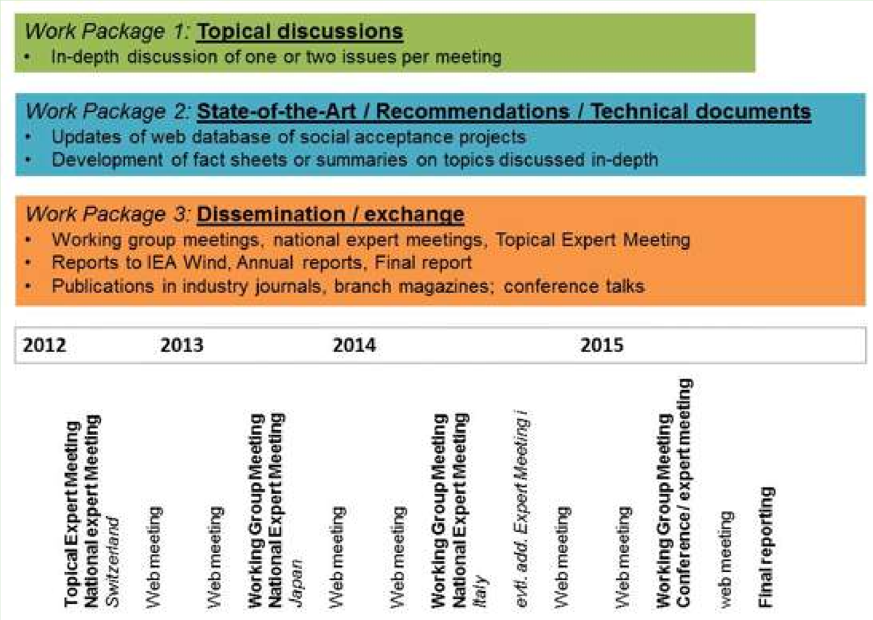


Figure 1. Work packages and timeline for IEA Wind Task 28, 2012–2015

- Working together on open issues and research gaps, including opportunities for joint research.
- Enlarging the network and knowledge of good practices by institutions, organizations, experts and practitioners.
- Providing reports, publications, and presentations in the language of planners, developers, authorities, and other stakeholders outside the research community who need to be sensitized on the issue to develop good projects.

The main issues of the 2012 to 2015 phase are "monitoring social acceptance" and "positive intermediaries." The means of Task 28 are working group meetings combined with national expert meetings, a Topical Expert Meeting, reports, recommendations and publications, and participation in conferences and the website, including a database of projects on social acceptance (See Figure 1).

3.0 Progress in 2014

As a highlight of 2014, IEA Wind Task 28 met for a working group meeting in Milano, Italy, in March 2014. The meeting was connected to a national expert meeting hosted by RSE, the Italian participant. About twelve Italian researchers and practitioners, as well as three IEA Wind Task 28 working group members, presented their activities and insights under the title of "Building and Measuring Public Acceptance of Wind Energy Projects" to provide a more thorough understanding of the current challenges in wind power implementation.

In connection with the IEA Wind Executive Committee (ExCo) meeting in the United Kingdom in May 2014, IEA Wind Task 28 organized a meeting of British experts on social acceptance of wind power and other energy technologies. While the response to the invitation was good in general, only a handful of the people could make it to the meeting. However, the discussions were fruitful, and some good relationships were established.

The in-person meetings were accompanied by several web meetings during the year covering preparation and small updates on projects from the different countries.

At the Milano meeting, the issue of positive intermediaries was tackled for the first time. The various experiences from the participating countries were collected, and parallels were drawn between the cases. A flash note presented to the ExCo in May 2014 described a characterization of the role and possible intermediaries, as well as suggestions for the further work on the issue. As a next step, the task members will document examples of positive intermediaries' work in different countries to give an overview of the possible approaches to this supportive kind of work.

The second focus of the task was to discuss monitoring the level of social acceptance further. It appears that the issue is much more complex than anticipated, and its in-depth treatment exceeds the current abilities of Task 28 members. Task 28 members will, thus, describe a number of different approaches to tackling the monitoring issue for research projects and have a follow-up in a next phase.

In 2014, IEA Wind Task 28 members collaborated with European research and exchange projects, namely the European Wind Energy Association (EWEA) WISE Power project, European Cooperation in Science and Technology (COST) Action TU1304, "Wind energy technology reconsideration to enhance the concept of smart cities" (WINERCOST), and the European Commission Joint Research Center's Energy—Transparency Center of Knowledge (E-TRACK) initiative. These collaborations will be increased in 2015.

4.0 Plans for 2015 and Beyond

The current phase of Task 28 ends in 2015. We plan a working group meeting in connection with a German expert meeting beginning of June in Berlin. The work will be dedicated to advancing the issue of positive intermediaries and finalizing the flash note on monitoring, as mentioned above. Task members will discuss the content of the final report, to be presented to the ExCo in the spring of 2016, as well as a possible succession of Task 28. The goal is to have the first discussion about continuation of the exchange on social acceptance issues at the ExCo meeting in the autumn of 2015. It remains to be seen whether there will be a second in-person meeting in 2015.

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9 Task 29 Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models (Mexnext I and II)

1.0 Introduction

It is well known that modeling wind turbine response (i.e., the power, load, and stability) is subject to large uncertainties. Many code validations; e.g., [1], show that most of these uncertainties come from aerodynamic modeling. This is not surprising given that every aerodynamic problem is covered by the "Navier Stokes" equations, which cannot be solved in an exact way.

A good illustration of the extreme complexity of fluid dynamics (hence aerodynamics) is that it is the subject of one of the seven millennium prize problems established by the Clay Mathematics Institute of Cambridge, Massachusetts (see www.claymath.org/millennium-problems/millennium-prize-problems). Within the class of aerodynamic problems, wind turbine aerodynamics even falls within the outer category in terms of uncertainties because wind turbines are exposed to very complex aerodynamic phenomena such as 3-D geometric and rotational effects, instationary effects, yaw effects, stall effects—where, moreover, the huge size of wind turbines adds complexity through large blade deflections, a very inhomogeneous inflow and very thick airfoils, see [51].

The availability of high quality measurements is the most important prerequisite to gaining insight into these uncertainties and validating and improving aerodynamic wind turbine models. At first, full-scale measurements seem to be preferred for this purpose. However, full-scale field experiments alone cannot answer all questions from the aerodynamic wind energy society because they suffer from large uncertainties caused by the stochastic atmosphere in which wind turbines operate. As such, the insights gained from full-scale field measurements have to be combined with insights from wind tunnel measurements, which are taken in a well-known, controlled environment.

The need for high-quality aerodynamic data was the most important reason for initiating IEA Wind Task 29 Mexnext. The first phase of Mexnext (Mexnext-I) ran for three years, beginning June 1, 2008. The main aim of Mexnext-I was to analyze the measurements from the European Union (EU) project "Mexico" (Model Rotor Experiments in Controlled Conditions) [2]. Ten institutes from six countries cooperated in experiments on an instrumented, three-bladed 4.5-m wind turbine placed in the largest (9.5 by 9.5 m^2) European wind tunnel at the Large Low-speed Facility (LLF) of German-Dutch Wind Tunnels (DNW) in the Netherlands. Measurements taken in December 2006 resulted in a database of combined blade pressure distributions, loads, and flow field measurements, which could be used for aerodynamic model validation and improvement. In Mexnext-I, a total of 20 participants from 11 countries participated. Mexnext-I ended in the end of 2011 [40]. Thereafter, a second phase of Mexnext (Mexnext-II) was approved and ran from 1 January 2012 to 31 December 2014.

In general terms, the work plan of Mexnext-II was very similar to the work plan of Mexnext-I. The main difference lies in the fact that the analyses included an inventory and further analysis of *all* historical aerodynamic wind turbine measurements (where history ranges from long ago to very recent and includes the Mexico experiment).

This was believed to lead to the maximum possible understanding of wind turbine aerodynamics. Note that the use of measurements from a large number of sources forms part of a sound scientific approach. In order to assess the general validity of aerodynamic models, they need to be validated with measurements on a wide variety of turbines.

Originally no new measurements were foreseen. However, in 2012 the EU Aerospace program ESWIRP approved a "New Mexico" project, which funded two weeks of (very expensive) tunnel time to carry out additional measurements in the DNW-LLF on the instrumented Mexico model wind turbine, which was still available from the Mexico project. As a result, the New Mexico experiment became one of the key activities in Mexnext-II.

The Operating Agent (OA) of Mexnext is the Energy Research Center of the Netherlands (ECN) (see Table 1).

2.0 Objectives and Strategy

The objective of the IEA Wind Task 29 Mexnext is to improve aerodynamic models used for wind turbine design based on aerodynamic (field and wind tunnel) measurements and on the resulting mutual cooperation and information exchange between aerodynamic experts worldwide.

The approaches in Mexnext-I and Mexnext-II are very similar, but there is a difference in the first Work Package (WP). The first WP in Mexnext-II carried out an inventory of unexplored experiments. In Mexnext-I the attention was focused on the Mexico measurements for which this inventory was not needed. Apart from that, both Mexnext-I and Mexnext-II were carried out according to the following WPs:

- WP2: Processing/presentation of data, uncertainties. The aim of this WP was to provide high-quality measurement data to facilitate and compare calculations. To that end, the quality of the data was assessed, and the data were reprocessed. Moreover, in the case of wind tunnel measurements, the tunnel effects were assessed.
- WP3: Comparison of calculated results from different types of codes with various measurement data. In this WP, the calculated results from the codes used by the participants were compared with the data from the various experiments.
- WP4: Deeper investigation into phenomena. Several phenomena were investigated with isolated sub-models, simple analytical tools, or by physical rules. The phenomena investigated include 3-D effects, instationary effects, yawed flow, and non-uniformity of the flow between the blades (i.e., tip corrections), the wake flow at different conditions, standstill, rotational effects, and boundary layer transition.

3.0 Progress in 2014

The main activity in 2014 was the New Mexico experiment, which was carried out in June and July, 2014. As mentioned before, the tunnel time for this experiment was funded by the EU ESWIRP project. It followed an extensive test matrix that included the "lessons learned" from the Mexico project so the quality of the New Mexico data could be even higher. The lessons learned were also used to design experiments aimed at understanding several unexplained phenomena found during the Mexico experiment. In addition to Mexico, the test matrix included acoustic measurements, measurements on flow devices, and measurements on "IEC aerodynamics" (measurements at faulty large-pitch misalignments for which it is generally very difficult to obtain measurements). The test matrix included pressure measurements, particle image velocimetry (PIV) measurements (covering a wider range than the PIV range in Mexico), load measurements, torque measurements, microphone array measurements, and application of several flow visualization techniques, as shown in the opening photo. The measurements were taken under several conditions, including yaw and dynamic pitch.

In preparation for the New Mexico experiment, the instrumented Mexico blades were placed in the Low Speed Tunnel (LST) of the TU Delft at quasi 2-D conditions. In the LST, the aerodynamic characteristics of the blades at standstill were measured (including flow visualization) so the blade instrumentation and data acquisition could be tested and recalibrated.

As a result of this thorough preparation, the New Mexico experiment was extremely successful. A first analysis of results [49], showed the data to be of very high quality. Generally speaking, the measurements from 2006 were reproduced very well, but some differences were found that explained the phenomena which, until now, appeared very puzzling.

Apart from the New Mexico experiment, the focus was on calculations carried out on the NREL Phase VI rotor at yaw. A very thorough analysis took place to understand the differences between calculations and measurements where, for example, a sensitivity study on discrepancies showed once more that care must be taken to draw the correct conclusions when comparing calculations with measurements. A good agreement between calculations and

Table 1. Countries and Organizations Participating in Task 29 During 2014

	Country	Institution(s)*
1	China	Chinese Wind Energy Association (CWEA)
2	Denmark	Danish Technical University (DTU)
3	Germany	Fraunhofer Institute for Wind Energy and Energy Systems Technology, University of Stuttgart (IAG), University of Applied Sciences at Kiel, ForWind, Windnovation, German Aerospace Laboratory DLR, Enercon
4	Japan	Mie University/National Institute of Advanced Industrial Science (Mie/AIST)
5	the Netherlands	Energy Research Center of the Netherlands (ECN), Delft University of Technology (TUDelft), Suzlon Blade Technology (SBT), and the University of Twente, Det Norske Veritas-Germanischer Loyd (DNV-GL)
6	Norway	Institute for Energy Technology/Norwegian University of Science and Technology (IFE/NTNU)
7	Spain	Renewable Energy National Center of Spain (CENER)
8	Sweden	Uppsala University Campus Gotland
9	the United States	National Renewable Energy Laboratory (NREL)

* Technion in Israel is a subcontractor to Task 29.

Figure 1. Mexnext project group in CARDC's large 12 x 16 m^2 wind tunnel (photo credit: CWEA)

measurement is generally seen as a strength of the code, but it can very well be caused by compensating errors, and, as such, it could be a sign of code weaknesses.

Finally, there were some other very interesting measurements from sources other than Mexico; e.g., PIV measurements from the Chinese Aerodynamics Research and Development Center (CARDC) on a scaled-down NREL Phase VI turbine.

All of the above mentioned results were discussed at the fourth meeting of Mexnext-II (i.e., the ninth meeting of the overall Mexnext project), which was held October 29–31, 2014 at CWEA in China. A visit to the large CWEA tunnel was included in the agenda, see Figure 1. In attendance was one of the former researchers who was responsible for the experiment carried out by the Aeronautical Research Institute of Sweden (FFA) in this large CWEA tunnel in the end of the 1980s. Measurements from this experiment have always been very interesting to the Mexnext team, but a lack of underlying information made the uncertainties large. The renewed contact with the former FFA researcher will make it possible to get the necessary information.

Note that, until now, results have been published and presented in numerous papers and articles, see [10], [11], [15]–[40], and [43]–[48], forming the basis for two PhD theses [41] and [42] and the wind tunnel data served for code validation purposes in a number of further PhD theses. Another very important means of dissemination of Mexnext information is through education; information from Mexnext is used in many lectures at universities.

4.0 Plans for 2015 and Beyond

Mexnext-II is finished and reported [50]. In October 2014, the IEA Executive Committee approved an extension of Mexnext: Mexnext-III. The kick-off meeting was held in March 2015. The main aim of Mexnext-III is to analyze the measurements from the New Mexico experiment (not forgetting the "other than (New) Mexico data" measurements).

Therefore, the project starts with a very detailed quality check of other than (New) Mexico data. Although several data have been checked already in [49] the remaining data still need to be assessed carefully. Thereafter, the measurements will be provided to the Mexnext project group in mid-2015, which enables the start of the data analysis. Parallel to that, a new calculational round is being carried out based on New Mexico data. This calculational round will be defined in April 2015, after which the Mexnext participants will start doing calculations.

Several "other than (New) Mexico data" have and will be provided; e.g., measurements and the underlying information on the experiment carried out by FFA in the large CARDC tunnel at the end of the 1980s [52] Also of interest are PIV data on a 1/8 scaled model of the NREL Phase VI turbine, which were provided by CWEA/CARDC in December 2014. These data will be compared to the original data from the NREL Phase VI experiment, which were heavily analyzed in the past IEA Wind Task 20.

The next plenary meeting of Mexnext will be held in January 2015 at NREL in the United States. The meeting will be held in combination with an IEA Wind expert meeting on aerodynamics organized by IEA Wind Task 11.

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Opening photo: Smoke visualizations in Large Low-Speed Facility (LLF) (9.5 x 9.5 m^2) of German-Dutch Wind Tunnel (DNW) (photo credit: T. Westra)

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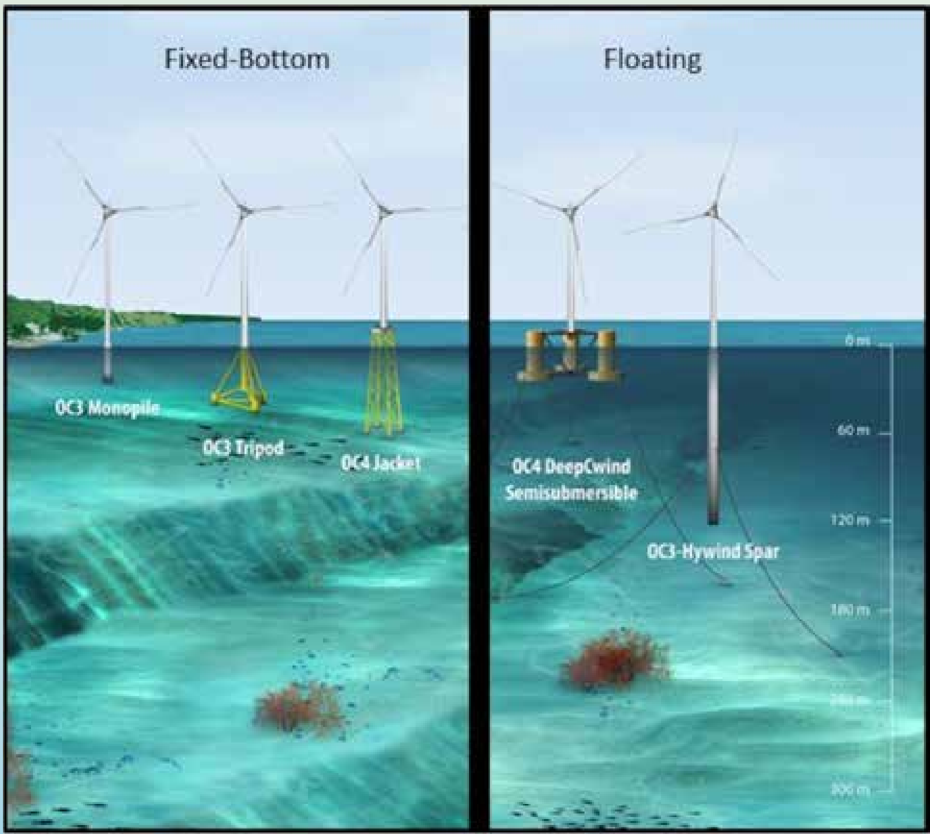
10 Task 30 Offshore Code Comparison Collaboration, Continued with Correlation (OC5) Project



1.0 Introduction

The vast offshore wind resources provide the potential for wind turbines installed offshore to make a significant contribution to the world's energy supply. Offshore wind turbine design can be complicated because offshore sites vary significantly in water depth, soil type, and wind and wave severity and require the use of a variety of support structure types, including fixed-bottom monopiles, gravity bases, space-frames—such as tripods and lattice frames ("jackets"), and floating structures. In this context, the offshore wind industry faces many new design challenges.

Wind turbines are designed and analyzed using simulation tools (i.e., design computer codes) capable of predicting the coupled dynamic loads and responses of the system. Land-based wind turbine analysis relies on the use of aero-servo-elastic computer codes, which incorporate wind-inflow, aerodynamics (aero), a control system (servo), and structural-dynamic (elastic) models in the time domain in a coupled simulation environment. In recent years, some of these codes have been expanded to include the additional dynamics pertinent to offshore installations, including incident wave characteristics, sea currents, hydrodynamics, and the foundation dynamics of the support structure. The high complexity and sophistication of these simulation codes underscores the need to verify and validate their accuracy.

The Offshore Code Comparison Collaboration (OC3), which operated under Subtask 2 of IEA Wind Task 23, was established to meet the need for model verification. Task 23 was completed in 2009. In 2010, a new project (OC4) was established to continue the work. OC4 ran from 2010 to 2013 and was led cooperatively by the National Renewable Energy Laboratory (NREL) and the Fraunhofer Institute for Wind Energy and Energy Systems Technology (IWES) under IEA Wind Task 30. The OC3 and OC4 projects were successful in showing the influence of different modeling approaches to the simulated response of offshore wind systems. Comparisons to measured data, however, will ensure that the solutions accurately represent physical behavior. To address this need for model validation, an extension of Task 30 was initiated in 2014, called OC5 (Offshore Code Comparison Collaboration, Continued, with Correlation).

The OC5 task has now finished its first year, during which 93 participants from 45 organizations in 15 countries participated in the task. Many more have participated via email but have not been able to attend physical meetings.

2.0 Objectives and Strategy

The purpose of the OC5 project is to perform a benchmarking exercise of offshore wind turbine dynamics computer codes. To test the codes, the main activities of OC5 are to (a) discuss modeling strategies, (b) develop a suite of benchmark models and simulations where corresponding physical data exists, (c) run the simulations and process the simulation results, and (d) compare the results in a side-by-side fashion to the physical response data. These activities fall under broader objectives, including:

- Assessing the accuracy and reliability of simulations to establish confidence in their predictive capabilities.

- Training new analysts to run and apply the codes correctly.
- Identifying, verifying, and validating the capabilities and limitations of implemented theories.
- Investigating and refining applied analysis methodologies.
- Identifying further research and development (R&D) needs.

The past verification work by OC3 and OC4 has led to dramatic improvements in model accuracy, as the code-to-code comparisons and lessons learned have helped identify deficiencies and needed improvements in existing codes. This new extension will further the accuracy assessment by comparing these simulated responses to response data recorded from actual offshore wind systems (a process called validation). The data used in this validation process will come from existing projects, and not be produced by OC5.

OC5 will contain a total of three different phases (see Figure 1). The offshore wind system concepts to be examined will not deviate far from those examined in the previous OC3 and OC4 tasks (while the concepts will be similar, the design details will change). The OC3 and OC4 projects, however, all contained the same wind turbine model, the NREL 5-MW reference turbine. Because we will be modeling real systems in OC5, each system will have a different wind turbine.

Phase I will actually contain no wind turbine in order to focus initially on the hydrodynamics modeling approaches and provide an easy first step for establishing appropriate validation practices to be used throughout the extension. Two different datasets will be examined, both consisting of tank tests of cylindrical members.

Phase II will re-examine the DeepCwind semisubmersible that was modeled during Phase II of OC4. The previous experience gained with this design will ease the validation process. The project will use data obtained from the testing of a 1/50th-scale model of the semisubmersible at MARIN in May 2013. A large number of tests were performed ranging from simple free-decay tests to complex operating conditions with irregular sea states and dynamic winds.

Phase III will use data obtained from a deployed open-water offshore system, at full scale. We are presently seeking permission from the Alpha Ventus project to use either their tripod or jacket design. If one of these systems is not available for OC5, we will seek out other alternatives.

Significant differences are expected in the validation approach used for these different types of systems and data, as well as significant differences in the challenges encountered. Tank test data provides good measurements of the excitation to the system, which is important in the validation process but inherently requires a scaled model, which will not necessarily capture the appropriate full-scale physics. Full-scale system data will provide more true physical responses, but it is much more difficult to accurately measure the environmental conditions that are causing those responses.

3.0 Progress in 2014

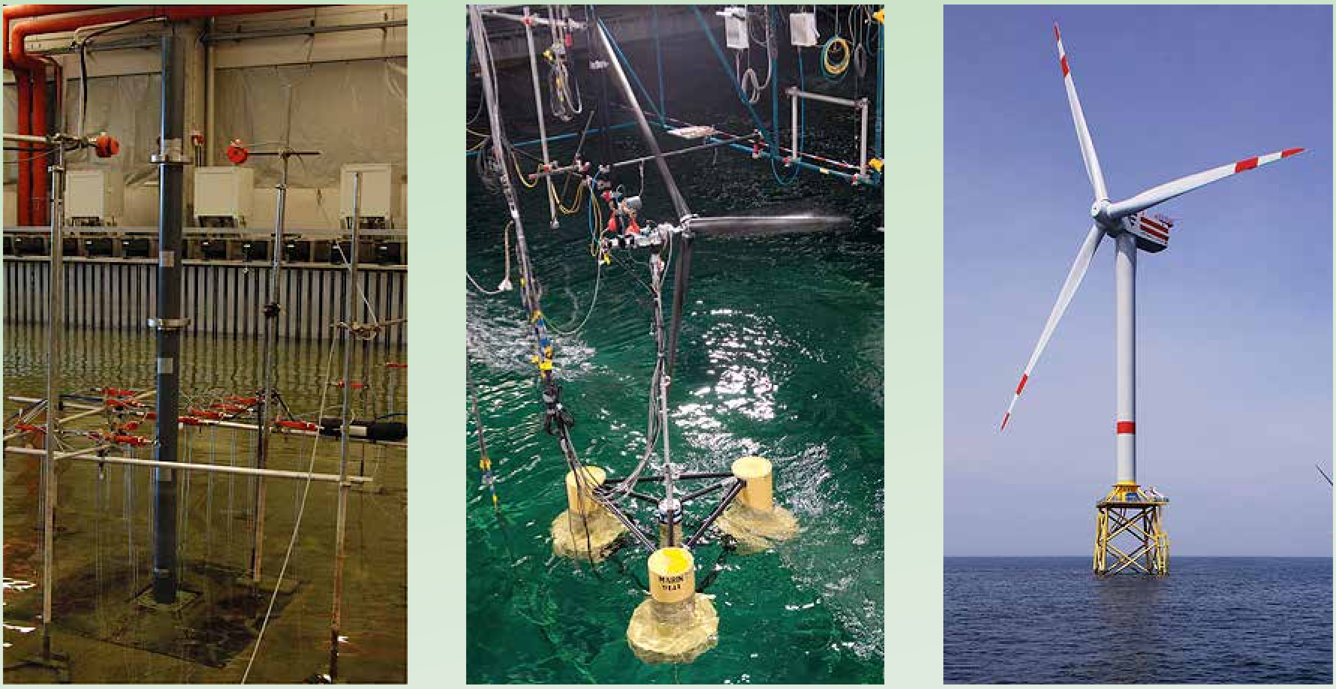
The OC5 project was initiated in April 2014 with a teleconference introducing participants to the scope and objectives of the work. This was followed by a physical meeting in conjunction with the Ocean, Offshore, and Arctic Engineering (OMAE) conference in San Francisco, CA in June. At this meeting, participants were given an overview of the OC5 project, and introduced to the first phase of work. Several other teleconferences were held throughout 2014 to review the work accomplished by the project team.

A number of tasks have been addressed since the project's initiation. The list below identifies the major accomplishments:

- The majority of original members of Task 30 have continued their participation in the extension. In addition, Italy has joined Task 30, and France and the United Kingdom are actively considering joining as well.
- Significant progress was made on Phase I of the project, which focuses on modeling cylinders in a wave tank.
- A specification document detailing the Phase I model to be built and available test data was created and disseminated to the project participants. The data was made available to the project by the Norwegian Marine Technology Research Institute (MARINTEK), the group that performed the tests.
- A set of load cases for the participants to simulate was decided and disseminated to the project participants.

Table 1. Countries and Organizations Participating in Task 30 During 2014

	Country	Institution(s)
1	China	China General Certification Center, Goldwind, Dongfang Electric Corporation
2	Denmark	Technical University of Denvark (DTU) Wind Energy (campus Risø), DHI, DONG Energy
3	Germany	Fraunhofer IWES, University of Stuttgart, Senvion, Leibniz University of Hanover (LUH), WindGuard Certification
4	Italy	Polytechnico Di Milano, Ricerca Sistema Energetico (RSE), University of Florence
5	Japan	University of Tokyo, Wind Energy Institute of Tokyo (WEIT)
6	Korea	Pohang University of Science and Technology, University of Ulsan
7	the Netherlands	Energy Research Center of the Netherlands (ECN), The Knowledge Center (WMC), Maritime Research Institute Netherlands (MARIN)
8	Norway	Norwegian University of Science and Technology (NTNU), Institute for Energy Technology, Marintek, 4Subsea, University of Stavanger, Simis
9	Portugal	Wave Energy Centre, Energias de Portugal (EDP), Center for Marine Technology and Ocean Engineering (CENTEC)
10	Spain	ALSTOM Wind, National Renewable Energy Center (CENER), Environmental Hydraulics Institute (IH Cantabria)
11	United States	ABS Consulting, National Renewable Energy Laboratory, University of Maine, Department of Energy, Penn State University, Texas A&M University
Observers	France	EDF Energy, INNOSEA, Direction des Constructions Navales (DCNS), French Institute of Petroleum New Energies (IFPEN))



(a) Phase I:
Monopile—Tank Testing
June 2014–June 2015

(b) Phase II:
Semi—Tank Testing
Jan 2015–May 2016

(c) Phase III:
Open Ocean Test
Jan 2016–May 2017

Figure 1. Offshore wind system designs to be examined in OC5

- Eighteen different organizations built a model for Phase I of the project. The first step by the group was to calibrate the models using a subset of the data provided, which included tuning the wave parameters and hydrodynamic coefficients. Participants then simulated the specified load cases and validation was performed by comparing the simulated total hydrodynamic force to the experimental measurements.

4.0 Plans for 2015 and Beyond

The IEA Wind Task 30 extension, OC5, will run for four years. Each phase will last for about one and a half years, with one year of overlap in the middle. Phase I of the project will consider two separate datasets. Work with the first dataset, provided by MARINTEK, is scheduled to be completed in February 2015. A paper summarizing the work will be presented at the International Society of Offshore and Polar Engineers (ISOPE) conference in June 2015. A second dataset of a fixed cylinder provided by DTU/DHI will be modeled by the group starting in February 2015, with an expected end date in the summer of 2015.

The next in-person meeting of the OC5 group will be held in February, 2015 in conjunction with the DeepWind conference in Trondheim, Norway. At this meeting, the work with the MARINTEK monopile will be summarized, and the second dataset from DTU/DHI will be introduced. A second in-person meeting will be held in June 2015 at the ISOPE conference, during which the work with the DTU/DHI data will be summarized and the modeling work for Phase II presented. Prior to the June meeting, a document describing the semisubmersible to be modeled in Phase II and the associated test data will be developed and provided to the group.

The verification activities that were performed in OC3 and OC4 are important because the advancement of the offshore wind industry is closely tied to the development and accuracy of dynamics models. OC5 will continue this important work by now focusing on validation using physical data measurements. Not only are vital experiences and knowledge exchanged among the project participants, but the lessons learned have and will continue to help identify deficiencies in existing codes and needed improvements, which will be used to improve the accuracy of future predictions.

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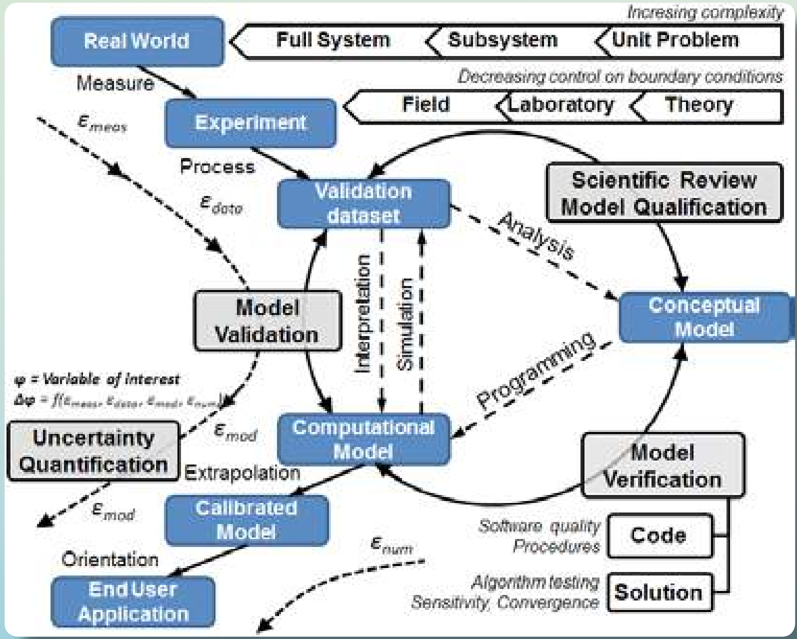
Opening photo: Graphic of the types of support structures considered in Task 30

Author: Walt Musial, Jason Jonkman, and Amy Robertson, NREL, the United States; Fabian Vorpahl and Wojciech Popko, Fraunhofer IWES, Germany.

11 Task 31 WAKEBENCH: Benchmarking Wind Farm Flow Models



1.0 Introduction

Since the late 1980s, with the appearance of the European Wind Atlas [1], the standard model for wind resource assessment has been the Wind Atlas Analysis and Application Program (WAsP) with its Wind Atlas Methodology. The alternative to linear models like WAsP, is to retain the nonlinearity of the Navier Stokes equations and simulate both momentum and turbulence with computational fluid dynamics (CFD) models adapted to atmospheric flows. Even though the computational cost is significantly higher compared to linear models, it is currently affordable for conventional personal computers.

Using CFD in operational wind resource assessment is less than ten years old, and there are currently a large variety of commercial and research models in the market. Yet, the transition from traditional linear models requires significant training and experience of the user due to the extended degree of freedom of the CFD solver, compared with the linear model, which is more user-dependent. To overcome this difficulty, commercial CFD software developers are designing user-friendly interfaces that can emulate, to some extent, the traditional way of working with linear models. CFD models for research, by contrast, are either based on generic commercial CFD solvers or in-house or open-source codes. They are used by researchers because of their flexibility to adapt to site-specific topographic and atmospheric conditions.

As with wind modeling, wake modeling for wind turbines originated in the 1980s with work by Ainslie (1988) [2]. These algebraic models, which are still widely used for wind farm layout today, are based on simple momentum and fluid dynamic similarity theories or simplified solutions to the Navier Stokes equations. The problem with these models is that they lack many of the required physical processes needed to predict wind turbine wake behavior, which results in unpredicted wake losses by 10% in many operational wind farms.

The turbine models embedded in an atmospheric model come in many different varieties and ranges of complexity, and they are used for different scales of calculations. As turbine models get more complicated, the details of the blade aerodynamics become more prevalent. With the need to calculate viscous aerodynamics of the blades, researchers have moved into CFD modeling. As with wind models, researchers have used Reynolds-averaged Navier Stokes (RANS), unsteady RANS, detached eddy simulations (DES), which is a hybrid of RANS and large eddy simulations (LES), and even full LES of rotating blades.

For both wind and wake modeling, the model developer has to design a model evaluation strategy that proves that the model is correctly formulated (verification) and provides an accurate representation of the real world from the perspective of the intended uses of the model (validation).

Verification, validation, and uncertainty quantification (VV&UQ) are fundamental problems in the development of any engineering model. This process allows a comprehensive transition from experience and test-based design to simulation-based design, producing more efficient and cost-effective design solutions [3]. The adoption of VV&UQ procedures is an unresolved issue in wind resource assessment due to the inherent complexity of the system to model.

As stated in the European Cooperation in Science and Technology (COST) 732 Action (2009) report on microscale model evaluation [4], there is no distinct definition of the requirements of a validation test case

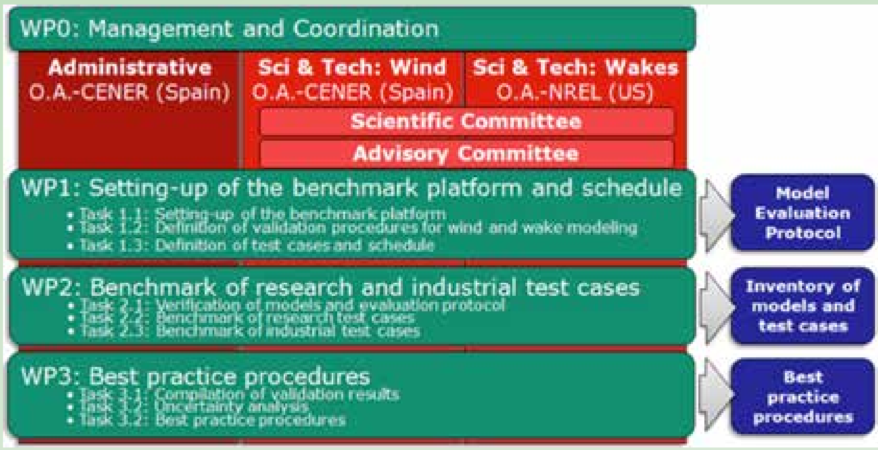


Figure 1. Structure of Task 31: Operating Agent (OA) duties, work packages (WP), and deliverables

dataset or the procedure to use it in a consistent and systematic way. A basic requirement for any validation exercise is that the model and the validation dataset share the same, or a very similar, hypothesis. This basic rule is already difficult to fulfil because most of the microscale wind assessment models are based on steady-state simulations, and field measurements are intrinsically transient and modulated by mesoscale effects. Intensive filtering of the field data and ensemble averaging is often necessary to match the desired flow conditions. A complementary solution to this "limitation" of the field data is to conduct wind tunnel measurements at a reduced scale. The controlled environment of the wind tunnel has been a fundamental tool for validation of CFD models even if, for atmospheric flows, all the similarity criteria cannot be met at the same time.

A clever strategy for VV&UQ that combines field and laboratory measurements will be developed in this IEA Wind Task. To this end, a set of verification and validation test cases will be selected for benchmarking of models with increasing levels of complexity. Some test cases are readily available from the literature; some others will come from experimental facilities and operational wind farms. These intercomparison case studies will produce enough background information for the discussion of the VV&UQ strategies.

2.0 Objectives and Strategy

The Task provides a forum for industrial, governmental, and academic partners to develop and define quality-check procedures, as well as to improve atmospheric boundary layer and wind turbine wake models for use in wind energy. The working methodology (Figure 1) is based on the benchmarking of different wind and wake modeling techniques in order to identify and quantify

Table 1. Countries and Organizations Participating in Task 31 During 2014

	Country	Institution(s)
1	Canada	York University, Montreal University
2	China	Chinese Wind Energy Association, China Aerodynamics Research & Development Center, North China Electric Power University, Nanjing University of Aeronautics, Goldwind
3	Denmark	Technical University of Denmark, Aarhus University, VESTAS Wind & Site, EMD International A/S, DONG Energy, Suzlon
4	Germany	ForWind - Oldenburg University, ZMAW - University of Hamburg, CFD+Engineering, DEWI, Helmholtz-Zentrum Geesthacht Centre for Materials and Coastal Research, Fraunhofer IWES, Anemos-Jacob GmbH
5	Greece	Center For Renewable Energy Sources
6	Italy	University of Perugia, University of Genoa, Italian Institute for Naval Hydrodynamic Research and Ship Model Basin (CNR-INSEAN), Sorgenia S.p.A., Karalit
7	Japan	University of Tokyo, Wind Energy Institute of Tokyo
8	Norway	Windsim, Statkraft, Agder Energy, Institute for Energy Technology, Sintef, CMR Gexcon
9	Spain	National Renewable Energy Center (CENER), Barlovento Recursos Naturales, ENEL Green Power, Iberdrola Renovables, Politechnic University of Madrid, Gamesa Eólica, AWS Truepower, Ereda, EDP Renovaveis, Suzlon, Vortex
10	Sweden	Gotland University, Statkraft, Vattenfall
11	Switzerland	École Polytechnique Fédérale de Lausanne, Swiss Federal Institute of Technology
12	United Kingdom	Oldbaum, Centre for Renewable Energy Systems Technology, Renewable Energy Systems Ltd, School of Engineering and Physical Sciences Heriot-Watt University, Mainstream, Natural Power UK, E.ON New Build & Technology, University of Surrey
13	United States	National Renewable Energy Laboratory (NREL), Indiana University, University of Washington, VESTAS U.S., AWS Truepower, Penn-State University, University of Minnesota, University of Wyoming, E.ON, Portland State University, University of Colorado, Johns Hopkins University, Case Western Reserve University, DNV Renewables (USA) Inc., Iowa State University, Los Alamos National Laboratory, Meteodyn U.S., Lawrence Livermore National Laboratory, 3Tier, WindLogics, General Electric, Rensselaer Polytechnic Institute, AES, RES Americas, Acusim

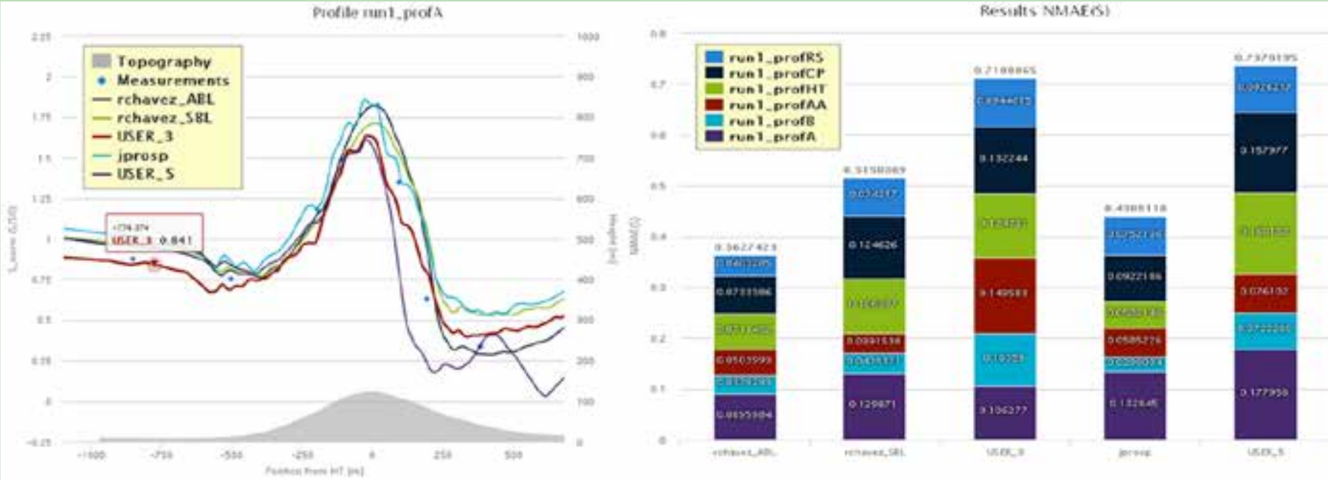


Figure 2. Example of model validation results for the Askervein hill test case

best practices for using these models under a range of conditions, both land-based and offshore, from flat to very complex terrain.

Most of the work is organized around benchmark exercises on verification and validation test cases. In order to facilitate the management of these exercises, the www.windbench.net web platform is made available by CENER. This tool is designed such that the test case can be managed by the owner of the data, with standardized procedures on how to define a test case, schedule the benchmark exercise, and administer access to the data. A set of questionnaires compile all the relevant information and guide the benchmark exercises. The evaluation process is ruled by a model evaluation protocol, the main deliverable of the Task [5].

3.0 Progress in 2014

Task 31 was completed in October 2014 with a final meeting in Beijing, China, hosted by the North China Electric Power University (NCEPU). An interim meeting took place in June at the Technical University of Denmark (DTU) right before the Torque 2014 Conference organized by the European Wind Energy Academy. Two papers were presented in the conference to summarize the benchmarking activities on flow over terrain [6] and wake models [7].

The Task has been successful at defining a framework for model evaluation activities (see opening graphic). This is quite challenging because different kind of models and user profiles, as well as different sources of experimental data, need to be reconciled. The model evaluation protocol [5] is accompanied by a website (Windbench.net), which contains a repository of test cases for validation, an inventory of models, and a workspace to organize benchmarking activities.

During the Task, new test cases have been progressively added to the Windbench portal following a validation building-block strategy of increasing complexity from similarity theory, flat and complex terrain flows, single turbines, and large offshore wind farm wakes. In total, 15 test cases have been proposed, around 30 benchmarks have been defined, and more than 20 models have been catalogued.

It will still take some time before everyone is acquainted with the benchmarking workflow of the Windbench platform. This training process is inherent to the Task goals of defining and improving the Model Evaluation Protocol (MEP) by practicing model intercomparison exercises to build consensus, a key aspect to arrive at consistent results in model validation.

A baseline metric based on the normalized mean absolute error has been established for model performance quantification. This metric is implemented in Windbench to produce automatic evaluation reports for benchmark participants using several variables of interest. Using an online evaluation tool reduces user dependencies by adopting a standardized metric and facilitates user interactivity and collaboration.

Figure 2 shows an example of model validation results for the Askervein hill test case automatically generated by the windbench platform. The stacked bar plot shows how the normalized mean absolute error from different models/users is added for different profiles of the experiment, while the figure on the left shows the model intercomparison results from one of these profiles, traversing the hill along its short axis at a height of 10 m above ground level.

4.0 Plans for 2015 and Beyond

The IEA Wind Executive Committee approved a three-year extension of Task 31 in October 2014. The extension of Task 31, still called WAKEBENCH will be titled "Verification, Validation, and Uncertainty Quantification (VV&UQ) of Wind Farm Flow Models." The kick-off meeting was scheduled for June 11, 2015, just after the Wake Conference hosted by Upsala University in Gotland, Sweden.

The model evaluation framework developed throughout the first phase of Task 31 for microscale wind farm flow models will be generalized to mesoscale and near-wake models in order to cover all the relevant atmospheric scales related to wind power meteorology. This will allow a more comprehensive approach to the wind farm integrated design process, facilitating the exchange of knowledge among various research communities: meteorologists, resource/site wind engineers, and wind farm/rotor aerodynamicists. The focus will still be on wind resource assessment, site suitability, and wind farm design, but also allows for a larger variety of modeling approaches. Some benchmarks will also be explored in finer detail to better quantify the uncertainty of a range of models for different phenomena.

Following Task 31 working procedures, the work will be organized around model intercomparison benchmarks and established on well-defined test cases from research and industrial measurement campaigns. High-fidelity data will come from large experiments planned in the frame of the New European Wind Atlas (NEWA) and Atmosphere to Electrons (A2e) research programs conducted in Europe and the United States, respectively. Uncertainty quantification of wind flow models will be considered as the final outcome of the evaluation process. As a result, a framework for model VV&UQ will be defined as a new edition of the MEP delivered in Task 31 and integrated in the windbench.net web portal.

References:

Opening photo: Graphic of Workflow of the VV&UQ framework as defined in the Wakebench Model Evaluation Protocol (Photo credit: Sanz Rodrigo and Moriarty, 2015)

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Authors: Javier Sanz Rodrigo, National Renewable Energy Centre of Spain (CENER), Spain; and Patrick Moriarty, National Renewable Energy Laboratory (NREL), United States.

12 Task 32 LIDAR: Wind Lidar Systems for Wind Energy Deployment

1.0 Introduction

Task 32 aims to address the very fast development of wind lidar technologies and their application to wind energy power systems. Specifically, the task investigates the use of lidar for more accurate measurement of wind characteristics that are relevant for a more reliable deployment of wind energy power systems. The task brings together the present actors in the industry and research community to create synergies in the many R&D activities already on-going in this very promising and new remote-sensing-based measurement technology. Task 32 is focused on lidar systems, while sodar has been addressed by previous IEA Wind Topical Expert Meetings. Task 32 was approved at Executive Committee meeting 68 in autumn 2011 and officially kicked off in May 2012. Currently, 45 institutions from 15 countries are involved in the task (see Table 1).

2.0 Objectives and Strategy

The main objective of the task is the publication of experimentally tested recommended practices and reports for wind lidar measurements based on the joint experience of the participants. The recommendations will be benchmarked with measured data collected at various meteorological and lidar operational conditions.

IEA Wind under Task 11 developed and approved in 2012 the *IEA Wind Recommended Practice 15: Ground-Based Vertically-Profiling Remote Sensing for Wind Resource Assessment* to set the stage for research on remote sensing. This document was also reviewed by participants of Task 32. Any further understanding gained in Task 32 will be collected and either summarized in an addendum to RP 15 or included in a second edition of this document.

State-of-the-art and technical reports will provide guidance for an accurate calibration of ground- and nacelle-based lidar. They will include information for a better understanding of lidar-measured wind and turbulence. They will also give indications about the application of lidar in flat terrain and complex flow conditions. Some reports will also be dedicated to the application of lidar for wind turbines, such as the application of rotor-equivalent wind speed or nacelle-based lidar for power curve assessment.

The scientific and technological content of Task 32 is subdivided in three subtasks, which are tailored into smaller work packages (WPs) as presented in Table 2. While ForWind–University of Oldenburg is acting as operating agent, the coordination of the three subtasks is delegated to the partners assisting the operating agent; i.e., DTU Wind Energy, NREL, and SWE–University of Stuttgart. One additional subtask is dedicated to the data management.

3.0 Progress in 2014

Two Task 32 meetings were held in 2014. The first was at the University of Stuttgart in March 2014, and the second at Strathclyde University in Glasgow in November 2014. These meetings included presentations from task participants and updates on the various WPs, and provided an opportunity to develop plans for the future.

3.1 Subtask 1: calibration and classification of lidar devices

This task addresses calibration of ground- and nacelle-based lidar. Participants in the task reported detailed studies that were carried out to better understand why the calibration of ground-based vertical profilers varies by around 1% from test to test, even in flat terrain (WP 1.1). In particular, data were analyzed applying either the standard averaging of the horizontal wind velocity provided by the lidar or by vector. Averaging was performed considering the average radial wind speeds measured by the individual laser beams before evaluating the horizontal wind vector.

The experimental results show a difference in the order of 0.2% between the two approaches. These results were found to be in agreement with theoretical models for atmospheric turbulence and lidar measurements. This study showed that the vector average has a lesser effect on the lidar measurements than on the reference sensor (cup anemometer) for the regression method and the mast shadow (flow distortion).

The influence of possible errors in the sensing height was investigated as a reason for poor repeatability of the calibration of vertical profilers. Lidar measurements were simulated in a sheared flow by different participants independently, and it was demonstrated that sensing height errors result in much larger errors than volume-averaging errors due to the curvature of the shear. A three-parameter procedure for the identification of the sensing height errors was defined. From these results it is possible to conclude that the variability in the calibration of vertical profilers is a consequence of the wind shear in the vertical profile, the different reactions of lidars and cup-anemometers to atmospheric turbulence, and also flow disturbance by the mast.

DTU published a technical report related to the calibration of nacelle-based lidar in 2013 (DTU Wind Energy E-0020). Participants were encouraged to apply it

Table 1. Countries and Organizations Participating in Task 32 During 2014		
	Country	Institution(s)
1	Canada	AXYS, Technocenter Eolien
2	China	China Renewable Energy Engineering Institute, Chinese Wind Energy Association (CWEA), Goldwind
3	Denmark	DONG Energy, Technical University of Denmark (DTU) Wind Energy
4	Germany	Deutsche WindGuard, German Wind Energy Institute (DEWI), ForWind – Oldenburg, Fraunhofer Institute for Wind Energy and Energy System Technology (IWES), DNV-GL, GWU, Senvion SE, Stuttgart Wind Energy (SWE)—University of Stuttgart
5	Japan	ITOCHU Techno-Solutions Corp., Mitsubishi Electric Corp.
6	Norway	Meventus, Norwegian Center for Offshore Wind Energy (NORCOWE), University of Bergen, Christian Michelsen Research Institute
7	United Kingdom	Carbon Trust, Frazer Nash, National Engineering Laboratory (NEL); Renewable Energy Systems (RES), Sgurr Energy, SSE, Zephir, Natural Power, Offshore Renewable Energy Catapult
8	United States	AWS TrueWind, University of Colorado, Cornell University, National Center for Atmospheric Research (NCAR), National Oceanographic and Atmospheric Administration (NOAA)—Earth System Research Laboratory (ESRL), National Renewable Energy Laboratory, Pacific Northwest National Laboratory
Participants in Progress		
9	Austria	Energiewerkstatt
10	Belgium	3E
11	France	Avent, IFP Energies nouvelles, Leosphere
12	Israel	Pentalum
13	Netherlands	Energy Research Center of the Netherlands (ECN)
14	Sweden	Windvector
15	Switzerland	Meteotest

during their experimental campaign and to provide feedback.

An IEA Wind Recommended Practice for the use of floating lidar systems is being prepared in WP 1.5. This document is mainly based on the experience of and data collected by participants in offshore experimental campaigns. It will be a high-impact result of Task 32.

Table 2. Organization of the Content in Task 32		
SUBTASK I: Calibration & classification of lidar devices M. Courtney (DTU	SUBTASK II: Procedures for site assessment A. Clifton (NREL	SUBTASK III: Procedures for turbine assessment A. Rettenmeier (SWE)
1.1 Ground-based lidar calibration (includes former 1.2)	2.1 *RP 15 Ground-based, vertically-profiling remote sensing for wind resource assessment*	3.1 Exchange of experience in power performance testing according to IEC 61400-12-1 ed. 2
1.3 Calibrating nacelle lidar	2.2 Wind field reconstruction methods in complex flow with wind lidars (includes former 1.2)	3.2 Wind field reconstruction from nacelle based lidar measurements
1.5 Calibrating floating lidar	2.3 Measurement of wind characteristics	3.3 Nacelle-based power performance testing
	2.4 Using lidar as part of a wind resource assessment	3.4 Load estimation using a lidar system

3.2 Subtask 2: procedures for site assessment

This subtask focuses on the uses of lidar when developing wind plants. A small group of participants is working to finalize minor revisions of RP 15 (WP 2.1). A draft state-of-the-art document on the use of lidar in complex flows was presented in Glasgow (WP 2.2) and is in revision. Material related to turbulence measurements collected by participants of WP 2.3 was elaborated in a technical report, which includes the state of the art of available technology and possible measurement configurations. This report is expected ultimately to include experimental results from different measurement campaigns. The final draft is to be submitted in spring 2015. A technical report on the use of lidar for resource assessment is also in preparation under WP 2.4.

3.3 Subtask 3: procedures for turbine assessment

In the framework of this subtask, participants were involved into two comparative studies: the first one, to test the rotor equivalent wind speed (REWS) method under different shear conditions and with different measurement technics (WP 3.1); the second one, to compare the different approaches applied by participants to reconstruct the wind vector from nacelle-based lidar measurements (WP 3.2). The results of the former study were summarized in a paper presented at the Science of Making Torque from Wind Conference in summer 2014. In this work, it was determined that the definition of the distribution of measurement heights and the related segment area of the rotor is still a challenge. Moreover, the application of the REWS method applied to the estimation of power curve in the considered cases didn't reduce the scatter of the results as expected. This is probably due to the effect of turbulence and the scatter of lidar measurements.

The results provided by the participant for the second study were compared to the corresponding data measured by a sonic anemometer. The average error that affects the different methods applied is in the range of 0.2–1.0 m/s.

Further contribution concerning the application of nacelle-based lidar measurements for power curve measurements was provided by new participants to WP 3.3. Participants in this WP are preparing a technical report that includes a total of nine chapters covering the installation and the system

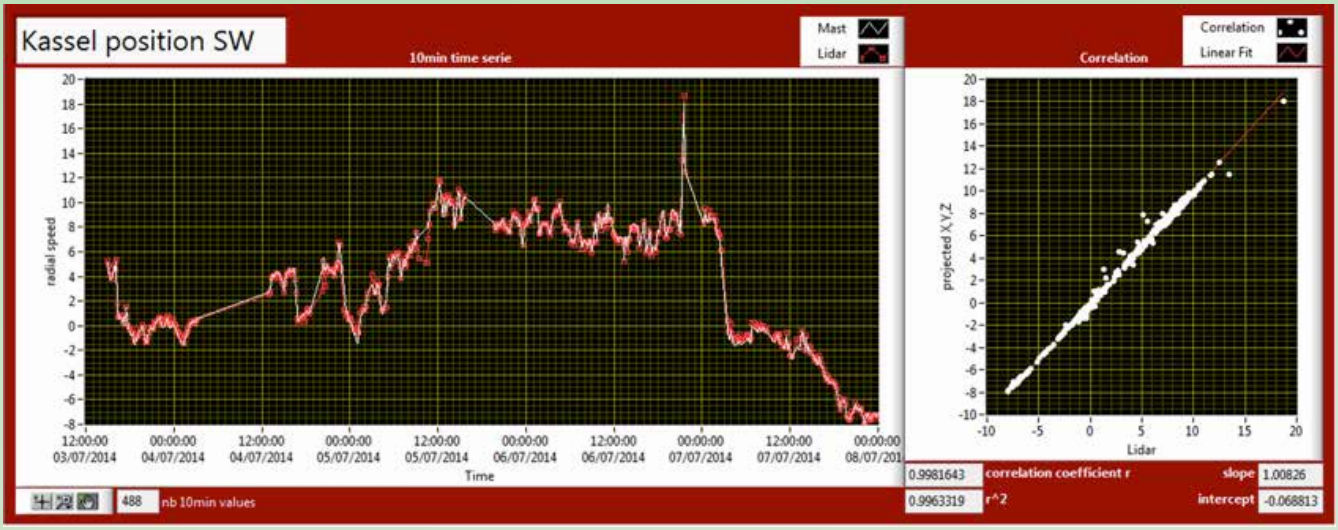


Figure 1. The 10-minute average of the radial wind speed and projected radial wind speed

description, as well as the approach applied in the evaluation of the wind speed. Two of the chapters are also dedicated to the evaluation of the uncertainty budget connected to this technology and results given by both experimental tests and simulations.

Because of a delay in the results expected from other projects related to the application of lidar systems for the estimation of wind turbine loads, WP 3.4 was put on hold and will be reactivated as soon as results from on-going experimental campaigns are made available.

3.4 Technology highlight: the lidar virtual met mast approach

Task 32 supports technology transfer from academic research to industrial application. Part of this role is highlighting important results from outside the task and bringing them to the attention of the community. In recent years, long-range scanning lidars have often been deployed in experimental campaigns. Because wind lidar technology makes it is possible to directly measure only the radial wind speed (i.e., the projection of the wind vector on the laser beam direction), dedicated measurement patterns, along with wind models, have to be applied for the evaluation of the horizontal and vertical wind speed. This entails a reduction of the accuracy of the final results, as well as a lower time resolution.

Performing concurrent and synchronized measurement with at least three conveniently located wind lidar units might overcome this limitation. In fact, it is possible to evaluate the full wind vector from three individual radial wind speeds, measured as close as possible to the target point at the same time by the three units. When the target point is shifted sequentially along a vertical line, it is possible to retrieve the vertical profile of the wind vector. This approach is commonly referred as virtual meteorological (met) mast, because its results resemble those of a meteorological mast.

In order to demonstrate how to overcome the issues in getting accurate measurements with the virtual met mast approach, an experimental campaign took place within the framework of the WindScanner.eu project in summer 2014. The virtual met mast configuration was achieved by four long-range scanning lidars installed within a radius of about 3 km around a 200-m-high meteorological tower. The target points of the virtual met mast were chosen as close as possible to the ultra-sonic anemometer installed on the physical mast. A fifth unit was installed at the feet of the mast to directly measure the vertical wind speed.

As an example, there was a good correlation between the wind vectors from the multi-lidar measurements and the ultra-sonic anemometer data, as shown in Figure 1. The figure shows a time series of the 10-minute average of the radial wind speed measured by one of the lidar located 3,047 m away from the mast and the projected radial wind speed from the data from the sonic anemometer installed on the mast at 188 m (source: DTU Wind Energy).

The results are promising and indicate that, in the future, the virtual met mast approach could be applied in combination or even instead of a meteorological mast to retrieve the vertical profile of the wind vector. However, some work is still needed to refine this approach. For this reason, virtual met mast measurements could be a possible topic for the second phase of Task 32.

4.0 Plans for 2015 and Beyond

In the upcoming year, the group will finalize all the documents, and the first phase of Task 32 will be concluded. In the meantime, the group will identify possible topics for an extension to a second phase of Task 32 and prepare a formal proposal. Official information about the task can be found at (www.forwind.de/IEAAnnex32). The activity of the various work packages can be followed at (sites.google.com/site/ieawindannex32/home).

Opening photo: Wind lidars at a test center

Authors: Martin Kühn and Davide Trabucchi, ForWind—University of Oldenburg; Andreas Rettenmeier, SWE—University of Stuttgart, Germany; Andrew Clifton, NREL, United States; Mike Courtney, DTU Wind Energy, Denmark.

13 Task 33

Reliability Data: Standardizing Data Collection for Wind Turbine Reliability and Operation & Maintenance Analyses

re•li´•a•bil´•i•ty (ri, līə 'bilətē) *n.*

a person or thing with trustworthy qualities.

Task 33 · Reliability Data

1.0 Introduction

In general, IEA Wind Task 33 supports reliability improvement and the optimization of operation and maintenance (O&M) procedures for wind turbines through analyses of reliability data. This goal is achieved by publishing suggestions in IEA Wind Recommended Practice reports.

Task 33 explores the initiatives of data and failure statistics collection in the wind energy sector of the participating countries. The group will prepare a survey on which data to collect and which analyses can be performed. Based on these results, the group will prepare and publish a summary of the data to record, how to transfer it into databases, and how to structure databases for storing and analyzing.

Task 33 plans to provide an open forum on failure and maintenance statistics for wind turbines to exchange the experiences of individual research projects, develop IEA Wind Recommended Practices for collecting and reporting reliability data, and identify research, development, and standardization needs for collecting and reporting reliability data.

Numerous countries showed strong interest in reliability data during a special IEA Wind Topical Expert Meeting in 2011. Nine countries and institutions have participated in IEA Wind Task 33 (see Table 1), since it began in October 2012. Additionally, the United Kingdom is clearly interested in joining Task 33.

2.0 Objectives and Strategy

The drivers for IEA Wind Task 33 are:

- Extensive national research projects dedicated to reliability analyses of wind turbine failures have been performed during recent years; e.g., Denmark, Finland, Germany, the Netherlands, Sweden, the United Kingdom, and the United States. However, a consolidated multi-lateral and international exchange has, to date, only partially taken place.
- The increasing future demands on reliability and profitability of wind energy use, especially offshore, require the optimization of wind-turbine maintenance. Appropriate data management and sophisticated decision-support tools are prerequisites for meeting these demands.
- Several working groups have been launched on national levels concerning appropriate standards for the O&M of wind power plants for land-based wind energy applications; e.g., joint activities on standardizing O&M measures, documentation, and data structure.

However, there are currently no guidelines or standards to reference so the results of existing initiatives cannot easily be compared and data cannot be jointly compiled and analyzed.

The establishment of recommended data collection techniques and procedures, database structures (e.g., database layout, component designation, and event description), and reliability analysis (e.g., mean time between failures [MTBF] and mean time to repair [MTTR]), based on international standards, aims to:

- Establish an international forum for exchange of knowledge and information related to wind turbine reliability data and failure statistics.
- Bring available knowledge together and use experience for improvements.
- Develop and define an internationally accepted data structure that can be used by the IEA and other organizations.
- Start a broad dialogue on an international level between operators, manufacturers, service, component suppliers, designers, and researchers.
- Simplify the monitoring process of wind turbines to improve financial and technical reporting, and facilitate cooperation with similarly oriented businesses.
- Provide a basis for sound conclusions in terms of reliability characteristics,

Table 1. Countries and Organizations Participating in Task 33 During 2014

	Country	Institution(s)
1	China	Chinese Wind Energy Association (CWEA), Goldwind Science & Technology Co., Ltd.
2	Denmark	Aalborg University, Technical University of Denmark (DTU) Wind Energy
3	Finland	Technical Research Center of Finland (VTT), ABB Finland
4	Germany	Fraunhofer Institute for Wind Energy and Energy Systems Technology (IWES)
5	Ireland	ServusNet Informatics
6	Netherlands	TU Delft
7	Norway	Norwegian University of Science and Technology (NTNU), SINTEF Energy Research
8	Sweden	Chalmers University of Technology, Royal Institute of Technology (KTH), Vattenfall
9	United States	Sandia National Laboratories

such as failure rates and repair times, based on operational experience.

The results of IEA Task 33 will be collected and summarized in an IEA Wind report, "Recommended Practices for Reliability Data."

Owners/operators, in particular, strive to optimize maintenance efforts against availability and life-cycle costs. Thus, their need for decision support using key performance indicators and other information from historical O&M data is the main driver for identifying the right data sets to record. In short, the objectives of Task 33 are identifying operator demands, selecting the most appropriate statistical methods for providing key figures, and suggesting which data to collect.

3.0 Progress in 2014

The work in Task 33 has been divided in several steps. Firstly, an overview about all the initiatives on wind turbine reliability in the participating countries was presented in an internal state-of-the-art report. It shows that there seems to be a huge demand for reliability figures, but none of the surveys described was detailed enough, and at the same time contained data from enough individual wind turbines, to derive sound reliability figures. However, it is clear that a wide database can only be set up if many operators collaborate in assembling their data. This, in turn, requires standards on which data to collect and how.

Secondly, the task members established three working groups, which are now exploring the three objectives above. Group members discuss and formulate maintenance tasks and derive demands for input from statistical analyses—the statistical methods themselves, as well as the data sets and structures (see Figure 1). The results will be presented in three individual reports.

In a third step, the Task 33 team will compile one joint document from these group reports, jointly derive suggestions from the group reports, discuss the main results with the industry sector—mainly owners/operators, and write an IEA Wind report, "Recommended Practices for Reliability Data."

Having started group work in October 2013, Task 33 met on May 6–7, 2014 at Vattenfall's headquarters in Solna near Stockholm to align the group work and the contents of the growing reports. Following the meeting, the groups worked individually. Group leaders and operating agents stayed in contact during this time for continued adjustment of contents. So far, three drafts have been worked out:

- "Maintenance Optimization and Need for Data"
- "Reliability Models and Reliability Data Analysis"
- "Data Collection."

Currently, the reports provide descriptions more than recommendations for certain data sets, taxonomies, and failure descriptions. However, the approximately 100 pages:

- Present maintenance strategies.
- Describe wind plant use case models and an information model.
- Explain statistical methods, including inherent uncertainties.
- Define data types.
- Provide an overview about existing standards.

Thus, in the second step, a basis for developing an IEA Wind Recommended Practice was provided, and the next step of deriving conclusions can start.

4.0 Plans for 2015 and Beyond

The contents of the group reports will be compiled into a first outline early in 2015. Gaps will then be identified and filled, and conclusions and recommendations will be derived. The main task will be getting feedback from the industrial sector, as owners/operators need to accept and apply the recommendations. Without this, they will have made no contribution to the improvement of reliability and maintenance efforts. Since the British offshore wind industry plays an important role in the development of wind energy use, the entry of the United Kingdom to Task 33 is quite valuable for the upcoming tasks.

Two meetings are planned for 2015. One in springtime (14–16 April in Dublin) after the three group reports having been compiled into a first outline of a joint document. A second meeting should take place in late summer (September) to present the first draft of recommended practices to the industry sector and gather feedback.

Authors: Berthold Hahn and Stefan Faulstich, Fraunhofer Institute for Wind Energy and Energy Systems Technology (IWES), Germany.

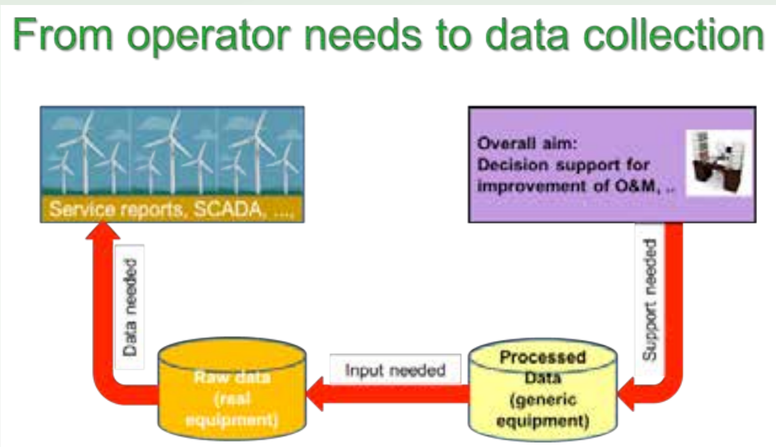


Figure 1. From operator's demands to the data collection needed

14 Task 34 Working Together to Resolve Environmental Effects of Wind Energy (WREN)

1.0 Introduction

Concerns over the environmental effects of wind energy continue to challenge the wide-scale deployment of both offshore and land-based wind energy projects. To address this challenge at an international level, IEA Wind Task 34 was formed to serve as the leading international forum for cultivating deployment of wind energy technology around the globe through a better understanding of environmental issues and demonstrated solutions for those challenges.

Originally approved in principle by the IEA Wind Executive Committee in October 2012, participating members spent 2013 working to refine the goals and objectives of the Task, identifying key focus areas, and organizing to ensure that the activities and products provide the highest value to the member countries. In 2014, task members made progress on many of the key focus areas outlined in the work package.

2.0 Objectives and Strategy

The primary objective of Task 34 is to facilitate international collaboration to advance global understanding of the environmental effects of offshore and land-based wind energy development. The strategy to accomplish this objective is to create a shared global knowledge base on research, monitoring, and management of the environmental effects of wind energy development.

3.0 Progress in 2014

Early in 2014, task members identified a more descriptive name for Task 34, WREN, with a tagline of "working together to resolve environmental effects of wind energy." Throughout the year, WREN members made progress on all the activities in the work package, with a focus on three key activities: the development of 1) the WREN

Table 1. Countries and Organizations Participating in Task 34 During 2014

	Country	Institution(s)
1	Germany	Berlin Institute of Technology
2	Norway	Norwegian Institute for Nature Research
3	Switzerland	Federal Department of the Environment, Transport, Energy and Communication (DETEC); nateco AG
4	United Kingdom	Marine Scotland Science
5	United States	National Renewable Energy Laboratory; Pacific Northwest National Laboratory; U.S. Department of Energy
Observers	Ireland	BirdWatch Ireland
	The Netherlands	Rijkswaterstaat—Department of Water Quality
	Sweden	Vindval

Hub, 2) a white paper on adaptive management, and 3) a webinar series.

To assist in the coordination of these activities, three virtual meetings and two in-person meetings were conducted during 2014. The in-person meetings were held in Blyth, United Kingdom, May 15–16, 2014, and Broomfield, Colorado, United States, December 2, 2014. Five participants representing three countries traveled to Blyth, United Kingdom, to attend the two-day WREN meeting. Discussions during this meeting led to a number of key recommendations for consideration by the members unable to attend the meeting, most importantly, which white paper topic to focus on first, and the next steps for developing the WREN Hub. Travel difficulties limited the level of in-person attendance of the December meeting in Broomfield, Colorado. Six participants from two countries attended the meeting in Colorado, and members from four additional countries participated by phone, which greatly improved the discussions.

3.1 Progress on developing the WREN Hub

The purpose of the WREN Hub is threefold: 1) to advance international understanding of, and disseminate information on, the environmental effects of offshore and land-based wind energy, 2) to facilitate international collaboration on common issues of concern, and 3) to create an international community with access to relevant information. The Hub is a concept for collaboration, supported by an information technology (IT) platform. It is designed to 1) act as a commons or gathering place for those interested in the environmental effects of wind energy development, 2) serve as an online platform for information sharing, 3) provide tools for communication and collaboration among the WREN member nations, 4) deliver expert content through seminars and workshops, and 5) act as a managed clearinghouse, events calendar, and bulletin board for key events and news items. Figure 1 provides a visual representation of the conceptual framework of the WREN Hub.

During 2014, progress was made developing the initial IT platform, populating the Hub with documents and information from other sources, and releasing a beta version for WREN members to review. The U.S. Department of Energy's Pacific Northwest National Laboratory (PNNL) developed Tethys as a knowledge base for marine and hydrokinetic energy environmental issues and proposed that a cost-effective solution would be to add the WREN Hub to the Tethys platform. Members agreed with this suggestion and PNNL made progress in adding WREN Hub functionality to Tethys.

All material on the WREN Hub will be made publicly available, with the exception of a members-only page where in-progress product development will be available to WREN members only. Once finalized, all such products will be migrated to the public access side. Ultimately, a link will be posted to the IEA Wind Task 34 website to ensure all interested parties will have easy access to the WREN Hub.

3.2 Progress on developing white papers

In 2014, members opted to focus on the adaptive management white paper first, but also developed a summary paper that described the linkage between all the proposed topics. This summary document explains the interrelationship between each topic and includes a simple graph to aid in visualizing the relationship, as shown in Figure 2.

The approach for developing the white papers includes: 1) identification of a core writing team, 2) development of the paper outline and annotated bibliography, 3) development of a draft paper, 4) conducting workshops to discuss the draft, 5) using input from workshops to inform development of the final draft document, 6) review, and 7) publication.

During 2014, progress was made on the adaptive management white paper. The proposed approach for this topic was modified to include interviews with those experienced in adaptive management, including wind energy project development, regulatory agencies, and environmental consultants. Although the final document is expected to have an international scope, most information gathered in 2014 came from U.S. input.

As a result of the progress to date on the adaptive management white paper, members decided to begin working on a second topic—individual effects to population impacts. Identification of a core writing team to develop an outline for the second topic was completed in 2014.

3.3 Progress on the webinar series

A webinar series on topics of interest to WREN members began in late 2014. Two webinars were held. The first webinar, on September 3, covered best practices for assessing the impact of wind energy development on bats, with a focus on the combination of operational minimization and deterrents as a possible strategy to minimize bat fatalities at wind turbines. Speakers included Cris Hein from Bat Conservation International and Oliver Behr from the University of Erlangen in Germany. The second webinar, on December 9, covered research efforts to measure seabird and

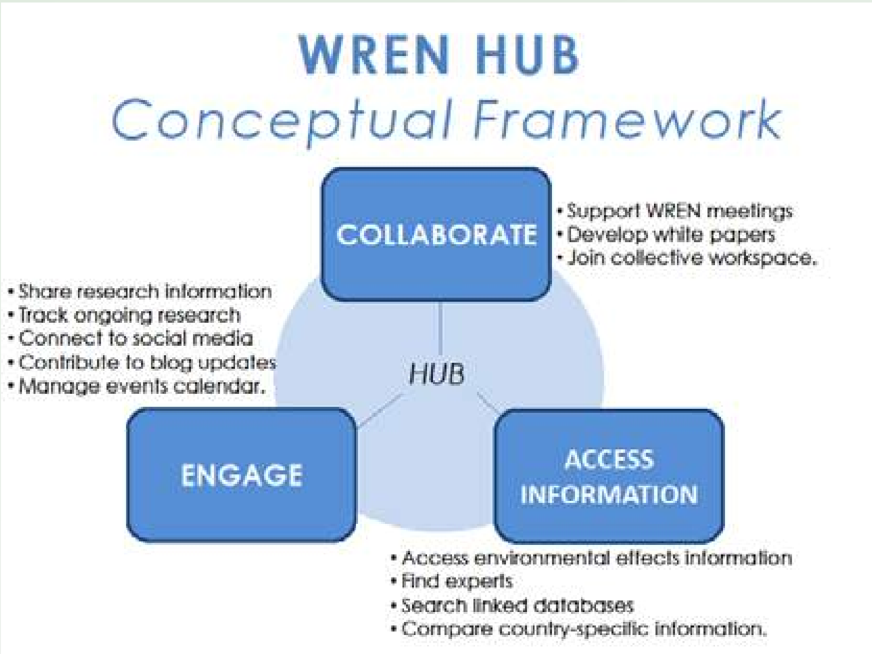


Figure 1. Conceptual Framework for the WREN Hub

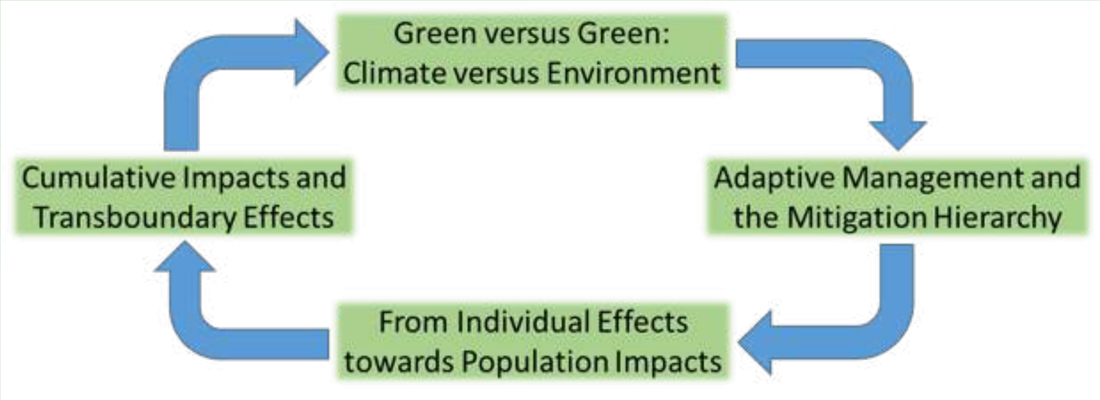


Figure 2. Interrelationship of WREN white paper topics

marine mammal attraction and avoidance at offshore wind plants. Speakers included Debbie Russell from the University of St. Andrews in Scotland, and Ross McGregor from the United Kingdom's Natural Power. The webinars were recorded and posted to the WREN Hub (tethys.pnnl.gov/environmental-webinars?content=wind).

3.4 Information dissemination

Throughout 2014, WREN members put effort into disseminating information about WREN through various mechanisms, including 1) developing a one-page fact sheet describing the purpose of WREN, 2) conducting discussions within member countries to gain input on what information would be of value to others, 3) aggregating information on the regulatory framework for addressing environmental issues pertaining to land-based and/or offshore wind energy development, and 4) informing interested parties about upcoming WREN-sponsored webinars. Additionally, members identified opportunities to present information on WREN at the National Wind Coordinating Collaborative (NWCC) meeting December 3–5, 2014, in Broomfield, Colorado, the United States and the following year at the Conference on Wind energy and Wildlife impacts (CWW) in Berlin, Germany, March 10–12 2015 (https://www.cww2015.tu-berlin.de/). Abstract proposals for the two conferences included an oral presentation on WREN, a poster on the WREN Hub, and a panel to discuss adaptive management. The poster was accepted by the NWCC committee and presented during the conference. All abstracts submitted for the CWW in 2015 were accepted and the presentations were made by WREN members.

4.0 Plans for 2014 and Beyond

Over the next two years, WREN members will continue to work on the activities identified in the work package. These activities will include: 1) the expansion of the WREN Hub to include more literature, engage the social media aspects available within the Hub, including blogs on technical subjects, and provide information on upcoming meetings, conferences, webinars and other activities of interest to WREN members; 2) continue work on white paper topics and publish papers as they are completed; and 3) continue to actively work to disseminate information through the WREN Hub, including webinars, social media, and participation in relevant conferences.

WREN members will engage in planned activities and product development using a variety of communication strategies, including virtual meetings, conference calls, webinars, the Hub, and other communication formats deemed appropriate. The members will meet at least twice a year in person. These meetings are tentatively scheduled for spring and fall each year. Topic-specific workshops will be scheduled, if needed, to expedite the development of the white papers.

The success of this Task will require all participating countries to be actively engaged in the various activities. The United States will support administrative and operating costs of the Operating Agent; no membership fees will be required to participate in this Task. However, each participating country must submit a formal commitment letter to IEA Wind and agree to provide in-kind contributions to cover staff time to contribute to the development of products and for travel costs to attend in-person meetings (at least two per year). In addition to the current member countries, representatives from several other countries who have expressed interest in participating in this Task will be encouraged to submit commitment letters.

Two in-person meetings are planned for 2015. The first will be held at the Berlin Institute of Technology in Berlin, Germany, on March 13, 2015 immediately following the CWW. During this meeting, member countries will continue to work on all the work package activities, including working toward the completion of the first white paper focused on adaptive management and preliminary discussions of the second white paper topic—the individual effects to population impacts. The second meeting will be held in Bern, Switzerland, October 21–22, 2015.

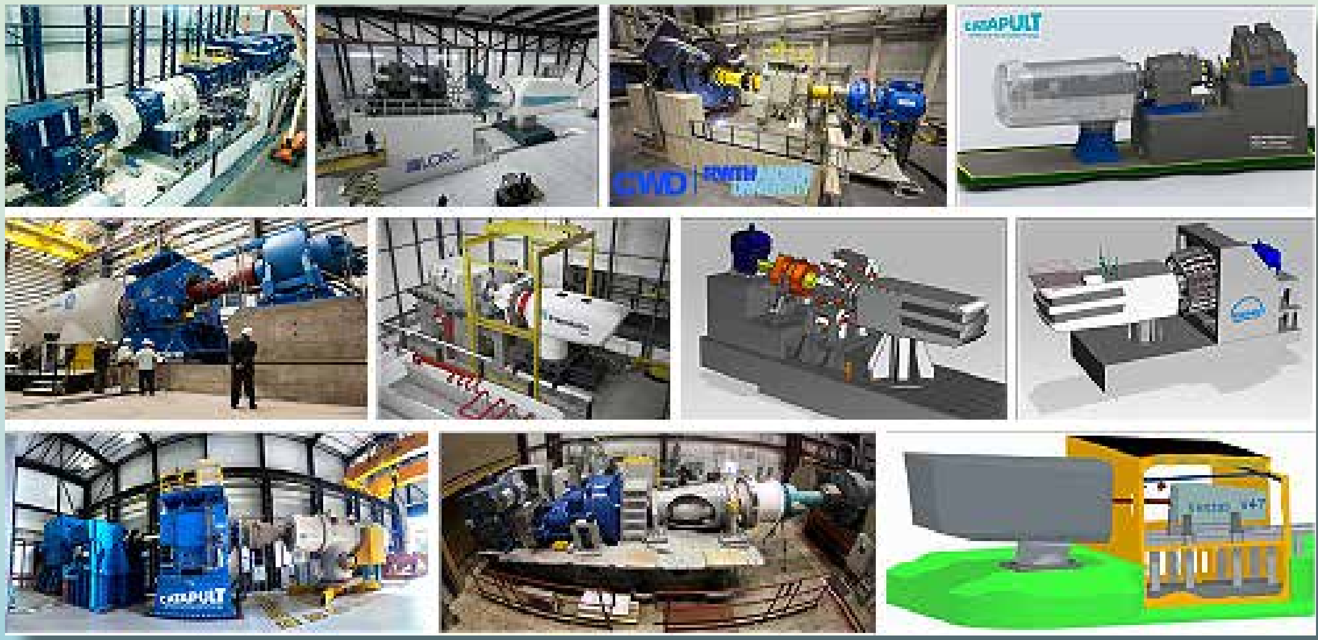
References:

Opening photo: A flock of black-tailed godwits (Limosa limosa) flies past Cahore Windfarm in southeast Ireland (Photo credit: Oran O'Sullivan). The island's strong and consistent wind speeds make it ideal for wind energy development, which represents an increasing amount of the total energy generation in Ireland. For birds, collision, displacement, and habitat loss are serious issues. A recently-completed sensitivity map for wind energy in Ireland hopes to mitigate these impacts.

Author: Karin Sinclair, National Renewable Energy Laboratory (NREL), United States.

15 Task 35

Full-Size, Ground Testing for Wind Turbines and Their Components



1.0 Introduction

As wind turbine generators (WTGs) continue to contribute an increasing portion of the electricity supply, it is crucial for design and testing standards to keep pace with the development of the technology. These standards need to reflect the requirement of improving reliability at low costs. Reducing the downtime and development costs of WTGs ensures that wind energy remains competitive in the global electricity marketplace. Although full-scale prototype turbine field testing is a common technique employed in the development of new products, it is expensive, time-consuming, and suffers from the predictability of site-specific load cases. As an alternative, ground-based test benches offer the opportunity to evaluate WTG components under reproducible, accelerated life conditions and may become an important tool for development and certification of new WTGs.

The following table shows the participants of Task 35. In late 2014, China, the Netherlands, and Spain expressed their interest and intention to join Task 35.

Table 1. Countries and Organizations Participating in Task 35 During 2014

	Country	Institution(s)
1	Denmark	Technical University of Denmark (DTU) Wind Energy DTU Mechanical Engineering Lindoe Offshore Renewables Center (LORC) Vestas Wind Systems A/S LM Wind Power A/S R&D A/S
2	Germany	Center for Wind Power Drives (CWD) Rhine-Westphalia Institute of Technology (RWTH) Aachen University GE Energy Power Conversion GmbH Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) MTS Systems GmbH Senvion SE Technical University of Berlin TÜV Rheinland AG Windtest Grevenbroich GmbH Siemens AG (Winergy)
3	United Kingdom	Offshore Renewable Energy (ORE) Catapult Lloyd's Register Group Services Limited
4	United States	Clemson University Wind Drivetrain Test Facility McNiff Light Industry MTS Systems Corporation National Renewable Energy Laboratory (NREL) National Wind Technology Center and Wind Technology Testing Center Sandia National Laboratories

2.0 Objectives and Strategy

IEA Wind Task 35 intends to address the emerging demand for reliable and cost-effective ground testing. Because the use of full-scale ground test facilities for validating WTG designs has become an attractive option to the component manufactures, WTG original equipment manufacturers (OEMs), and WTG owner/operators [1], [2], the challenge is to exploit the potential of each facility and combine all specific capabilities.

Therefore Task 35 aims to:

- Improve the quality and reliability of ground-based component testing of WTG nacelles and blades in order to evaluate the in-field performance and possible failure modes under accelerated life test conditions.
- Specify the requirements and boundary conditions of test bench configurations.
- Refine the standardization and certification procedures of the entire WTG and its components.
- Emphasize the use of test facilities as a reliable alternative or complement to field tests for design validation and demonstration of functionality, service life, and safety response.
- Reduce design and development time, as well as the overall costs.

Through this investigation, the expert teams of Task 35 will formulate recommendations to incorporate new and emerging test methods and standardize them across multiple laboratories with various capabilities. Depending on the recommended configuration, most test benches will be capable of performing the same standardized test with equivalent results at the same confidence level. As a long-term goal, the expected results can be used for the advancement of the present certification processes and to improve extant basis test procedures for WTGs and their components.

3.0 Progress in 2014

3.1 Subtask nacelle

3.1.1 Scope definition

In December 2013, the participants of Task 35 decided to agree to the scope of the Task, including relevant types of testing for both nacelle and blade subsystems, and to estimate their future prospects. Table 2 shows the relevant test category type certification, design and model validation subdivided into several test clusters. The long-term prospect of type certification testing is to substitute type certification field tests with full-size ground tests. Laboratory testing with system test benches can be a cost-effective alternative with several advantages like independent wind and grid states and reproducible conditions. In addition to this goal, the design and model validation testing aims to reduce costs of WTG product development and to increase WTG reliability. These two categories of type tests allow for verification of design assumptions and model qualities within a flexible and controlled environment. So far, 62 single tests have been agreed upon and assembled in these test clusters. Table 2 summarizes the achieved outcome (functionality matrix and system test cluster description) and future outcome (abstraction, interfaces, and load cases) of Subtask Nacelle.

In addition to the testing scope, the capabilities of the test facilities have been compared to get an overview of the testing performance and compatibility. Table 3 shows the test facility comparison.

3.1.2 Functionality matrix

According to the relevant system tests, a so-called functionality matrix was set up to determine all test-bench functions for each test that is necessary. With this matrix, the potential customer will know which tests can be performed at a particular test facility. Figure 1 shows the plan for the functionality matrix and the consensus that has been reached on the test procedures and the functionality aspects.

The 19 functionality aspects are divided into the groups' wind loads, grid loads, control structure, and environment. All these aspects represent the minimal requirements and capabilities of a system test bench to perform a certain test. About 80% of the type certification tests and 60% of the design and model validation tests are already defined. Some aspects, like the dynamic requirements, require that further information be gathered during the task progress. As an example, table 4 shows the requirements of the electrical robustness testing with electrical failures (design validation test).

3.1.3 System test cluster description (model/design validation)

After determining the link between the test procedures and the test bench functionality the subtask nacelle focuses on the description of the system test cluster (see Table 2). The objective of this step is to agree about the general test procedure definition for system tests (full nacelle). In particular, the design and model validation tests are poorly defined. Every test facility participating in Task 35 has different conceptions of these relatively new test procedures. The first step of the test procedure standardization is to define the following aspects:

1. Test description
2. Objectives
3. Purpose/rationale
4. Value to customer
5. Limitations
6. Methodology
7. Risks

The agreed description of the test cluster is an important step towards uniform testing standards across test facilities around the world. Moreover, the OEM and other potential customers have trustworthy documentation and can easily incorporate and adapt their testing objectives.

3.2 Subtask blade

In 2014, the rotor subtask group convened meetings to identify and outline subtasks to be performed. Work in the rotor subtask concentrates on topic areas where a greater

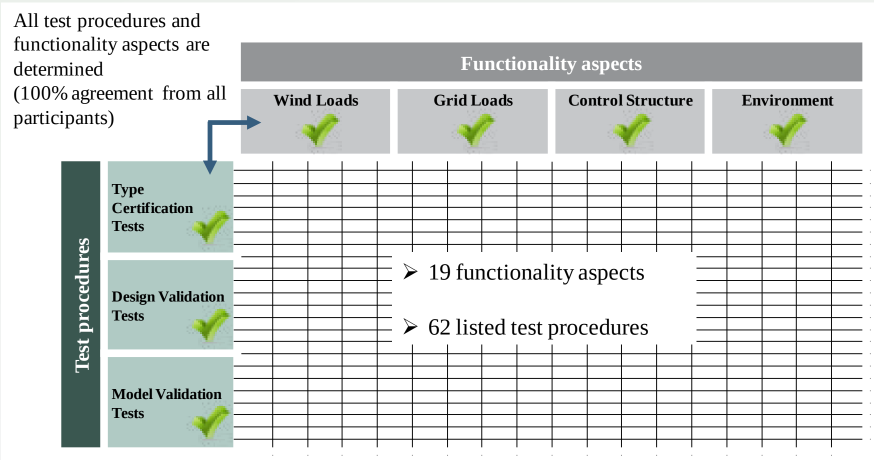


Figure 1. Plan for the functionality matrix

Table 2. Status of Nacelle Test Descriptions

	Outcome Scope of Subtask Nacelle ✓ Already done ⏱ In progress – Not available IEC Described in standards like the IEC 61400	Test Description	Objectives	Purpose/ Rationale	Value to Customer	Limitations	Methodology	Risks	Test Bench Functionality	Influence of Abstraction	Interfaces communication	Load Cases
	Test Cluster											
Type Certification	Load Measurements	IEC	IEC	IEC	–	IEC	IEC	–	✓	⏱	⏱	IEC
	Power Performance Measurements	IEC	IEC	IEC	–	IEC	IEC	–	✓	⏱	⏱	IEC
	Gearbox Tests	✓	✓	✓	✓	✓	✓	✓	✓	⏱	⏱	IEC
	Grid Code Compliance	✓	✓	✓	✓	✓	✓	✓	✓	⏱	⏱	IEC
	Acoustic Noise Measurement	IEC	IEC	IEC	–	IEC	IEC	–	✓	⏱	⏱	IEC
	Behavior	IEC	IEC	IEC	–	IEC	IEC	–	✓	⏱	⏱	IEC
Design Validation	Robustness Tests with Forced Failure (mechanical)	✓	✓	✓	✓	✓	✓	✓	✓	⏱	⏱	⏱
	Robustness Tests with Forced Failure (electrical)	✓	✓	✓	✓	✓	✓	✓	✓	⏱	⏱	⏱
	Accelerated Life Tests	✓	✓	✓	✓	✓	✓	✓	✓	⏱	⏱	⏱
	System Efficiency	✓	✓	✓	✓	✓	✓	✓	✓	⏱	⏱	⏱
	Load Distribution Measurement	⏱	⏱	⏱	⏱	⏱	⏱	⏱	⏱	⏱	⏱	⏱
	WT Controller Operation and Optimization (mechanical)	✓	✓	✓	✓	✓	✓	✓	✓	⏱	⏱	⏱
	WT Controller Operation and Optimization (electrical)	⏱	⏱	⏱	⏱	⏱	⏱	⏱	⏱	⏱	⏱	⏱
	Overspeed Protection	⏱	⏱	⏱	⏱	⏱	⏱	⏱	⏱	⏱	⏱	⏱
	Alternative Concepts	✓	✓	✓	✓	✓	✓	✓	✓	⏱	⏱	⏱
Model Validation	Mechanical Model Validation	✓	✓	✓	✓	✓	✓	✓	✓	⏱	⏱	⏱
	Electrical Model Validation	✓	✓	✓	✓	✓	✓	✓	✓	⏱	⏱	⏱

Table 3. Test facility comparison

DD = Direct drive Gear = Geared drive		Prime Mover			Wind Load Application			Load Emulation				
Organization	Country	Drive	Power [MW]	T_{max} [MNm]	Mb_{max} [MNm]	$F_{max\ rad}$ [MN]	$F_{max\ ax}$ [MN]	Real-Time Wind	Real-Time Grid	FRT-Scenarios	Industrial available	Operating
Catapult ORE	UK	DD	15	14.3	43	8	4	?	×	×	✓	✓
		Gear	3	5	15	4	4	×	×	×	✓	✓
Clemson	US	Gear	15.7	15	50	8	4	?	✓	✓	✓	2015
		Gear	7.5	6	10	2	2	?	✓	✓	✓	✓
NREL	US	Gear	5	4.6	7.2	3.2	4	✓	✓	✓	✓	✓
		Gear	2.5	1.4	1	0.44	0.16	✓	✓	✓	✓	✓
LORC	DK	DD	7.2	~7.2	~35	~2	~2	×	✓	✓	✓	2016
		DD	13.8	12	N/A	N/A	N/A	(✓)	✓	✓	✓	✓
RWTH	DE	Gear	1	0.33	0.22	0.2	0.48	✓	✓	✓	✓	✓
		DD	4	3.4	7	3.3	4	✓	✓	✓	✓	✓
IWES	DE	DD	10	13	28	4.5	2.2	✓	✓	✓	✓	2015
AREVA	DE	?	5	?	?	?	?	?	?	?	×	✓
Vestas	DK	DD	18	18	18	4	5	?	?	×	×	✓
Siemens	DK	?	>6	?	?	?	?	?	?	?	×	?
DTU	DK	Gear	1	?	?	?	?	?	?	?	?	?
Cener	ES	Gear	8	?	?	?	?	×	✓	✓	?	✓
CWEA/CGC	CN	Gear	6	?	?	?	?	?	?	?	?	?
		Gear	3	?	?	?	?	?	?	?	?	?
		Gear	1	?	?	?	?	?	?	?	?	?

Table 4. Test Bench Requirements for Electrical Robustness Testing with Electrical Failures

Wind Loads	Torque dynamic excitation frequency Steady torque according to nominal torque Peak torque according to nominal torque Speed dynamic excitation frequency Non-torque wind load application Load dynamic excitation frequency Turbulence category	<5 Hz <110% <110% <2 Hz not necessary not necessary A (high)
Grid Loads	Grid model simulation (weak/micro grid, wind plant) Grid short circuit capacity Positive sequence voltage magnitude Grid's frequency according to nominal frequency Voltage unbalance factor Voltage harmonic emission (up to 2.5 kHz)	not necessary 10 pu 1.0 pu 94–106% 2% not necessary
Control Structure	Hardware in the loop wind loads Hardware in the loop grid loads Original WTG control strategy Wind farm control strategy	necessary necessary necessary not necessary
Environment	Temperature emulation Humidity emulation	not necessary not necessary

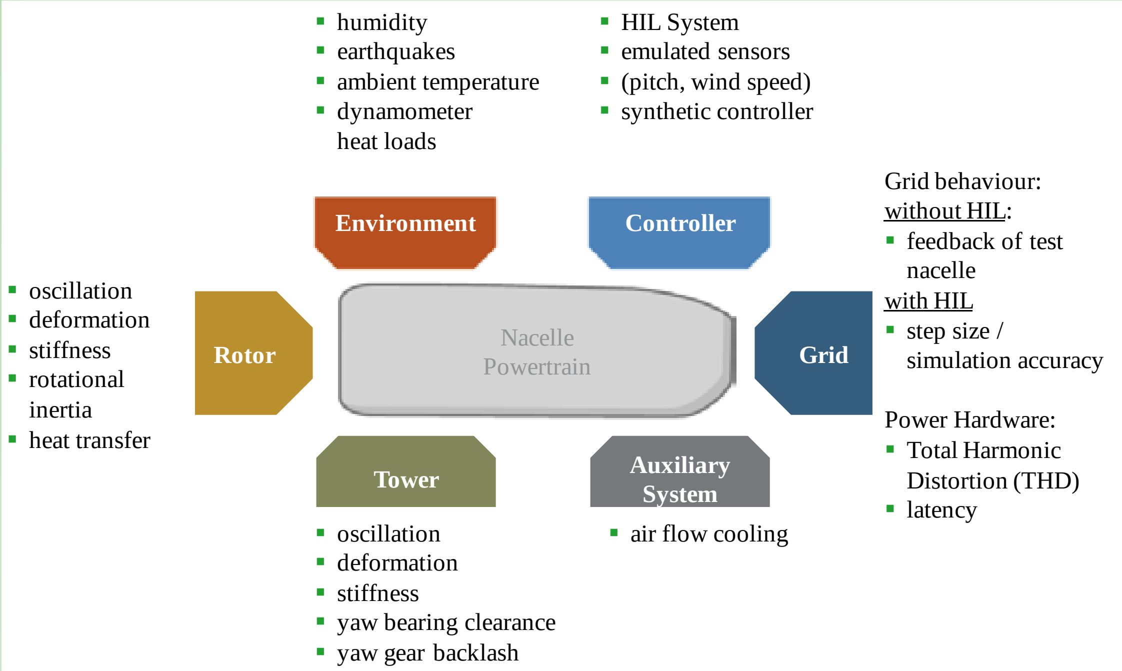


Figure 2. Sources of abstractions

body of knowledge and information on existing and emerging practices can be used to inform development of blade testing standards. Four general topic areas are considered: 1) fatigue test methods, 2) rotor subcomponent testing, 3) non-destructive test methods, and 4) uncertainty analysis of wind turbine blade testing. The Technical University of Denmark will lead the discussion on wind turbine blade test methods, evaluating and comparing current practices. Fraunhofer will lead the subcomponent testing topic, in part using recent advancements of subcomponent test methods, including beam subelement tests. Sandia National Laboratories will be taking the lead on non-destructive test methods for rotor blades. The National Renewable Energy Laboratory will lead the discussion on implementation of uncertainty estimation for blade tests. Subtask work in 2014 also included canvasing and comparing static and fatigue wind turbine test methods and capabilities of worldwide laboratories.

4.0 Plans for 2015 and Beyond

4.1 Subtask nacelle

In 2015, the test cluster descriptions will be revised and expanded to single test procedures. The next step to determining further test bench requirements is to estimate the benefits and losses of the abstraction due to the laboratory testing environment.

Figure 2 shows the sources of abstraction due to the interfaces to the rotor, tower, auxiliary system, grid, controller, and environment. The influences on specific testing results have to be evaluated. The rotational inertia of the rotor, for example, has to be considered when applying dynamic torque on the drivetrain. It is crucial for the fidelity and development of ground test procedures to consider the influence of abstraction and to find compensation strategies.

In late 2015, the current system test repertory will be expanded by additional component test procedures. Therefore, the Subtask Nacelle group will agree on reasonable component tests and suitable test-bench configurations. Similar to the system test procedures, the component test procedure will be described and standardized.

4.2 Subtask blade

In 2015, each working group of the rotor subtask will develop framework documents covering the respective topic areas. Framework documents will outline existing practices, identify new approaches and new technologies, and identify areas of opportunity for improved practices. These documents are intended to promote a robust discussion within each group and provide the framework for developing recommended practice documentation. Documentation of best practices and areas for continued improvement will be conducted in 2016. While each topic has a defined lead, all groups will be active participants in reviewing and providing content for the framework documents.

References:

Opening photo: A collage of test centers participating in Task 35.

[1] Areva; www.areva.com/EN/news-9108/offshore-wind-turbines-arevas-5-megawatt-full-load-test-benchin-operationsinceoctober2011.html, 23.11.2011

[2] Vestas; worldofwind.vestas.com/en/verification-testing; 17.01.2013

Authors: Stefan Franzen, Dennis Bosse, and Georg Jacobs, Center for Wind Power Drives at RWTH Aachen University, Germany; and Scott Hughes, National Renewable Energy Laboratory (NREL), United States.

2014 IEA Wind Annual Report Country Chapters

16 Austria

1.0 Overview

With nearly 70% of renewable energy in its electricity mix, Austria is among the global leaders in this respect. Without any doubt, it is the natural conditions in Austria—hydropower, biomass, and a high wind energy potential—that allowed such a development. For the third year in a row, wind energy in Austria increased by more than 300 MW (Table 1) reaching an all-time high with 411 MW.

By the end of 2014, nearly 2,100 MW of wind power were operating in Austria. An additional 390 MW of wind power will be constructed in Austria in 2015. Burgenland, the easternmost of Austria's nine federal states, reached its goal and now generates enough electricity from wind power to cover more than the overall annual energy usage of the state.

2.0 National Objectives and Progress

The Ökostromgesetz (GEA) 2012 launched a significant expansion in wind power installations in 2012 and 2013. This law sticks to the existing feed-in-tariff (FIT) system and established a target of adding 2,000 MW of wind power to the capacity of 2010 (1,011 MW) by 2020. The FIT is still set by an ordinance of the Minister for Economic Affairs and is not fixed in the GEA itself. At the end of 2013, for the first time, tariffs for two years were fixed by the ministries, bringing some certainty for investors. The FIT for 2014 was fixed at 0.0935 EUR/kWh (0.1132 USD/kWh); for 2015 it is fixed at 0.0927 EUR/kWh (0.1122 USD/kWh). For 2016 the FIT has to be fixed in a new ordinance.

2.1 National targets

The GEA 2012 adheres to the existing target of 15% of renewable energy supply without large hydro and a specific target of an additional 700 MW of wind power capacity by 2015 (an increase to 1,700 MW). This target was already reached in the first quarter of 2014, but GEA 2012 establishes a new long-term target of adding 2,000 MW of wind power to the existing capacity (1,011 MW) by 2020, which means a target of 3,000 MW by 2020. This target is even higher than Austria's target for wind energy in its National Renewable Energy Action Plan (NREAP). In this NREAP (according to European Union directive 2009/28/EC), Austria set a target of 1,951 MW by 2015 and 2,578 MW by 2020. In a 2014 study, the Austrian consultant Energiewerkstatt (www.energiewerkstatt.org) estimated that by 2020 a total wind power capacity of 3,808 MW (annual production of 9 TWh) can be achieved, by 2030 a total capacity of 6,649 MW (annual production of 17.7 TWh) can be achieved. (Figure 1).

2.2 Progress

The large expansion of wind power installations started in 2012 (Figure 1). At the end of 2013, 1,684 MW of wind capacity were installed in Austria, counting for an annual production of around 3.6 TWh of electricity production. By the end of 2014 the capacity increased to 2,095 MW or, with 4.5 TWh electricity produced, 7.2% of the Austrian electricity demand (end energy consumption of households). Wind electricity avoids 3 million tons of CO_2 emissions every year. With an estimated 2,486 MW in 2015, the annual production of all Austrian wind turbines counts for an equivalent of more than 8% of the Austrian electricity demand and avoids approximately 3.5 million tons of CO_2.

Most wind turbines (963 MW) are still installed in Lower Austria, followed closely by Burgenland (962 MW), Styria (121

For the third year in a row, wind energy in Austria increased by more than 300 MW with a record 411 MW installed in 2014.

Table 1. Key National Statistics 2014: Austria	
Total (net) installed wind capacity	2,095 MW
New wind capacity installed	411 MW
Total electrical output from wind	4.5 TWh
Wind generation as percent of national electric demand	7.2%
Average national capacity factor	***24%***
Target:	3,000 MW wind power by 2020
Bold italic indicates an estimate	

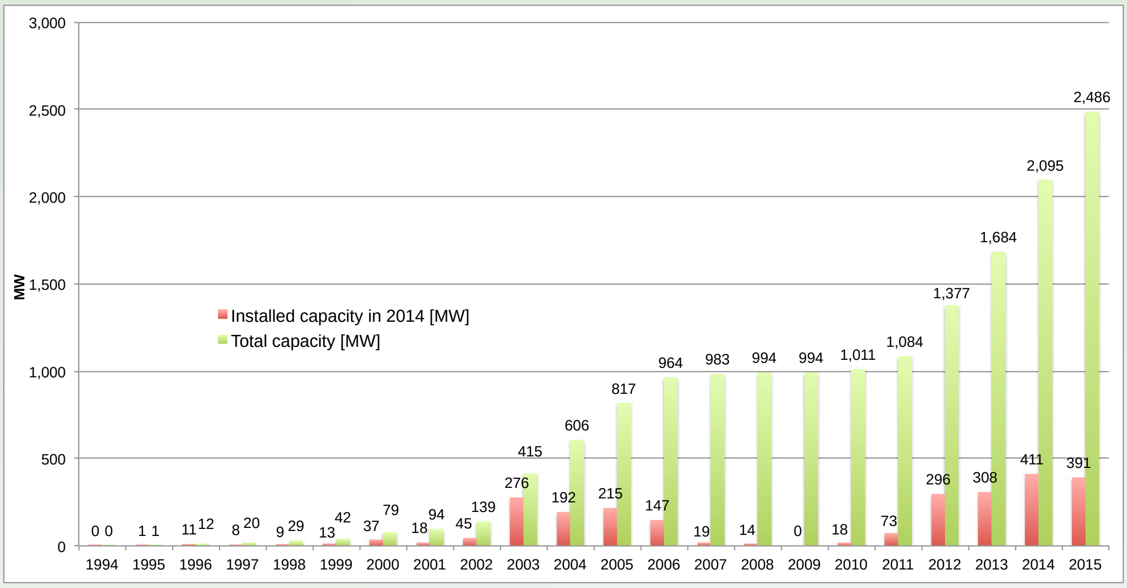


Figure 1. Cumulative installation of wind power in Austria

MW), Upper Austria (41 MW), Vienna (7.4 MW), and Carinthia (0.5 MW), as shown in Figure 2.

2.3 National incentive programs

2.3.1 GEA 2012

The GEA adopted in 2002, triggered investments in wind energy in 2003–2006 (Figure 1). Then, an amendment in 2006 brought uncertainty to green electricity producers and new restrictions for projects. This led to nearly four years of stagnation of the wind power market in Austria. A small amendment to the GEA in 2009 and a new FIT set in 2010 (0.097 EUR/kWh; 0.117 USD/kWh) improved the situation.

In July 2011 the Austrian parliament adopted new legislation for electricity from renewable energy sources, GEA 2012. This law sticks to the existing FIT system but for the first time establishes a stable legal framework through 2020, with a target of adding 2,000 MW wind power to the existing capacity (1,011 MW) by 2020. However, there are still restrictions for new projects; those projects only get a purchase obligation and a FIT if they get a contract with the Ökostromabwicklungsstelle (OeMAG), the institution in charge of buying green electricity at the FIT and selling it to the electricity traders. The OeMAG has to give contracts to green electricity producers as long as there are enough funds for new projects. The budget started with 50 million EUR/yr (61 million USD/yr) for new projects. This is enough

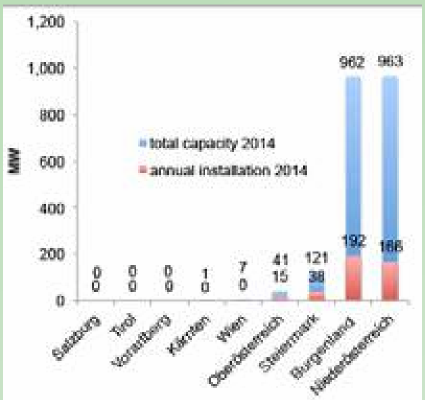


Figure 2. Wind power capacity of the federal states

for approximately 120 MW to 350 MW of new wind capacity per year depending on the market price for electricity and the applications from PV and small hydro power plants. For the first ten years the law is in action, this budget decreases by 1.0 million EUR/yr (1.2 million USD/yr). Applicants have to submit all legal permissions to get money from these funds. After a positive state-aid decision of the European Commission dating from February 2012, the GEA 2012 entered into force on 1 July 2012.

2.3.2 Green Electricity Regulation–Ökostromverordnung 2012

The FIT is still set by an ordinance and is not fixed in the GEA 2012 itself. The FITs are fixed in the Ökostromverordnung/Green Electricity Regulation by the Minister of Economy in accordance with the Minister of Environment and the Minister of Social Affairs. The tariffs are guaranteed for 13 years. The purchase obligation is limited to a specific amount of capacity (depending on the available funds for new projects). Currently, there are 1,555.4 MW supported by a FIT under the Green Electricity Regulation, producing more than 3.3 TWh/yr. The FIT for 2014 is fixed at 0.0936 EUR/kWh (0.1133USD/kWh). For 2015 it is fixed at 0.0927 EUR/kWh (0.1122 USD/kWh). For 2016 the FIT has to be set by a new ordinance.

2.4 Issues affecting growth

Crucial for the growth of wind power capacity are the amounts of the FIT, the stability of the incentive program, and the annual amount of money for new projects (annual funds). Due to the adoption of the GEA 2012, the determining factor for wind power growth will be the amount of the FIT. Because the tariffs are fixed for two years, some stability is guaranteed. But with the growing demands from the grid providers, the installation costs are expanding rapidly and constrain growth. Another issue are growing burdens coming from ancillary services which rose from 89 million EUR (108 million USD) in 2011 to more than 200 million EUR (242 million USD) in 2014. Rising costs are mainly the result of market failure. Unlike the situation in most of Europe, power producers bear a major share of the ancillary cost, which decreases competitiveness, especially of renewables.

3.0 Implementation

3.1 Economic impact

The Austrian wind power market is made up of wind turbine operators and planning offices as well as component suppliers for international wind turbine manufacturers. In 2013, (the latest year with statistics available) the annual turnover of operators of existing wind parks was over 260 million EUR (315 million USD).

Austria's wind energy industry includes more than 120 supplier and service companies. These are leading companies in the fields of conducting, wind power generators, wind turbine generator design, and high tech materials. Moreover, Austrian service providers such as crane companies, planning offices, and software designers work intensively abroad. Local companies are successful both in the land-based and the offshore sector. At the same time, many wind energy operators have taken the step abroad to be able to realize their know-how on a global level. Following a study conducted by the Austrian Wind Energy Association, one-third of the Austrian industry in the wind energy supply chain obtains an export volume of more than 600 million EUR (727 million USD). This strongly increasing tendency reflects in growth rates between 20–25% of their turnover.

3.2 Industry status

Cooperatives own 20% of all existing wind turbines, and another 40% are owned by utilities. The rest are owned by private companies. The first wind turbines in Austria where built in 1994 when cooperatives or single wind turbines built by farmers were most common. With a more stable framework in the support system since 2000, but especially since 2003, utilities and other companies entered the market. The Austrian operators are very active in the neighboring countries of Central and Eastern Europe, and some independent companies have also started businesses outside Europe. There are no major manufacturers of wind turbines in Austria, however there are manufacturers of small (micro) wind turbines.

Austrian component suppliers also serve the international wind turbine market. Bachmann Electronic GmbH is a leading manufacturer of turbine control systems. Hexcel Composites GmbH develops and produces materials for blades. Elin EBG Motoren GmbH is an important supplier for the global market for generators. There is also a number of global players with wind competence centers in Austria. A well-known company is, for example, SKF.

Fostered by the growth of the domestic market, the number of Small and Medium Enterprises (SMEs) entering the market increased during the last years. Due to the economic structure of the Austrian industry there is a significant potential for high quality products on the software, service and component sector, which is partially transferred from the automotive and aerospace industry.

3.3 Operational details

Enercon and Vestas are the most important suppliers of turbines (Figure 3). Most of the turbines in Austria are 1.8 MW to 2.3 MW

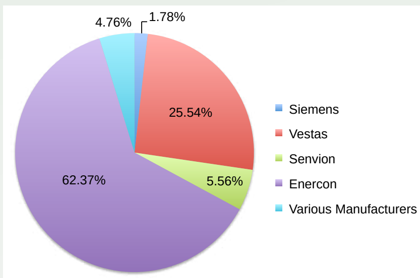


Figure 3. Market shares of wind turbine manufacturers in 2014

Table 2. Cost of New Wind Energy Projects		
	EUR/kW	USD/kW
Total investment costs	1,715.00	2,077.00
Turbine costs	1,390.00	1,683.00
Incidental costs (planning, connection to grid and grid reinforcement, etc.)	325.00	394.00
O&M costs average	0.02	0.03

in capacity, but since 2013 more than 80% of new installations are 3-MW turbines or larger. Enercon and Energie Burgenland Windkraft GmbH built two of the largest wind turbines in the world—E-126 models rated at 7.5 MW each. In 2013, Windkraft Simonsfeld built the tallest turbine in Austria. The 3.2-MW turbine reaches a total height of 200 m (tower plus blade).

4.0 R, D&D Activities

4.1 National R, D&D efforts

Since 2007, 13 wind energy related R&D projects were supported by the Austrian Climate and Energy Fund (4.0 million EUR; 4.8 million USD). One two-and-a-half-year project is improving understanding of the risk of ice fall from wind turbines. The project (ending in 2014) will develop a model to estimate risk zones near wind turbines, taking site-specific parameters into account.

4.2 Collaborative research

In 2009, Austria joined IEA Wind Task 19 Wind Energy in Cold Climates. The Ministry for Transport, Innovation and Technology has assigned Energiewerkstatt as the Austrian representative in this Task due to long-time experience with wind energy projects in the Austrian Alps. The research activities will continue until end of 2015 and focus on the following research aspects:

- Evaluation and comparison of the licensing process and the legislative requirements in each partner country in terms of the assessment concerning the risk of down-falling ice fragments from wind turbines.
- Evaluation of the operational performance of a stand-alone power supply unit for an intelligent, demand-oriented energy supply of heated wind measurement sensors.

In 2013, Austria joined IEA Wind Task 27, Small Wind Turbines in High Turbulence Sites. The cooperation will continue until end of February 2016.

Besides those activities within the IEA Wind research collaboration the following R&D projects, currently receive public funding:

The FP6 Project SEEWIND is a research and demonstration project with ten partners from six European countries. SEEWIND has a total budget of 9.6 million EUR (11.6 million USD) to install one pilot wind turbine each in Bosnia-Herzegovina, Croatia, and Serbia. The project began in May 2007 and will last seven years (www.seewind.org). The experiences of SEEWIND are also important for the Austrian market, because the three SEEWIND project sites have challenges similar to many locations in Austria.

Furthermore, two national research projects in the context of small wind turbines are currently being carried out: The 'Urban Small Wind Power Project' addresses the challenges of installation and operation of small wind turbines in urban, highly-turbulent areas. The project 'Icing of Small Wind Turbines' has been initiated by a cooperation of the national task representatives in IEA Wind Task 19 Wind Energy in Cold Climates and Task 27 Small Wind Turbines in High Turbulence Sites and deals with the challenges of operation under icing conditions.

5.0 The Next Term

The GEA 2012 and the FIT for 2015 provide a solid basis for the further development of wind power in Austria. It will be crucial for the growth of wind power capacity for measures to be taken for grid reinforcement and enlargement in the eastern part of Austria. Furthermore, Lower Austria decided on new zoning restrictions. The installation of new wind farms is therefore restricted to just 2% of the federal state. It is questionable whether Lower Austria can achieve the renewable energy goals set out in its 2030 energy road map. A serious uncertainty is imposed by the new state aid guidelines from the European Commission, which threaten an economic and stable growth of wind energy as well as a stable framework for companies in the supply chain.

Opening photo: Windfarm in Lower Austria (Photo credit: IG Windkraft/ Jürgen Pletterbauer)

Authors: Florian Maringer, IG Windkraft, Austria; Andreas Krenn, Energiewerkstatt, Austria.

17 Canada

1.0 Overview

Canada is the seventh largest producer of wind energy in the world. It has over 9.6 GW of installed wind energy capacity, which produces enough power to meet about 3.8% of the country's total electricity demand. Canada has approximately 230 wind farms, spread across ten provinces and two territories.

In 2014, Canada ranked sixth globally in terms of new wind energy capacity, with nearly 1,900 MW installed in five provinces. This is the largest increase in cumulative capacity ever in Canada, with 37 new projects commissioned, comprised of 938 wind turbines. The province of Ontario led the way, with approximately 1 GW of new installations and now has more than 3 GW of installed capacity.

Nearly half of the 37 new wind energy projects commissioned in 2014 included significant ownership stakes by First Nations, municipal corporations, and local farmers. These projects were contracted under calls for tender or feed-in-tariff (FIT) programs that targeted these partnerships.

In November 2014, Health Canada released the summary results of its study "Wind Turbine Noise and Health Study." The study concludes that there is no evidence of a causal relationship between exposure to wind turbine noise and self-reported medical illnesses and health conditions, although it did identify a relationship with annoyance. More detailed analyses will be released through peer-reviewed conference papers and journals in 2015.

The trend toward improving approaches to the grid integration of wind energy and other variable energy generation sources continued in 2014. Examples of this include: the electricity system operators in the provinces of Alberta and Ontario dispatching wind energy; the Ontario Independent Electricity System Operator (IESO) procured 34 MW of grid-connected electricity storage facilities; and the continued progress on the Pan-Canadian Wind Integration Study, which is the first time that a study will model the interconnected Canadian bulk power transmission system.

Canada also demonstrated that electricity generated by wind energy is becoming a cost-competitive option. In 2014 Hydro-Québec issued a call for tenders for 450 MW. Through this process, Hydro-Québec selected three projects totaling 446.4 MW, and will pay an average price of 0.063 CAD/kWh (0.045 EUR/kWh; 0.054 USD/kWh) for the energy.

2.0 National Objectives and Progress

2.1 National targets

Although there is no national wind energy deployment target, Canada's federal government has set a goal to reduce greenhouse gas emissions to 30% below 2005 levels by 2030. In the *2013 Long-Term Energy Plan* (LTEP), for the province of Ontario, the Ministry of Energy forecasts that wind energy will be 15% of Ontario's supply mix in 2025, up from 6% of total capacity in 2013. Overall, this will contribute to the 20,000 MW of renewable energy that is forecasted to be online by 2025, representing about half of Ontario's supply mix.

Nearly 1,900 MW of new wind capacity were installed in five provinces. This record increase included 37 new projects and 938 wind turbines.

Table 1. Key National Statistics 2014: Canada	
Total (net) installed wind capacity	9,691 MW
New wind capacity installed	1,871 MW
Total electrical output from wind	***22.1 TWh***
Wind generation as percent of national electric demand	***3.8%***
Average national capacity factor	***31%***
Bold italic indicates estimates	

On the Atlantic coast, the province of Nova Scotia has set aggressive goals for renewable energy. In 2010, Nova Scotia passed a law requiring 25% of the province's power to come from renewables by 2015 and 40% by 2020.

Also on the Atlantic coast, the province of New Brunswick (NB) released their *Climate Change Action Plan 2014–2020*. The government of New Brunswick will require NB Power to source 40% of in-province electricity sales from renewable sources by 2020. The Plan sets a greenhouse gas (GHG) emissions reduction target of 10% below 1990 levels by 2020 and 75% to 85% below 2001 levels by 2050.

2.2 Progress

Following a pilot project in 2012, Alberta introduced dispatching for wind in 2013, to allow for consistent application of market rules across generator types.

The largest wind farm in Western Canada under one power purchase agreement (PPA), the 300-MW Blackspring Ridge project, located 50 km north of Lethbridge, Alberta, started feeding power to the provincial grid in May 2014. The 600 million CAD (427 million EUR; 518 million USD) project comprises 166 Vestas V100 1.8-MW turbines, and is expected to produce more than 1,000 GWh of electricity per year, enough to meet the needs of 140,000 households. EDF EN Canada and Enbridge each own 50% of the project.

Ontario saw approximately 1 GW of wind energy capacity installed in 2014, leading all other provinces. Wind comprises approximately 7.4% of the installed generation capacity, while providing approximately 4% of electricity output. At the end of 2014, Ontario had approximately 3.5 GW of wind power online.

Ontario introduced dispatching of wind generation to the transmission grid in September 2013. Prior to this date, wind generators were treated as "must-run" units. Since September 2013, wind generators became subject to dispatch instructions from the IESO.

Ontario's largest wind facility entered commercial operation as of March 2014—the 270-MW South Kent project, owned by Pattern Energy and Samsung Renewable Energy Inc. The South Kent facility has 124 2.3-MW Siemens Energy wind turbines that have been de-rated to a range from 1.903 MW to 2.221 MW in order to facilitate permitting compliance. The wind turbine blades were manufactured by Siemens in Tillsonburg, Ontario and the towers were manufactured by CS Wind in Windsor, Ontario. Overall, Pattern Energy and Samsung renewables commissioned approximately 420 MW of wind energy projects in Ontario in 2014.

In Quebec, 460 MW of installed capacity was commissioned in 2014, second only to Ontario. All 210 turbines installed in Quebec were Enercon or Senvion and all but a single off-grid turbine had contracted PPAs through the Hydro-Québec competitive bids.

Phase 1 of EDF EN Canada's 350-MW Rivière-du-Moulin Wind Project in Quebec was commissioned in November. The wind farm is being developed in two phases; the second phase of 200 MW is scheduled to be commissioned in December 2015. When fully completed, the project will be the largest wind energy facility in Canada.

In Nova Scotia, wind energy now provides close to 10% of the electricity used. All wind farms commissioned in 2014 are a part of the community feed-in-tariff (COMFIT) program. Overall, 7 projects were put online in 2014 for a total of 30.6 MW. Four of these wind farms, totaling 24 MW, were developed by juwi Wind Canada and are owned by Firelight Infrastructure Partners and various community partners. Each of these projects installed Vestas V100-2.0 turbines. The three other wind energy projects in Nova Scotia commissioned in 2014 were single turbine installations.

With the addition of the Hermanville/ Clearspring Wind Development, Prince Edward Island (PEI) is now generating approximately 30% of its electricity from wind energy. This project was the first North American commercial operation of the Acciona AW 116/3000 turbines. Each of the ten turbines has a nominal generating capacity of 3 MW, a hub height of 92 m, and a rotor diameter of 116 m. The project is owed by the PEI Energy Corporation.

In December 2013, the territorial government of Northwest Territories released its *Energy Action Plan*. The development of new renewable energy capacity is a key part of the plan. For wind energy development, the plan allocates 100,000 CAD (71,200 EUR; 86,300 USD) to install a wind monitoring tower at the proposed 1.8-MW Storm Hills project site outside of Inuvik and 50,000 CAD (35,600 EUR; 43,150 USD) per year, over three years, to monitor wind speeds at various sites near communities in the Northwest Territories.

2.2.1 Energy storage

Two energy storage projects began operations in Ontario, in 2014:

- A 2-MW flywheel facility owned by NRStor using Temporal Power technology, located in Harriston. The system was commissioned in July and is the first grid-connected commercial flywheel facility in Canada.
- A 4-MW grid-connected lithium ion phosphate battery system. This system, located in Central Strathroy and owned by Renewable Energy Systems Canada, was connected to the grid in August.

In addition to the above storage projects, in March the Ontario IESO issued a request for proposals for up to 35 MW of storage capabilities. In July, the IESO finalized contracts with the following organizations:

- Canadian Solar Solutions Inc., battery technology, 4 MW
- Convergent Energy and Power LLC, battery flywheel technology, 12 MW
- Dimplex North America Ltd., thermal technology, 0.74 MW
- Hecate Energy, battery technology, 14.8 MW
- Hydrogenics Corp., hydrogen technology, 2 MW

2.3 National incentive programs

The government of Canada, through the Wind Power Production Incentive (WPPI) and the ecoENERGY for Renewable Power (ecoERP) programs, committed about 1.4 billion CAD (0.93 billion EUR; 1.3 billion USD) toward wind energy projects. A total of 89 projects, representing 4,442 MW of installed capacity, qualified for an incentive of 0.01 CAD/kWh (0.007 EUR/kWh; 0.009 USD/kWh) for the first ten years of operation, over and above the price paid by utilities through PPAs. The incentive under the WPPI program will end in fiscal year 2016–2017, and the incentive under the ecoERP will end in fiscal year 2020–2021.

The ecoENERGY for Aboriginal and Northern Communities Program 2011–2016 (EANCP) is focused exclusively on providing funding support to aboriginal and northern communities for renewable energy projects, with the objective of reducing GHG emissions arising from electricity and heat generation. It is delivered by Aboriginal Affairs and Northern Development Canada (AANDC). Since 2011, EANCP has provided 919,000 CAD (654,328 EUR; 793,097 USD) to nine communities for the design, development, and implementation of wind projects.

Provinces across Canada continue to offer a range of incentives for renewable power, including wind. In some cases, existing programs are being reviewed and changed. Ontario is developing a competitive Large Renewable Procurement (LRP) process for projects over 500 kW to replace the existing FIT program. The first round of procurement (LRP I) targets 300 MW of wind. The Ontario Power Authority (now IESO) posted the LRP 1 Request for Proposal in March 2015.

In Nova Scotia, the provincial government passed Bill No. 1: The Electricity Reform Act in December 2013. The bill opens the electricity market to renewable energy producers and creates local investment opportunities for renewable electricity developers. This Bill ends the utility monopolies over the retail electricity market in the province. Licensed suppliers will be allowed to sell locally generated, renewable, low-impact electricity (such as wind-generated electricity) directly to end users. The process to establish distribution tariffs before opening the market is now underway with the final proposed tariff regime to be brought to the regulator in fall 2015 and market opening expected in early to mid-2016.

Also in Nova Scotia, the COMFIT program exceeded expectations, having awarded 89 approvals totaling 200 MW of capacity since the program began in 2011, which is twice its original target. The program no longer accepts applications for wind projects larger than 500 kW, and will limit the number of approvals per organization or private partnership. The COMFIT is designed to promote community-owned projects that are connected at the distribution level.

In Quebec, Hydro-Québec Distribution issued a call for tenders for 450 MW of wind power to be delivered in 2016 and 2017. The energy price was capped at 0.09 CAD/ kWh (0.064 EUR/kWh; 0.078 USD/kWh). Hydro-Québec announced in mid-December that it had selected three projects totaling 446.4 MW: EDF EN Canada's 224.4-MW Parc Éolien Nicolas-Riou; Invenergy Wind Canada's 74.8-MW Roncevaux project; and Renewable Energy Systems Canada and Pattern Renewable Holdings Canada's 147.2-MW Parc Eolien Mont Sainte-Marguerite. The utility will pay an average 0.063 CAD/ kWh (0.045 EUR/kWh; 0.054 USD/kWh) for the energy, and calculates additional costs for transmission and to connect the facilities will result in a total average price of 0.076 CAD/kWh (0.054 EUR/kWh; 0.066 USD/kWh).

2.4 Issues affecting growth

The Canadian Wind Energy Association (CanWEA) identifies low load growth as one of the main issues affecting the growth of the wind energy sector in Canada. The focus for many jurisdictions will be new markets—electrification of transportation and non-traditional sectors including export of Renewable Portfolio Standard (RPS) eligible power.

3.0 Implementation

3.1 Economic impact

Wind projects contribute millions to local communities in the form of new tax revenues, lease payments and royalty payments. For example, the 270-MW K2 Wind Power Project in Goderich, Ontario, owned by Samsung Renewable Energy Inc., Pattern Renewable Holdings Canada ULC, and Capital Power LP, is expected to be online in 2015. It will employ more than 1,000 workers in the manufacturing and assembly of the wind turbines, site construction, and operations. The project is expected to inject 5–6 million CAD (3.5–4.2 million EUR; 4.3–5.2 million USD) into the local economy each year of its operation. Siemens Canada will supply turbines for the project with the blades from its Tillsonburg facility and the 140 towers will be manufactured at CS Wind's facility in Windsor.

CanWEA estimates that, in the province of Quebec alone, the wind energy industry has created over 5,000 jobs and generated 10 billion CAD (7.1 billion EUR; 8.6 billion USD) worth of investments over the past decade. The wind industry now contributes 500 million CAD (356 million EUR; 432 million USD) to Quebec's GDP every year. The wind energy sector in Quebec has benefited from a ten-year period of predictable and integrated approaches of successive governments. For example, more than 80% of construction costs for the 211.5-MW Gros Morne Wind Farm in Quebec were spent in the administrative region of Gaspésie-Îles-de-la-Madeleine and the municipalité régionale de comté Matane.

3.2 Industry status

3.2.1 Ownership

In Canada, wind farms are typically owned by independent power producers (IPPs), utilities, or income funds. However, in the last decade, the provinces of Nova Scotia, Ontario, and Quebec have introduced policies to encourage community and First Nations ownership. Of the 37 new wind energy projects installed in 2014, 15 projects include significant ownership stakes from First Nations, municipal corporations, or local farmers.

3.2.2 Manufacturing

Canada continues to attract wind power equipment manufacturers. Senvion, having opened its PowerBlades Inc. manufacturing plant in 2013 in Ontario, supplied blades for a number of projects in 2014. There were no new wind energy manufacturing facilities announced or opened in 2014.

In August 2014, the provincial government in Quebec established a working group to examine the required conditions for the continued development of the province's wind energy industry and associated manufacturing. This group is the first dedicated group to support the long-term strategic development of a provincial manufacturing sector dedicated to wind energy.

3.3 Operational details

Thirty-seven wind farms were commissioned across five provinces in 2014 (Table 2).

3.4 Wind energy costs

The PPAs signed in 2014 show that the cost of electricity generated by wind continues to drop. Most recently these low prices have emerged in distinct markets in Canada (Alberta and Quebec). In their *2014 Long Term Outlook*, the Alberta Electric System Operator published data regarding the relative cost of seven different electricity sources on a CAD/MWh basis. In their analysis wind was the second lowest cost source of electricity, slightly more expensive than combined-cycle natural gas-fired generating stations. In Quebec, the latest request for proposal contracts demonstrate the low cost of electricity generated by wind energy technologies with an average price of 63 CAD/MWh (45 EUR/MWh; 54 USD/MWh). With the current cost of wind energy, it has proven itself to be a significant contributor to stable, low-cost electricity pricing.

Table 2. Statistics for New Wind Farms Commissioned in 2014 in Canada

Smallest wind farm	2 MW – Kaizer Meadow Community Wind, Nova Scotia
Largest wind farm	300 MW – Blackspring Ridge, Alberta
Wind farm locations	Alberta, Nova Scotia, Ontario, Quebec, Prince Edward Island
Turbine manufacturers	Acciona, Enercon, Gamesa, GE, Senvion, Siemens, Vestas
Turbine sizes (range)	1.62–3.0 MW
Average turbine size	2 MW

4.0 R, D&D Activities

4.1 National R, D&D efforts

4.1.1 Federal

The focus of Canada's wind energy R&D activities is the integration of wind energy technologies into the electrical grid and off-grid remote community applications. Natural Resources Canada (NRCan) is the primary federal government department in wind energy R&D.

In November 2014, Health Canada released the summary results of their epidemiological study on noise and health impacts of wind turbines. The study is an "in the field" study that measured health effects of people living in proximity to wind turbines through both a survey of a large sample, conducted by Statistics Canada, and personal measurements, in a smaller sampling of respondents, of stress hormone indicators and sleep monitoring. It also measured the noise from the wind turbines near the studied populations. The study found that there are no links between exposure to wind turbine noise and any of the self-reported or measured health endpoints examined. The study did demonstrate that there is a relationship between increasing levels of wind turbine noise and annoyance towards several features associated with wind turbines, such as: noise, vibration, shadow flicker and the aircraft warning lights. For more information, see www.hc-sc.gc.ca/ewh-semt/noise-bruit/turbine-eoliennes/summary-resume-eng.php.

NRCan's CanmetENERGY is collaborating with the Caribou Wind Park in New Brunswick to quantify the wind energy production loss due to icing, and to characterize the wind resource during icing episodes. In addition to the typical wind energy and icing parameters, information will be collected on cloud physics—specifically liquid water content and median volume diameter. The data will be used to validate a meso-scale icing model currently under development.

On 3 May 2013, the government of Canada announced the following wind related projects to receive funding through NRCan's ecoENERGY Innovation Initiative (ecoEII):

- A Front End Engineering and Design (FEED) study for a wind biomass battery project on a diesel grid in Whapmagoostui, northern Quebec. The project lead is Nimschu Iskudow Inc., and the government of Canada has contributed 700,275 CAD (498,596 EUR; 604,337 USD) to this 2,534,250 CAD (1,804,386 EUR; 2,187,058 USD) study.
- Tugliq Energy Co. installed and is operating a 3-MW Enercon E-82 wind turbine at the Glencor Raglan mine in Nunavik, Northern Quebec as part of a wind-diesel-energy storage demonstration project. The energy storage technologies being demonstrated are a flywheel, a Li-Ion battery, and hydrogen systems, connected to a diesel grid. (see cover photo of annual report). This project demonstrates an industrial-scale wind hydrogen smart grid system operating in a remote northern location, under severe arctic climate conditions, and its capability to offset diesel usage. The government of Canada initially contributed 720,000 CAD (512,640 EUR; 621,360 USD) to the 2 million CAD (1.4 million EUR; 1.7 million USD) FEED study for this project. The total value of the demonstration project is approximately 18.98 million CAD (13.51 million EUR; 16.38 million USD) and is being supported by the government of Canada (7.8 million CAD (5.6 million EUR; 6.7 million USD)) and the Quebec government under the Plan Nord (6.5 million CAD (4.6 million EUR; 5.6 million USD)).
- An assessment of GTRenergy Ltd.'s Virtual Blade Wind Power configuration of turbine blades to achieve an increase in energy production. The government of Canada contributed 600,000 CAD (427,200 EUR; 517,800 USD) to this study, which has a total project cost of 1,107,243 CAD (788,357 EUR; 955,551 USD).
- A study to evaluate the technical aspects and operational tools needed for high wind energy grid penetration on a national basis. CanWEA is the lead on this Pan-Canadian Wind Integration study. This will be accomplished by matching time series modelled wind energy production data with electricity demand data, and evaluating how different wind penetration levels influence the rest of the electricity grid with specific considerations to system operations and reliability. This study will model the inter-connected Canadian bulk power transmission system, including information on the United States transmission interconnections with Canada. The government of Canada contributed 1.8 million CAD (1.3 million EUR; 1.6 million USD) to this 2.7 million CAD (1.9 million EUR; 2.3 million USD) study.

4.1.2 Test centers

TechnoCentre éolien (TCE) is a center of expertise related to wind energy in cold climates and complex terrain, adaptation of technologies, and integration of Quebec businesses into wind industry supply chains. TCE owns an experimental cold climate wind energy site in Rivière-au-Renard where there are two Senvion MM92 CCV wind turbines, each with a capacity of 2.05 MW.

In 2014, TCE collaborated with Valtion Teknillinen Tutkimuskeskus (VTT) Technical Research Centre of Finland and Senvion to assess the effect of ice on the fatigue loads of wind turbines. The results of this research have contributed directly to new design loads under ice induced conditions in the next edition of the IEC61400-1 standard on design requirement for wind turbines. Also in collaboration with VTT, TCE developed an ice map of Quebec based on historical meteorological data correlated to production losses due to icing. This preliminary map provides insight on the severity of icing in different regions of the province: (http://www.eolien.qc.ca/images/documents/autres/Quebec_icing_map_A0_PUBLIC.pdf).

TCE also installed and commissioned a second 126-m meteorological mast on its test site. The new mast is instrumented with 40 sensors and will gather data which will be used to characterize wind energy production in cold climates and complex terrain, in addition to cloud liquid water content measurements (Figure 1).

TCE inaugurated its Dynamic Smart Microgrid to test and validate wind-solar-diesel-coupling technologies (Figure 2). This infrastructure focuses on the integration of renewable energies onto remote micro-grids and distributed grids.

The Wind Energy Institute of Canada (WEICan), located at North Cape, Prince Edward Island is a non-profit, independent research and testing institute. WEICan is recognized as a preferred non-accredited test site for small wind turbines by the Small Wind Certification Council and a non-accredited test site by TUV-NEL for United Kingdom Micro-generation Certification Scheme certification. WEICan has completed testing on three small wind turbines for the purpose of undergoing the certification process in North America and Japan.

WEICan's Wind R&D Park was commissioned in April 2013 (Figure 3). The Wind Park features five 2-MW DeWind D9.2 wind turbines and incorporates a battery energy storage system from S&C

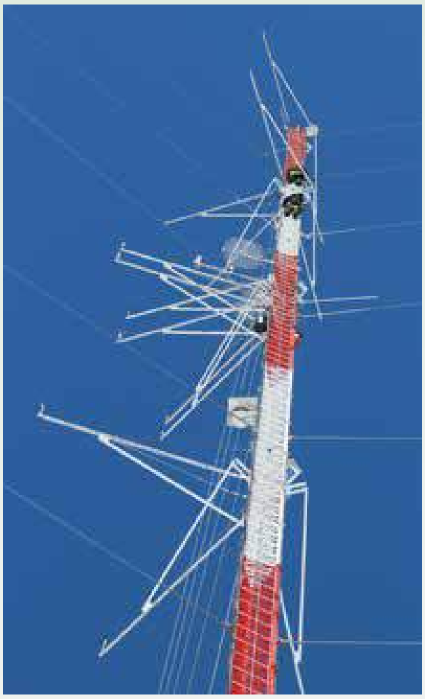


Figure 1. One of TechnoCentre éolien's 126-m met masts (photo credit: TechnoCentre éolien)

Figure 2. TechnoCentre éolien's Dynamic Smart Microgrid (photo credit: TechnoCentre éolien)

Electric Canada and General Electric. This project was awarded 12.0 million CAD (8.2 million EUR; 11.3 million USD) from the government of Canada's Clean Energy Fund, and a loan of equal amount from the government of Prince Edward Island. Its objective is to demonstrate the benefit of energy storage under various scenarios such as time-shift mode, power smoothing, and voltage control. WEICan is also using its Wind R&D Park to perform research in the area of service life estimation and in the effects of wakes and cliffs on wind energy and turbine performance. The research will be aided by installing multiple LIDARs and additional meteorological masts on the site.

4.1.3 Industry

Hydro-Québec and Sony Corporation created a new company called Esstalion Technologies, Inc. in May 2014 to research and develop large-scale energy storage systems for power grids. This new company, headquartered in Varennes, Quebec, will conduct R&D of systems and battery material technology for power grids, and their use for integrating renewable energy sources.

4.2 Collaborative research

Canada participates in the IEA Wind Task 19 Wind Energy in Cold Climates, led by TechnoCentre; Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power, led by Hydro-Québec; and Task 32 Wind Lidar Systems for Wind Energy Deployment. Canada also participates in Technical Committee-88 of the IEC.

5.0 The Next Term

According to CanWEA, Canada's wind power industry is expected to add over 2,000 MW of new capacity over the next several years with new projects in Ontario, Quebec, and Alberta.

Opening photo: Vestas 1.65-MW V-82 turbines at Mohawk Point Wind Farm, Ontario (Photo credit: Jimmy Royer: Natural Resources Canada)

Author: Tracey Kutney, Natural Resources Canada, Canada.

Figure 3. Wind Energy Institute of Canada, North Cape, Prince Edward Island (photo credit: WEICan)

18 CWEA

1.0 Overview

China saw 23,186.4 MW of new wind power capacity installed in 2014, increasing the accumulated capacity to 114,599.3 MW. China continues to have the highest wind power capacity in the world. In the past year, 19,813 MW of wind capacity were integrated to the grid, increasing the grid-connected capacity to 96,370.9 MW, which accounted for 7% of installed power capacity nationwide. In 2014, the average full-load-hour of wind power was 1,893 hours, a decrease of 181 hours compared to 2013. Wind power generation increased by 13.7%, amounting to 153.4 TWh, which accounted for 2.78% of total electricity generation, an increase of 0.2% compared to 2013. Wind power remains the third largest generation source in China, following thermal electricity and hydroelectricity. The average wind curtailment rate was 8%, a decrease of 4% compared to 2013. Wind energy represented the largest energy investment in 2014, surpassing thermal, hydro, and nuclear power, with an investment of 99.3 Billion Yuan (13.2 billion EUR; 16.0 billion USD), accounting for 27.2% of total project construction investment nationwide.

In 2014, the Chinese government considered wind power development as an important tool to promote an energy revolution, adjust the energy structure, and promote national energy security. To achieve these results, the government issued a series of policies and regulations. It adjusted feed-in tariffs (FIT) for land-based wind generation and published tariffs for offshore wind. Both land-based and offshore wind power approval policies were adjusted and are being implemented. Though wind power curtailment decreased in 2013, the government still took many measures in 2014 to further resolve this problem. Also this year, the government required that wind turbine generator systems connected to the grid pass type certification, including certification of the key components. A national wind power equipment quality information monitoring and evaluation system was also established.

2.0 National Objectives and Progress

2.1 National targets

In 2014, the Chinese government released the *Energy Development Strategy Action Plan (2014-2020)*. In this plan, the cap on annual primary energy consumption is set at 4.8 billion metric tons of standard coal equivalent until 2020, and annual coal consumption will be held below 4.2 billion metric tons until 2020. To meet the government's target of having about 15% of non-fossil fuels in total primary energy consumption by 2020, the National Energy Administration (NEA) identified management measures, such as renewables portfolio standards (RPS) and full protection of the renewable energy acquisition, which must be formulated and implemented. The NEA also outlined the necessary decrease in the cost of wind generation to realize the goal of 200 GW of wind capacity at a price equal to that of thermal electricity by 2020. Yearly wind power generation in 2020 will be 390 TWh, which will account for 5% of all power generation.

Wind energy represented the largest energy investment in 2014, surpassing thermal, hydro, and nuclear power, accounting for 27.2% of total project construction investment nationwide.

Table 1. Key National Statistics 2014: China	
Total (net) installed wind capacity	***114,599.3 MW***
New wind capacity installed	***23,186.4 MW***
Total electrical output from wind	153.4 TWh
Wind generation as percent of national electric demand	2.78%
Average national capacity factor	***21.6%***
Target:	By 2020: wind capacity is 200 GW, price of wind generation equals thermal electricity, annual wind generation is 390 TWh, and wind accounts for 5% of all electric generation.
Bold italic indicates estimates	

2.2 Progress

By the end of 2014, China had installed 23,186.4 MW of new wind power capacity during the year (exclusive of Taiwan). This added capacity in China accounted for 45.2% of new global wind capacity for the year. The accumulated wind power capacity in China reached 114,599.3 MW, accounting for 31% of wind power capacity worldwide and maintaining the highest wind power installation in the world. Compared to 2013, new wind installations increased by 44.1%, and the accumulated installation increased by 25.4%, as shown in Figure 1. In 2014, wind power generation reached 153.4 TWh, accounting for 2.78% of electricity generation.

2.3 National incentive programs

In order to promote the healthy development of the wind power industry, the Chinese government released a series of policies and regulations in 2014 to direct development of the wind power market, to promote wind power integration and consumption, and to adjust the supportive FIT.

To regulate development of the wind power market, the Chinese government will establish a national wind information monitoring and evaluation system about the quality of wind power equipment; strengthen wind power equipment quality analysis; and disclose wind power market supervision and information. Meanwhile,

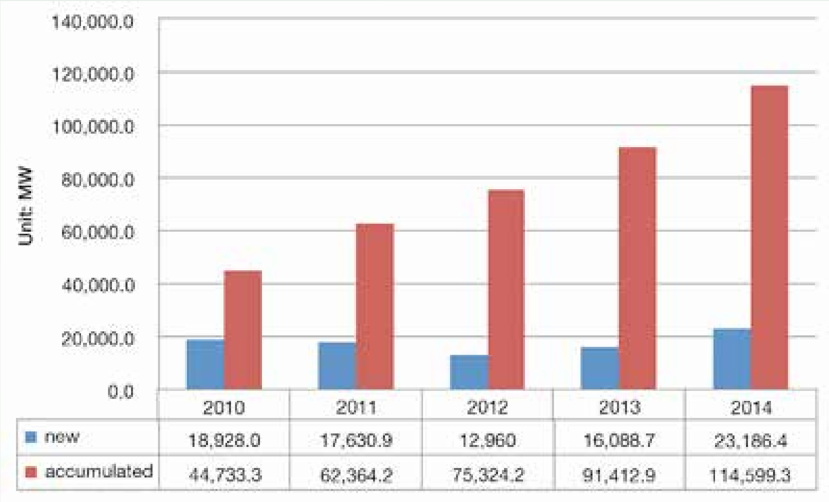


Figure 1. New and accumulated wind capacity in China 2010–2014

the government required that wind turbine generating systems that are integrated to the grid should pass type certification, with key components also included. Passing type certification should be completed before wind power developers begin equipment bidding.

Though wind power curtailment decreased slightly in 2013, the government formulated a series of policies to support wind power integration and consumption in 2014. The new policies stipulate that the grid companies should reply within 30 working days after negotiations begin on grid integration. The new policies also stipulated that on the premise of grid stability, renewable generation should be fully integrated, and renewable generators are positively encouraged to replace thermal generators.

In 2014, the National Development and Reform Commission (NDRC) announced the offshore wind FIT of 0.85 Yuan/kWh (0.11 EUR/kWh, 0.14 USD/kWh) for offshore areas and 0.75 yuan/kWh (0.1 EUR/kWh, 0.12 USD/kWh) for intertidal areas. The new offshore FIT is applicable to projects operating prior to 2017. The NDRC adjusted the land-based FIT as well. Tariffs for Class I, II, and III wind source areas decreased by 0.02 Yuan to 0.49 Yuan/kWh (0.065 EUR/kWh; 0.079 USD/kWh), 0.52 Yuan/kWh (0.069 EUR/kWh; 0.083 USD/kWh) and 0.56 Yuan/kWh (0.074 EUR/kWh; 0.09 USD/kWh) respectively. Tariffs for Class IV areas remain at 0.61 yuan/kWh (0.081 EUR/kWh, 0.098 USD/kWh). New offshore FIT are applicable to projects approved after 1 January 2015 or approved before 1 January 2015 but operated after 1 January 2016.

2.4 Issues affecting growth

Integration and consumption are still the significant problems limiting wind power development in China. Though wind generation increased by 13.7% in 2014, the average full-load-hour of wind power decreased by 181 hours compared to 2013. The decrease in full load hours was partly due to the fact that annual average wind speeds at 70 meters height decreased by 8% to 12% in 2014. However, wind curtailment was still the main restriction on wind power development.

3.0 Implementation

3.1 Economic impact

According to the sampling of domestic enterprises and considering the mean labor productivity of the manufacturing industry in China, currently about 15 jobs could be produced by every 1 MW of wind installation. Among this, 13–14 jobs are produced by the manufacturing industry, and about 1.5 jobs are created by installation and maintenance, etc. Therefore, it is estimated that in 2014 about 470,000 people worked in wind power industry.

3.2 Industry status

3.2.1 Developers

In 2014, the top five developers in China were Huadian Group (3,354.5 MW), Guodian Group (3,025.2 MW), CGN (2,523.4 MW), Huaneng Group (2,452 MW), and China Power Investment Group (2,022.7 MW), which together accounted for 57.7% of new wind installation. The top ten developers accounted for 71.93% of new wind capacity, as shown in Table 2.

3.2.2 Manufacturing industry

In 2014, the top five manufactures of new installation were Goldwind (4,434 MW), United Power (2,582.5 MW), Mingyang (2,058 MW), Envision (1,962.6 MW) and XEMC-Wind (1,781 MW). There were 26 manufacturers which occupied part of the new market share, 13 of which had new installations over 500 MW. The top ten manufacturers accounted for 80.32% of China's new wind installation, as shown in Table 3.

3.3 Wind farm operation

In 2014, a total of 13,121 new wind turbines were installed. This brought the national total 76,241 operating turbines. At the provincial level, the five provinces with the most new installations were Gansu (3,630.0 MW), Xinjiang (3,216.0 MW), Inner Mongolia (2,081.0 MW), Ningxia (1,717.7 MW) and Shanxi (1,590.2 MW), which together accounted for 52.77% of national new additions. The average full-load-hours of operating wind farms was 1,893 hours, a decrease of 181 hours compared to 2013.

3.4 Capital expenditures

According to land-based wind power resources, construction conditions, and

Table 2. Top Ten Developers of New Installation in China in 2014

No.	Developer	Capacity/MW	Share
1	Huadian Group	3,354.5	14.47%
2	Guodian Group	3,025.2	13.05%
3	CGN	2,523.4	10.88%
4	Huaneng Group	2,452.0	10.58%
5	China Power Investment Group	2,022.7	8.72%
6	Huarun	1,092.1	4.71%
7	Datang Group	830.0	3.58%
8	CASC	500.0	2.16%
9	The Three Gorges	480.5	2.07%
10	Guohua	397.9	1.72%
	Others	6,508.1	28.07%
	Total	**23,186.4**	**100.00%**

Table 3. Top Ten Manufacturers of New Installation in China in 2014

No.	Manufacturer	Capacity/MW	Share
1	Goldwind	4,434.0	19.12%
2	United Power	2,582.5	11.14%
3	Mingyang	2,058.0	8.88%
4	Envision	1,962.6	8.46%
5	XEMC-Wind	1,781.0	7.68%
6	Shanghai Electric	1,735.6	7.49%
7	Dongfang Turbine	1,298.0	5.60%
8	CSIC Haizhuang	1,144.0	4.93%
9	Windey	898.0	3.87%
10	Sinovel	729.0	3.14%
	Others	4,563.7	19.68%
	Total	**23,186.4**	**100.00%**

mainstream wind turbines technologies and wind farm operation levels, in 2013, the development cost of onshore wind power was 0.32–0.47 yuan/kWh (0.04–0.06 EUR/kWh; 0.05–0.08 USD/kWh). Under the current technology, without considering the cost of long-distance transmission or the resource and environmental benefits of wind power, the cost of wind power is higher than that of coal-fired power by 0.20 Yuan/kWh (0.027 EUR/kWh; 0.032 USD/kWh). If resources and environmental benefits are taken into consideration, the cost of wind power was nearly equal to that of coal-fired power generation.

4.0 R, D&D Activities

4.1 National R, D&D efforts

4.1.1 Fundamental research

In 2014, the Ministry of Science and Technology of the People's Republic of China continued to support the High Technology Research and Development Plan (863 Plan), the Key Fundamental Technology Research and Development Plan (973 Plan), and the Science and Technology Support Research Project. Six projects were related to wind power, as follows:

1. Research on optimization design of wind turbine blade airfoil families, focusing on the optimization design of aero structure and aerodynamic noise of flat trailing edge airfoil for multi-MW wind turbines

2. Research on key mechanical issues and design of large scale wind turbines, focusing on aerodynamic loading, nonlinear aero-elasticity, offshore hydrodynamic load, and bracing structure of multi-megawatt wind turbines

3. Research on fundamental scientific matters of large-scale wind power integration, focusing on basic theory and key technologies for long-distance, large-scale, and centralized wind power integration systems

4. Design and experimental research on new foundation structures for offshore wind turbines were completed—design of composite, single-pile foundations; preliminary design of single-pile foundations in non-batholith area for 5-MW turbines; preliminary design of assembly type multi-pile foundations and composite multi-pile foundations; and design of combined gravity foundation in batholith, typhoon area for 5-MW turbines

5. Finish the overall design and main components R&D of a 7-MW, permanent-magnetic, semi-direct driven wind turbine

6. Complete separately the preliminary design of key components and the conceptual design of 10-MW direct-drive, double-fed, superconducting wind turbines

The research projects above aimed to solve important technical problems in wind energy. They will improve key technologies,

Figure 2. Intelligent wind farm lifecycle management platform of Envision

Figure 3. Wind-photovoltaics-storage intelligent micro-grid application project in Yancheng

promote the competitiveness of the industry, and provide technical support for the healthy and sustainable development of the wind industry in China.

4.1.2 Application research

In 2014, China added 241.3 MW of offshore wind power installations, increasing the cumulative capacity to 669.6 MW. All of these offshore projects provided valuable experience for development of offshore wind power in China. International standards and experiences for developing offshore wind power, combined with China's offshore environment-specific conditions contributed to R&D of foundation designs and construction plans suitable for the offshore conditions of China. These experiences and R&D also helped with formulation of technical standards for design and construction of offshore wind power projects in China.

With the increase of wind power installation, wind farm management, operation, and maintenance are playing an increasingly important role. A lifecycle management platform for wind farms is crucial to improve generation proficiency and the quality of wind farm development. This platform combines technologies such as intelligent control, intelligent sensors, cloud-service and big data with transparent digital wind resource evaluation, wind farm design, wind farm operation and maintenance, and assets management. The Chinese company Envision has developed the "intelligent wind farm lifecycle management platform," shown in Figure 2, and Goldwind has developed the "wind farm lifecycle management system."

A wind-photovoltaics-storage demonstration project in Zhangbei by State Grid and an intelligent micro-grid demonstration project in Beijing by Goldwind have been completed. Following these, in 2014 Goldwind developed another wind-photovoltaics-storage intelligent micro-grid application project in Yancheng, Jiangsu Province, as shown in Figure 3. This micro-grid system consists of one 2-MW wind turbine, one 100-kW wind turbine, one 1-MW photovoltaics station, and one 1-MW battery storage plant. All electricity generated by this system will be provided to factories nearby. This application project should promote the development of micro-grid projects and distributed wind generation projects.

4.2 Collaborative research

By the end of 2014, CWEA had organized 29 domestic wind power companies, research institutes, and universities to attend meetings of nine IEA Wind Tasks: Task 11 Base Technology Information Exchange, Task 19 Wind Energy in Cold Climates, Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power, Task 27 Small Wind Turbines at Turbulent Sites, Task 29 Aerodynamic Models, Task 30 Codes for Offshore Support Structures, Task 31 Wind-farm Flow Models, Task 32 Lidar Systems for Wind Energy Deployment, and Task 33 Reliability Data. Results relevant to the actual problems of wind power development in China are as follows:

1. Research on joint transmission of wind power and thermal electricity in Jiuquan, Gansu Province

2. Experimental research of icing impacts

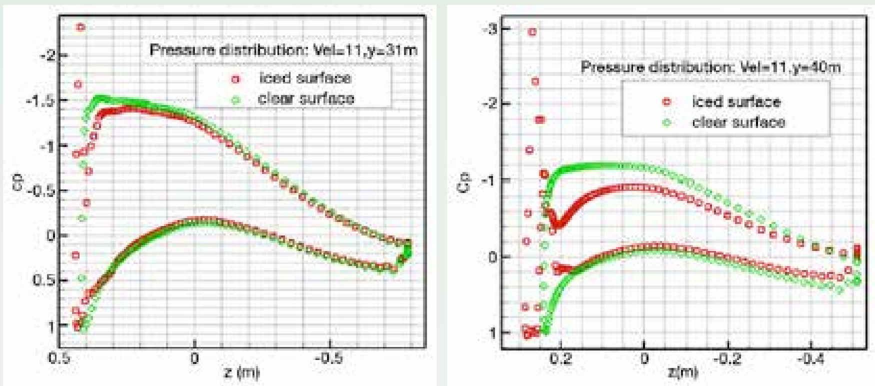


Figure 4. Pressure distribution on iced blade of wind turbine

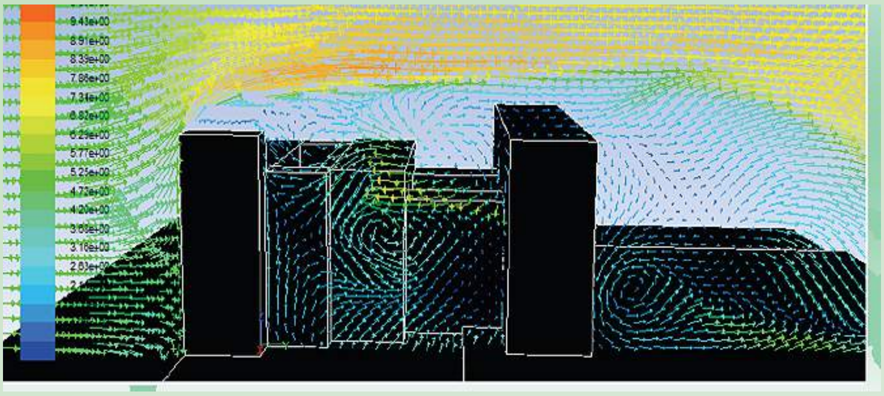


Figure 5. Computational fluid dynamics model research of wind characteristics in a high-turbulence urban environment

on wind turbine blade under cold climate conditions (see Figure 4)

3. Research on wind character computational fluid dynamic model in urban high-turbulent environment (see Figure 5)

4. Research on floating offshore wind turbine generation systems dynamic response characteristics

5. Observation and experimental study on the vertical wind profile near surface layer in grasslands and inshore areas in China

Also, CWEA is considering taking part in Task 35 Full-Size, Ground Testing for Wind Turbines and Their Components in 2015. We believe this cooperative research will play an important role in developing the wind energy industry, advancing wind energy technology, and maintaining wind energy as a sustainable energy option worldwide.

5.0 The Next Term

In 2014, the rate of wind power development in China returned to high levels, and a record amount of new capacity was installed. This achievement was made possible by the release of the Energy Development Strategy Action Plan (2014–2020) and a series of policy measures to promote the development of wind power, to regulate the wind power market, and to further resolve wind power curtailment issues. It is estimated that wind power will continue rapid development in 2015. With the rapid increase of wind power installations, the whole industry will focus on changing the development model, improving product quality, and advancing innovation. The execution of the offshore FIT will propel the development of offshore wind power in China. All of these measures will become important drivers to take part in IEA Wind Tasks, and CWEA will continue to do its best to organize all related works.

Opening photo: Wind farm in China (Photo credit: some photographer or organization)

Authors: He Dexin, Du Guangping, and Yan Jing, Chinese Wind Energy Association (CWEA), China.

19 Denmark

1.0 Overview

In 2014, 25.5% of Denmark's energy consumption came from renewable sources: 40% from oil, 16% from natural gas, 15.1% from coal, and 2.3% from nonrenewable waste. The production from wind turbines alone corresponded to 39.1% of the domestic electricity supply, compared to 32.7% in 2013.

Wind power capacity in Denmark has increased by 77 MW in 2014, bringing the total to 4,896 MW (Table 1). In 2014, 106 MW of new turbines were installed while 29 MW were dismantled. No new wind turbines were installed offshore in 2014. The largest rated turbine to be installed in 2014 was the 8-MW Vestas erected at Oesterild test site in the beginning of 2014.

2.0 National Objectives and Progress

The Energy Agreement from March 2012 is still the latest political Energy Agreement in Denmark.

The content of the agreement has been explained in earlier annual reports and can be found in the in the report "Accelerating green energy towards 2020" [1], the publication "Energy Policy in Denmark," Danish Energy Agency, December 2012 [2] and in the Minister's report to parliament in April 2013 [3].

A number of reports and recommendations to follow up the agreement were released during 2014. In January, the Danish Energy Agency prepared documents (in Danish) on coordination of the planning process on land [4] and on the terms, procedure, and responsibilities for the grid connection of near-shore wind farms [5]. Energinet.dk released a technical project description on near-shore wind farms [6]. The tendering processes for both large and near-shore wind farms was prepared in 2014 and will take place in 2015 (reports and information can be downloaded from www.ens.dk [7] and www.energinet.dk [8].

In July 2014, the Danish government and the Parliament revised the agreement about financing the future development of wind Power. The revision includes a reduction in the cost to public service obligation (PSO) for both industry and private households, which partly finance the wind development up to 2020. The result is an extension of the period for construction of Kriegers Flak to 2022 and a reduction of the plans for near-shore offshore wind farms with 100 MW from a total of 500 MW to 400 MW. However, the future wind share still will be above the 50% by 2020 goal, and increase further when Krieger Flak is in full operation in 2022. Also, an increase in capacity of new land-based wind is expected up to 2020.

2.1 National targets

The Wind Power the Agreement now includes:

- 1,000 MW of large-scale offshore wind farms before 2022 (tendering process)
  - o Horns Rev III 400 MW (in operation in 2017–2020)
  - o Krieger Flak 600 MW in operation before 2022 (EU support to grid connection 1.1 billion DDK (1.5 million EUR; 1.8 million USD)),
- 400 MW near-coast offshore installations (tendering process) including 50 MW of offshore turbines for R&D (according to the reduction mentioned above).
- 500–600 MW of added capacity on land before 2020; 1,800 MW new land-based including 1,300 MW for repowering.

2.2 Progress

As shown in Table 1 and Figure 1, the contribution from wind alone to the domestic electricity supply was 39.1% in 2014 compared to 32.7% in 2013.

The added net wind capacity in Denmark in 2014 was 77 MW, bringing the total to 4,896 MW (Table 1). In 2014, 105 MW (93 new turbines) were installed all on land, while 29 MW (69 turbines) were dismantled

Production from wind turbines in 2014 corresponded to 39.1% of the domestic electricity supply, compared to 32.7% in 2013.

Table 1. Key National Statistics 2014: Denmark	
Total (net) installed wind capacity	4,896 MW
New wind capacity installed	77 MW
Total electrical output from wind	13.1 TWh
Wind generation as percent of national electricity demand*	39.1%
Average capacity factor**	30.8%
Target***	50% wind energy by 2020

*In 2014, the wind index was 99.7%
**Average Capacity factor based on production from turbines installed before 1 January 2014
***Out of electricity demand

(Figure 2). A large part of the dismantled capacity came from come from one wind farm in Northern Jutland (Klim), where 35 600-kW turbines were dismantled to make room for a new windfarm in 2015 with 22 new 3.2-MW turbines owned by Vattenfall.

Figure 3 shows capacity and production of wind turbines in Denmark since 1980, A detailed history of installed capacity and production in Denmark can be downloaded from the Danish Energy Agency Web site [7]. The largest rated turbine installed in 2014 was the 8-MW Vestas erected at Oesterild in January 2014 (Figure 4).

The environmental benefits due to the 2014 wind energy production have been calculated using preliminary data. Assuming coal is being substituted, saved coal = 4,246,856 tons (325 g/kWh); reduced CO_2 = 9,745,872 tons (746 g/kWh); reduced SO_2 = 1,045 tons (0.08 g/kWh); reduced NO_x = 2,874 tons (0.22 g/kWh); reduced particles = 392 (0.03 g/kWh); and reduced cinder/ash 701,546 tons (51 g/kWh) [9].

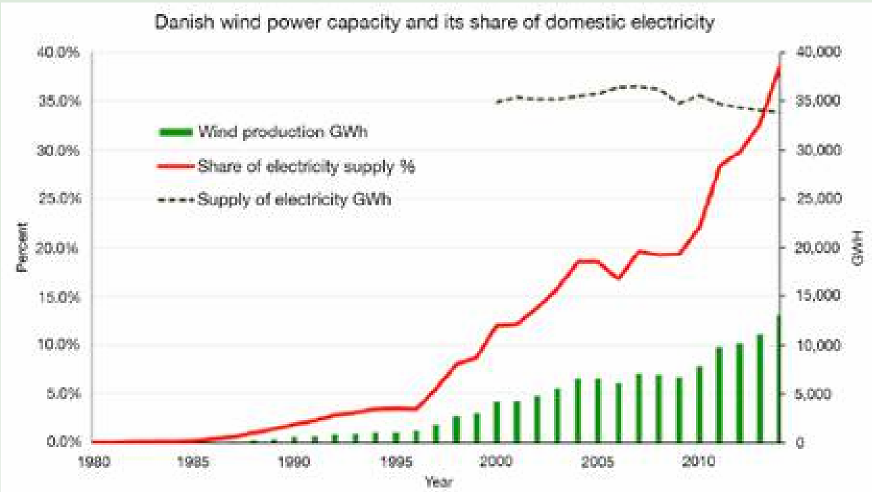


Figure 1. Danish wind power capacity and share of domestic electricity supply from 1980–2014

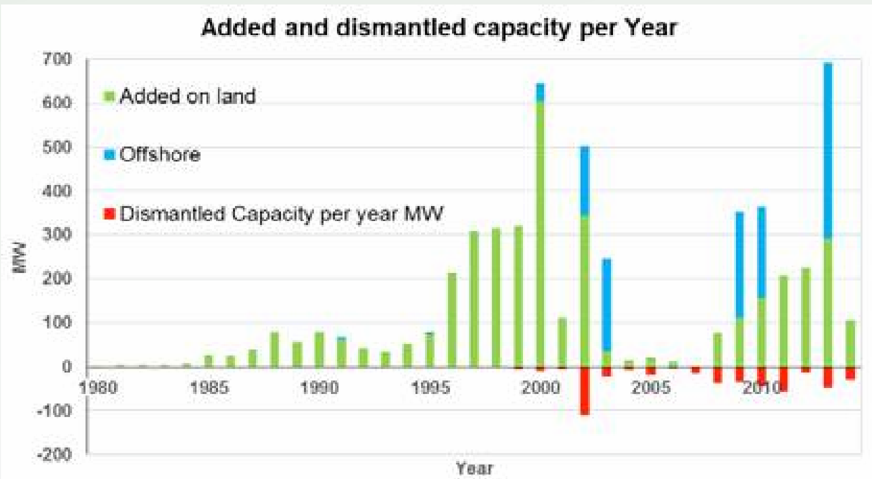


Figure 2. Added and dismantled capacity per year

2.3 National incentive programs

Information about the existing incentive programs can be found in the *IEA Wind 2013 Annual Report*.

In 2014 new feed-in premium tariffs were introduced for small wind turbines connected to the grid after November 2012, but due to EU regulation of subsidies they have not come into force before February 2015. For turbines with a capacity of 10 KW and below, the market price plus the feed-in premium is 2.5 DDK/kWh (0.34 EUR/kWh; 0.41 USD/kWh) for power delivered to the grid. For turbines with a capacity between 10 kW and 25 kW, the price is 1.5 DDK/kWh (0.20 EUR/kWh; 0.25 USD/kWh). The tariffs for small wind turbines are valid for a total capacity up to 2.5 MW and will be evaluated depending on the development

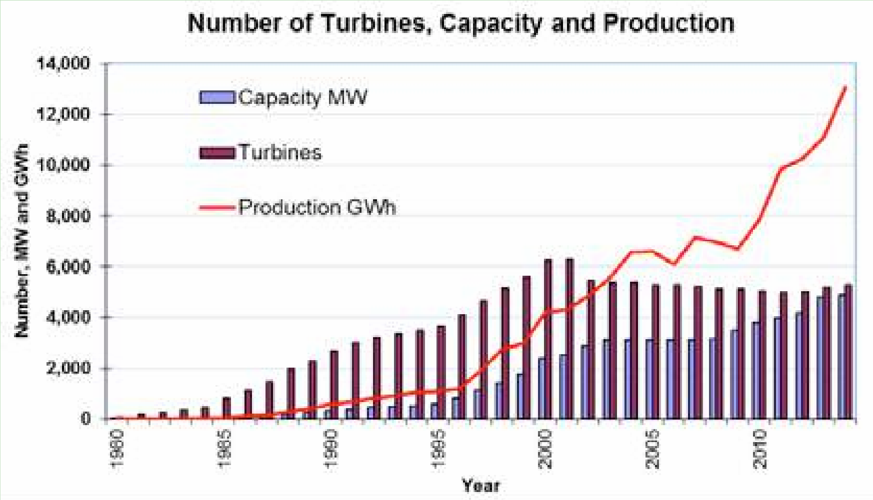


Figure 3. Development in number of turbines, capacity and production

and future EU regulation for feed-in premium systems after 2016.

2.4 Issues affecting growth

In 2014, 93 MW of new turbines were installed in Denmark. Of those, 56 turbines had a capacity below 25 kW, and 36 had a capacity between 2 MW and 4 MW. One 850-kW turbine was moved to another site. During the year, 69 smaller and older wind turbines were dismantled, representing a capacity reduction of approximately 29 MW (Figure 2).

3.0 Implementation

3.1 Industry

The wind turbine industry's annual report *"Branchestatistik 2015"* [10] includes statistics for 2014.

The turnover in 2014 was 84.4 billion DKK (11.3 billion EUR; 13.8 billion USD) compared to 78.6 billion (10.5 billion EUR; 12.8 billion USD) in 2013. The industry exported 53.5 billion DKK (7.2 billion EUR; 8.7 billion USD) in 2014 compared to 45.8 billion DKK (6.1 billion EUR; 7.5 billion USD) in 2013, which is an increase of 16.7%.

3.2 Operational details

The largest projects are the five offshore farms: Horns Rev I and II in the North Sea, Nysted and Roedsand II in the Baltic Sea, and Anholt (400 MW). Maps of existing offshore winds farm can be found in earlier annual reports or in [7].

At the end of 2014, 5,269 turbines with a capacity of 4,896 MW were in operation and the total production in the year was 13.1 GWh. The average capacity factor was 30.8% (average wind index 99.7%) for the turbines, which have been in operation the whole year. The 1,271 MW of offshore wind farms alone counted for 40% of the production with an average capacity factor of 46.4%.

The largest rated turbine to be installed in 2014 was the 8-MW Vestas erected at Oesterild in January 2014. The total amount of wind power in the grid system rose to nearly 39.1% in 2014 compared to 32.7% in 2013.

The average capacity of turbines installed fell to 1.1 MW in 2014 because of installation of many small household turbines. The average capacity of the 36 turbines above 1 MW was nearly 2.9 MW.

Figure 4. Vestas 8-MW wind turbine (Courtesy of Vestas Wind Systems A/S)

4.0 R, D&D Activities

An annual report on the energy research program's budget, strategy, and projects by technology is published in cooperation among Energinet.dk, the Energy Technology Development and Demonstration Programme (EDDP), the Danish Council for Strategic Research (DCSR), the EC representation in Denmark, and the Danish Advanced Technology Foundation. The 2014 report is expected to be available in May 2015 together with an updated list of Danish funded energy technology research projects available online at (www.energiforskning.dk).

4.1 National R, D&D efforts

Since 2007, the main priorities for R, D&D in wind have been defined in cooperation with the partnership Megavind [11]. No new strategy reports were published in 2014, but a report on modeling the levelized cost of energy (LCOE) will be published at the European Wind Energy Association (EWEA) offshore conference in March 2015 [12].

The most recent strategy is Megavind's report *The Danish Wind Power Hub* from May 2013 [13]. Also in May 2013, Megavind released a roadmap for Megavind's Strategy for Offshore Wind Research, Development, and Demonstration, Denmark – Supplier of Competitive Offshore Wind Solutions [14].

4.1.1 Megavind report recommendations

In October 2014, Megavind published a report, *Increasing the Owners' Value of Wind Power Plants in Energy Systems with Large Shares of Wind Energy* [15]. The report includes recommendations for policymakers, industry, and research regarding important future initiatives for further development of and research in wind power. All the Megavind Strategies and reports can be downloaded from [11].

Key messages to policy makers: Policy makers in this context include politicians, energy system development planners, regulators, and transmission system operators. The report identifies the following needs.

1. Develop more international and larger energy markets
2. Further develop transmission grids to promote well-functioning energy markets
3. Provide economic incentives to promote the integration of energy systems in order to transfer demand from other energy systems to electricity, for

example, replace fossil fuels by electricity in the transportation sector
4. Shape markets so that it becomes more attractive for wind power to participate to all power system services
5. Continue public funding of new CAPEX projects as is done by public service obligation resources in Denmark today
6. Consider changing the tax on electricity to increase demand flexibility
7. Consider larger tenders to accelerate value chain maturation
8. Reduce the regulatory risks, which are presently disproportionately high compared to the market risks.

Key messages to industry: The following key messages are addressed to industry companies including owners, wind turbine manufacturers, and sub-suppliers:
1. It is important to have clear strategies and roadmaps on how to reduce the cost of electricity produced by wind power plants.
2. There is potentially a very high value in utilizing portfolio and cluster synergies, especially if the industry will cooperate.
3. The industry should aim to collaborate across the value chain.
4. The industry should communicate to potential investors that wind power is a sound, long-term investment in order to mitigate capital sourcing challenges.

Key messages to researchers: R&D is needed to support the development of the measures identified in this strategy:
1. Development of data mining techniques to handle the "big data" for the purpose of diagnostics and condition monitoring.
a. Studies of the technical and economic feasibility of: wind power joining markets (frequency control, balancing, ramping); use of probabilistic forecasts; and new market designs.
2. Development of new tools for economic assessment with special focus on higher resolution market models enabling studies of real-time balancing.
3. Technical studies of ancillary services from wind power plants: Uncertainties and values of ancillary services depending on service lifetime; new ancillary services from wind power plants allowing higher instantaneous penetration of wind power plants; dynamic modeling of ancillary services from wind power plants.
4. Cost reductions of O&M: use of condition monitoring (diagnostics); development of optimization tool(s).
5. Technical and economic feasibility studies of new electrical concepts: DC wind turbines and collection grids; low frequency AC transmission.
6. Power quality and harmonics: development of new test and assessment procedures to reduce costs for ensuring the necessary power quality; development of converter technologies and active control to mitigate the harmonic emission.

Statistics and information about supported energy research is published on a common website for all Danish Energy Research and Development Funding programs [16]. All funded projects within R, D&D can be found in the project gallery, as well as deadlines for applications and more information about the various programs. The latest annual report is "Energi14" with data from 2013 [17].

4.1.2 Public supported projects in 2014

In 2014 the following projects (Table 2) received grants with a total of 136 million DDK (18 million EUR; 22 million USD). The total research budget for the projects is more than 200 million DDK (27 million EUR; 33 million USD).

4.1.3 DTU wind energy tests [18]

Test Centre for Large Wind Turbines at Høvsøre

During the ten years existence of Høvsøre, innumerable tests have been performed on 19 different wind turbines, and the demand for new tests and measurements on turbines at Høvsøre will continue.

At Høvsøre, the wind conditions allow an almost uninterrupted, high wind speed coming from the North Sea that corresponds to conditions offshore. The flat terrain west of the test center means that the wind conditions at the turbines are very well defined. Wind speeds, wind direction, temperatures, and atmospheric pressure are being measured on all meteorological masts, and a few of the masts provide measurements at different heights. An average wind speed of 9.3 m/s has been measured at the height of 80 meters. All data is continuously gathered, and many are compared to measurements performed on the wind turbines.

National Test Centre for Large Wind Turbines at Østerild

In 2014, all test stands have been rented to companies. The two new tenants are EDF Enérgies Nouvelles from France and Vestas Wind Systems A/S from Denmark. Three new wind turbines were installed on test stands 2, 3, and 7 at the Test Centre, and one turbine on stand 6 was taken down. Siemens Wind Power has one turbine erected and a new one will be installed; Vestas Wind Systems installed two wind turbines.

4.1.4 LORC Lindoe Offshore Renewables Center [19]

Nacelle testing

LORC nacelle testing is a two test-dock design and a result of close cooperation between industry and academia. On one test dock, a mechanical test can be conducted, applying forces and moments on the nacelle main shaft, static as well as dynamic. This dock also offers Highly Accelerated Lifetime Testing (HALT). It enables customers to verify the expected quality level of the nacelle because it can simulate 20 years of operation in less than half a year depending on the size of the machine.

The other function tester dock tests the functionalities and performance of the nacelle. The function tester performs tests of the full nacelle and can include the hub where the blades are normally mounted. The absolute benefit of including the hub, and hence allowing the pitch system to be operational, is that it opens a range of opportunities for software testing. This is because communication signals and voltage supply can be used unmodified from the wind turbine controller inside the nacelle to the hub and rotor components.

LORC Component & Substructure Testing Centre

The LORC Centre focuses on mechanical and climatic testing of such areas as foundations' joints, experiments with new design rules, corrosion protection testing, etc. It was established in cooperation with industrial partner FORCE Technology.

Mechanical testing

With the aim of addressing practical challenges in the offshore wind turbine sector, the LORC Component & Substructure Testing Centre is establishing a strong basis for large-scale mechanical testing of materials, foundation structures, and components. The facility allows for static and dynamic testing and identification of structures' strength and durability.

The strong floor will have a number of generic load frames and actuators for static tension/compression, cyclic loading, bending,

Table 2. Supported Wind Energy R&D Projects in 2014				
English title	Company	Program Total budget: 1.40 (1.93) Grant: 0.70 (0.96)	Grant (million DKK; million EUR; million USD)	Project budget (million DKK; million EUR; million USD)
ERA-NET Plus - New European Wind Atlas	DTU Wind Energy	EUDP	15.0; 2.0; 2.4	26.4; 3.5; 4.3
Multi-level medium voltage converter	PowerCon	EUDP	15.7; 2.1; 2.5	29.8; 4.0; 4.9
Enhanced LIghtning effect TEsting capabilities for optimized wind turbine	Global Lightning Protection Systems A/S	EUDP	8.9; 1.2; 1.5	15.3; 2.1; 2.5
Offshore wind foundation node on an industrial scale	SIEMENS WIND POWER A/S	EUDP	8.5; 1.1; 1.4	21.3; 2.9; 3.5
Active filter functionalities for power converters	Aalborg Universitet	ForskEL	4.1; 0.6; 0.7	5.7; 0.8; 0.9
FORIDA TOWERS II - demomstration and further development	FORIDA DEVELOPMENT A/S	EUDP	7.7; 1.0; 1.3	15.5; 2.1; 2.5
Full scale basis test of wind turbines and their components Task 35	Danmarks Tekniske Universitet	EUDP	1.8; 0.2; 0.3	2.0; 0.2; 0.3
Cost-efficient lidar for pitch control	WINDAR PHOTONICS A/S	EUDP	8.6; 1.1; 1.4	13.0; 1.7; 2.1
Robot for automated assembly of bolts in the flange joints in wind turbines	Seagar ApS	EUDP	6.5; 0.9; 1.1	11.7; 1.6; 1.9
IEA Wind Task 29 Mexnext III	DTU Wind Energy	EUDP	1.1; 0.15; 0.17	1.3; 0.17; 0.21
IEA Task 30 Offshore Code Comparison Collaboration, Continued with Correlation	DTU Wind Energy	EUDP	1.31; 0.18; 0.21	1.83; 0.25; 0.30
DTU Wind Energy	Liftra ApS	EUDP	3.1; 0.42; 0.50	6.8; 0.91; 1.1
EUDP	Terma A/S	EUDP	4.2; 0.56; 0.7	6.9; 0.92; 1.1
1.31; 0.18; 0.21	DTU Wind Energy	EUDP	1.5; 0.2; 0.24	2.1; 0.28; 0.34
1.83; 0.25; 0.30	J Lemming Consulting	EUDP	0.13; 0.017; 0.05	0.15; 0.02; 0.024
Understanding the waves creates cheaper power from offshore wind turbines	DTU Wind Energy	Innovation Fund	20.2; 2.7; 3.3	24.9; 3.3; 4.0
The InnoMill project. Mobile robots to turn giant wind turbines into the profitable energy source of the future	DTU Mechanical Engineering, DAMRC research centre	Innovation Fund	13.5; 1.8; 2.2	24.7; 3.3; 4.0
Speedier production of long offshore wind turbine blades of a high quality	DTU Wind Energy	Innovation Fund	15.0; 2.0; 2.4	30.0; 4.0; 4.9

and torsion. The set-up includes modularized and flexible anchorage points for clamping and hydraulic equipment intended for static and dynamic loading.

- Loads and forces applied to simulate realistic offshore conditions
- Strong floor measures 20 x 9 meters
- 22 meters of 4-meter-high reaction walls
- Actuator capacities in the MN regime

Climatic testing

The LORC Component & Substructure Testing Centre establishes a climatic chamber for exposure of structures and components to varying climatic conditions, primarily low and high temperatures, temperature cycles, and corrosive environments. This can be used for the testing of cooling systems, transformers, hydraulic systems, generators, gears, etc.

- Very large components' functionality at extreme conditions like offshore
- Only commercially available climate chamber in Northern Europe with combination of temperature, humidity and corrosive environment
- Climate chamber: 14 x 8 x 8 meters
- Temperature: -38° C to +60° C
- Humidity control: 10% to 100% relative humidity
- Salt spray simulating offshore corrosive environment

4.2 Collaborative research

Danish energy policy objectives are achieved among other measures by taking part in international co-operation regarding R, D&D in energy technologies and public support is offered in order to promote that Danish companies and universities/research institutions take part in international co-operation regarding R, D&D in energy technologies.

International Energy Agency (IEA)

Within IEA, Denmark is participating in approximately 20 Implementing Agreements. The Energy Technology and Demonstration Program (EUDP) is offering support to the costs of participating in the Agreements. More information can be found at (http://www.iea.org/) and (http://www.ieawind.org).

EU programs

Danish companies and universities/research institutions very actively take part in EU R, D&D programs. Further information about Danish companies participating in EU programs may be found at (http://ufm.dk/en/) or on (http://cordis.europa.eu/fp7/).

Nordic Energy Research

Nordic Energy Research offers grants to projects and Danish companies, universities, and research institutions participate in

Figure 5. The HALT Tester of LORC Nacelle Testing - 6 degrees of freedom loads

projects supported by the program. The Nordic Energy Research Program is financed mainly by national programs and the Danish contribution is financed by EUDP. More information about the Nordic energy research program can be found at (http://www.nordicenergy.org/).

5.0 The Next Term

The next large offshore wind farms planned are Horns Rev III and Krieger's Flak, with a total capacity of 1,000 MW [1]. The detailed planning of these two projects and the near-shore projects, which were already described in earlier annual reports, has continued during 2014. The tendering process can be followed on The Danish Energy Agency's website (http://www.ens.dk/en/supply/renewable-energy/wind-power/offshore-wind-power) [7].

In total, three licenses are required to establish an offshore wind project in Denmark. The three licenses are granted by the Danish Energy Agency, which serves as a "one-stop-shop" for the project developer in relationship to the many interests connected to the establishment of offshore wind power projects:

1. License to carry out preliminary investigations
2. License to establish the offshore wind turbines (only given if preliminary investigations show that the project is compatible with the relevant interests at sea)
3. License to exploit wind power for a given number of years, and an approval for electricity production (granted if conditions in license to establish project are kept)

Horns Rev III and Krieger's Flak and the near-shore project follow the government tender procedure, while a number of other projects have been applied for though open door procedures. For more information see the above mentioned website at [7].

At the end of 2014 several offshore projects were in the planning process: 6 demonstration turbines at Frederikshavn; up to 14 demonstration turbines at Nissum Bredning; 20 turbines, 60–120 MW at Mejlflak; 400 MW at Horns Rev 3 (2020); 600 MW at Kriegers Flak; 200–320 MW at Omø Syd; 400 MW (50 MW demonstration turbines) at Near Shore offshore wind farms; and 120–240 MW at Jammerland Bugt.

The government plan includes new land-based wind turbines with a total capacity of 1,800 MW, expecting that over the same period a capacity of 1,300 MW will be dismantled. Energinet.dk's website [8] provides information on current projects.

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Opening photo: Giant new bench will test Vestas 8-MW offshore turbine (Photo credit: LORC)

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20 European Union/EWEA

1.0 Overview

In 2014, the EU installed and connected 11.79 GW of new wind energy capacity, for a cumulative wind capacity of 128.75 GW. The total electric generating capacity (including wind) increased by 26.9 GW, reaching 910 GW. Since 2000, 29% of new generating capacity installed has been wind power, 56% renewables, and 91% renewables and gas combined.

The EU's power sector continues to move away from fuel oil, coal, nuclear, and gas while increasing its total installed generating capacity with wind and solar photovoltaics (PV).

Wind power accounted for 43.7% of total 2014 power capacity installations. Renewable power accounted for 79% of new installations during 2014: 21.3 GW of a total 26.9 GW of new power capacity.

The total wind power capacity installed by the end of 2014 would, in a normal wind year, produce 265 TWh of electricity, enough to cover 9.5% (of which an estimated 1% from offshore wind) of EU's final electricity consumption— up from 8.5% the year before [1].

2.0 EU Objectives and Progress

The main legislation in the EU promoting the deployment of wind energy is the Renewable Energy Directive that came into force in 2009. It sets a target of 20% renewable energy in gross final energy consumption at the EU level, broken down into 28 distinct national targets.

The European Heads of State have now also set a binding renewable energy EU-wide objective of at least 27% in the context of the 2030 Climate and Energy package. This figure of 27% was chosen as, according to the modeling of the European Commission (EC), this would be the share of renewable required to meet the EU's target of 40% CO_2 emissions reduction.

The Heads of State have decided to move away from binding national targets, which means the EU objective will have to be delivered by a new governance system. The EC, the executive body of the European Union, made initial proposals on this governance in

Since 2000, 29% of new electric generating capacity installed in the European Union has been wind power.

Table 1. Key Statistics 2014: European Union	
Total (net) installed wind capacity*	128,751 MW
New wind capacity installed	11,791 MW
Total electrical output from wind [1]***	265 TWh
Wind generation as percent of EU electric demand [1]***	9.5%
Average EU capacity factor***	23.4%
Target:	208 GW by 2020

*Capacity figures in this table are grid-connected at the end of 2014.
**Based on the weighted average of wind energy installations in EU countries at the beginning and end of 2014.
***Estimation based on installed capacity at end-2014 and a normal wind year

its Communication on the Energy Union [3] of 25 February 2015. Detailed proposals on the implementation of the 2030 Climate and Energy package are also expected before the end of the year. Eventually the EC is expected to come forward with a proposal of a post-2020 Renewable Energy Directive.

In terms of wind energy penetration in the EU electricity market, electricity that would be generated by wind energy from the installed capacity at end-2014 (approximately 265 TWh) would be enough, in a normal wind year, to satisfy the electricity demand of Spain and Ireland together or 9.5% of all EU electricity demand [1]. It would save around 157 million tonnes of CO_2 emissions, equal to 2.35 billion EUR (2.85 billion USD) CO_2 cost (assuming a CO_2 price of 15 EUR/tonne; 18 USD/tonne) [9].

2.1 EU targets

The EU Member States set up mandatory country targets that, for the whole EU represent a 20% share of renewable energy in final energy consumption by 2020. The Member States then proposed national sectorial targets that, for the EU as a whole are 172.6 GW of land-based and 38.5 GW of offshore wind for a total of 207.7 GW.

2.2 Progress

By the end of 2014, Denmark and Sweden had already achieved their 2020 targets, whereas Austria, Croatia, and Germany reached above 80% of their targets. On the opposite end, Malta (with no wind capacity at all), Slovenia and Slovakia (both with less than 5 MW installed cumulatively), Latvia (only 15% of the 2020 target achieved), the Netherlands, Greece, Finland (the three with 25% of the target achieved), France, and the Czech Republic (with 38% of the target achieved) are unlikely to reach the target. Other countries have achieved a large part of their target, but then some have put in place policies that will likely prevent them from reaching their 2020 self-defined targets. These countries that have chosen to slow development include Spain (currently 64% of the target) and Hungary (44%). In particular, Spain implemented in 2014 a regulatory system establishing in principle the maximum profit wind farm operators should make and adjust the support to that. The system runs retroactively and excludes wind farms commissioned before 2004, for which support was cancelled altogether.

2.3 EU incentive programs

The predominant support scheme for wind energy production in the EU has traditionally been the feed-in tariff (FIT). This system prevents plant operators from being exposed to market price fluctuations and guarantees a fixed income per unit of electricity sold to the grid. The second most implemented system is feed-in premium (FiP), which grants a variable or fixed income to wind power plant owners on top of the electricity price. FIT proved very effective: 76% of the EU cumulative installed capacity at the end of 2012 was installed under a FIT system and 7% under a FiP system, according to JRC data and/or estimates. Other systems implemented in the EU are quota/portfolio schemes coupled with green certificates schemes and/or tenders. Only 17% of the cumulative capacity in 2012 was installed under this scheme.

In order to better integrate large amounts of variable renewables in the electricity markets and system, the EU recently started to phase out FIT schemes in favor of tender systems. Countries which have already changed their regulatory schemes towards tenders or are in the process of changing them include Spain, Germany, the UK, and the Czech Republic.

2.4 Issues affecting growth

The main issue affecting growth is the idea that is popular among certain policymakers: support for renewables is expensive and the culprit of high electricity prices in some countries. However, a recent report on subsidies and costs of EU energy [4] showed land-based wind energy to be the cheapest technology when external factors are taken into consideration along with the levelized cost of energy and subsidies. Another key barrier is retroactive legislative changes in some countries that prevent investors from the clarity needed to build consistent business plans. Lastly, some economic, social, and

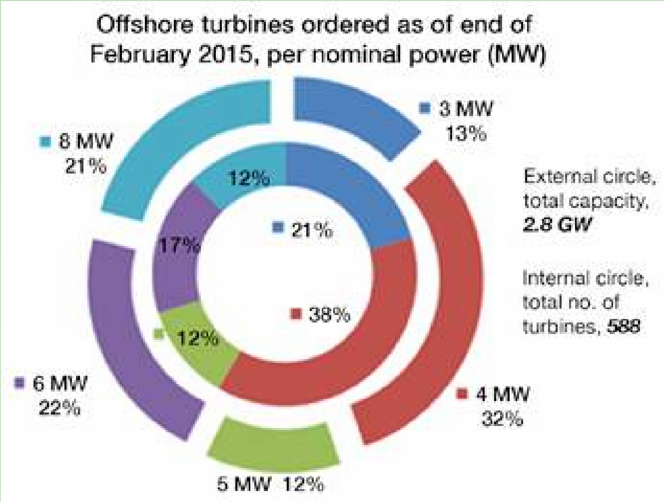

Figure 1. Offshore turbines orders by February 2015 (Source: JRC data from company announcements)

environmental drawbacks are perceived at a local level and generate oppositions to wind energy development. Sometimes this opposition leads to more stringent spatial planning and consent restrictions that prevent the use of the latest technologies, e.g. taller towers.

3.0 Implementation

Of the 11.8 GW of new capacity in the EU in 2014, 59.5% were installed in just two countries (Germany and the UK), emphasizing the market concentration seen in 2013 (46% of total installations). Moreover, 77.2% of all new installations were concentrated in four countries (France, Germany, Sweden, and the UK). This is a level of concentration that has not been seen in the EU's wind power market since 2007 when the three wind energy pioneering countries (Denmark, Germany, and Spain) together represented 58% of all new installations in that year. A number of previously large markets such as Denmark, Italy, and Spain have seen their rate of wind energy installations decrease significantly in 2014, by 90.4%, 84.3% and 75.4% respectively [1].

Offshore wind power saw almost 1.5 GW installed and connected in 2014, which was 5.3% less than 2013. Offshore wind power installations represented 12.6% of the annual EU wind energy market, down from 14% in 2013. Moreover, there are twelve projects under construction—representing 2.9 GW—in the pipeline for the next 12–18 months. Five of these projects had some wind turbines connected to the grid in 2014; once completed they will result in a further 1.18 GW of capacity taking the cumulative offshore wind capacity to a minimum of 9.2 GW in Europe [6].

3.1 Economic impact

In 2014 investment in EU wind farms was between 13.1 billion EUR and 18.7 billion EUR (15.9 billion USD and 22.6billion USD). Land-based wind farms attracted around 8.9 billion EUR to 12.8 billion EUR (10.8 billion USD and 15.5 billion USD), while offshore wind farms accounted for 4.2 billion EUR to 5.9 billion EUR (5.1 billion USD to 7.1 billion USD) [2].

New players are investing in the wind energy sector in the EU. In particular, the financial markets in 2014 continued to support the offshore wind sector across a variety of instruments, and a broadening investor and creditor base, issuing 3.17 billion EUR (3.84 billion USD) record level of non-recourse debt. More non-European banks, trading houses, and semi-public institutions are entering the European offshore industry, a trend that will likely continue.

Wind farms contribute to the wealth of local population and communities in a number of ways including community funds, land rental payments, and local levies. Under the assumption of a land rental fee of 1,500 EUR/MW (1,817 USD/MW), the currently land-based installed capacity contributes every year around 180 million EUR (218 million USD) to rural areas [5].

3.2 Industry status

The trend toward cost reduction and increased efficiency of the value chain is forcing manufacturers to come together and share financial and technological wealth. This is the case for Danish wind turbine manufacturer (original equipment manufacturer, OEM) Vestas which formed an offshore wind Joint Venture (JV) with Japanese power house Mitsubishi. Other notable JVs include Spanish Gamesa, French Areva, American General Electric, and French Alstom—although the latter is broader than the respective wind sections and does not include offshore.

Many investment funds, institutional players such as pension funds and insurance companies, and banks are entering the wind energy market. Some of them are coupling with veterans of the business such as global investment firm KKR acquiring one third of the shares of Acciona Energía Internacional, owner of Acciona's generation portfolio which includes wind.

The European Investment Bank (EIB) has provided financial support to the sector in two broad areas: financing OEM R&D programs (e.g. Senvion and Nordex in 2014) and providing debt to wind farm projects. During 2014 the EIB funded the construction of West of Duddon Sands, Gemini, Nordergründe, Baltic II, and Sandbank offshore wind farms and of a number of land-based projects in Lower Austria.

European OEMs have been able to react to the European financial crisis and return to healthy financial conditions, supported also by their global operations. For the four companies who already published their annual reports at the time of writing [6], EBIT increased from 223 million EUR (270 million USD) in 2013 to EUR 915 million EUR (1.1 billion USD) in 2014, and a weighted-average EBIT ratio increased from around 2.8% to some 7.5%. Turbine sales increased by 22% in MW terms, which compares with 52% increase in global market minus China [6].

3.3 Operational details

As mentioned above, trends in offshore wind are toward bigger projects, further away from the shore, and in much deeper waters. Average capacity of offshore projects commissioned in 2014 reached 368 MW, while their average water depth was 22.4 m and the average distance to shore 32.9 km. Projects under construction, consented, and planned confirm that average water depths and distances to shore are likely to increase [7].

Average capacity of offshore wind turbines has as well increased by 86% between 2000 and 2014 reaching 3.7 MW in the latter year. The trend toward larger offshore turbines is clear among the last announced purchase agreements, and turbines 6 MW or above represent 29% of total orders in terms of turbines and 43% in terms of total capacity.

Calculations on 2013 Eurostat data estimate wind energy average capacity factor in the EU at 23.9%. Other estimates and data from the industry indicate that land-based wind capacity factor in some areas of the EU as well as new wind farms all around the EU is higher, around 24% and offshore wind capacity factor is 42%. Wind energy capacity factor and offshore wind in particular is likely to grow significantly over the next years due to the ongoing trend towards bigger, taller and more efficient wind turbines.

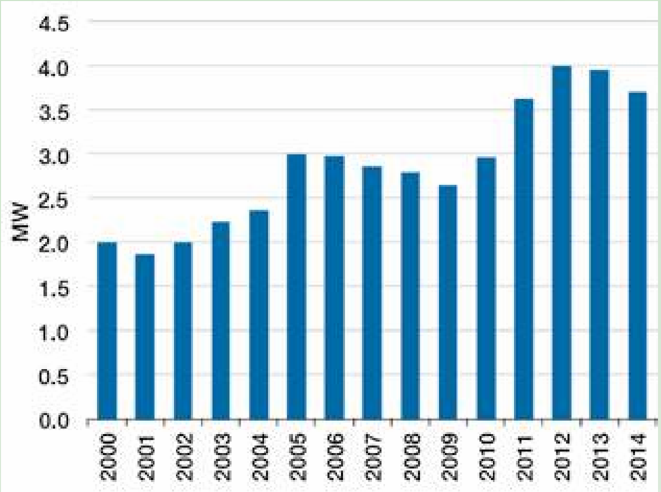

Figure 2. Average offshore wind turbine rated capacity, 2000–2014 (Source: EWEA [7])

3.4 Wind energy costs

Global figures presented in OEM annual reports suggest that wind turbine unit prices continue to descend as the trend shown in the Figure 4.

3.5 Future investment

On 26 November 2014 the EC announced a 315 billion EUR (381 billion USD) investment plan. Its objective is to get Europe growing again and get more people back to work, and a part of it includes wind energy and electricity interconnections. The plan is built on three main strands:

- Financing strand: the creation of a new European Fund for Strategic Investments (EFSI), guaranteed with public money, to mobilize at least 315 billion EUR (381 billion USD) of additional investment (public and private) over the next three years (2015–2017);
- Information strand (pipeline building and assistance): the establishment of a credible project pipeline in the form of a European Investment Opportunity Web (EIOW) coupled with a user-friendly technical assistance program to channel investments where they are most needed under the co-ordination of the European Investment Advisory Hub (EIAH);
- Regulatory strand: an ambitious roadmap to make Europe more attractive for investment by legislative action and removing regulatory bottlenecks.

The centerpiece of the plan is investment. Identified eligible projects will be analyzed on an individual merit basis emphasizing the projects' potential to create sustainable socio-economic benefits for the Member States and the EU as a whole. The plan promotes strategic investments of European significance in areas including energy networks, research and innovation and renewable energy. Examples of wind energy projects on this pipeline list:

- Belgium: offshore wind parks (Norther, Rentel, Seastar, Mermaid, Northwestern) with granted concessions required to support Belgium to achieve its renewable energy target. Expected project cost: 4.8 billion EUR (5.8 billion USD) with 2.0 billion EUR (2.4 billion USD) needed for the next three years.
- Romania: LEA 400 kV circuit

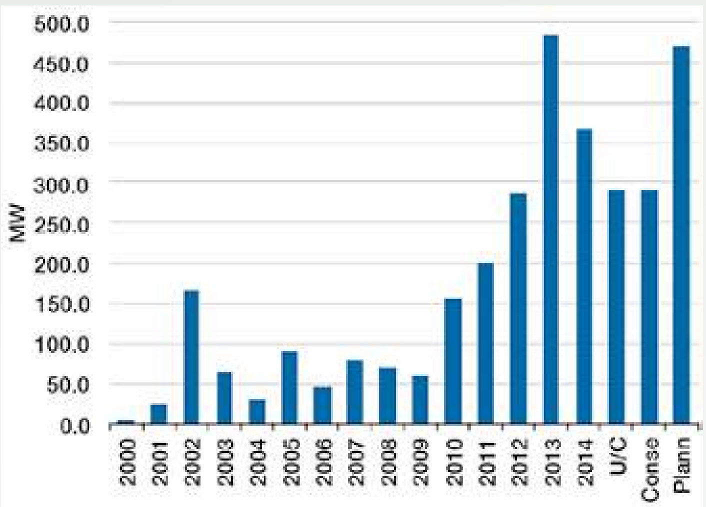

Figure 3. Average size of offshore wind farm projects, 2000–2014 (Source: EWEA [7])

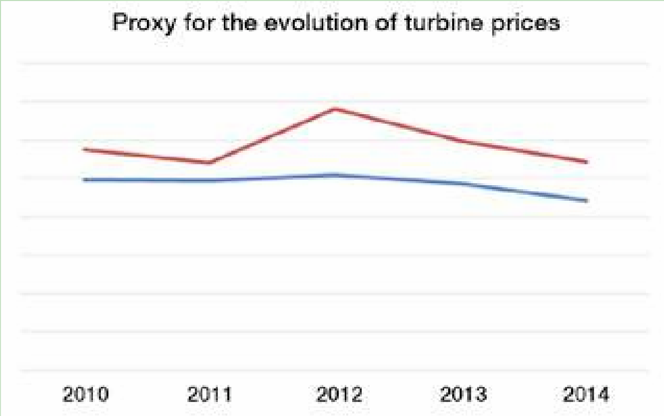

Figure 4. Wind turbine price proxies; JRC calculation

Suceava—Gadalin: A new line 400-kV circuit between existing stations (approximately 260 km) aiming to increase grid capacity between the production center of wind energy in the Eastern Region of Romania and the inland parts of the country.

4.0 R, D&D Activities

The Horizon 2020 (H2020) program for R, D&D support is being implemented and includes a double budget for energy R&D from the previous program (FP7) to 5.93 billion EUR (7.18 billion USD) in seven years. H2020 focuses on technology readiness levels 1–7. In particular, demonstration projects shall integrate innovative technology development and business models; shall develop plans for market uptake; and shall check existing market barriers and work out proposals for solutions (policy, legislation, regulation, etc.).

The projects listed in the next subheadings are funded by the different EU funding mechanisms, which are managed by the EC and its delegated agencies and other entities. Projects funded by Member States without EC contribution are not included here.

4.1 National R, D&D efforts

At the EU level, R, D&D priorities embrace the whole spectrum of elements necessary to reduce the cost of wind energy: basic and applied research, and demonstration.

Basic research includes:

• SPEED - Silicon Carbide (SiC) Power Technology for Energy Efficient Devices. With a budget of 18.6 million EUR (22.5 million USD) (12.3 million USD; 14.9 million USD EC contribution), SPEED started on 1 January 2014 and will last four years. If focuses work on a new generation of high power semiconductor devices, operating above 10 kV, based on SiC. SiC power electronics already exist but they perform rather poorly compared to the predictions and the production costs are by far too high. SPEED aims at a breakthrough in SiC technology along the whole supply chain: (a) growth of SiC substrates and epitaxial-layers; (b) fabrication of power devices in the 1.7/>10kV range; (c) packaging and reliability testing; (d) SiC-based highly efficient power conversion cells; and (e) real-life applications and field-tests in close cooperation with two market-leading manufacturers of high-voltage (HV) devices. SPEED will include two demonstrators: a cost-efficient solid-state transformer and a wind turbine power converter with improved capabilities for generating AC and DC power.

• CARBOPREC - Renewable source nanostructured precursors for carbon fibers. With a budget of 8.6 million EUR (10.4 million USD) (6.0 million EUR; 7.2 million USD EC contribution), it will last four years from 1 January 2014. CARBOPREC aims at developing low-cost precursors for carbon fiber (CF), from renewable materials, reinforced by carbon nanotube (CNT) to produce high performance yet cheaper CF for automotive and wind energy applications. To achieve this objective, two white fiber processes will be studied to produce continuous fibers: (a) wet spinning approach for the cellulose dissolved in phosphoric acid (H_3PO_4); and (b) melt spinning by extrusion for the lignin.

Applied research includes:

The European Institute of Innovation and Technology's KIC-InnoEnergy funds MD-Wind, a project starting in February 2015. MDWind will launch a new remotely-operated seafloor-based geotechnical site investigation system for the offshore wind market. An existing general-purpose submarine drilling robot will be tooled for the specific site investigation requirements and conditions of offshore wind developments. The system will be tested at sea, to provide a demonstration of its capabilities in a realistic commercial-like scenario.

Non-technology research includes:

The Intelligent Energy Europe program funded WISE Power, aiming at accelerating the planning processes for wind power by decreasing local community opposition to wind energy, and also by promoting existing Social Acceptance Pathways engaging citizens in the development of wind power projects. The wind industry and other stakeholders will benefit from the project's collaborative approach in the sharing of best practices aimed to foster social acceptance. The findings are targeted at key actors such as local communities, regional/ national authorities, wind energy developers, system operators, citizens groups, ethical banks, co-operatives and social and environmental organizations. The total costs for WISE Power is 1.46 million EUR (1.77 million USD), with a 75% EU contribution, the project began on 5 May 2014 and will last 30 months. Any information can be found on (http://wisepower-project.eu/).

The EU Marie Skłodowska-Curie Actions Innovative Training Networks (ITN) funded AWESOME, a project aiming "to cater for the growing demand of knowledge and the lack of qualified workers" in wind turbine O&M, in particular offshore. The project will develop new default maintenance planning and prevention strategies and will give rise to new know-how and experiences by training specialized professionals. To do so, AWESOME will select 11 researchers and guide them through their doctoral theses

Table 2. Wind power installations in Europe, 2013 and 2014. Source: EWEA [1]

	Installed 2013	End 2013	Installed 2014	End 2014
Austria	308.4	1,683.8	411.2	2,095.0
Belgium	275.6	1,665.5	293.5	1,959.0
Bulgaria	7.1	681.1	9.4	690.5
Croatia	81.2	260.8	85.7	346.5
Cyprus	-	146.7	-	146.7
Czech Republic	8.0	268.1	14.0	281.5
Denmark	694.5	4,807.0	67.0	4,845.0
Estonia	10.5	279.9	22.8	302.7
Finland	163.3	449.0	184.0	627.0
France	630.0	8,243.0	1,042.0	9,285.0
Germany	3,238.4	34,250.2	5,279.2	39,165.0
Greece	116.2	1,865.9	113.9	1,979.8
Hungary	-	329.2	-	329.2
Ireland	343.6	2,049.3	222.4	2,271.7
Italy	437.7	8,557.9	107.5	8,662.9
Latvia	2.2	61.8	-	61.8
Lithuania	16.2	278.8	0.5	279.3
Luxembourg	-	58.3	-	58.3
Malta	-	-	-	-
Netherlands	295.0	2,671.0	141.0	2,805.0
Poland	893.5	3,389.5	444.3	3,833.8
Portugal	200.0	4,730.4	184.0	4,914.4
Romania	694.6	2,599.6	354.0	2,953.6
Slovakia	-	3.1	-	3.1
Slovenia	2.3	2.3	0.9	3.2
Spain	175.1	22,959.1	27.5	22,986.5
Sweden	689.0	4,381.6	1,050.2	5,424.8
UK	2,075.0	10,710.9	1,736.4	12,440.3
FYROM	-	-	37.0	37.0
Serbia	-	-	-	-
Turkey	646.3	2,958.5	804.0	3,762.5
Iceland	1.8	1.8	1.2	3.0
Liechtenstein	-	-	-	-
Norway	110.0	771.3	48.0	819.3
Switzerland	13.3	60.3	-	60.3
Faroe Islands	4.5	6.6	11.7	18.3
Ukraine	95.3	371.2	126.3	497.5
Russia	-	15.4	-	15.4
Belarus	-	3.4	-	3.4
Total	**12,228.5**	**121,572.2**	**12,819.6**	**133,968.2**
EU28	**11,357.3**	**117,383.6**	**11,791.4**	**128,751.4**

on topics linked to wind farm operation and maintenance. AWESOME has a budget of 2.8 million EUR (3.4 million USD) and it started 1 January 2015.

4.2 Collaborative research

Although by nature all EU-supported R, D&D projects are collaborative, ERA-NETs [2] are even more clearly so. An ERA-NET is a collaborative research project where each of the Member States that join fund the part of the research carried out by its companies or research centers, and the EC supplies 30% of the total project cost. It is open to non-EU countries. Two ERA-NETs have been launched recently, DemoWind and NEWA.

DemoWind is a joint 31.6 million EUR (38.3 million USD) fund with 33% participated by the EU and six countries (Belgium, Denmark, Netherlands, Portugal, Spain, and the UK) contributing the rest. The fund runs from 1 January 2015 to 31 December 2019 [12]. DemoWind has published a call for industry-led research and innovation projects in the participating countries having as theme the development and demonstration of innovative technologies for reducing the cost of offshore wind energy. DemoWind will target capital-intensive demonstration projects that would be difficult or impossible for a single country to support. The joint call will support innovation in the following wide range of offshore wind technologies: turbine components; foundation structures (fixed and floating); electrical networks; installation and decommissioning practices; O&M; and large met-ocean databases. Projects must advance innovative technologies from Technology Readiness Levels 5 or 6 to Technology Readiness Levels 6 or 7.

NEWA is a Joint Programme aiming to integrate and coordinate national and regional programs towards the development of a new European Wind Atlas, allowing for a more efficient use of financial resources and research capabilities. The new atlas will be based on improved modeling competencies on atmospheric flow and its interactions with wind turbines and wind farms, land-based and offshore. By reducing the overall uncertainties in determining wind conditions—through a more accurate wind condition mapping—the new European Wind Atlas will become an essential tool for manufacturers and developers, public authorities and decision-makers. NEWA's budget is 13.1

Figure 5. Wind turbines in Europe

million EUR (15.9 million USD) of which the EU will contribute 4.3 million EUR (5.2 million USD), and will last from May 2014 until April 2019.

5.0 The Next Term

Annual wind energy installations in the EU have registered a 10% compound annual growth rate (CAGR) since 2000; cumulative installations in 2014 grew by 9.8% with respect to 2013. Wind energy is expected to grow both in installations and in share of final electricity demand and generation in the years leading up to 2020 although the growth after 2020 is not certain. The industry is working hard to cut costs and improve its processes' efficiency along the whole value chain, but it needs to be able to rely on a clear and stable regulatory framework.

6.0 Contacts

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Opening figure: Wind power installations in Europe by end of 2014 (Source: EWEA [2])

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21 Finland

1.0 Overview

Finland is a 14-GW winter-peaking power system with 83 TWh demand in 2014. Already, 30% of electricity consumption was provided by renewables in 2014: 16% by hydro power, 13% by biomass, and 1.3% by wind power. Installed wind power was 627 MW at the end of 2014, generating 1.1 TWh. The target is 6 TWh/yr in 2020 and 9 TWh/yr for 2025. In 2015, there were more than 9,100 MW of land-based wind power projects in various phases of planning and 2,200 MW of announced projects offshore.

Growing construction of wind power started in Finland in 2012 following the legislation for guaranteed price for renewable generation, which was set in 2010. Before the market began to grow, there were delays in receiving building permits for wind power plants related to permitting procedures and especially radar issues.

Wind power technology in Finland employs about 3,000 people—mainly in component and sub-system manufacturing (in order of size: Moventas, ABB, The Switch, Hydroll), sensors (in order of size: Vaisala and Labkotec) and material production (Ahlstrom and Ruukki). Project development activities are increasing, and also innovative operation and maintenance (O&M) methods have been developed (Bladefence). Currently project development, construction, and O&M employ approximately 2,200 people in Finland.

2.0 National Objectives and Progress

2.1 National targets

The target for renewable energy sources (RES) in Finland is 38% of final energy consumption (RES share in 2012 was 31%). This reflects the targets for renewables arising from the EU target of 20% of energy consumption from renewable sources in 2020.

The target set for wind power in the climate and energy strategy 2008 is 6 TWh/yr (2,500 MW) for the year 2020, corresponding to 6–7% of the total electricity consumption in Finland. The new energy strategy published at the beginning of 2013 has an increased target for wind power of 9 TWh/yr in 2025.

To achieve the goal set for 2020, a guaranteed price of 83.5 EUR/MWh (101.1 USD/MWh) was adopted in March 2011. The difference between the guaranteed price and three-month average spot price of electricity will be paid to the producers as a premium. To encourage early projects and market growth, a higher guaranteed price level of 105.3 EUR/MWh (127.5 USD/MWh) is available until the end of 2015. The premium is paid from the national budget to the projects up to the capacity limit of 2,500 MW (measured as MVA), for 12 years.

2.2 Progress

The implementation of the guaranteed price system has led to a market of nearly 200 MW/yr. Production from wind power increased by 44% in 2014, to 1,112 GWh. This corresponds to 1.3% of the annual gross electricity consumption of Finland (Table 1). The environmental benefit of wind power production in Finland is about 0.8 million tons of CO_2 savings per year, assuming 700 g/kWh CO_2 reduction for wind power (replacing mostly coal and also some gas power production).

Total wind capacity in Finland was 627 MW by the end of 2014 from which 184 MW (59 turbines) were installed in 2014 (Figure 1). The new wind farms have 2–17 turbines each with total capacity ranging from 3 MW to 54 MW and turbines ranging from 0.8 MW to 5 MW (average: 3.1 MW). The largest wind power plants were erected in Tornio (eight 4.5-MW turbines) and Raahe (ten 3.3-MW turbines). In 2015, close to 400 MW are anticipated.

Twelve turbines were removed in 2014: one of the Pori turbines (1 MW started in 1999) was damaged in April and the turbine was decommissioned. Eight turbines (0.3–0.6

By January 2015, 9,100 MW of land-based wind power projects were in various phases of planning, and 2,200 MW of offshore projects had been announced.

Table 1. Key National Statistics 2014: Finland	
Total (net) installed wind capacity	627 MW
New wind capacity installed*	178 MW
Total electrical output from wind	1.1 TWh
Wind generation as percent of national electric demand	1.3%
Average capacity factor	27%
Target:	6 TWh/yr (2,500 MW) in 2020, 9 TWh/yr in 2025
*This is net capacity increase after 6 MW were removed.	

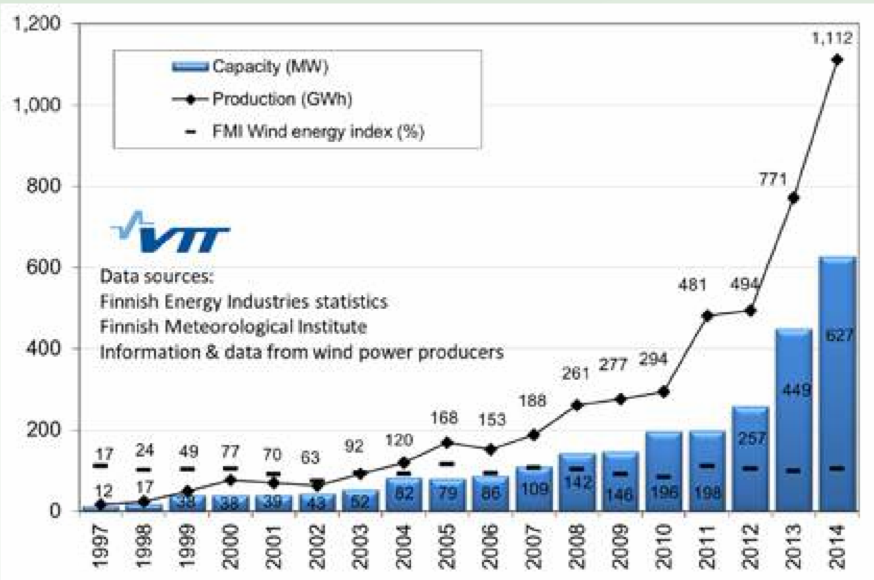

Figure 1. Wind power capacity and production: FMI Wind energy index is calculated from Finnish Meteorological Institute (FMI) wind-speed measurements and converted to wind power production; 100% is average production from 1997–2011.

MW started in 1993–1997) in Hailuoto and Siikajoki were disconnected from grid and are waiting for repowering. A 660-kW turbine in Lumijoki and a 1-MW turbine in Pori have been replaced with 2-MW turbines. A 225-kW turbine (started in 2004) in Ahvenanmaa has been removed.

The net increase was 178 MW (40%) bringing the total capacity at the end of 2014 to 627 MW with a total of 260 wind turbines (Figure 1). The size of the installed capacity ranges from 75 kW to 5 MW (average: 2.4 MW). About 12% of the capacity is from turbines originating from Finland, 46% from Denmark, 23% from Spain, 14% from Germany, 1% from South Korea, and 1% from the Netherlands, as shown in Figure 2 (left). Almost 75% of total wind capacity is from turbines with rated power of 3 MW or more, as shown in Figure 2 (right). This development towards larger turbines is expected to continue in near future.

Most of Finland's wind capacity is land-based and distributed over the coastal areas of Finland, see Figure 3. More inland sites have been developed and deployed during the last few years following the introduction of tall turbines with large rotors into the market. Turbine icing is expected to become a greater issue both from an economic and safety point of view.

Total capacity offshore is 28 MW. The offshore wind turbines are located mainly on small cliffs or artificial islands, being semi-offshore; so far only one is constructed on a caisson. The number of turbines is small because the guaranteed price is not sufficient to start offshore projects. Based on a competitive process, an extra investment subsidy of 20 million EUR (24 million USD) was granted in December 2014 to Suomen Hyötytuuli Oy to enable the construction of an approximately 50-MW offshore wind farm on the Finnish west coast. Apart from this demonstration project, one larger offshore wind power plant (288 MW) has received a building permit according to the water act, and six other offshore projects (almost 1,200 MW) have finished their environmental impact assessments.

The Åland islands between Finland and Sweden constitute an autonomous region with its own legislation, budget, and energy policy. Wind energy covered 20% of electricity consumption in 2014 with 22 MW of installed capacity. The region is not included in the guaranteed price mechanism but Åland is planning its

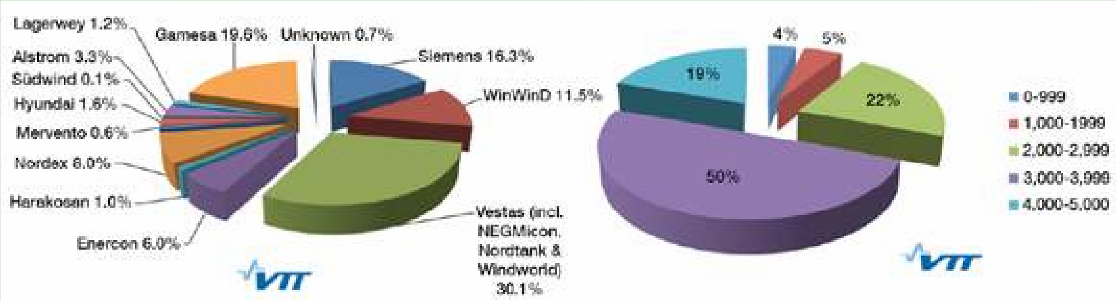

Figure 2. Distribution of wind turbine capacity in Finland by make (left) and size (kW) (right)

own legislation for subsidy system. A 100-MW transmission line to mainland Finland is anticipated in 2015 to help further deployment of wind power in this wind-rich region.

2.3 National incentive programs

A market based feed-in system with guaranteed price entered into force on 25 March 2011 in Finland.

A guaranteed price of 83.5 EUR/MWh (101 USD/MWh) for 12 years is set for wind power, where the difference between the guaranteed price and spot price of electricity will be paid to the producers as a premium. There is a higher guaranteed price level of 105.3 EUR/MWh (127.5 USD/MWh) until the end of 2015 to encourage early projects.

A three-month average spot price (day-ahead electricity market price at the Nordic market Elspot) will be the comparison price to determine the payments to the producers. The producers will be paid the guaranteed price minus the average spot price, after every three-month period. Should the average spot price rise to above the guaranteed price, the producers will get this higher price. Should the average spot price drop to below 30 EUR/MWh (36 USD/MWh), the producers would only get production premium based on 30 EUR/MWh (36 USD/MWh) level. And if the price is 0 in any of the hours the producers will not get payments, to enable wind power plants to help the power system in cases of surplus power production—so far, these situations have only happened in Denmark with larger wind shares than are planned for Finland.

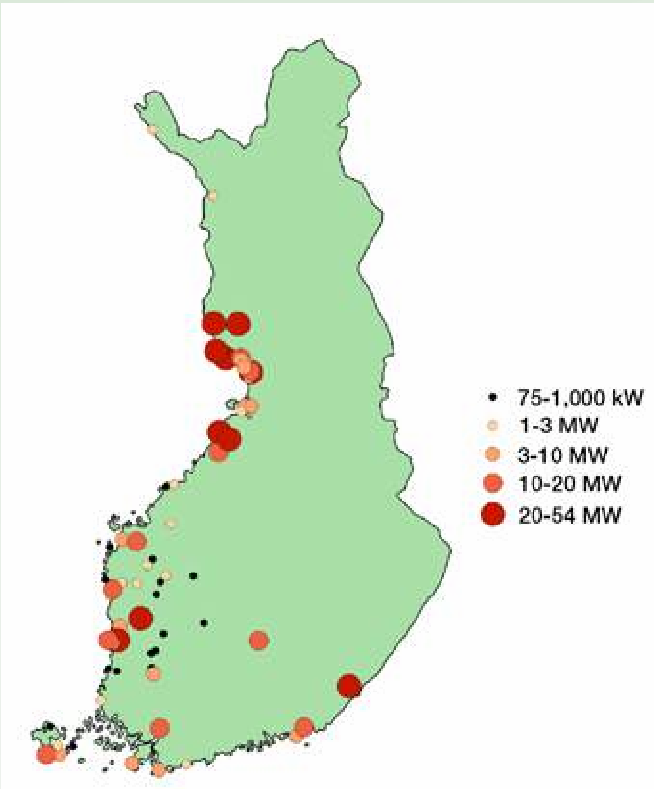

Figure 3. Wind power plant sites for turbines operating in Finland at the end of 2014

Wind power producers will also be responsible for paying the imbalance fees from their forecast errors. This has been estimated to add 2.0 EUR/MWh to 3.0 EUR/MWh (2.4 USD/MWh to 3.6 USD/MWh) to the producers, if they use a weather forecast based prediction system for the day-ahead bids to the electricity market.

If the emission trading of fossil fuel prices raises electricity market prices, this will reduce the payments for this subsidy. The cost for the subsidy will be recovered by taxes. The regulator Energy Authority is managing the system. In 2014, the total amount paid as a subsidy was still moderate even if the higher guaranteed price was paid and market prices were low, 54.7 million EUR (66.2 million USD), as there are not yet very many projects operating under the scheme.

There is no special subsidy for offshore wind power. An offshore wind power plant demonstration subsidy of 20 million EUR (24 million USD) was granted in December 2014 for the Hyötytuuli project in Pori (about 50 MW).

2.4 Issues affecting growth

The main challenges to growth during the last few years have been related to planning and permitting problems.

The **planning and permitting** process with the environmental impact assessment is considered lengthy by developers and has also regionally-different processes. Local communities have declined building permits for sites marked in regional plans. Land use and building laws changed in 2013 to enable easier permitting to industrial sites. Also, there is an on-going practice in all regional plan updates to add sites for wind power plants by the authorities. This will help in permitting future wind power projects.

Noise, especially low-frequency noise, has become an issue on many sites. New regulations published by the Ministry of Environment in 2012 used lower noise limits than the building law (by 5–10 dB). This is challenging in many sites, especially a night-time limit of 35 dB near summer cottages. The Ministry of Environment published guidelines on modeling and measuring the wind turbine noise in February 2014. If there is a possibility for especially disturbing noise emission, a 5-dB increase to modeled values can be made. A governmental decree on noise limits is foreseen for spring 2015.

Public acceptance of wind power is generally high. According to annual surveys, 81% of Finns see the need to increase the wind production capacity. However, local resistance to the projects has sometimes slowed down project development. The Finnish Wind Power Association has published guidelines of best practices for project development to improve local acceptance of the wind farm projects. A recommendation for a compensation scheme has also been published by Finnish Wind Power Association to improve local acceptance, including the land owners that are neighboring a wind power plant site.

Impact of wind turbines and wind farms on **radar** systems stopped permitting processes in 2010. Procedural and modeling tools were set up to help the Ministry of Defence to assess radar impact, after which a majority of the sites have been released to further development. A working group investigated necessary changes to radars for two regions (northern coast and south-eastern Finland). A compensation scheme to invest in new radar and to gather costs from the developers has been developed for the former case.

Safety distances from roads/railways and aviation routes limited the development. The Ministry of Traffic and Communication has acted to relieve limitations by reducing the required distance between wind turbines and roads from 500 m to 300 m. Flight barrier limitations are now only 15 km along the runway (previously 30 km) and 6 km across runway direction (previously 12 km). In some areas the height of the turbines is limited. The rules for flight obstruction lights at nacelles of turbines have been relieved, enabling fewer disturbances to local inhabitants.

In the near future one **challenge** will be the continuation and content of the subsidy system after the 2,500-MW target is reached. One challenge for public acceptance is related to the premium paid over the electricity market price to wind power producers connected with the concern of the domestic content in the value of a wind farm over the lifetime. There may also be challenges regarding the unexpected effects of turbine's real lifetime, turbine reliability, O&M cost, in-cloud icing of taller and larger turbines, etc. on the economic performance of wind farms over their lifetime.

3.0 Implementation

3.1 Economic impact

Direct and indirect employment by development and O&M is increasing. The technology sector is strong in Finland, employing about 3,000 people. Project development, construction, and O&M employ more than 2,200 people currently. All in all, there are more than 100 companies in the whole value chain from development and design of wind farms, to O&M and other service providers. The deployment of the targeted 2,500 MW wind power is estimated to create employment of at least 12,000 person-years.

Wind power technology is one of the top Finnish Cleantech opportunities. Finnish wind power technology companies group under Technology Industries Finland published their roadmap in 2014. The wind power industry has delivered around 750 million EUR to 1.0 billion EUR (908 million USD to 1.2 billion USD) in revenue during the past five years, corresponding to a market share of 1.5–3.0% in the global equipment market. Just keeping the market share is a challenge in a business-as-usual scenario. Moderate actions could keep the market share until 2020 and help the industry grow. Roadmap implementation could lead to doubling of the market share and 2.0 billion EUR (2.4 billion USD) in revenues.

3.2 Industry status

3.2.1 Manufacturing

More than 20 technology and manufacturing companies are involved in wind power in Finland. Most of the companies are in planning and construction of wind farms in the domestic market. After the bankruptcy of WinWind only Mervento remains as a domestic turbine manufacturer, offering a 3.6-MW, direct-drive turbine, especially designed for near-shore and off-shore applications.

Several industrial enterprises have developed important businesses as world suppliers of major components for wind turbines. For example, Moventas Wind is the largest independent global manufacturer and service provider of gears and mechanical drives for wind turbines. ABB is a leading producer of generators and electrical drives for wind turbines and wind farm electrification, both land-based and off-shore. The Switch supplies individually-tailored permanent-magnet generators and full-power converter packages to meet the needs of wind turbine applications, including harsh conditions. In addition, materials such as cast-iron products, tower materials (SSAB, formerly Rautaruukki), and glass-fiber products (Ahlstrom Glasfiber) are produced in Finland for the main wind turbine manufacturers. Sensors especially for icing conditions are manufactured by Vaisala, and Labkotec. Foundation solutions for ice infested waters are developed by many companies, like Technip. Peikko is offering foundation technologies based on modular components. A growing number of companies offer operation and maintenance services in Scandinavian and Baltic markets, including (in order of size) a.o. Bladefence, JBE Service, Wind Controller, and Airice.

3.2.2 Ownership and applications

Many newcomers have entered Finnish wind power market. They include both domestic and foreign investors and project developers. Power companies and local energy works are active in building wind power and green electricity is offered by most electric utilities. The supply of used turbines has encouraged some farmers to acquire second-hand turbines, but the wind resource is limited inland at heights below 60 m due to forested landscape.

New projects are seen in the forested inland locations, using towers up to 140 m high. High towers and new designs with larger rotors provide considerably higher capacity factors than experienced before in Finland, from 20-23% up to 24-37%.

The first semi-offshore projects were built in 2007. Total capacity offshore is 24 MW. Hyötytuuli Oy was granted a demonstration subsidy for a 50-MW offshore demonstration wind farm, which will locate outside Pori on the west coast. The wind farm is planned to be constructed in 2016–2017. One larger offshore wind power plant (Suurhiekka, 288 MW) has received a building permit according to the water act and six other offshore projects (almost 1,200 MW) have finished their environmental impact assessments.

3.3 Operational details

The average capacity factor from wind turbines operating the whole year (167 turbines) was 27% (calculated as total generation 926 GWh divided by total capacity 386 MW and total hours 8,760 hours). Average capacity factor of the 167 individual turbines was 26% in 2014. As reported in the annual wind energy statistics of Finland, the capacity factor of the taller new turbines is considerably higher than for older ones: average capacity factor was 30% or above for the 74 turbines with hub height 100 m or more. The total average capacity factor has ranged from 17% to 28% in previous years. The wind power production index ranged from 84% to 114% in different coastal areas in Finland (average: 104%). The average technical availability of wind turbines operating in Finland has ranged from 84% to 96% between 2001 and 2012, but not all turbines report availability.

3.4 Wind energy costs

All wind energy installations are commercial power plants and have to find their customers via a free power market. In most cases, an agreement with a local utility is made that gives market access and financial stability. The average spot price in the electricity market Nordpool was 36 EUR/MWh (44 USD/MWh) in 2014 (41 EUR/MWh; 50 USD in 2013). Wind power still needs subsidies to compete, even on the best available sites. The guaranteed price, feed-in premium for wind energy fits the Nordic electricity markets, as the producers will sell their energy in the market or by bilateral contracts, and account for the balancing costs for their production.

4.0 R, D&D Activities

4.1 National R, D&D efforts

The Finnish Funding Agency for Technology and Innovation (Tekes) is the main public funding organization for research, development, and innovation in Finland. Tekes invested 185 million EUR (224 million USD) in energy-related R&D projects in 2014. Tekes funding for wind power in the last seven years is presented in Figure 4. Tekes granted 1.0 million EUR (1.2 million USD) in wind power R&D projects in 2014. Since 1999, Finland has had no national research program for wind energy. Individual industry coordinated projects can receive funding from Tekes, and some projects are linked to research programs Groove, Serve, and Concepts of Operations.

There were 15 ongoing wind power-connected R&D projects funded by Tekes in January 2014—most of them are industrial development projects. The main developed technologies were power electronics, generators, permanent-magnet technologies, gearboxes, wind turbines (large and small ones), sensors, blade manufacturing, foundry technologies, construction technologies, automation solutions, offshore technology, and services.

VTT is developing technologies, components, and solutions for large wind turbines. An icing wind tunnel for instrument and material research and testing in icing conditions began operation in 2009. Industrial collaboration in the development of reliable and cost-efficient solutions for drive trains for future wind turbines continued. Several technical universities also carry out R&D projects related especially to electrical components and networks (Aalto, Lappeenranta, Tampere, and Vaasa).

4.2 Collaborative research

VTT has been active in several international projects in the EU, Nordic, and IEA frameworks. As part of the EU project REServiceS (2012–2014), the possibilities of system services from wind power are studied to help wind

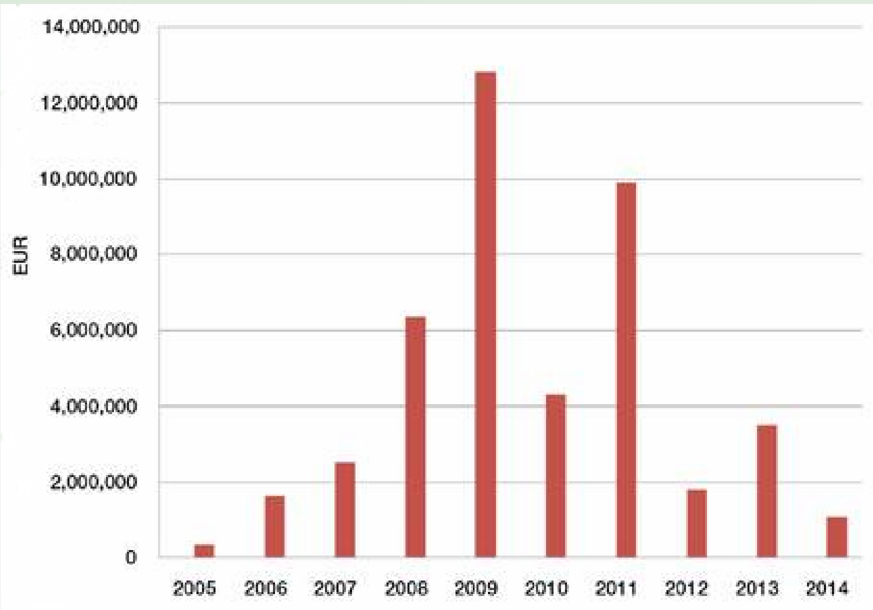

Figure 4. Tekes funding for wind power R&D projects in the last ten years

integration. VTT is participating in two Nordic Energy Research projects: Offshore DC Grid and IceWind. VTT is a founding member of the European Energy Research Alliance (EERA) and participating actively in the joint programs in wind energy and smart grids.

Finland is taking part in the following IEA Wind research tasks:

- Task 11 Base Technology Information Exchange (VTT)
- Task 19 Wind Energy in Cold Climates (OA, VTT)
- Task 25 Power Systems with Large Amounts of Wind Power (OA, VTT)
- Task 33 Reliability Data (VTT and ABB)

5.0 The Next Term

More installations are expected in 2015 for Finland, as developers try to take advantage of the higher guaranteed price period expiring at the end of 2015. By the end of 2014, 711 MW had been accepted to the guaranteed price system. The Finnish Wind Power Association estimates that approximately 400 MW of new capacity is anticipated for 2015 and between 300 MW and 400 MW are anticipated for 2016. A huge number of projects are planned, under feasibility studies, or have just been proposed: 9,100 MW land-based and 2,200 MW offshore. Offshore demonstration of roughly 50 MW will start construction in 2016–2017.

Overcoming limits of cold climate is important to wind power development in Finland. The blade heating system developed at VTT is now in commercialization; a spin-off from VTT (Wicetec) started activities in 2014. Further research and development in this area will continue in 2015.

References:

Opening photo: Kopsa wind power plant in Raahe, Finland (Credit: Puhuri)

Further reading: The statistics for wind power in Finland can be found at http://www.vttresearch.com/services/low-carbon-energy/wind-energy/wind-energy-statistics-in-finland

Authors: Hannele Holttinen and Esa Peltola, VTT Technical Research Centre of Finland, Finland.

22 France

1.0 Overview

Wind is the second largest renewable source of electricity in France after hydroelectricity. With close to 1 GW of incremental wind capacity installed, 2014 has proven to be the year with largest installation rate since 2010, leading to a total land-based wind capacity of approximately 9.3 GW.

The increase in the installation rate reflects the impact of the recent regulatory changes such as the confirmation of the Feed-In Tariff (FIT) after EU validation, or the simplification of administrative procedures. The yearly wind production was 16.2 TWh, close to 20% of the 91 TWh renewables produced in France in 2014. Wind and all renewables covered 3.5% and 19.5% of electricity demand respectively.

A strong will to develop offshore wind has also been reaffirmed with the announcement of the winners of the second round of tenders for two areas totaling close to 1 GW. The French government announced a third round for the end 2015/early 2016 and a specific call for projects for pilot farms of floating wind for mid-2015. The emergence of an offshore wind industry is also accompanied by the development of industrial facilities of wind turbine manufacturers as well as other suppliers.

On the R&D side, floating wind proves to be a very active sector in France with several projects aiming at developing innovative technologies. During 2014, France officially joined IEA Wind, with 16 organizations participating in several R&D tasks.

2.0 National Objectives and Progress

The directive 2009/28/CE sets a target of 23% for the contribution of renewables to final energy consumption by 2020. This objective has been translated into French law through the so-called multiannual programming of investment (Programmation Pluriannuelle des Investissements (PPI)), which defines targets for the capacity of power generation by primary energy source and, where appropriate, by production technology and geographic area. The PPI materializes both the "Grenelle de l'environnement" and the adoption of the package European Energy Climate of December 2008.

The PPI defines the national objectives of energy policy (security of supply, competitiveness, and environmental protection) in terms of development of the electricity production by 2020. It contributes to the implementation of non-CO_2-emitting energy sources, including renewable or nuclear. A new round of the Programmation pluri-annuelle de l'Energie (PPE) is expected to be completed by end 2015, with targets to be fixed until 2023.

2.1 National targets

For renewable energy, the PPI provides for the year 2020 the following development targets:

- 25,000 MW of wind energy, specified as 19,000 MW land-based and 6,000 MW offshore
- 5,400 MW of solar energy
- 2,300 MW of biomass
- Additional 3 TWh/yr and 3,000 MW peak capacity for hydroelectricity

The development of renewable energies aims at increasing its production by 20 million tonnes of oil equivalents. It is also worth noting that further objectives for 2030 are currently being debated, within the framework of the Law for Energy Transition. This Law was adopted by the National Assembly

In 2014, close to 1 GW of wind capacity was added for the largest installation rate since 2010.

Table 1. Key National Statistics 2014: France	
Total (net) installed wind capacity	9,278 MW
New wind capacity installed	1,071 MW
Total electrical output from wind	17.0 TWh
Wind generation as percent of national electric demand	3.5%
Average national capacity factor	***22.8%***
Target:	By 2020: 19 GW of land-based wind and 6 GW of offshore wind
Bold italic indicates estimates	

in October 2014, and is still awaiting its final adoption, after exchange with the Senate. This law defines, among others, long-term objectives in the framework of a transition toward a low-carbon economy and energy system, and aims at defining new policy tools. It addresses several aspects including energy efficiency, renewables deployment, and the future of nuclear energy.

The Law defines several targets, in terms of greenhouse gas emissions, primary energy consumption, share of renewables, and share of nuclear in electricity production.

New targets for each renewable energy source will be defined in PPE.

2.2 Progress

The rate of installation of wind turbines in France has experienced a positive trend between 2007 and 2010, with yearly figures above 1,000 MW, followed by a significant decrease from 2011 to 2013. With close to 1 GW of incremental capacity installed, 2014 proves to be the year with largest installation rate since 2010, leading to a total land-based wind capacity of approximately 9.3 GW (see Figure 1).

The increase in the installation rate reflects the impact of the recent regulatory changes such as the confirmation of the FIT after EU validation, or the simplification of administrative procedures. This led to a global yearly production of 16.2 TWh, as part of the 91 TWh renewables produced in France in 2014. This was also the first year where other renewables than hydroelectricity produced more (27.9 TWh) than conventional fossil fuel power plants, the main contributor to that number being wind.

In 2014, wind and all renewables covered 3.5% and 19.5% of electricity production respectively.

It is interesting to note that, according to the transmission system operator in France, the electricity consumption in France amounted to 465.3 TWh, which was 6% below the 2013 figure. This is a result of, among other things, quite favorable meteorological conditions (average winter temperatures were recorded to be 0.5°C higher than corresponding reference temperatures), reducing the demand for heating.

Despite the encouraging acceleration of activities during year 2014, a strong and even more rapid increase of the installation rate would be needed to reach the 2020 PPI target of 19 GW of installed land-based wind capacity.

2.3 National incentive programs

In 2014, the French government confirmed the support mechanism for land-based wind, which was validated by the European Commission. The FIT consists in a fixed amount of 82 EUR/MWh (99 USD/MWh) for the first ten years of exploitation, followed by an additional five years of purchase, at a level depending on average production hours experienced during the first ten years.

Specific regulations (FIT level and conditions) were defined for wind turbines installed in cyclonic areas in French overseas territories.

Offshore wind development has been defined through the launch of two calls to tender for the development of projects in predefined specific areas and for a predetermined capacity. Grid connection has been systematically guaranteed for each area tendered. The selection of winning consortia was made on the basis on several criteria, including a proposed level of electricity FIT. Contrary to what has somehow been circulated by the press, French tenders do not include any requirement for local content.

Possible evolution of the support mechanism for all renewables is being assessed for year 2016 and beyond. The considered mechanism is based on so-called "Complément de rémunération" (Feed-in Premiums), which will be granted as a premium in addition to the market price whereby the generators sell their electricity directly in the market. This current consultation aims to discuss the evolution of the support scheme and to provide the European Commission with a French-shared position in the context of the elaboration of the new state aids guidelines, in order to have this support mechanism applicable by 1 January 2016. That being said, the French government has made public its intention to keep the land-based wind FIT as is for the time being, the evolution of the FIT possibly applying to the third round of offshore wind tenders. In parallel, as part of the preparation work for a third round of tenders, a wide consultation with all

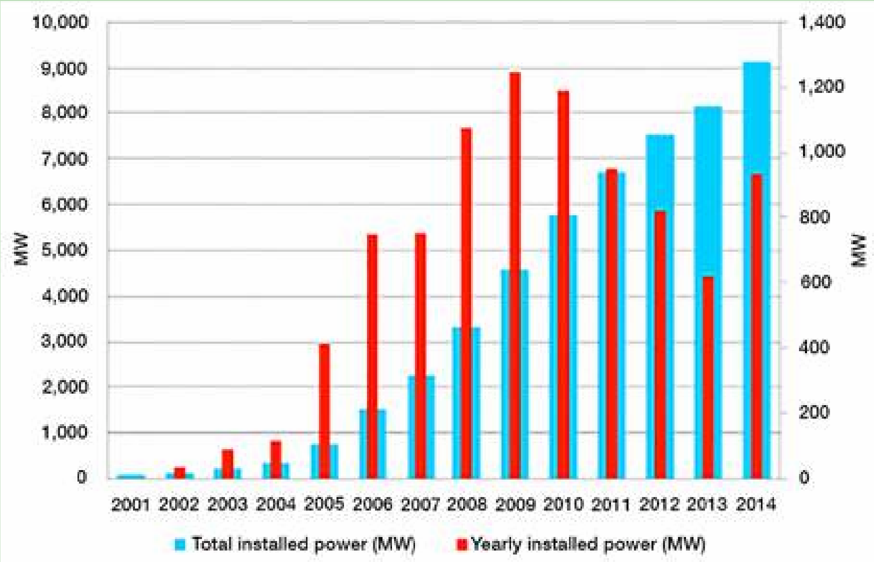

Figure 1. Yearly and total installed power in France

stakeholders is being carried out by the French administration.

2.4 Issues affecting growth

Along with the validation of the funding mechanism (see above), several administrative simplification measures were adopted:

- Suppression of the "Wind Development Areas" (Zones de Développement de l'Eolien or ZDE) and of the so-called rule of the five turbines (defining a minimum number of wind turbines per installation), as part of the French law for Energy transition n°2013-312 voted 15 April 2013.
- Specific support mechanisms and regulations were also adopted to foster the installation of wind turbines in the French overseas territories.
- A single authorization process ("one-stop-shop" approach) has been approved and extended to the whole territory after being tested in seven of the 22 administrative regions.
- A revision of several technical constraints has recently been decided to facilitate the coexistence of wind turbines with radars, leading to an update of administrative rules for the installation of wind turbines near meteorological radars.

3.0 Implementation

3.1 Economic impact

According to the Syndicat des Energies Renouvelables (SER), the French industry employs approximately 10,000 people. Industrial players located in France are represented along most of the value chain of the wind sector, ranging from development and studies, component manufacturers and providers, engineering and construction, and finally operation and maintenance. This represents close to 100 small to medium enterprises (SMEs) with a set of 15 larger players.

The only wind turbine manufacturing facility installed in France has historically been Vergnet, which produces so-called "far-wind" wind turbines for cyclonic areas. More recently, the French company DDIS is developing a patented technology of innovative direct drive electrical machines. A large range of suppliers already exist such as Nexans for the electric cables, Leroy-Somer for generators, Rollix for blade and yaw bearings, etc. Several SMEs are also providing advanced technologies such as LeoSphère, a leading lidar provider, METEODYN, METEOPOLE, providing service and software for wind resource assessment. This situation is currently evolving very fast, along with the development of a local offshore industry.

3.2 Industry status

Further to the attribution of the offshore farms in 2012 and 2014, both Alstom and AREVA Wind (now ADWEN) have announced the installation of major industrial facilities in France. Indeed, Alstom inaugurated a new nacelle assembly factory near Saint-Nazaire, with plans for two new factories near Cherbourg for wind turbine towers and blades. AREVA also plans to install several facilities near le Havre. These important developments are expected to attract a strong network of local and European industry suppliers.

Other players are active in the development of foundations for offshore wind, such as STX France, which recently delivered a substation for DONG and actively works to promote jacket solutions for offshore wind turbines. STX then launched an investment for new facilities for future substations and foundations in their Saint-Nazaire premises. It is also worth mentioning that the development of the floating wind projects has fostered the creation of start-ups like Nenuphar, which is developing a vertical axis wind turbine for floating applications, and IDEOL, which develops a concrete floater solution (see below).

In order to encourage the development of a local industry, a dedicated initiative called Windustry was launched with governmental support to encourage industrial development in the wind market, by strengthening the supply chain offering. It provides guidance and advice for companies seeking to enter the wind industry and diversify their activities. About fifty companies have been involved in the Windustry initiative, up to now. The Windustry initiative aims at creating 50,000 jobs by 2020.

3.3 Operational details

France is divided into 22 administrative regions. From these 22 regions, five of them represent more than the half of the installed power. The leading regions, in terms of installed power, are Champagne-Ardenne, Picardie, Bretagne, Lorraine, and Centre, with installed power ranging from approximately 700 MW to more than 1,500 MW. In 2014, six regions represented more than 80% of the newly installed capacity, with five of them each accounting for additional 100 MW or more (see Figures 2 and 3).

France benefits from three different wind regimes, corresponding to the Mediterranean, the Atlantic Coast, and the North Sea/Channel ("Manche" area). This situation therefore leads to a non-homogeneous installation density of wind turbines in France, with very strong activity in the north and west. Consequently, this translates into higher capacity factors in the south/southeast and north (see Figure 4).

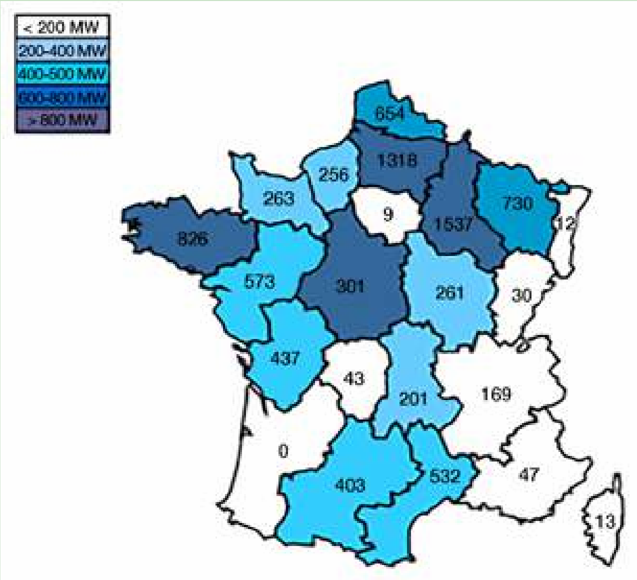

Figure 2. Total installed wind power per region

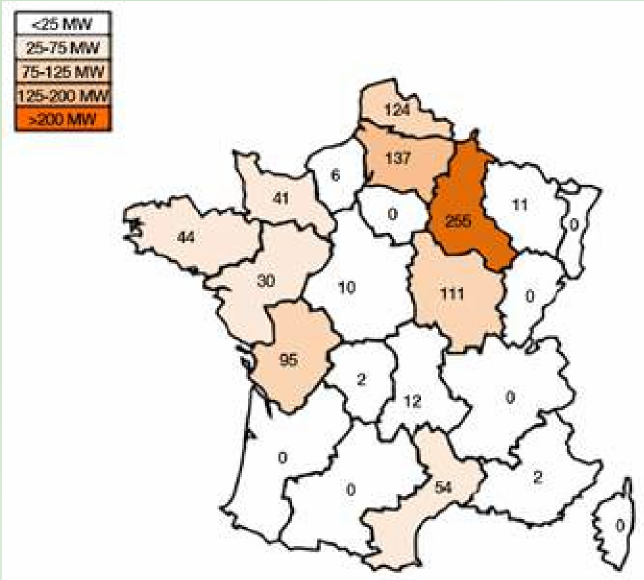

Figure 3. Installed wind power during 2014 per region

In terms of wind turbine suppliers, the main ones in 2014 were Enercon, Senvion, and Vestas, covering more than 75% of the local market. Looking at the whole installed capacity, Enercon, Nordex, Senvion, and Vestas reach approximately 75% cumulative market share.

Though the current wind turbine installations are located on land, offshore wind is considered to be a strategic sector and has been highly supported in the recent years. More precisely, two tenders were initiated in July 2011 and March 2013 to develop offshore wind farms. Four areas were attributed for a total of approximately 2,000 MW in the first round and two others for a total of 1,000 MW in the second round (see Figure 5).

Eolien Maritime France, a consortium led by EDF EN and Dong Energy was awarded the Fécamp, Courseulles-sur-Mer and Saint-Nazaire wind farms, where the 6-MW Alstom Haliade wind turbine will be installed, for a total of approximately 1,500 MW. Ailes Marines SAS, a consortium led by Iberdrola and Eole-RES was awarded the Saint-Brieuc wind farm, where AREVA's wind turbines are expected, for a capacity of 500 MW. A consortium led by GDFSuez, EDP Renewables, and Neon Marine were awarded the Tréport and Iles d'Yeu-Noirmoutier areas, where the future AREVA 8-MW turbines are expected, for a total of 1,000 MW. Preparatory work for a future round has also started along with the decision to launch a call for pilot farms of floating wind turbines in 2015.

4.0 R, D&D Activities

4.1 National R, D&D efforts

As presented above, the development of offshore wind and large wind turbine technology has been a priority in the recent years. ADEME has been the driving funding agency for applied R, D&D projects in the area. Indeed, after a call in 2009 on ocean energies which included floating wind technologies, another call was launched and four projects awarded by ADEME in 2013. These four projects are:

1. The EOLIFT project, led by Freyssinet, proposes the development of innovative pre-stressed wind turbine concrete towers for high power (more than 3 MW) and large height (more than 100 m), incorporating lifting equipment to avoid the use of high capacity cranes. The objective is to increase the speed of construction of wind turbine farms, and to reduce costs related to the tower and foundation by 15%.

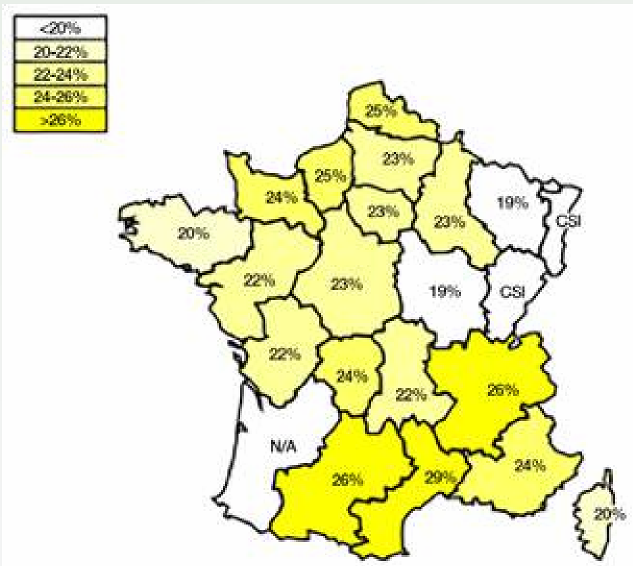

Figure 4. Capacity factors during 2014 per region (Source RTE)

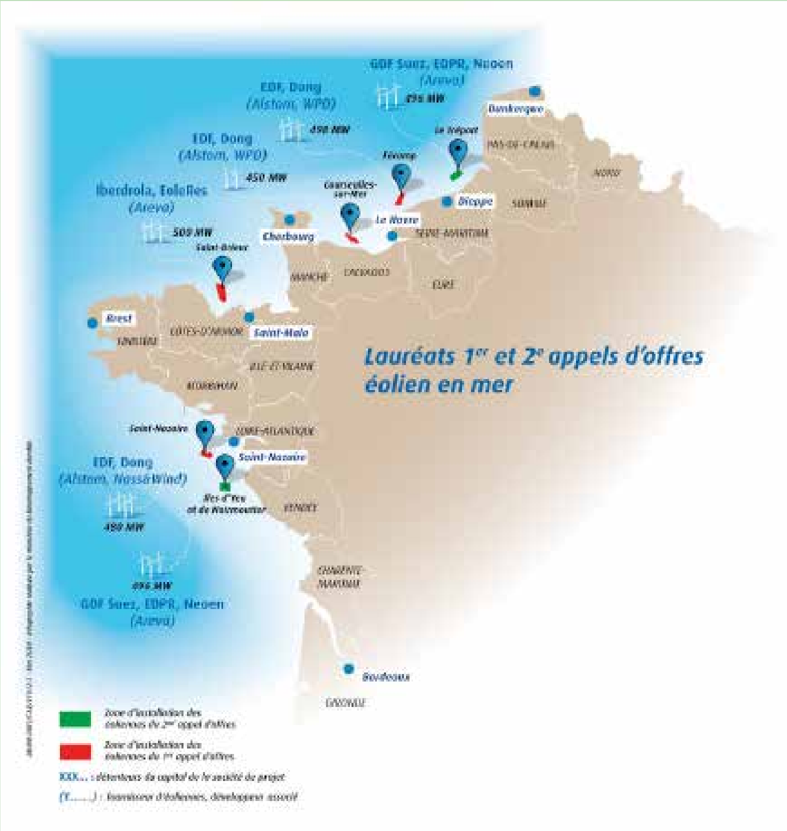

Figure 5. Results of first (in red) and second (in green) rounds of offshore tenders (Source: DGEC)

2. The JEOLIS project, led by Jeumont, aims to develop a new hybrid generator to optimize the electric conversion chain of wind turbines. It is composed of generator with a winding on the rotor, whose performance is enhanced by a much reduced number of permanent magnets.

3. The WINDPROCESS project, led by NTN-SNR, is focused on the development of new manufacturing processes for large size bearings (up to 4 m in diameter) for wind turbines. It aims to increase the reliability of the bearings and dividing by 20 the amount of energy needed for the surface treatment of such bearings.

4. The Alstom Offshore France (AOF) project, coordinated by Alstom Renewable Power, is dedicated to the creation of industrial facilities in France for the production of the Haliade 6-MW offshore wind turbines. The project includes the creation of three industrial facilities near Saint-Nazaire and Cherbourg one for the assembly of nacelles, one for manufacturing permanent magnet generators, and the third to manufacture blades.

Among the selected topics, floating wind technology was identified as a strategic area, since France has a favorable situation for floating wind, local harbor facilities, and a local naval and offshore oil and gas industry capable of addressing this market. More precisely, three projects are currently under development for floating wind:

- The Vertiwind project aims at developing an innovative vertical axis wind turbine technology designed by the start-up Nénuphar, along with EDF Energies Nouvelles, Oceanide, Bureau Veritas, and IFP Energies Nouvelles. This project is associated with the EC FP7 INFLOW project, and is planned to qualify the technology for the Provence Grand Large pilot farm (see below).
- The Winflo project, led by the DCNS Group and Nass & Wind, aims to develop a first 1-MW prototype based on a semi-submersible floater technology. This project was followed by the Sea Reed project led by DCNS and Alstom to develop a specific semi-submersible floater for the Haliade 6-MW wind turbine.

Recently, another project was launched based on an alternative technology:

- IDEOL, a start-up located in the South of France, developed a concrete barge using the Damping Pool™ concept as part of the OceaGen project. A prototype is scheduled to be installed in 2015, on the SEMREV test site.

Besides these R&D projects, the SEMREV test site is now operational to test floating wind turbines off the coast at Le Croisic, on the Atlantic Ocean. Several environmental measurement devices are already present on the site to allow for the evaluation of the local sea and wind conditions.

In the framework of France Energies Marines (Institute for Energy Transition), Phase 1 of the VALEF project was carried out. This project aims at providing adequate methodologies and validation data to ensure the accuracy of the software modeling the dynamic behavior of floating wind turbines. It includes several partners (Areva Wind, Ecole Centrale Nantes, DCNS, EDF, IFP Energies Nouvelles, INNOSEA, Nenuphar and Technip). This first phase, started at the beginning of 2013, was dedicated to the definition of both the verification (code to code comparisons) and validation (code to experimental data comparisons) procedures. It was based on a detailed review of the state of the art and of wind tunnel and wave basin testing. It proposed recommendations for specific methodologies for an experimental campaign to be carried out in Phase 2.

4.2 Collaborative research

Along with several national projects, France is also active in several European projects, such as:

- The Spinfloat project, led by ASAH LM /EOLFI and Gusto MSC, which is based on a vertical axis wind turbine with pitched blades installed on a three-column, braceless, semi-submersible floater. This project also involves SSP Technology a Danish blade manufacturer, Fraunhofer IWES the German Institute for Wind Energy, in charge of the drive train, GustoMSC the Dutch designer of mobile offshore units, ECN the Dutch energy research Institute, and the Italian University Politecnico di Milano for wind tunnel testing.

• The INFLOW project, which is carried out in close relation with Vertiwind and addresses the industrialization phase of the latter project, as well as the development of a test site located in the Mediterranean, near Fos-Sur-Mer. It also involves ten partners from six European countries, including the Nenuphar Start-up, EDF Energies Nouvelles, DUCO Vicinay Cadenas, VryHof Anchors BV, Fraunhofer IWES, DTU, Eiffage Constructions Métalliques.

• The VertiMED project, led by EDF Energies Nouvelles, which was awarded the NER 300 fund. It aims at developing a demonstration pilot farm of a total of 26 MW power, using the vertical axis floating wind turbines technology developed in the Vertiwind and INFLOW projects.

During 2014, France also officially joined the IEA Wind Energy Technology Initiative.

5.0 The Next Term

After a very active 2014, 2015 also promises to be an important year for wind development in France. Indeed, the new Law for Energy Transition will propose a new scheme to support the development of renewables and especially wind, where onshore installations are poised to keep growing. The development of offshore wind is also expected to continue, with the definition of new areas for a third round of tenders. A specific call for pilot farms of floating wind turbines is also expected to be launched in 2015, and should give a strong momentum for the development of this technology.

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Opening photo: Nénuphar vertical axis wind turbine prototype being erected) (Photo credit: D. Averbuch)

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23 Germany

1.0 Overview

The wind energy development in Germany in 2014 underlines the importance of wind energy for the success of the German Energy Transition. The share of renewable energy sources in Germany's gross electricity consumption continued rising in 2014 to reach 27.8%, with 160.6 billion kWh. This represents an ongoing increase of nearly two and a half percentage points compared to the previous year (25.4%).

Wind energy provided 34.8% of all renewable energy generation in 2014, making it one of the most important renewable energy sources. For Germany, 2014 was, capacity-wise, a year of exceptional increase in newly installed wind energy, especially offshore. Never before have more wind turbines been installed than in 2014. At the end of the year wind conditions and production were very good.

The immense added installation regarding offshore wind farms took place with 529 MW of newly-installed, grid-connected offshore turbines. In total 1,037 MW were installed offshore in 2014. Another 268 turbines with a capacity of 1,303 MW were erected but have not been connected to the grid by 31 December 2014. That means that the added offshore capacity was more than twice as high as it was in the previous year.

The construction of new turbines added 4,385 MW on land and 529 MW offshore, a clear increase over the previous year (2013: 2,998 MW on land and 520 MW offshore). Consequently, at the end of the year, the installed wind capacity in Germany was nearly 38,116 MW on land and 2,340 MW offshore, with 25,410 wind turbines installed in total (39,153 MW with a grid connection). Repowering and decommissioning measures accounted for an estimated 1,511 MW, giving a net added capacity in 2014 of 4,914 MW on land and offshore.

This leads to an estimated capacity factor of 18.65%, which is within the long-term average. The use of wind energy avoided 40.52 million tons equivalent of carbon dioxide emissions in 2014.

Concerning R&D activities within the ongoing German 6th Energy Research Program from 2011, the Federal Ministry for Economic Affairs and Energy (BMWi) provided 38.51 million EUR (46.64 million USD) of funds for new research projects in 2014 [1–10].

2.0 National Objectives and Progress

2.1 National targets

With a 10-point energy agenda, the German federal government underlines its main topics for the German Energy Transition (the so called "Energiewende") as well as the revision of the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG) in 2014. The German federal government adheres to its ambitious development goals of a share of renewable energies from 40% to 45% of gross electricity consumption by 2025, and 55% to 60% by 2035. These goals are implemented by the EEG, which was revised in 2014. This revision of the EEG led to adjustments of the national renewable

Germany installed a record 4.9 GW of wind capacity in 2014 and reached half of the offshore wind target for 2020.

Table 1. Key National Statistics 2014: Germany

Total (net) installed wind capacity (grid connected)	39,153 MW
New wind capacity installed (grid connected)	4,914 MW
Total electrical output from wind	55.9 TWh
Wind generation as percent of national electric demand	9.6%
Average national capacity factor	***18.65%***
Target:	Land-based net added capacity wind: 2.5 GW/yr Offshore wind: 6.5 GW total (by 2020) and 15 GW (by 2030); RES to contribute 40–45% of gross electricity consumption in 2025 and 55–60% by 2035;
Bold italic indicates estimates	

energy targets, which are valid since 1 August 2014. They describe how important renewable energies are for the success of the German Energy Transition. The main objectives of the revision were to make renewables expansion easier to plan, to better control cost developments, and to improve the integration of wind and other renewable energies into the market.

Regarding wind energy, the targets were specified to a "breathing cap" for land-based wind of around 2.5 GW per year and for offshore wind a 6.5 GW installation ceiling by 2020 and 15 GW by 2030. Several aspects are included within the EEG 2014 revision, including counting only the net increase of wind energy projects within the land-based cap and adjusting the remunerations by the yearly added net capacity. Furthermore, the EEG 2014 gives the possibility to choose between two offshore models for remuneration (compression model or so-called "Stauchungsmodell" vs. base model). Within the compression model (valid until 2019) electricity generation from offshore wind turbines is funded with more Euro per MWh over a shorter period in the beginning years of operation, whereas the base model guarantees a lower feed-in tariff (FIT) per MWh over a longer period in the beginning. Afterwards both models provide the same FIT in the following period (see section 2.3 for more details). Thus, the EEG 2014 emphasizes that the operation of wind turbines shall still be commercially profitable. From 2017 on, technology-specific tendering procedures for land-based and offshore wind, as well as for all other renewable energy sources, are foreseen within a planned, further revision of the Renewable Energy Sources Act [11–13, 23].

2.2 Progress

Germany made immense progress toward reaching its renewable energy targets with the record wind capacity added in 2014. Wind energy contributed 9.6% of total electricity demand, more than any other renewable energy generation source. In addition to added land-based capacity, offshore wind energy proceeded well in 2014, as shown in Figure 1. Half of the German offshore wind target (6.5 GW by 2020) was reached by the end of 2014, counting 3,263 MW of installed and grid-connected wind turbines, turbines that were erected but not yet grid-connected, and turbines under construction. In 2015, the further land-based capacity will likely remain on a stable level. Offshore added capacity of around 800 MW/yr are expected as planned by the German federal government [1, 3–6, 8, 22, 24].

2.3 National incentive programs

With the revision of the EEG in 2014, the major national incentive program was adjusted. For wind turbine installations operating after 1 August 2014, the land-based basic value for the FIT was newly described (49.5 EUR/MWh; 60.0 USD/MWh) as well as the initial value (89.0 EUR/MWh; 107.8 USD/MWh) for the first five years during operation, amendable in duration by comparison with a reference yield. A yearly target of 2.4–2.6 GW of added land-based wind energy capacity serves as "breathing cap" only counting the net increase of wind energy capacity per year and forming the yearly degression of the FIT accordingly.

Offshore, the initial FIT is 154.0 EUR/MWh (186.5 USD/MWh) within the first 12 years (amendable in duration regarding water depth and distance from shoreline, see base model) up to 194.0 EUR/MWh (234.9 USD/MWh) within the first eight years corresponding to the compression model ("Stauchungsmodell"). Afterwards, the FIT goes back to 39.0 EUR/MWh (47.0 USD/MWh). Offshore degression rules have been implemented so far, they start in 2018, 2020, and the following years. There are two main installation caps with 6.5 GW by 2020 and 15 GW by 2030. Furthermore, former bonuses (i.e., for ancillary services) were abolished.

Wind turbine operators have to merchandise the produced electricity directly, if the capacity is above 500 kW (respectively 100 kW from 2016 on). For wind turbines rated above 3 MW, operators get a gliding market premium (including a management premium), which can also go partially to zero under special market conditions (negative price at European Power Exchange Spot, (EPEX), for more than six hours). From 2017 on, the German federal government plans to manage the reimbursement height via technology-specific tenders for all renewable energy plants [11].

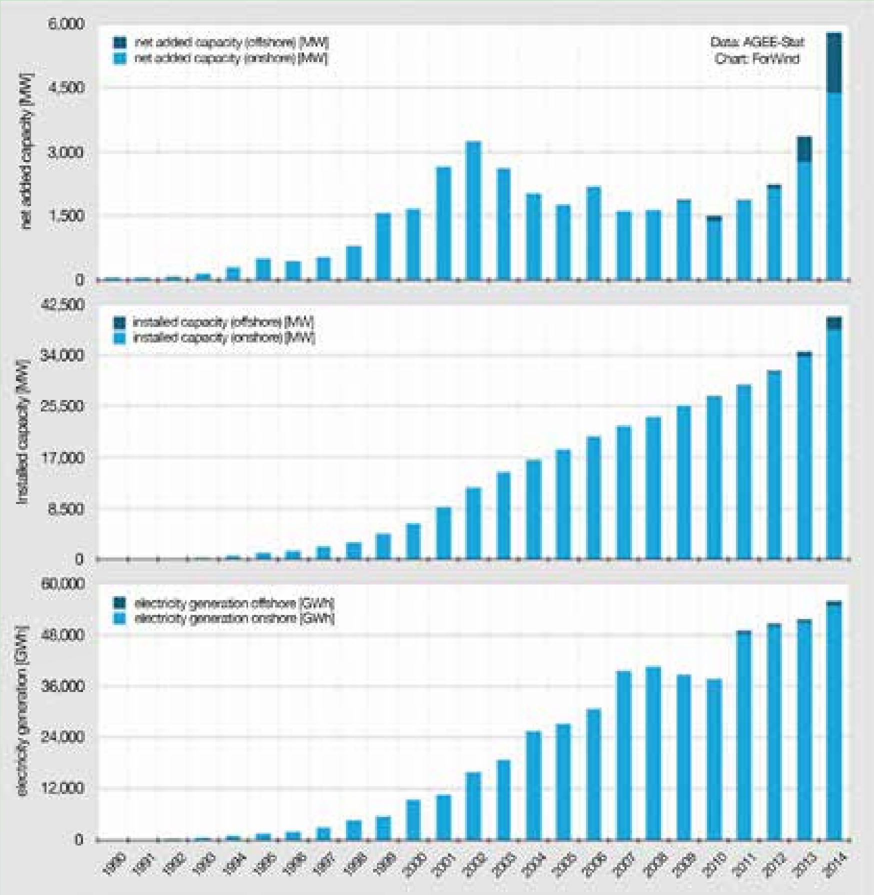

Figure 1. Contribution of wind energy to capacity and electricity generation [1, 2, 3–6]

2.4 Issues affecting growth

The first half of 2014 has been dominated by political discussions with respect to the revision of the EEG. After negotiations with the European Commission the new law became effective on 1 August 2014. For the first time ever a corridor (2.5 GW net) and breathing cap (2.4–2.6 GW) for the annual wind energy growth have been introduced. If the annual installed capacity is outside these caps the degression (from 2016 on: 0.4% per quarter) of the FIT will be adjusted accordingly.

From 2017 on, the recompense for electricity from renewable energy sources will be based on tendering auctions. The final design of which is a topic of ongoing discussions. Combined with the adaptions of the FIT (see section 2.1 and 2.3), those changes stimulated an enormous growth of annual added land-based wind energy capacity in Germany in order to still fall under the old regulations.

Regardless of the adaptions of the EEG, the new law gave confidence back to the market by providing a stable framework.

Another legal framework affecting growth within the building law is the "Länderöffnungsklausel," which allows German federal states to individually determine the minimum distance between wind farms and residential areas. The federal state of Bavaria has announced that it intends to use this clause and to set the minimum spacing requirement to ten times the turbine's height. Due to the dense population of the state, this would stop any additional wind energy installation in Bavaria almost entirely. Another intense discussion with Bavaria and its neighboring federal states is the path and building of a power transmission line from northern to southern Germany, being necessary for transporting the offshore wind electricity to industrial consumers in the south of Germany [11, 12, 14, 15].

3.0 Implementation

The year 2014 has been a record when it comes to newly added capacity—both for land-based and offshore wind. In total, more than 6,726 MW have been installed (offshore, not all grid connected). With approximately 544 decommissioned turbines (364 MW), land-based capacity now reaches 38,116 MW (33,757 MW in 2013). Offshore, turbines with a combined capacity of 2,340 MW (903 MW in 2013) are installed, of which 1,037 MW are connected to the grid. At the end of 2014, another 923 MW of offshore wind turbines were already under construction. On that basis, wind energy provided, with 55.97 TWh (51.708 TWh in 2013), 9.6% (8.7% in 2013) of the overall electricity demand in Germany (see Figure 1).

3.1 Economic impact

Investments in wind energy summed up to 12.3 billion EUR (14.9 billion USD) with nearly two thirds of all renewable energies investment in Germany. In addition, turnovers from operation contributed another 1.7 billion EUR (2.1 billion USD) to added value. With the enormous increase of added capacity in 2014, the number of people employed in the wind energy sector is expected to be well above 140,000. Due to the distribution of sub suppliers in Germany, federal states in the north, the middle, as well in the south are benefiting from added value and employment [2, 9, 19].

3.2 Industry status

In early 2014, wind turbine manufacturer Repower Systems SE changed its name to Senvion SE. In March 2014, the company announced that it broke the milestone of 10 GW of worldwide installed capacity, approximately 75% of which are installed in Europe. With an export rate of more than 80%, the non-domestic markets are playing an important role for the company. In January 2015, Suzlon announced that it had sold its 100% German subsidiary Senvion to a U.S.-based private-equity fund for 0.96 billion EUR (1.16 billion USD).

Also in March 2014, turbine manufacturer Nordex SE announced that its global installed nominal output from almost 6,000 turbines has passed the 10 GW mark. With exports accounting for more than 85% of Nordex's business, the company is also very internationally oriented. In January 2014, the Bremerhaven-based turbine manufacturer Areva and the Spanish company Gamesa announced a 50/50 joint-venture company in the field of offshore wind power. The merger was sealed in spring 2015 and the joint venture company will now trade under the new name Adwen.

Some companies stepped out of the offshore wind energy sector. After Strabag stopped its offshore activities in 2013, construction companies HOCHTIEF and Bilfinger announced the sale of their offshore business units in 2014. Foundation structure manufacturer WeserWind had to file for insolvency in early 2015.

Of all newly added turbines which fed into the grid 2014 for the first time, Enercon has the largest share as in past years, see Figure 2. Offshore, Siemens has been dominating the market. The company has manufactured almost 90% of those turbines delivering electricity to shore [1, 2, 3–6, 21].

3.3 Operational details

In 2014, German market leader Enercon launched the serial installation of its new E-115, targeting low-lying inland locations with moderate wind conditions (IEC IIa). Hub heights for this 3.0-MW turbine may vary between 92 m and 149 m. In order to simplify logistics and to access more challenging sites, the 55.9 m long rotor blades are segmented. Those and also other Enercon blades can now be tested in-house at the company's new 70-m rotor blade test stand, allowing for static (maximum static bending moment: 50.000 kNm) as well dynamic (maximum dynamic bending moment: +/- 25.0000 kNm) fatigue tests. Also in 2014, the Aurich based turbine manufacturer announced that it will add wind class I versions of both the E-82 (2.3 MW) and the E-101 (3.0 MW) series to its product portfolio.

Nordex introduced its 64.4-m-long rotor blade of the light wind turbine N131/3000 and increased the nominal power to 3.0 MW, which is again by 25% in comparison to the turbine's predecessors. The serial installation of this turbine with hub height options of 99 m, 114 m, and 134 m will start in 2015.

Land-based and offshore turbine manufacturer Senvion installed the prototype of its new 6.2M152 (6.15 MW) machine, the commercial production of which will start in 2015. Compared to the turbine's predecessor the rotor diameter has been increased from 126 m to 152 m, increasing the swept area by approximately 50%. The Hamburg-based company also announced two new turbines, the 3.4M114 (3.4 MW) and the vortex generator equipped 3.2M114VG (3.2 MW). The 3.4-MW turbines will be available with hub heights of 93 m, 119 m, and 143 m, while the 3.2-MW turbines will be available with hub heights of 93 m, 123 m, and 143 m.

With those new turbines, the selection of land-based and offshore turbines has been widened and possible combinations of different hub heights and rotor diameters led to a broad range of differently sized turbines in 2014. For land-based wind turbines, the average hub height is ranging between 110 m and 138 m, with the exception of the most northern situated German federal state of Schleswig-Holstein where the average hub height is just 88 m. In total, the average hub height of new land-based turbines is 116 m (116.96 m in 2013) and the average rotor diameter was 98.45 m (95.05 m in 2013), nearly the same as the previous year. The same holds for the average land-based power rating of 2,690 MW (2,598 MW in 2013). Offshore, the average rated power of new capacity dropped to 3,725 MW (5,000 MW in 2013), while the rotor diameter of 119.8 m (126 m in 2013) and the hub height of 89.2 m (90 m in 2013) did not change much.

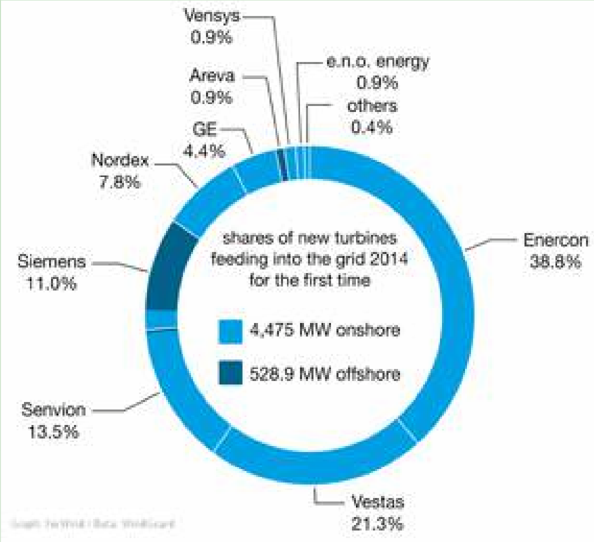

Figure 2. Shares of new turbines feeding into the grid 2014 for the first time

The average capacity factor for 2014 is estimated to be 18.65%. However, it has to be stated that due to the enormous added capacity during the whole year and a rather weak to moderate wind year with a very strong month of December, the uncertainty of this value cannot be neglected [1, 2, 3–6, 21].

3.4 Wind energy costs

For details of wind energy FITs see section 2.3. Individual turbine and project costs vary from site to site. Average numbers have been given in section 3.4 of the German chapter of the *IEA Wind 2013 Annual Report*. Further numbers are not available in 2014.

4.0 R, D&D Activities

4.1 National R, D&D efforts

The use of wind energy in 2014 provided the biggest and most economic contribution to enlarging the share of renewable energies. The German national R, D&D efforts within the ongoing 6th Energy Research Program therefore intend to lower the costs by increasing the yields and making operation reliable. In total, 63 new research projects were initiated in 2014 by the Federal Ministry for Economic Affairs and Energy with funding of 38.51 million EUR (46.64 million USD). In 2013 the funding amounted to 37.3 million EUR (45.17 million USD). With 242 ongoing projects in 2014 the fund's flow amounts to 53.06 million EUR (64.26 million USD), compared to 2013 with 52.57 million EUR (63.66 million USD) remaining on a stable level.

While land-based wind energy is highly available, challenges remain with bigger rotor diameters and hub heights with in relation to the small generators. The project "Magnetring II" addresses reducing the mass of generators and keeping them efficient. It is developing a 10-MW gearless ring generator. Another focus of "Magnetring II" is to project wind yield over complex terrain or in forests as well as advancement in wind load simulation models for wind farm dimensioning. Finally, the project addresses reliable operation of wind farms. All of these aspects contribute mainly to a cost reduction of wind power on land. Another important aspect is the social acceptance of wind energy which matters for the whole range of wind energy issues.

Offshore, a state-of-the-art procedure was developed for low noise installation of offshore foundation in water depths up to 25 m. With the help of big bubble curtains, cofferdams, and hydrosound dampers, the national thresholds of sound emission could be met and the disturbance area for marine mammals was reduced by 90%.

Figure 3. ForWind's test center support structures (Source: Faculty of Civil Engineering and Geodetic Science, Leibniz Universität Hannover)

Thus they contributed to the species conservation in the German Exclusive Economic Zone.

Further offshore research concentrates on low-noise foundation techniques like suction buckets, vibro-piling, and gravity-based foundations. The main focus of the research is to significantly reduce the cost of installation, logistics, operation and maintenance of offshore wind farms. Approaches include developing intelligent software tools and further reducing the ecological effects of offshore wind. The new project "KrOW" develops a simulation tool for strategic operation management of wind farms by considering cost and risk controlled wind farm operation.

The German testing facilities for nacelles in Aachen (Center for Wind Power Drives—CWD) and Bremerhaven (Dynamic Nacelle Testing Laboratory—DyNaLab) conduct research projects dealing with load cases and also look at wind turbines' reliability. In 2015, a newly-started project "FVA Gondel" will deal with several drive train load cases to optimize wind turbine models and to better understand their damage mechanisms. While DyNaLab will be officially inaugurated in autumn 2015, the wind turbine generator system test bench started operation at the CWD in Aachen in March 2014. The test bench has a high dynamic direct drive with a nominal capacity of 4 MW and a maximum torque of 3.4 Mega newton meters (MNm). The test system can be loaded with highly dynamic wind loads in six degrees of freedom, with forces of up to 4 MNm and bending moments up to 7.2 MNm by means of a backlash-free, hydrostatic load unit. At the electrical side, the test bench provides an emulated network connection at 20 kV power. The dynamic loads on the rotor flange and the power connection can be calculated in real-time using the worldwide unique HiL mode of operation.

Another testing facility regarding foundation and tower structures is the test center support structures by ForWind. In February 2014, ForWind celebrated its tenth anniversary and could inaugurate its test center support structures in September of that year in Hanover, see Figure 3. The new facility will mainly be used by ForWind's strategic partner Fraunhofer IWES and offers a unique infrastructure for testing all types of (offshore) support structures (towers and foundations) on a scale of 1:10 and larger. The foundation test pit and the span can be used to investigate fatigue and extreme load behavior under multi-axial loading. The test center also offers four specially equipped laboratories to carry out scientific investigations, such as structural health monitoring, soil mechanics, concrete, and fiber composites.

Further topics of research interest are concerning grid integration of offshore windfarms, load management, and wind energy specific issues of energy storage as well as the optimization of wind prognosis prediction [7, 8, 16, 17, 18].

4.2 Collaborative research

German scientists and experts from industry keep on participating in 14 of 15 active IEA Wind research tasks (Task 11 Base Technology Information Exchange, Task 19 Wind Energy in Cold Climates, Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power, Task 26 Cost of Wind Energy, Task 28 Social Acceptance of Wind Energy Projects, Task 29 Mexnext: Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models, Task 30 Offshore Code Comparison Collaboration with Correlation (OC5) Project, Task 31 WAKEBENCH: Benchmarking of Wind Farm Flow Models, Task 32 LIDAR: Lidar Systems for Wind Energy Deployment, Task 33 Reliability Data: Standardizing Data Collection for Wind Turbine Reliability, Operation, and Maintenance Analysis, Task 34 Assessing Environmental Effects and Monitoring Efforts for Offshore and Land-Based Wind Energy Systems, Task 35 Full-Size, Ground Testing for Wind Turbines and Their Components, as well as the two new ones in 2015: 36 Forecasting and 37 Systems Engineering). Four of these tasks are chaired or co-chaired by German research institutions as operating agent.

Besides this collaborative research in the IEA Wind Energy Technology Initiative, Germany intends to strengthen its European networking within the implementation of the European Strategic Energy Technology (SET) Plan via research co-operations like ERA-Nets+ (European Research Area Networks) or bi-/multi-lateral research projects on basis of the so called "Berlin model." Before multilateral research projects apply for European funding in the latter case, they go through a national process of applying for funding. In Germany this includes a two-stage proposal process in which they have to succeed [8].

5.0 The Next Term

As mentioned earlier, the next few years will show whether Germany can reach its national wind energy targets according to the reviewed EEG 2014. This would include a stable land-based increase and a yearly added capacity offshore of around 800 MW.

Future focuses for research topics shall lower the costs of wind energy regarding installation, logistics, operation and maintenance. This shall be done by increasing the yields and making wind farms' operation more reliable. This includes ongoing research on components, developing optimized simulation models and processes with respect to wind physics, wind turbines, and wind farms, looking at boundary conditions like financing and certification, considering the essential aspect of social acceptance of wind energy as well as the effects that wind turbines cause during their operation. In addition, collaborative research with a mutual benefit for Germany and its international partners shall be followed up.

Furthermore, to distribute the gathered knowledge on offshore wind energy within the RAVE-initiative (Research at Alpha Ventus) a conference will take place in October 2015. Finally, in autumn 2015 the DyNaLab testing facility will be officially inaugurated [20].

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Opening photo: Ausschnitt EnBW Windpark (Photo credit: Matthias Ibeler)

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24 Greece

1.0 Overview

In 2014, 114 MW of new wind capacity were installed in Greece (Table 1). The total installed wind capacity is 1,980 MW, a 6% increase over 2013. Greece also added 20 new wind farms, bringing the total to 141, comprised of 1,186 wind turbines [1]. Greek wind energy will have to increase significantly in order to reach the target of 7,500 MW by 2020 set by the National Renewable Energy Action Plan.

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Opening photo: Wind farm in Antia, Greece (Photo credit: Iberdrola)

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Wind capacity in Greece grew to 1,980 MW in 2014, a 6% increase over 2013.

Table 1. Key National Statistics 2014: Greece	
Total (net) installed wind capacity[a]	1,980 MW
New wind generation installed[a]	114 MW
Total electrical output from wind	3.3 TWh
Wind generation as percent of national electric demand	***6.1%***
Average capacity factor	***27.5%***
Target:	7,500 MW by 2020

Bold Italics indicate estimates
[a]Global Wind Energy Council Global Wind Statistics 2014

25 Ireland

1.0 Overview

Good progress was made in constructing new wind farms to meet national targets in 2014, with 270 MW of new capacity being added, the highest annual installation rate to date. The continued strong growth in capacity resulted in the wind energy contribution to electricity demand in 2014 increasing to 18.3%—an increase of 13% over 2013. Wind energy provides the dominant share of the 22.6% total renewable energy contribution to electricity demand. This increase was achieved despite a below average annual aggregate wind plant capacity factor of 28.7%

With market uncertainties around wind production curtailment having been addressed in 2012, developers are seeking to execute projects in time to meet support scheme deadlines.

Wind farm project economics continued to improve in Ireland in 2014 due to falling wind turbine prices internationally, although unfavorable Euro exchange rate trends from mid-2014 may begin to counteract this benefit.

Several challenges to future development of the wind energy sector emerged or grew in 2014. The proposed implementation of the ISEM—modified electricity market arrangements to conform to the EU Target Market Model—may disadvantage small independent wind power plants and wind farms that have exited support schemes. Disquiet among potential host communities for new wind farm developments and their elected representatives increased in 2014. Increasing numbers of judicial reviews were granted of the planning appeals board's decisions in favor of wind farm developments with some decisions being overturned.

2.0 National Objectives and Progress

2.1 National targets

Ireland is committed to an EU target of meeting 16% of its total energy demand from renewable energy by 2020. The greatest share of this target will be met in the electricity sector with an indicative target of 40% of electricity demand to be met from renewable sources in 2020. The most recent assessment of projected contributions to this renewable electricity target indicates that 32% of demand, or 80% of the renewable electricity target, will be met from land-based wind energy and it is forecast that wind energy will contribute approximately 7% out of the overall 16% national renewable energy target.

A 2014 review of electricity generation capacity [1] indicates that 3,500 MW of operational wind generation will be required in 2020 to meet 40% renewable electricity, as set out in the National Renewable Energy Action Plan (NREAP) [2]. This will involve almost 1,300 MW of new wind power capacity being added over the next six years.

Ireland added 270 MW of new capacity in 2014, the highest annual installation rate to date.

Table 1. Key National Statistics 2014: Ireland	
Total (net) installed wind capacity	2,211 MW
New wind capacity installed	270 MW
Total electrical output from wind	5.1 TWh
Wind generation as percent of national electric demand	18.3%
Average national capacity factor	***28.7%***
Target:	40% RES-E in 2020
Bold italic indicates estimates	

2.2 Progress

The installed and energized wind capacity at the end of 2014 was 2,211 MW, the 270 MW added during 2013 is a substantial increase over the 178 MW in 2013, which set a new record for annual capacity addition. The deployment rate is now on trajectory to achieve the anticipated wind energy contribution to Ireland's 2020 renewable energy targets.

The 5.1 TWh output from wind energy accounted for 18.3% of electricity generated in 2014 and was the second most significant source of electricity after natural gas at 45.8%. Renewable energy in total generated almost as much electricity as coal and peat combined in 2014 (22.6% compared with 23.1% for coal and peat). This had the effect of lowering the carbon intensity of electricity generation, measured in grams of CO_2/kWh of electrical output, to a record low of 457g CO_2/kWh. Other national benefits primarily accruing from increasing wind energy output in 2014 were: overall primary use of renewable energy increased by 10%; primary consumption of fossil fuels fell in 2014 by 1.2%; import dependency fell to 85.5% in 2014 (from 89% in 2013); energy-related CO_2 emissions fell by 0.8% (-1.0% if aviation is excluded)

In June 2014, the Sustainable Energy Authority of Ireland (SEAI) published a report [3] of a detailed study on avoided fuel use and CO_2 emissions brought about by wind energy, based upon dispatch modeling of 2012 real-time operation of the all-island electricity system. This study found that wind energy, which accounted for 15% of all-island electricity demand in 2012, displaced 826 ktoe of fossil-fuel and brought about a CO_2 emissions reduction of 2.33 million tonnes, 61% of these CO_2 savings being from natural gas, and 39% from coal. The resulting displacement intensity of fossil fired plant CO_2 emissions by wind generation was 0.46 tonnes CO_2/MWh. This result was confirmed independently by the Economic and Social Research Institute which, in econometric modeling of electricity system emissions for 2008-2012 [4], also arrived at avoided emissions due to wind energy of 0.46 tonnes CO_2/MWh for 2012.

2.3 National incentive programs

The primary support scheme for renewable electricity in Ireland is the Renewable Energy Feed-in Tariff (REFIT) scheme [5]. This scheme has been in place since 2006 and the REFIT 1 [5] tariff arrangements applied to wind farm projects applying to the scheme up until 2010. Projects qualifying for the scheme may be executed up to the end of 2015. The replacement REFIT 2 [4] scheme was opened for applications in March 2012 and has a deadline of the end of 2017 for the energization of qualifying projects. The tariff levels defined under REFIT 1 and REFIT 2 are identical but the arrangements for market compensation accruing to power purchase agreement counterparties are modified under

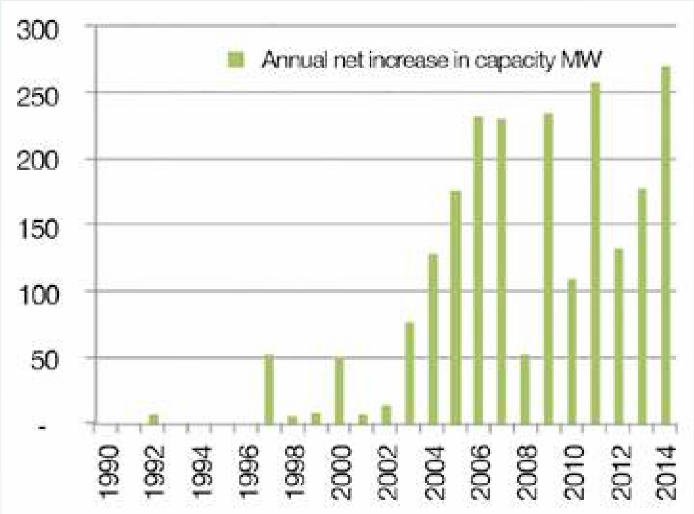

Figure 1. Annual wind farm capacity additions 1992–2014

REFIT 2. There is no feed-in tariff for offshore wind.

The cost of the REFIT support scheme is recovered through a levy on all electricity consumers. The projected cost of this levy for wind power in 2013–2014 was approximately 40 million EUR (33 million USD) [6]. This cost projection does not consider the compensating depression of electricity prices by wind power. The inflation adjusted REFIT tariffs for wind in 2014 were 69.235 EUR/MWh (57.188 USD/MWh) for wind farms larger than 5 MW and 72.023 EUR/MWh (59.491 USD/MWh) for wind farms smaller than 5 MW [3].

2.4 Issues affecting growth

The 270 MW of capacity additions in 2014 represented a new record annual installation and, if sustained, places Ireland on a trajectory to achieve its 2020 targets. Sufficient clustered wind farm grid connections are being provided under the group processing approach to allow the trajectory to continue. After rising sharply in 2011–2012 curtailment of wind output leveled off with commissions of the second Great Britain–Ireland interconnector, while increases in wind power penetration grew. Recent wind turbine price decreases have left the industry with good economic underpinnings and there is a strong appetite to build out permitted projects. The number of significant challenges to sustaining that rate of capacity addition continued to mount during 2015. The primary challenges are as follows:

- The end of the current REFIT support mechanism with a deadline of the end of 2017 for initiation of construction of projects benefiting from the scheme;
- The absence of any early signal on a replacement scheme conforming with recent EU state aids guidance;
- The proposed introduction of new ISEM electricity market arrangements to replace the current SEM mandatory gross pool market in conformance with the EU target market model [8];
- The proposed implementation of an ISEM balancing market may disadvantage small wind farms;
- Slow progress on implementation of proposed transmission systems operator measures to reduce curtailment [9];
- Increased community and political disquiet about wind farm developments;
- Increasing numbers of judicial reviews of the planning appeals board's decisions in favor of wind farm planning applications;
- A common practice of submitting separate environmental impact assessments for a wind farm and its grid connection was deemed to be "project splitting"; and a
- Revised wind farm noise guidance may reduce the potential viable deployment area for future proposed wind farms in Ireland.

3.0 Implementation

3.1 Economic impact

A report, entitled "An Enterprising Wind; An Economic Analysis of the Job Creation Potential of the Wind Sector in Ireland" was jointly published by Siemens and the Irish Wind Energy Association (IWEA) in 2014. It suggested that an overall private sector investment of between 7.0 billion EUR (5.7 billion USD) and 29 billion EUR (24 billion USD) would be required in the Irish wind energy sector to 2030, depending on the level of ambition pursued [10]. As many as 35,000 jobs could be generated by developing Ireland's wind energy sector further. Among the possible jobs that could be created are roles in construction, engineering, manufacturing, and the information technology sector.

According to the study, if Ireland were to meet its current 2020 targets and install 400 MW of wind energy, 8,355 new positions would be created—more than double the number of jobs that currently exist in the sector. The report went on to suggest that if Ireland was to build on the existing target and add an additional 4,000 MW of land-based and offshore wind energy capacity for export, over 17,000 jobs could be created. In the most ambitious scenario outlined, a decision to develop 12 GW of installed wind capacity, of which 4 GW would be for export, would result in 35,275 new jobs created.

3.2 Industry status

Presently, ownership of projects in the wind energy generation sector in Ireland can primarily be broken down into five segments, defined by owner scale and source of finance, namely: utilities, large serial developers, small serial developers, single project developers, and asset management companies (representing institutional investors).

The utilities are vertically integrated to varying degrees within the electricity supply chain and primarily utilise on balance sheet finance. Large serial developers can source equity and debt finance from both within Ireland and overseas. Small serial developers execute a series of wind-farm projects but have limited ability to raise funds overseas. Single project developers are defined as having only developed a single windfarm. Asset management companies tend not to develop wind farms but acquire operational wind farms.

Figure 2 shows the current market-share of wind farm ownership for the above developer categories in Ireland, the utilities hold 52% of installed capacity. The second largest share belongs to single project developers; large serial developers hold 16% of the market, while the small serial developers hold 13%. A more recent development has been the entry of asset management companies representing institutional investors who have 2% of the capacity [11].

Ireland does not have indigenous manufacture of large scale wind turbines but does have manufacturers of several small wind turbines and also of companies providing components, sub-systems and services for utility scale wind turbines. A 2014 SEAI report, *Ireland's Sustainable Energy Supply Chain Opportunity*, carried out in consultation with the enterprise agencies, examined in detail how well the Irish supply chain is positioned to capture new business arising from expected investment products and services required to meet energy targets for 2020 [12]. This reported on the size, opportunities, and value of the wind energy supply chain in Ireland for both the indigenous and export markets. In the wind energy export sector, Irish exports of wind turbines, products and services grew from 22 million EUR (27 million USD) in 2010 to 74 million EUR (90 million USD) in 2012. The report estimated that from 2012 to 2020 the average annual value of the land-based wind energy supply chain for Ireland would be 330 million EUR/yr (400 million USD/yr) but also highlighted that this represents only 2% of the total EU land-based wind energy. Up to 87% of the national onshore supply chain value has the potential to be captured indigenously if support is given

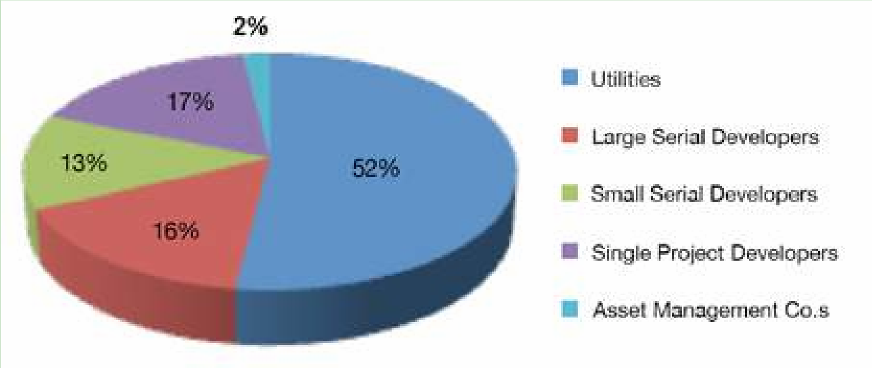

Figure 2. Current market-share of wind farm ownership in Ireland

to developing capacity and exploiting local advantages.

Small wind turbine manufacturer C&F Green Energy manufactures a product range up to 100 kW in size and announced a 250-kW model in 2014. Kingspan Wind (formerly Proven) relocated manufacture of their 15-kW wind turbine to Ireland during 2014. New entrant Airsynergy attracted investment capital for its ducted small wind turbine concept and announced a pilot 5-kW model in 2014.

3.3 Operational details

The largest new wind farm in 2014 was Bord na Mona's 84-MW Mount Lucas wind farm consisting of 28 Siemens 3-MW turbines. It was constructed and commissioned during 2014 on a former milled peat production area in Co. Offaly [13]. This is the largest wind farm construction project in Ireland to date and it made a significant contribution to attaining the new record annual national installed capacity in 2014.

Another noteworthy project in 2014 was the installation of two 3-MW turbines by the Janssen Biologics and DePuy healthcare and pharmaceuticals companies within industrial facilities in the Ringaskiddy area of Cork Harbour. These are the first two of a total of five wind turbines for which the Cork Lower Harbour Energy Group collaboration have been granted planning permission [14].

The average annual aggregate wind plant capacity factor in 2014 was 28.7%; this was below the long-term mean of 30.8%. Extended periods of fine weather during the summer and early autumn led to protracted wind lulls. Figure 3 shows the historic trend of annual capacity factors.

3.4 Wind energy costs

Wind turbine prices in 2014 averaged in the range 800–1,000 EUR/kW (661–826 USD/kW) for medium to large projects involving multiple turbines. The downward trend in the per installed kW price of wind turbines towards the lower end of the above price range is continuing, with the exception of the newer large rotor, low specific power models which represent the upper end of the cited cost range. As these turbines yield a higher energy capture per installed kilowatt, they will allow continued reduction in the cost of wind energy. Total wind farm development costs averaged 1,550 EUR/kW (1,280 USD/kW) for a typical project in 2014 but exhibit a wide spread, primarily due to wide variations in grid connection costs and also, to a lesser extent, in civil engineering costs due to ground conditions.

4.0 R, D&D Activities

4.1 National R, D&D efforts

The main funding bodies funding state sponsored wind energy R, D&D in Ireland are as follows:

• SEAI carries out energy policy research and implements R, D&D programs on behalf of the DCENR supporting renewable energy deployment.

• Science Foundation Ireland funds academic basic research on science and technology. Its priorities are guided by the 2013 report of the Research Prioritisation Steering Group which recommended 14 areas of opportunity as well as underpinning technologies and infrastructure to support these priority areas which should receive the majority of competitive public investment in STI over a five year period to the end of 2017 [15]. The 14 identified national priorities included two energy priorities: Marine Renewable Energy and Smart Grids and Smart Cities. Wind energy was not identified as a research priority even though it will make the largest contribution to Ireland's 2020 renewable energy target.

• Enterprise Ireland funds research commercialisation within indigenous small to medium enterprises. Wind energy projects it has funded include small wind turbine development and data systems for wind farm O&M.

• Eirgrid, the all-island transmission system operator, carries out and funds research on the electricity system integration of wind energy and has also established the Smart Grid Innovation Hub within the National Digital Research Centre to promote the development of innovative Smart Grid solutions, with a focus on entrepreneurial initiatives by companies, academics, and entrepreneurs.

• ESB Networks, the Irish Distribution Network Operator, has sponsored

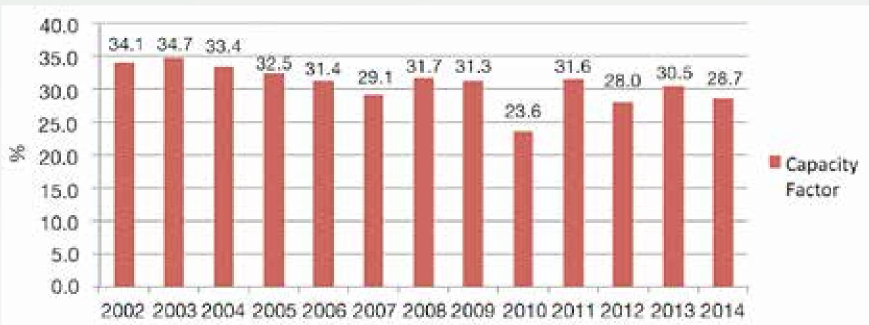

Figure 3. Annual capacity factors

research on distribution network development for high renewable electricity penetrations. Projects have included research on maximising the levels of distribution connected wind and the EU Horizon 2020 funded Smart Green Circuits project.

• The Commission for Energy Regulation has an energy research remit within its regulatory functions and has commissioned research on the market considerations for increasing wind energy penetration in the electricity system.

Wind energy R, D&D projects which SEAI funded in 2014 are: the Stochastic Model for Optimisation of Transmission System with High Wind Penetration: ERC/UCD; Social Acceptance of Wind Farms: Donegal Co. Council, Letterkenny I.T.; and Wind Micro-Generation Information System–Galway-Mayo Institute of Technology.

In SEAI commissioned research on wind energy topics during 2014, work supporting the implementation of draft revised Wind Farm Planning Guidelines on noise and shadow flicker obtained a high priority including: completion of supporting detailed technical appendices on assessment and post construction monitoring, and impact assessment of the draft revised Wind Farm Planning Guidelines.

4.1.2 SEES wind energy-related research projects

The Sustainable Electrical Energy Systems Strategic Research Cluster (SEES Cluster) was formed in late 2010 to bring together the necessary multi-disciplinary expertise in electrical, mechanical and electronic engineering, applied mathematics, economics, and geology to tackle fundamental applied research and demonstration challenges to underpin the emergence of future integrated, smart and sustainable electrical energy systems [16]. The SEES Cluster, with the financial support of Science Foundation Ireland and ERC industry members, involves researchers in six research institutes—UCD, TCD, UL, NUIM, and the ESRI. The Cluster has also attracted further industry interest and support.

The challenges addressed include the integration and optimization of very high, variable renewable penetrations (40% energy and above); the development of an active, smarter electricity network enabled by the deployment of information and communication technologies; facilitation of customer and utility demand management; and electrification of segments of the heat and transport markets. The research program addresses key issues that underpin the successful transformation of the sustainable electrical energy system, including: flexibility to complement renewables while maintaining reliability; optimization and control of dispersed generation and demand side resources; new loads and storage, and their characteristics; stochastic processes and optimization; electricity market and policy issues; and ICT to enable the smart, flexible system.

Projects with a particular relevance to wind energy under execution during 2014 were:

– Optimizing the floor price and balancing payment in REFIT scheme stochastic
– Wind turbine architecture and interconnection for offshore wind farms
– Operational characteristics of non-firm wind generation in distribution networks
– Optimal allocation of wind generation subject to voltage stability constraint
– Distribution system planning, operations, and technological applications, integrating high wind penetration
– Measuring the disamenity value of wind farm development in Ireland
– On-line risk assessment on a power system with high wind power penetration
– Wind generation flexibility
– Grid scale storage at high wind penetrations

For more information see (http://erc.ucd.ie/projects/sees-cluster).

The Eirgrid "Delivering a Secure Sustainable Electricity System" (DS3) R, D&D project is central to the delivery of Ireland's renewable electricity targets. Work completed to date includes: installation of the Wind Security Assessment Tool (WSAT); Grid code modifications to facilitate moving to 75% instantaneous asynchronous generation penetration; performance monitoring and testing of all generators for meeting grid code requirements; and definition of expanded system services to facilitate the future high asynchronous penetration. With respect to the last item, the All-Island Single Electricity Market Committee published its decision on the Procurement Design of System Services for the Detailed Design Phase in December 2014 to implement a new framework for the procurement of system support services anticipating a future high penetration of asynchronous generation. Some changes to the Grid Code central to facilitating the complete implementation of the DS3 project have been delayed. Several technology demonstration projects have been funded by Eirgrid at the Smart Grid Innovation Hub within the National Digital Research Centre.

4.2 Collaborative research

Ireland is very active within the IEA Wind Energy Technology Initiative and participates in seven R, D&D tasks: Task 11 Base Technology Information Exchange, Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power, Task 26 Cost of Wind Energy, Task 27 Development and Deployment of Small Wind Turbine Labels for Consumers (2008–2011) and Small Wind Turbines in High Turbulence Sites (2012–2016), Task 28 Social Acceptance of Wind Energy Projects, Task 33 Reliability Data: Standardizing Data Collection for Wind Turbine Reliability, Operation, and Maintenance Analysis, and Task 34 Assessing Environmental Effects and Monitoring Efforts for Offshore and Land-Based Wind Energy Systems. SEAI places IEA Wind participation at the heart of its national wind energy R, D&D program, utilizing the international collaboration to establish international best practice and stimulate national research projects in areas facilitating local deployment, initiating the formation of new tasks in areas where Ireland has research leadership or which present particular barriers to wind energy in Ireland. Participation in IEA wind has proven to be a very effective manner in which to bring research effort to bear to effectively facilitate the growth of the wind energy sector in Ireland.

SEAI published a request for tenders in 2014 to fund new or continued participation by researchers across six of the eight IEA implementing agreements within which it participates. The largest number of tenders was received in response to the IEA Wind agreement, tenders were received in respect of IEA Wind Tasks 25, 26, 27, 28, 33, and 34.

Highlighted national research projects in 2014 included a project led by the National Economic and Social Council to report on measures to improve societal acceptance of wind energy [17]. The project involved widespread stakeholder consultation and input from SEAI and Ireland's national participant in IEA Wind Task 28 Social Acceptance of Wind Energy Projects. Community shareholding or ownership of wind farms was strongly advocated in the final report.

5.0 The Next Term

The Irish government published new energy policy green paper in 2014 outlining the high-level energy policy options for the period from 2020 to 2030 [18]. The Department of Communications Energy and Natural Resources (DCENR) engaged in national stakeholder engagement events and invited public submissions to contribute to the shaping of energy policy for this period. The DCENR is developing a policy white paper taking account of the submissions received. At the end of 2014 the DCENR announced that it would engage in the development of a new Energy Research Strategy and Implementation Plan for Ireland in 2015. The process will initiate with consultations involving energy research stakeholder groups.

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26 Italy

1.0 Overview

In 2014, with a new installed net capacity of just 105 MW (-76% with respect to 2013), wind energy deployment in Italy declined further, in addition to the considerable decrease in new installations observed in 2013. In the last two years the annual new installed capacity dropped from 1,266 MW to only 105 MW. Cumulative installed capacity at the end of 2014 reached 8,663 MW.

This context represents the dreaded consequences of the new support scheme for renewable energy sources (RES), which came into force at the end of 2012. Under this scheme, incentive access is constrained by established annual quotas, which involve a severe limitation for new installations with respect to the trend in the previous years. This scheme considers three different incentive access mechanisms: direct access, access by registration, and access by auction. Registration and auction access is constrained by established annual quotas. The access mechanism depends on the wind farm size and characteristics (i.e., integrally rebuilt, repowered, or refurbished plant). Incentive tariffs depend on project size and characteristics as well (i.e., land-based or offshore). According to investors, the critical aspects of this scheme are the annual established quotas (thought to be too low with respect to the annual new added capacity usually installed so far), the low basic tariff of the incentive, and the auction access threshold of 5 MW as plant capacity (also considered to be too low).

In 2014, 56 new turbines were deployed, reaching a total of 6,358 installed wind turbines. Wind electricity generation increased from 14.9 TWh in 2013 to 15.0 TWh in 2014, corresponding to about 4.9% of total electricity demand on the Italian system (decreasing from 318.5 TWh in 2013 to 309.0 TWh in 2014). Wind production curtailments ordered by transmission systems operators (TSO) are no longer a problem for the producers as they have been in the past. Curtailment is estimated to be the same as in 2013, less than 2%. The regulatory authority AEEG has provided for curtailed production to be estimated and wind farm owners indemnified. This authority has also updated the regulation for sharing balancing costs among RES producers that are not programmable—deliberation 522/2014/R/eel. This deliberation allows producers to choose between two different options in computing the due amount. This provision was made in order to overcome the remarks of the State Council decision—Sez. VI, n. 2936—9 June 2014, regarding the previous AEEG deliberation 281/2012/R/efr on the same subject.

Because few Italian industries engage in large wind turbine manufacturing, most of the turbines installed in 2014 were supplied by foreign producers. In the small wind energy systems market, this situation is completely reversed, with a very strong presence of Italian industries. This market is supported by a quite good incentive level and a cumulative installed capacity exceeding 45 MW was estimated at the end of 2014.

Because of the lack of a national program, wind energy R, D&D activities have been carried out by different entities, mainly the National Research Council (CNR), the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) (the first and second national research institutions respectively),

Wind generation increased from 2013 to 2014 and corresponds to about 4.9% of total electricity demand on the Italian system.

Table 1. Key National Statistics 2014: Italy	
Total (net) installed wind capacity	8,663 MW
New wind capacity installed	105 MW
Total electrical output from wind	***15.0 TWh***
Wind generation as percent of national electric demand	***4.9%***
Average capacity factor*	***20%***
Targets:	12,680 MW and 20 TWh/yr by 2020
Wind generation goals from Italy's National Action Plan (PAN) **Italy's overall RES target from Directive 2009/28/EC::**	17% of total energy consumption from RES by 2020 12,680 MW wind and 20 TWh/yr from wind by 2020
Bold italic indicates estimates *based on the average installed capacity during the year	

Ricerca sul Sistema Energetico (RSE S.p.A.), some universities, and other companies.

2.0 National Objectives and Progress

2.1 National targets

In 2009, Italy accepted a binding national target equaling 17% of overall annual energy consumption from RES as part of the EU renewable target of 20% of primary energy, electricity, heat, and transport. The Italian National Action Plan (PAN) for Renewable Energy issued on 30 June 2010 shared this overall national target among sector-based targets. A target of 26.39% by RES was established for the electrical sector, corresponding to approximately 43.8 GW of RES on-line capacity and 98.9 TWh/yr production from RES to be reached by 2020. Wind, biomass, and solar were the main energy sources designated to hit this target. As far as 2020 wind energy targets are concerned, 12,680 MW (12,000 MW land-based and 680 MW offshore) was set as the installed capacity target and 20 TWh/yr (18 TWh/yr land-based and 2 TWh/yr offshore) as the energy production target.

2.2 Progress

The steep decreasing trend in new added wind capacity continued also in 2014: only 105 MW of net capacity was installed. This led to an overall grid-connected wind capacity of 8,663 MW at the end of 2014, with an increase of 105 MW over 2013 (including an installed capacity decrease of 2.6 MW due to old installation decommissioning). The corresponding growth rate was 1.2%, considerably lower than in 2013 (5.3%). In order to find a comparable value in the historical series one would have to go back to the years before 2000 (Figure 1).

According to the Italian wind resource availability, most of the new installations took place in the south of Italy (mainly in Apulia and Basilicata). The wind cumulative installed capacities for the Italian regions are shown in Figure 2.

Overall, 2014 energy production from renewable sources was about 116 TWh (estimated by TERNA—the Italian leading grid operator for energy transmission—provisional data). The production from wind farms, 15.0 TWh (almost the same as in 2013) represents about 4.9% of total electricity demand on the Italian system (total consumption plus grid losses). Italian wind-energy production development is shown in Figure 3. A significant decrease (-3.0%) in the total electricity demand (309 TWh) was recorded in 2014 with respect to 2013. An 85.9% quota of this demand was satisfied by domestic production and 14.1% by imports.

2.3 National incentive programs

The current incentive mechanism for RES was introduced and implemented as a consequence of the government Legislative Decree No. 28 on 3 March 2011, which recognized the EU Directive 2009/28/EC on RES promotion. The main issues of the mechanisms are special energy purchase prices fixed for RES-E plants below a capacity threshold depending on technology and size (no lower than 5 MW). Special energy purchase prices are assigned to larger plants through calls for tenders (lower bids gain contracts) and prices are granted over the average conventional lifetime of plants (20–25 years). Three different access schemes are provided for wind plants depending on plant size (direct access, access by registration, and access by auction) and

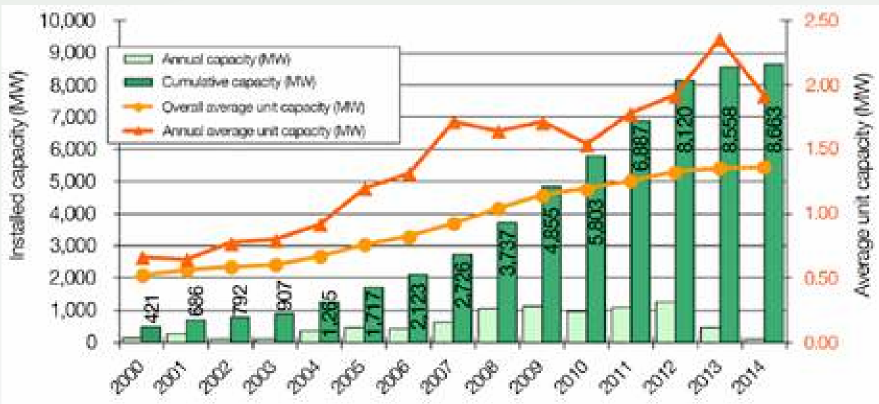

Figure 1. Trend of Italian annual and cumulative wind turbine installed capacity and new added and overall average unit capacity

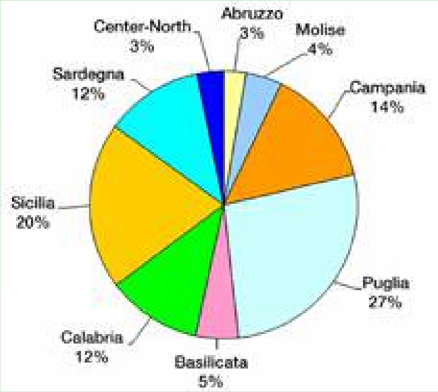

Figure 2. Wind capacities in the regions of Italy at the end of 2014

annual quotas are established both for registration and auction accesses, as shown in detail in Table 2.

Between 2013 and 2015, an annual quota (by registration and by auction) of 710 MW (registration: 60 MW; auction: 500 MW of new capacity; plus 150 MW for rebuilt and repowered plants) has been established for land-based wind capacity and a quota of 650 MW for offshore wind capacity has been established for the whole period (Table 2). Plants with a capacity up to 1 MW can choose between two different incentive typologies. The first typology is a feed-in tariff, composed by a basic incentive tariff plus additional components related to specific conditions. In this case the producer sells the energy directly to the Gestore dei Servizi Energetici (GSE), the national company which manages the RES incentive system, so the feed-in tariff represents its total revenue. The second option is an incentive computed as the difference between a basic incentive tariff (plus additional rewards related to specific conditions) and the local hourly cost of electricity. As the produced energy remains the producer's property, the total revenue from these plants is represented by the sum of the incentive plus the energy sale price. This latter option is the only one available for plants with a capacity exceeding 1 MW. Conventional plant life is set at 20–25 years for land-based and offshore plants. In Table 3 the basic incentive tariff set for the period 2013–2015 are shown.

Regarding the Table 3 values, it has to be noted that small (P<200 kW) and offshore plants still benefit from higher incentives than the onshore ones (P>200kW). Due to these more favorable incentives, small plants are growing quite fast in Italy. According to a preliminary Association of Wind Energy Producers by Small Systems (CPEM) estimate of small wind plant deployment, more than 45 MW of capacity are already installed.

2.4 Issues affecting growth

The 445 MW of new capacity installed in 2013 was much less than the 1,200 MW installed in 2012. Some of the 2013 projects (installed before 30 April 2013) benefited from the more favorable old incentive scheme. Under the new incentive scheme, even less wind capacity was installed in 2014 (105 MW), all land-based. No offshore wind parks are installed in Italy yet, in spite of the authorization of a 30-MW offshore wind park near Shore Park in Taranto. For small wind turbines, the incentive mechanisms are still favorable and 15 MW to 20 MW of new capacity were estimated in 2014 (data from unofficial census). This confirms the interest of many national small-to-medium enterprises in this sector.

The dramatic reduction in new wind capacity is only partially due to the introduction of an annual quota. In 2014, the added capacity (105 MW) was very far from the quota of 450 MW actually set by GSE. The reduction is mainly due to the low level of the basic incentive tariff and to the very high downward trend. This leaves many doubts about the economic sustainability of the winning plants that are realized only in a very low percentage. In October 2014, the National Wind Energy Association (ANEV) reported that among the ranked plants for 2013, 49% are grid connected, 5% are under construction, and the remaining 46% are not yet under construction. Among the ranked plants for 2014, none are grid connected and only 25% are under construction. These data, together with the steep downward trend for 2015 and the uncertainty in incentive mechanism after 2015, do not suggest success for the short-term future of the wind energy sector in Italy.

If this annual growth were constant in the next years, the 2020 national target of 12,000 MW installed land-based wind capacity could not be achieved. The current quota and basic incentive tariffs are set until 2015. An adjustment in the incentive mechanism is expected by the operators in the next few years. This adjustment would be made to match both the land-based and offshore targets. However, further reduction in basic tariffs is under consideration probably due to the spending review induced by the Italian government.

Among the 22 new wind parks, only six have a capacity greater than 5 MW (with a maximum of 22.8 MW), ten have 0.8 MW and six have 0.2 MW. It has to be noted also that many of the smaller projects have only one turbine. This scenario is very different from recent years characterized by many big projects connected to the grid every year. The authorization process is simplified for small

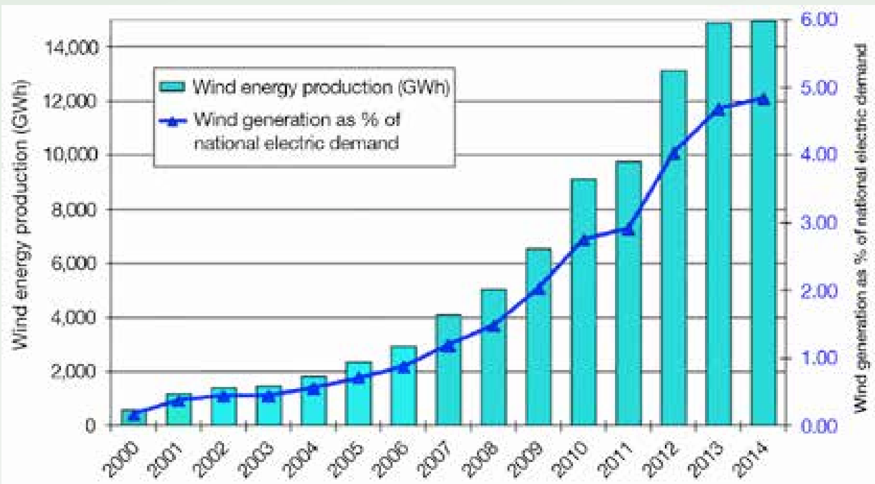

Figure 3. Italian wind energy production and percent of national electric demand

Table 2. Access schemes and established quotas depending on plant size				
Plant size	Access scheme	Quota 2013	Quota 2014	Quota 2015
<60 kW	direct access; for new, integrally rebuilt and repowered plants			
<60 kW to 5 MW	access by registration	60 MW	60 MW	60 MW
>5 MW	access by auction through calls for tenders onshore	500 MW	500 MW	500 MW
>5 MW	access by auction through calls for tenders offshore		*650 MW	
>60 kW	access by registration for refurbished plants	150 MW	150 MW	150 MW

*quota for 2013–2015 period

wind plants, but the landscape impact can be greater and less controlled for many isolated single wind turbines. Moreover, the impact on the electrical grid can be greater because small operators and plants cannot generally guarantee quality and safety as the larger ones do. Most of the new capacity was installed in the Apulia region that still confirms its first place among the Italian regions in terms of installed capacity.

Regarding offshore installations in addition to the absence of applications in 2014, at the end of 2014 only six offshore wind projects were present on the Environmental Impact Assessment (EIA) website of the Ministry of the Environment and Protection of Land and Sea of Italy. This confirms that the interest of developers in offshore wind is decreasing. The authorization for offshore wind plants in Italy is given by the central government (for land-based wind plants the authorization is given by regional government) after very long and complex procedures. These long and complex procedures, together with the lack of clear policies in the sector, are perceived by the operators as the main issues that are delaying the offshore wind sector development. In 2014, as in 2013, several offshore park projects have been definitively rejected by government. Strong opposition to these initiatives has been shown from both regional and local administrations as well as from some environmental associations.

Other issues affecting growth are still related to connection of wind farms to the grid and curtailments, although these are less important than in the past. Italy's 2010 PAN for Renewable Energy required TERNA to plan the upgrading of the grid, which is needed to guarantee full access of RES electricity. For the period 2013–2022, TERNA planned an investment of 7.9 billion EUR (9.6 billion USD) for grid reinforcements and started to build them. Despite that, delays in grid connection, especially in the permitting of new electrical lines by local authorities, are still reported.

In the past, TERNA was compelled to ask wind farms to stop or reduce output, because of overloads or planned work in grid zones that were not yet fully adequate. In 2013, curtailments accounted for 1.8% of production. The same percentage is expected for 2014. GSE calculates the value of "missed production" and indemnifies the owner for it.

3.0 Implementation

3.1 Economic impact

In 2014 the economic impact of wind energy in Italy can be estimated to be about 2.86 billion EUR (3.46 billion USD). This value represents the overall contribution of three different business areas: new installations, operation and maintenance (O&M) of the online plants, and energy production and commercialization. An estimate of the contribution of new installations, including both preliminary (design, development) and executive (construction, equipping, grid-connection) activities, was about 160 million EUR (194 million USD). O&M of the online plants contributed about 300 million EUR (363 million USD). Finally, wind energy production and commercialization had an impact valued at 2,400 million EUR (2,906 million USD). In 2014, O&M expenditures overtook the investment for new installations, due to the dramatic decrease in new added capacity.

According to ANEV, the previous trend of increased employment has reversed in the last three years, as a consequence of the dramatic investment reduction due to the new incentive system. In 2014, overall reduction of jobs in the wind energy sector was estimated in about 4,000 units, which means about 30,000 people were employed at the end of 2014 (including direct and indirect involvement).

3.2 Industry status

Foreign manufacturers prevail in the Italian large-sized wind turbine market. This is clear from Figure 4, where the overall market shares of wind turbine manufacturers in Italy at the end of 2014 are shown. The shares of the wind turbines erected in 2014 alone are: 40.8 MW by Vestas (Denmark), 19.4 MW by Gamesa (Spain), 13.1 MW by Enercon (Germany), 9.2 MW by REpower (Germany), 7.0 MW by Nordex (Germany), 4.9 MW by GE Wind (U.S.), 2.1 MW by Alstom (France), 1.4 by Siemens (Germany), 1.4 MW by Leitwind (Italy) and 1.6 MW by other manufacturers.

As for the large-sized wind turbine sector, Leitwind is the only Italian manufacturer. This company, with headquarter in Vipiteno, produces turbines in the range of 1–3 MW in factories located in Telfs (Austria) and Chennai

Table 3. Conventional plant life and basic incentive tariff vs plant type and size			
	Power kW	Conventional Plant Life Years	Basis Incentive Tariffs year 2014 EUR (USD)
Land-Based	1 < P ≤ 20	20	291 (352)
	20 < P ≤ 200	20	268 (325)
	200 < P ≤ 1,000	20	149 (180)
	1,000< P ≤ 5,000	20	135 (163)
	P > 5,000	20	127 (154)
Offshore	1 < P ≤ 5,000	25	176 (213)
	P > 5,000	25	165 (200)

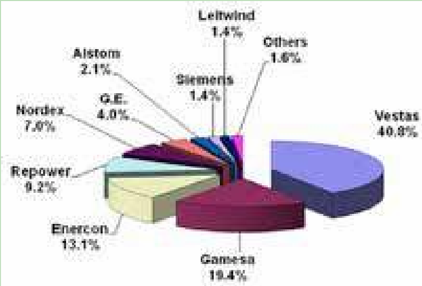

Figure 4. Market shares of wind turbine manufacturers in Italy at the end of 2014 (as percentage of total online capacity)

(India). Vestas operates in Italy through its corporate Vestas Italy, which has two production facilities, an operations office, and a customer service center in Taranto as well as offices in Rome. All the other large wind-turbine foreign manufacturers operate in Italy by their commercial offices. Italian firms have a significant share of the large wind-turbine component market, mainly for pitch and yaw system components, electrical and electronic equipment, bearings, flanges, towers, cast and forged components (hubs, shaft supports), as well as for machine tools.

In contrast to the large wind-turbine sector, Italian firms have a significant presence in the small-sized wind turbine market (i.e., turbines having a capacity up to 200 kW). The Italian companies account for half the wind turbines and components manufacturers and the entirety of producers and sellers of energy by small wind energy conversion systems.

3.3 Operational details

The 56 new wind turbines (108 MW) installed in 2014 have an average capacity of 1,920 kW. As a consequence, the cumulative number of online wind turbines rose to 6,358 (including decommissioned turbines) with an overall average capacity per turbine of 1,360 kW. This corresponds to an overall capacity of 8,663 MW for the national wind system. There are no offshore wind farms in Italy, so all the plants are land-based. Hill or mountain sites are typical for Italian wind farms.

The registration and auction procedure for 2015 was completed by GSE in compliance with the 6 July 2012 Implementing Decree. For the registration procedure, applications totaled 162 MW, exceeding the annual available quota of 65 MW established for 2015. For the auction procedure, land-based applications of 1,261 MW exceeded the quota of 356 MW established for the same year.

Regarding offshore projects, the full 2013–2015 established quota of 650 MW was still available in the 2015 auction procedure for incentive allocation: no offshore applications at all were recorded in this procedure.

The average capacity of the new wind projects connected to the grid in 2014 was about 4.5 MW. The largest projects built in 2014 are Ponte Albanito (22.8 MW), Monteleone di Puglia (22 MW), and Manfredonia (17.5 MW)—all located in Apulia.

3.4 Wind energy costs

No special news is to be reported on costs with respect to previous years. For 2014 an average capital cost of 1,500 EUR/kW (1,817 USD/kW) has been estimated. This cost shows a large variability in the Italian context. It is about 20% higher than average European installation cost, because of the Italian site characteristics and the extra costs induced by the permitting procedures length and complexity.

There are two typical wind farm types in Italy. The first types are installed in the plains of southern regions. The second types are built at rather remote hill or mountain sites, with higher wind regimes, but with increased costs for transportation, installation, grid-connection, and operation. RSE estimated the levelized cost of energy (LCOE) for typical land-based wind farms installed in Italy in the last two years. The LCOE results in the range 106–159 EUR/MWh (128–193 USD/MWh). The reference value of 127 EUR/MWh (154 USD/MWh) refers to 1,750 average annual equivalent hours, close to the capacity factor registered in 2013 and 2014.

4.0 R, D&D Activities

4.1 National R, D&D efforts

R, D&D activities have been carried out mainly by CNR, ENEA, RSE S.p.A., and universities.

CNR's activity in wind energy involves eight institutes and is in the frame of National and EU FP7 projects. The main topics are as follows: wind conditions; atmospheric boundary layer research on offshore, coastal, and complex terrain, extreme winds (ISAC); atmospheric and ocean interaction modeling from climate to high resolution (ISAC and ISMAR); offshore and land-based wind mapping using models and space-borne measurements (ISAC and IREA); forecast of wind power production at different time horizons (ISAC); aerodynamics including characterization and modeling of flow around a wind turbine and wakes (INSEAN); environmental impacts and noise (IDASC); offshore deployment and operations including the interaction of offshore wind parks with ocean circulation and geological risk assessment related to development of offshore wind parks (ISAC, ISMAR, ITAE and INSEAN); wind generator emulators, DC/DC converter and control schemes for grid integration (ISSIA-ITAE); innovative materials (ISTEC). CNR participates in the FP7 EU projects COCONET (Towards Coast to Coast Networks, ending 2014), MARINET (Marine Renewables Infrastructure Network), and IRPWIND (Integrated Research Program on Wind Energy - A part of European Energy Research Alliance (EERA), on Wind Energy Joint Program).

ENEA has been working with its wind tunnel facility on aerodynamic studies of vertical axis wind turbines. Moreover, ENEA has been involved in defining methods of validation of in-situ non-destructive testing of small wind turbine blades. The analyses are performed by using an x-ray high-resolution computed tomography system in the laboratory. The goal of this research is to calibrate in-situ non-destructive testing techniques so that they could be used to perform quantitative analysis of defects inside the component.

RSE S.p.A. has been doing research on wind energy mainly under its contract agreement with the Ministry of Economic Development for research on the electrical system. Wind energy has been allotted a total commitment of 2.0 million EUR (2.4 million USD) for 2012-2014. For land-based and offshore wind energy, the main concerns are resource assessment through measures and models (Italian Wind Atlas http://atlanteeolico.rse-web.it/viewer.htm), national repowering potential, simulation of the dynamical behavior of an offshore floating wind turbine, and social acceptance.

The POLI Wind Group of the Department of Aerospace Science and Technology of the Polytechnic of Milan has been working on wind turbine aero-servo-elasticity, blade design, load mitigation, and advanced control laws. The POLI-Wind has developed a wind tunnel testing facility, which includes actively controlled and aero-elastically scaled wind turbine models. The facility has been recently expanded for the simulation of wind parks and the study of wake interactions. The department is also a member of two major FP7 EU funded projects, which study advanced technologies for very large wind turbines in the 10–20 MW range. The Department of Mechanical Engineering has been working on large eddy simulation (LES) modeling and simulation of turbulent flows and wind turbine wakes, offshore floating wind turbines and their aero-elastic modeling. The Department of

Electrical Engineering has been working on generator technology, while the Department of Energy has been working on grid and wind energy economics. The Polytechnic of Milano is part of European Academy of Wind Energy (EAWE) as a national node member, and the EERA Joint Program on Wind Energy as associate member.

The Department of Mechanical and Aerospace Engineering (DIMEAS) of the Polytechnic of Turin has been working on a small floating wind turbine (3-kW horizontal axis—spar buoy type), with the design of the ballasted floating system and its mooring system (water depth of 50 m), the collective blade pitch control with its electromechanical components, sensors, and control drives. The system has been installed in Lake Maggiore, near Cannobio, in February 2015. Behavior of the system will be monitored for one year, while the system works in real environmental conditions. The Department of Energy (DENERG) has been working on models of wind energy conversion and on the comparison between statistical data of wind resources and weather forecasts for the prediction of power injection into the grid.

The Inter-University Research Center on Building Aerodynamics and Wind Engineering (CRIACIV) has developed accurate simulation tools for large fixed-bottom offshore wind turbines, with particular emphasis on the effects that nonlinear waves produce on the dynamic structural response and associated loads. Additional ongoing research is aimed to study the coupled behavior of floating offshore wind platforms. In this research framework, CRIACIV collaborates with CNR-INSEAN and other national and international research institutions. CRIACIV is partner of FP7 EU project MARINET, and participate in the TUD COST Action TU1304: Wind energy technology reconsideration to enhance the concept of smart cities (WINERCOST).

The ADAG applied research group of University of Naples "Federico II," in cooperation with Seapower Scarl, has been for long time involved in design, development, installation, and field testing of small/medium vertical and horizontal wind turbines also according to IEC-61400-1 standards. Main research regards: blade design, airfoil wind tunnel test, aeroelastic behavior of the whole turbine, identification of aerodynamic characteristics from field test, windmill cost optimization for low wind speed sites, and optimization of composite manufacturing techniques to minimize the cost of blades.

The University of Trento is active in the field of small turbine design and testing on its own experimental test field. The group leads a national research project on aerodynamic characterization on vertical axis wind turbines and is part of a FP7 UE project on vertical offshore floating turbines (Deepwind). Dedicated research on wind energy exploration in cold climates and anti-icing systems for wind turbines has been running for more than ten years.

The Department of Mechanical and Aerospace Engineering (DIMA) of the Sapienza University of Rome has been working on turbine aerodynamic and structural design. Since 2013, the Department is the headquarters of the OWEMES association (www.owemes.org). OWEMES is devoted to the promotion of off-shore wind and ocean energy sources and cooperate with several universities and research institutes in Italy (RSE S.p.A., CNR, ENEA, etc.). Several joint studies were carried out by DIMA and OWEMES and they were devoted to: definition of guidelines for the design of offshore wind parks; assessment of the more promising solutions for floating platform design; and design of advanced system for floating platform stability.

The Department of Civil and Environmental Engineering of the University of Genoa (DICCA) has been working on small-size wind turbines response to ambient turbulence.

The KiteGen Research and Sequoia Automation companies have set up a 3-MW kite wind generator in southern Piedmont for testing.

4.2 Collaborative research

RSE has long been the Italian participant in IEA Wind Task 11 Base Technology Information Exchange. TERNA joined Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power. RSE joined Task 28 Social Acceptance of Wind Energy Projects. The Universities of Genoa and Perugia, the CNR-INSEAN Institute, the wind park developer SORGENIA S.p.A., and the company KARALIT s.r.l. joined Task 31 WAKEBENCH. In 2014, RSE and Department of Mechanical Engineering of Polytechnic of Milan joined the extension OC5 of Task 30 Offshore Code Comparison Collaboration. Within EERA's joint program on wind energy, CNR is a full participant and Polytechnic of Milan is an associated partner. CNR and RSE are participating in the COST ACTION WIRE "Weather Intelligence for Renewable Energy" concerning wind energy short-term forecast finalized to grid integration.

5.0 The Next Term

The Italian Prime Minister announced on January 2015 the "Green Act," a government legislative initiative focused on economics and the environment, in which RES should be with the next term guidelines. A Government's Decree at the end of 2013 allows renewable energy producers that have operating plants the option to get a reduction of the incentive tariff in exchange for a seven-year extension of the incentive period. This was issued in order to reduce the burden of incentives on the electricity cost for the final user.

Growth in wind capacity is expected to be fully controlled by quotas, but the resulting annual new installed capacity is less than half of the quota value. For this reason, an adjustment is expected after in 2015 to the incentive mechanism (quotas and/or tariffs) in order to reach the target of 12 GW of wind capacity on land in 2020.

Opening photo: Deliceto wind plant (Source: Leitwind)

Authors: Laura Serri, Ricerca sul Sistema Energetico (RSE S.p.A); Giacomo Arsuffi, and Alberto Arena, the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA).

27 Japan

1.0 Overview

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

Japan's wind power market has yet to take off. Currently, the biggest obstacle is the procedural delay due to the Environmental Impact Assessment (EIA) procedures applied to all wind farms over 10 MW since October 2012, which takes about four years to complete. Only ten projects totaling 203 MW have completed the process, although there are 88 projects totaling 6,226 MW are still in progress.

2.0 National Objectives and Progress

2.1 National targets

Since the Fukushima nuclear power plant accident in 2011, the Basic Energy Plan has been reconsidered and the Ministry of Economy, Trade, and Industry (METI) published the Fourth Strategic Energy Plan in April 2014. In this plan, it was reconfirmed that renewable energy is a promising source of domestic energy, although nuclear was re-evaluated as an important base-load power source. There were no specific targets for renewable energy in the plan; however, the energy mix of power sources in 2030 will be drafted by METI in 2015.

2.2 Progress

Sixty four wind turbines with a total of 130.4 MW were installed in 2014. Cumulative wind power capacity reached 2,788 MW (1,9241 turbines), with 119 MW of annual net increase in 2014 (Figure 1). The low growth of total capacity has continued, and the reason for recent year's low annual net increase may be attributed to the enforcement of a strict EIA law to wind farm projects started after October 2012. This law requires developers of wind power plants that have a total capacity of more than 10 MW to implement an EIA of the project. The assessment and approval process takes about four years, so it causes delays in wind farm projects in Japan.

Figure 2 shows an example of a wind farm that began operation in 2014. The installation of the Kaminokuni wind farm began in September 2012, while the commercial operation began in March 2014. On the other hand, the commercial operation of the Minamiehime wind farm was delayed because of the EIA, even though the commercial operation was originally scheduled for September 2014 and the installation of wind farm began at the same time as the Kaminokuni wind farm.

No additional offshore wind turbines were installed in 2014. In Japan, 49.6 MW of offshore wind power capacity are operational: 4 MW on floating foundations, 4.4 MW on fixed foundations, and 41.2 MW of semi-offshore wind turbines that were installed very close to the coastlines. One 3-MW semi-offshore wind turbine will start operation in February 2015 at Akita port, and one 7-MW offshore wind turbine with a floating foundation is due to start operation in the summer of 2015 as part of the Fukushima FORWARD project.

2.3 National incentive programs

In Japan, the incentive program was changed from investment subsidies and renewable portfolio standards to the feed-in-tariff (FIT) scheme starting in July 2012. The first FIT scheme began in November 2009 and was only for photovoltaics (PV). The new FIT scheme covers all practical renewable energy sources such as wind (including small wind), small- and medium-scale hydropower, geothermal, and biomass. At the initiation of the FIT system, the tariffs are 22 JPY/kWh (0.152 EUR/kWh; 0.185 USD/kWh) for wind power greater than or equal to 20 kW of capacity and 55 JPY/kWh (0.380 EUR/kWh; 0.462 USD/kWh) for small wind with less than 20 kW of capacity.

The premium tariff for offshore wind was set to 36 JPY/kWh (0.25 EUR/kWh; 0.30 USD/kWh) in 2014. The above tariffs do not include

In Japan, 49.6 MW of offshore wind includes 4.0 MW on floating foundations, 4.4 MW on fixed foundations, and 41.2 MW installed very close to the coastlines.

Table 1. Key National Statistics 2014: Japan	
Total (net) installed wind capacity	2,788 MW
New wind capacity installed	119 MW
Total electrical output from wind*	***5.1 TWh***
Wind generation as percent of national electric demand	***0.5%***
Average capacity factor	***22%***
Target:	Not specified
Bold italics indicate estimates *Wind-Generated Electricity from October 2013 to September 2014	

the 8% consumption tax. The duration is 20 years for wind, including small wind and offshore wind.

The tariff will be re-assessed every year based on the latest market experience in Japan. Projects can qualify for the FIT only after the project is almost finished with the very costly EIA procedure. This forces Japanese developers to spend millions before knowing whether they qualify for the FIT. Only a few developers with strong balance sheets can afford such uncertainty. Therefore, the Japan Wind Power Association (JWPA) has requested the government to move the FIT qualification timelines to earlier in the process so as to make wind power development bankable.

2.4 Issues affecting growth

The Ministry of Environment (MOE) and the METI are working to shorten the EIA process period from four to two years. The MOE recently started to support 50% of the cost of pre-EIA investigations. This support was applied for by about 20 potential projects in fiscal year (FY) 2014.

Strict rules for land use, especially for farmland, have formed another barrier to wind development in Japan. However, The Ministry of Agriculture, Forest, and Fisheries (MAFF) made a new law called the "Act for the Promotion of Renewable Energy in Rural Districts" (APRERD), which came into effect in May 2014. APRERD was designed to revitalize rural districts by harmonized promotion of renewable energy with sustainable and sound development of agriculture, forestry, and fisheries by coordination of land use for farmland, afforested land, etc. In the long run, this could mean a significant increase in the potential area available for land-based wind projects in Japan.

After the introduction of the FIT scheme, PV that are free from the EIA procedures have been rapidly introduced. This raised the possibility of disruption to the balance of the demand-and-supply for electric power. Thereafter, Kyushu Electric Power Company announced the suspension of grid connections for all renewable energy projects, including wind power, from September 2014. Four other electric power companies (Hokkaido, Okinawa, Shikoku, and Tohoku) followed the Kyusyu Electric Power Company's decision. Subsequently, METI formed a working group on grid connection of renewable energy. It announced a draft of the new grid connection rule on 18 December 2014, after discussions with various stakeholders to explore the actions taken by the electric power companies. The new grid connection rule will be enforced after completing its public comment procedures and the electric power companies will resume the grid connections for all renewable energy projects beginning early next year.

The Japanese government is looking at the overall reform of its electricity sector. On 22 August 2014, METI authorized establishment of the Organization for Cross-regional Coordination of Transmission Operators (OCCTO) based on a request submitted on 30 July 2014, by Mr. Masayoshi Kitamura, president of Electric Power Development Co., Ltd., a representative of the founders of the organization. OCCTO is an organization that will be established to promote the development of electricity transmission and distribution networks, which are necessary for cross-regional electricity use, and to enhance the nationwide function of adjusting the supply-demand balance of electricity in both normal and emergency situations. OCCTO will be established on 1 April 2015.

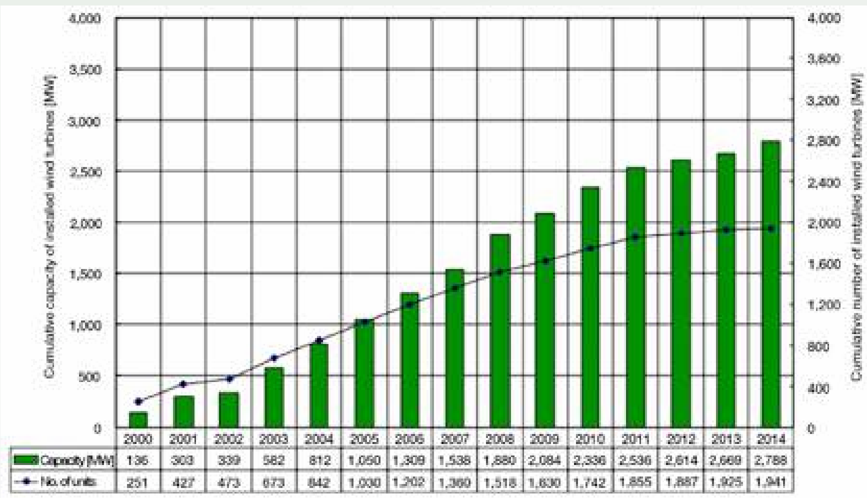

Figure 1. Total installed wind capacity and number of turbine units in Japan

Figure 2. Kaminokuni Wind Farm in Hokkaido prefecture—12 MHI 2.3-MW turbines with a total capacity of 28 MW (Source: Electric Power Development Co., Ltd. (J-POWER))

Most of Japan's land-based wind resource is in the sparsely populated northern rural regions of Hokkaido and Tohoku. METI is beginning to build new grid lines for wind power in Hokkaido and Tohoku. METI subsidizes about 50% of the construction cost to the tune of 25 billion JPY (173 million EUR; 210 million USD) annually. The grid development consortium for Hokkaido was granted the task to add about 3 GW in new transmission capacity last year, and two new consortiums for Tohoku (600 MW at Akita and 900 MW at Aomori) were also announced in 2014.

3.0 Implementation

3.1 Economic impact

According to the latest investigation report by the Economic Research Institute in Japan Society for the Promotion of the Machine Industry, 59 companies with 72 factories and with about 3,000 people were manufacturing wind turbines and their components during FY 2013. Annual sales were estimated at close to 54 billion JPY (373 million EUR; 454 million USD), and this corresponds to one-fifth of the annual sales in FY 2009. This may be due to the shrinking of the domestic market.

3.2 Industry status

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

Several new flagship wind turbines will start operation from 2012 to 2015. Hitachi developed a new 5-MW, downwind turbine, the HTW5.0-126. The first machine will be installed in March 2015 in Kamisu city, Ibaraki prefecture. Hitachi engineers maintain that the downwind configuration has several merits such as the passive fan-less cooling system and high reliability against extreme wind speed and events of grid loss. MHI's MWT167/7.0 7-MW turbine is to be installed at the Fukushima FORWARD floating offshore wind power demonstration project in the summer of 2015 (opening photo). JSW developed a new 2.7/3.0-MW gearless, permanent-magnet, synchronous generator wind turbines, the J100-2.7 and J100-3.0. These machines have almost same concept as JSW's existing 2-MW models, JSW70-2.0 and JSW80-2.0. Toshiba began a business partnership with Korean wind turbine manufacturer UNISON in 2011. Toshiba supplies UNISON's U88/93 2-MW turbines with medium speed gearboxes and permanent-magnet, synchronous generators and develops wind farms using their world-wide business sales network.

Because of the shrinking of the domestic market, Japanese companies intend to expand their business worldwide by merging or collaborating with foreign companies. MHI and Vestas established a new joint venture company for offshore wind business in April 2014. Toray has acquired Zoltek—a producer of carbon fiber for wind turbine blades of Vestas and Gamesa—for 504 million EUR (610 million USD). Yasukawa Electric Co. is cooperating with the Finnish company The Switch, and it is expected that the combination of Yasukawa's high-voltage technology and The Switch's wind power experience will enable them to produce compact generators for bigger wind turbines. In addition, several Japanese trade companies have started investing in the European offshore wind power business.

Table 2. New Wind Turbines Developed by Japanese Manufacturers

Company	Model	Rated output	Start of operation	Type
MHI	MWT167/7.0	7.0 MW	***2015***	Digital hydraulic drive
Hitachi	HTW5.0-126	5.0 MW 2.0 MW	***2015*** 2014	Downwind Downwind
HTW2.0-86	5.0 MW	2.7 MW	2013	Gearless PMSG
JSW	J100-2.7/3.0	2.7/3.0 MW	2013 (2.7 MW)	Gearless PMSG
Toshiba	U88/93	2.0 MW	2012	Medium speed gear with PMSG

Bold italics indicates prospective project

3.3 Operational details

The average capacity of new wind turbines was 2.04 MW in 2014, compared to 1.45 MW in 2013, and 2.44 MW in 2012. The mean capacity of new turbines from 2007–2011 was 1.89 MW. The estimated average capacity factor of wind turbine generation in Japan was 22% in 2014, compared to 17% in 2013, and 20% in 2012.

3.4 Wind energy costs

The values/costs of wind energy are estimated as follows, and unchanged from 2011.

- Total installed cost: 300,000 JPY/kW (2,070 EUR/kW; 2,520 USD/kW)
- Cost of energy: 11.0 JPY/kWh (0.0759 EUR/kWh; 0.0924 USD/MWh)
- Operation and maintenance costs: 6,000 JPY/kW/unit/yr (41.4 EUR/kW/unit/yr; 50.4 USD/kW/unit/yr)
- Wind electricity purchase price: 22 JPY/kWh (0.152 EUR/kWh, 0.185 USD/kWh) for wind power greater than or equal to 20 kW of capacity, and 55 JPY/kWh (0.380 EUR/kWh, 0.462 USD/kWh) for small wind less than 20 kW of capacity (see Section 2.3 for details).

Figure 3. Hitachi 5-MW "HTW5.0-126" wind turbines (Source: Hitachi, Ltd.)

4.0 R, D&D Activities

4.1 National R, D&D efforts

The main national R&D programs by METI, the New Energy and Industrial Technology Development Organization (NEDO), and MOE are as follows.

NEDO Research and Development of Offshore Wind Power Generation Technology (FY 2008 to FY 2016). In this project, an offshore wind turbine and an offshore measurement platform were installed at two offshore sites: Choshi in Chiba prefecture, and Kitakyusyu in Fukuoka prefecture. The main purpose of this offshore R&D project is to demonstrate reliability against Japan's severe external offshore conditions such as typhoons. There were several very large and very strong typhoon attacks in Japan from 2013 to 2014. An example is typhoon Wipha that was category 4 by Safiir-Simpson Hurricane Scale and the lowest central pressure was 935 hPa. Typhoon Wipha directly hit the Choshi offshore wind site, and some minor damages such as a disconnection of grounding wire and deflection of the support structure of submarine cables, however, there were no serious damages to the offshore wind turbines at Choshi offshore wind site.

MOE Floating Offshore Wind Turbine Demonstration Project (GOTO-FOWT PJ) (FY 2010 to FY 2015). In this project, a Hitachi 2-MW downwind turbine on a hybrid (steel and concrete) spar type floater was installed. Located about 1 km offshore in Nagasaki prefecture, it began operation for demonstration research in October 2013 (Figure 4). At this offshore site, the water depth is about 100 m, and the extreme significant wave height is 7.7 m.


Figure 4. Hitachi 2-MW wind turbine with spar type floater in the MOE floating offshore wind turbine demonstration project (Source: GOTO-FOWA PJ)

METI Floating Offshore Wind Farm Demonstration Project (Fukushima FORWARD PJ) (FY 2011 to FY 2015). In the METI project, several offshore wind turbines with various types of floaters were planned to be installed in the Pacific Ocean more than 20 km offshore of Fukushima prefecture. A Hitachi 2-MW, downwind type wind turbine with a 4-column, semi-submersible floater and a 66-kV floating offshore electrical substation with a measurement platform were installed and they began operation in November 2013. In Phase 2 (FY 2014 to 2015) of this project, a MHI 7-MW wind turbines with three-column, semisubmersible (opening photo) floater and a Hitachi 5-MW wind turbine with advanced spar type floater will be installed by the end of the FY 2015. The water depth around this offshore site is 100–150 m, and the extreme significant wave height has been estimated at 10–15 m. The annual average wind speed at hub height has estimated at 7.0 m/s or more.

NEDO Advanced Practical Research and Development of Wind Power Generation. In this national project, R&D on advanced components and maintenance technologies applicable to next-generation very large wind turbines began in FY 2013 with the aim of the further reduction of cost of wind energy. They include: D1. Advanced Practical Development of Wind Turbine Component (FY 2013 to FY 2015); D2. R&D of Smart Maintenance Technologies (FY 2013 to FY 2015); and D3. Research on over 10-MW class wind turbines, (FY 2013 to FY 2014).

4.2 Collaborative research

Japan is participating in IEA Wind Task 11 Base Technology Information Exchange, Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power, Task 27 Small Wind Turbines in High Turbulence Sites, Task 28 Social Acceptance of Wind Energy Projects, Task 29 Mexnext II: Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models, Task 30 OC5: Offshore Code Comparison Collaboration, Continued with Correlation, Task 31 WAKEBENCH: Benchmarking of Wind Farm Flow Models, and Task 32 LIDAR: Wind Lidar Systems for Wind Energy Deployment. Japan also participates in many maintenance teams, project teams, and working groups in IEC TC 88.

5.0 The Next Term

The Japanese wind power market has significant challenges to overcome before the sector emerges strongly. However, efforts are being made to reconsider the regulations and grid concerns that are slowing wind power development in Japan. Japan is expected to emerge as a strong wind power market after 2016. Japan's wind industry is making every effort to realize this future.

References:

Opening photo: Fukushima FORWARD floating offshore wind power demonstration project (Photo credit: Fukushima FORWARD project, Ministry of Economy, Trade and Industry (METI))

Author: Tetsuya Kogaki, National Institute of Advanced Industrial Science and Technology (AIST), Japan.

28 Republic of Korea

1.0 Overview

The cumulative installed wind power in The Republic of Korea was 553 MW in 2013 and estimated as 643 MW in 2014, increasing by 16% over the previous year (see Table 1). Most wind turbine systems installed in 2014 were supplied by the local turbine system manufacturers. A renewables portfolio standard (RPS) proposal for new and renewable energy was enacted in 2012 and the required rate of RPS in 2013 was 2.5%; this will increase to 10% by 2022. In 2013, the second year of RPS, more than 76% of the target rate was achieved. A nine-year construction plan for a 2.5-GW offshore wind farm in the west coast was announced in 2010 and the first stage of the project—construction of a 60-MW wind farm—is in progress. The 2.5-GW offshore wind farm construction and the RPS are expected to accelerate the growth of wind energy in Korea. Since 2009, the government has concentrated on the localization of components to secure the supply chain, and more R&D government budget is allocated to localize component supply and develop core technologies for wind power.

2.0 National Objectives and Progress

The Republic of Korea has focused on wind energy as the clean energy resource possibly replacing fossil fuel and the nuclear power, as well as a new area of heavy industry to escalate the Korean economy. Therefore, the Korean government has increased the R&D budget continuously to support wind turbine and component manufacturers to develop their own technologies and products. Some shipbuilding and heavy industry companies have been involved in the renewable energy business, especially wind energy. In 2014, total installed wind power (turbines larger than 200 kW) is estimated as 643 MW, with 16% growth over the previous year, as shown in Table 2.

2.1 National targets

The national target is to promote renewable energy and replace 11% of total energy consumption with the renewable energy. Currently, renewable energy production depends mostly on biomass. The Korean government will try to reduce the dependency on biomass by focusing on wind energy and solar photovoltaics (PV). Table 3 shows the detailed target for each resource.

Also, another goal is to improve the level of the technology associated with wind energy and lead the wind energy industry.

2.2 Progress

The estimated installation for 2014 is 89.4 MW, an increase of 16%, which is a similar installation to the previous year. Most turbine systems were supplied by the domestic manufacturers such as DSME, Hyundai, Hyosung, and Samsung. Domestic manufacturers have commercial systems and are tracking performance. However, the growth of the wind energy industry has slowed because of the difficulties of wind farm construction, as well as severe competition with major global wind turbine manufacturers. The net sales of the wind energy products in 2013 decreased over the previous year, but it is estimated that they increased slightly in 2014. The net sales were mostly occupied by the tower and casting components, but the production of casting components has decreased because its market is competitive. However, the sales of turbine systems were steadily increasing. In 2013, the market for turbines increased 70% over the previous year to an estimated 425 million EUR (515 million USD). Table 4 shows the total sales of turbine systems.

The number of manufacturers has increased steadily, as 38 companies were involved in wind energy in 2012 and 44 in 2013. The number of employees was estimated to be 2,030 in 2012 but decreased to 1,988 in 2013. Restructuring of the wind energy industry is in progress and the companies for the casting components have changed their business because of the severe competition with the Chinese companies.

The first phase to construct 60 MW of a 2.5-GW offshore wind farm has begun.

Table 1. Key National Statistics 2014: Korea	
Total (net) installed wind generation	***643 MW***
New wind generation installed	***89.4 MW***
Total electrical output from wind	1.148 TWh (2013)
Wind generation as percent of national electric demand	0.21% (2013)
Target:	2% wind energy by 2035
Bold italic indicates estimates	

Table 2. Total Installed Wind Capacity in Korea													
Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
Capacity (MW)	18	50	31	79	18	108	47.3	30.9	26.6	54.5	89.6	**89.4**	643
Electrical Output (GWh)	25	47	130	239	376	436	685	817	863	913	1,148	-	-

Therefore, the employees for the casting components steadily decreased from 1,163 in 2009 to 347 in 2013, but that of turbine system has increased from 236 in 2007 to 1,112 in 2013.

2.3 National incentive programs

The government subsidizes the installation of New and Renewable Energy (NRE) facilities to enhance deployment and to relieve the end user's burden. The government has specially focused on the school buildings, warehouses, industrial complexes, highway facilities, factories, and electric power plants. For wind power installation, especially for demonstrations or private use, 50% of the installation cost is compensated by the government.

Other incentive programs are as follows:

• Million Green Homes Program: In order to encourage the deployment of the renewable energy in residential areas, the government expanded the 100,000 solar-roof program to one million green homes for diversifying and optimizing the renewable energy use. The target is to construct one million homes equipped with the green energy resources by 2020. By the end of 2013, 192,000 homes were equipped with the green energy.

• Green energy requirement for public buildings: New construction, expansion, or remodeling of public buildings having floor area exceeding 1,000 m^2 have been required to supply more than 10% of total energy with the renewable energy.

• Feed-in Tariffs (FIT): The standard price has been adjusted annually reflecting the change of the NRE market and economic feasibility of NRE. Concerning wind energy, the feed-in tariff was 0.08 EUR/kWh (0.10 USD/kWh) as a flat rate for 15 years in 2013. FIT are being applied to wind farms installed by 2011 and new farms constructed from 2012 are supported with RPS.

• RPS: RPS was enacted from 2012 and more than 2.5% of the electric power should be supplied with the renewable resources in 2013. This regulation is applied to electric power suppliers providing more than 500 MW. The required rate will increase to 10% in 2022. The weight factors for land-based wind farms is 1.0; for offshore farms less than 5 km from shore it is 1.5; and for offshore farms more than 5 km from shore it is 2.0. In 2013, 76% of the yearly target was achieved and it was the second year of RPS. The suppliers must pay 38 million EUR (47 million USD) for the insufficient supply. Some complaints about the RPS target have been reported and the government is considering relieving the burden on the

Table 3. National Targets of Renewable Energy Resources								
	Solar PV	Solar Thermal	Wind	Geothermal	Biomass	Bioenergy	Hydro	Ocean
2020	11.1	1.4	11.3	2.5	47.3	17.6	6.3	2.4
2025	13.3	3.9	12.5	4.6	40.2	19.6	4.3	1.6
2035	14.1	7.9	18.2	8.5	29.2	17.9	2.9	1.3

Table 4. Total Sales of Wind Turbine Systems in Korea

Year	2007	2008	2009	2010	2011	2012	2013
Total Sales (million EUR; million USD)	0.15; 0.19	1.98; 2.4	68; 82	175; 212	135; 164	250; 303	425; 515
Growth Rate (%)		1,200	3,273	157	-23	85	70

Table 5. Number of Employees for Wind Energy Industry

Year	2007	2008	2009	2010	2011	2012	2013
Turbine System	236	312	727	957	1,021	1,000	1,112
Casting Components	925	1,193	1,163	1,032	810	431	347
Total	1,434	1,860	2,332	2,554	2,456	2,030	1,988

electric power suppliers by reducing the RPS rate.

In addition, Loan & Tax Deduction, Local Government NRE Deployment Program, and others are available as the national incentive programs.

2.4 Issues affecting growth

Two major issues escalate the growth of wind energy. The first issue is the construction of the 2.5-GW offshore wind farm in the west sea. According to the original roadmap announced by the government, the 2.5-GW farm would be constructed through three stages over nine years, beginning in 2011. For the first four years, 100 MW of wind power would be installed to test the technology of site design, and then 400 MW of wind power will be installed for accumulating operation experience and commercial purposes over the next two years. At the final stage, a 2-GW wind farm would be constructed with 5-MW wind turbines for the commercial purposes. The total budget was estimated to be 6.2 billion EUR (7.5 billion USD). However, the construction has been delayed for several reasons and the government modified the construction plan as shown in Table 6.

The other issue is the RPS program that started in 2012. Major electric power suppliers are required to provide some amount of the electric power with renewable energy (including wind power) and the amount will increase to 10% in 2022. This regulation was expected to provoke the power suppliers to invest in wind energy deployment, and Table 7 shows its favorable effect. New installations have doubled since 2012.

In Korea, most high mountains were categorized as the strictly preserve areas and it was very difficult to get approval for new wind farm construction. But the central government has reduced the severe regulations for environmental protection and this change will expedite the deployment a little.

3.0 Implementation

3.1 Economic impact

As reported in the *IEA Wind 2013 Annual Report*, major shipbuilding and heavy industry companies have developed their own wind turbines and some companies have accumulated good track records. The net sales of 2013 were less than 2010 and recorded only 757 million EUR (916 million USD). Exports of turbine systems were initiated in 2009, but oversea sales were not very active. Even employment was slightly decreased and recorded at 1,988 people. The overall size of the wind energy industry is very small compared to the Korean industry and the impact is still very weak.

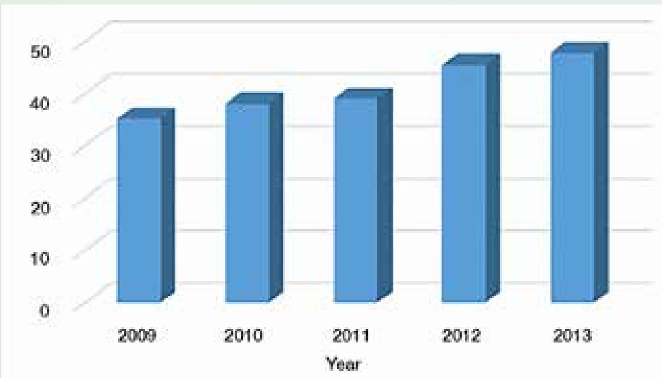

Figure 1. The budget trend of government sponsored R, D&D (million USD)

3.2 Industry status

Some manufacturers expanded their business into other renewable resources such as solar energy, tidal energy, etc. to provide stable renewable energy. The renewable energy industry, including wind energy, is steadily growing but the growth is very slow. Difficulties with new wind farm construction and severe global competition have caused some manufacturers close.

3.3 Operational details

In 2013, 89.6 MW of wind power were newly installed and most turbines were supplied by domestic manufacturers. Eight units of 2-MW and 3 units of 3-MW turbines were supplied by Doosan, and Hyundai supplied 7 units of 2-MW and one unit of 1.65-MW turbines. STX also installed one 2-MW turbine. However, Samsung and Hyundai Heavy Industries closed their wind energy business and other companies have downsized.

3.4 Wind energy costs

Newly installed wind turbines, especially supplied by domestic manufacturers, are not operated for commercial purposes but for system checks and accumulating a clean

Table 6. The 2.5-GW Offshore Wind Farm Construction Plan			
	Demonstration	Standardization	Deployment
Objective	Test record set up; Track record & site design	Operation experience; Validation of comm. operation	Cost effectiveness; GW site develop' Comm. operation
Wind power	60MW	400 MW	2,000 MW
Schedule	2011~18 (7 yrs)	2019~2020 (2 yrs)	2021~2023 (3 yrs)

Table 7. Comparison of the RPS Effects with New Installation Record						
Year	2009	2010	2011	2012	2013	2014
New installation (MW)	47.3	30.9	26.6	54.5	89.6	***89.4***

Table 8. Government R&D Budget Allocation from 2009 to 2013 (million USD)										
Category	2009		2010		2011		2012		2013	
System	13	36%	7	19%	13	32%	4	8%	9	19%
Core Components	12	35%	16	42%	10	25%	10	23%	11	22%
Wind Farm Development	3	8%	7	19%	8	20%	12	27%	8	16%
Grid Connection	5	15%	6	16%	3	8%	11	25%	12	24%
Etc	2	6%	2	5%	6	15%	8	17%	9	18%
Total	35	100%	38	100%	39	100%	46	100%	48	100%

track record. Therefore, there is not enough electric output to record and it is still difficult to estimate the real cost of wind energy.

4.0 R, D&D Activities

4.1 National R, D&D efforts

The government has continuously increased the R&D budget and ensured strong support for wind energy. The government has allocated an R&D budget for local production of wind turbines and has also realized the importance of the stable supply chain. The government, therefore, has increased the budget to develop the technologies for components and several government-sponsored R&D projects are under way. More component development projects, as confirmed in Table 8, have been launched every year. Table 8 presents the budget and the portion of the turbine system, core components, wind farm development, grid connection, etc. among the government R&D. The budget for turbine system development has decreased, while the budget for wind farm development and grid connection have increased.

5.0 The Next Term

The first stage of the 2.5-GW offshore wind farm was initiated in 2011 and RPS was enacted in 2012. These major issues were expected to encourage the electric power suppliers and turbine system manufacturers to plan for profitable wind farm construction. However, the optimistic vision about wind energy has been reduced by bad wind conditions, small land, strong environmentalist reactions, the opposition of local communities and government. The 2.5-GW offshore wind farm construction has been delayed for several years and some major wind energy component manufacturers have closed their businesses. Therefore, for the active deployment of wind energy, Korea desperately needs some breakthroughs.

Opening photo: Baeksu wind farm (Photo credit: Honam Wind Power Co.)

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29 México

1.0 Overview

México is one of 24 countries in the world with more than 1,000 MW of installed wind power. In 2014, México added 634 MW of new wind power to the existing 1,917 MW installed, bringing the total to 2,551 MW. This wind energy comes from 1,200 turbines over 31 wind farms located in Oaxaca, Baja California, Chiapas, Jalisco, Tamaulipas, San Luis Potosí and Nuevo León regions. México's largest wind energy resource is found in the Isthmus of Tehuantepec in the state of Oaxaca. Average annual wind speeds in this region range from 7–10 m/s, measured at 30 m above the ground. It is estimated that more than 6,000 MW of wind power could be commercially tapped there. Using reliable and efficient wind turbines in this region could lead to annual capacity factors around 40%.

In December 2013, México's Energy Reform legislation was enacted, and is still in the process of being fully implemented. México has a target of 35% of electricity from renewable energy by 2024, specifically with 9.5 GW of wind power by 2018. This legislation has encouraged installations in 2014 and will make for a strong 2015 as well.

The Sustainable Energy Fund created by the the Secretariat of Energy (SENER) and the National Council for Science and Technology (CONACYT), under the mandate of the Law for Science and Technology, is sponsoring the Mexican Wind Energy Innovation Center (CEMIE-Eólico). The main purpose of the CEMIE-Eólico is to increase and consolidate the country's scientific and technical capacities in the field of wind energy by means of building synergy among national institutions so that activities on innovation, research, and technology can be oriented towards the construction of a stronger national wind energy industry. The CEMIE-Eólico is a consortium led by the Instituto de Investigaciones Eléctricas (IIE). It is integrated by six public research centers, 14 universities, and ten private companies. The CEMIE-Eólico started operations in 2014, developing 13 projects that will be carried out during the next four years.

References:

Opening photo: Eurus wind farm

[1] Global Wind Energy Council (GWEC). 2015. "Global Wind Report 2014: Annual Market Update."

México is one of 24 countries in the world with more than 1,000 MW of installed wind power.

Table 1. Key National Statistics 2014: México [1]	
Total (net) installed wind capacity	2,551 MW
New wind capacity installed	634 MW
Total electrical output from wind	5.7 TWh
Wind generation as percen of national electricity demand	***2.0***
Average capacity factor	***30%***
Target:	9.5 GW of wind power by 2018
Bold italics indicate estimates	

Figure 1. The Wind Turbine Test Center operated by the Instituto de Investigaciones Eléctricas

30 the Netherlands

1.0 Overview

From the perspective of changes in politics and policies, 2014 was a calm year. The main drivers of the national energy policy are the EU objectives (14% renewable energy in 2020) and the so called "SER Agreement" (2013), in which five objectives are defined:

- A decrease in final energy consumption averaging 1.5% annually—this is expected to be more than enough to comply with the relevant EU Energy Efficiency Directive;
- In this context, a 100-petajoule (PJ) saving in the country's final energy consumption by 2020;
- An increase in the proportion of energy generated from renewable sources from 4.4% currently to 14% in 2020, in accordance with EU arrangements;
- A further increase in that proportion to 16% in 2023;
- At least 15,000 full-time additional jobs.

The SER agreement also contains guidelines for feedback and implementation. The offshore wind energy targets were redefined for 2014 (Table 2).

The 228 MW of offshore capacity already installed, and the approximately 745 MW that are planned, will add up to a total installed offshore wind capacity of ± 4,450 MW in 2023.

2.0 National Objectives and Progress

2.1 National targets

In addition to the intermediate targets for offshore wind between 2019 and 2023, the SER agreement also sets a target for land-based wind by 2020 of 6,000 MW. Because social acceptance is a major bottleneck in the deployment of land-based wind energy, the SER agreement describes tools to enhance the acceptance of wind energy—including the possibility for civilians to participate financially. The law will require project developers to maximize the acceptances. Furthermore, multifunctional spatial use has to be forced (e.g., wind energy along dikes and dams and near sluices).

2.2 Progress

The Netherlands had a net installation of 44 MW in 2014. This value consists of a gross installation of 52 wind turbines (165 MW), while approximately 110 wind turbines (121 MW) have been dismantled. This shows there is a clear tendency for smaller wind turbines (1-MW class) being replaced by bigger ones (3-MW class). All changes are happening on land, while the installed capacity of offshore remained unchanged at 228 MW. Projects in progress that are larger than 10 MW are in Vlissingen (four 3-MW turbines), Rotterdam (eight 3-MW and seven 3-MW turbines) and NoordOostpolder (seven 7.5-MW turbines).

There is a clear tendency for land-based wind turbines of 1-MW class being replaced by 3-MW class turbines.

Table 1. Key National Statistics 2014: The Netherlands	
Total (net) installed wind capacity	2,753 MW
New wind capacity installed	45 MW
Total electrical output from wind	5.8 TWh
Wind generation as percent of national electric demand	***4.8%***
Average national capacity factor	Land-based 22.0% Offshore 37.5%
Target:	---
Bold italic indicates estimates	

2.3 National incentive program

In 2011, the system of SDE+ subsidy was introduced and since then the whole system has further been fine tuned. In principle, the SDE+ systematics requires the applicant to define for himself a certain 'claimed energy price' (misleading term in SDE+: 'basis price' or 'basis tariff'). The basic price is the final price which the producer wants to receive for its generated renewable energy. To obtain this final price (basis tariff) the renewable energy producer is assumed to receive a (more or less fixed) pay back price from the utility. The SDE+ fills the gap between pay back tariff and desired final price (basis tariff).

The basic principle of SDE+ is that every generation technique has its own maximum allowed basis tariff. SDE+ can be applied April through November, and the earlier in the year applications are done, the lower the basis tariffs for the projects will be—meaning a lower SDE+ subsidy but a higher chance for grant approval. The purpose of this system is to ensure that the cheapest option will be granted first. Offshore wind energy is excluded from this system and is expected to get its own subsidy program by the end of 2015.

Table 2. Additional Offshore Wind Energy Targets Defined in the SER Agreement (2013)		
Call for tender	Offshore additional wind power	Operational by
2015	700 MW (was 450)	2019
2016	700 MW (was 600)	2020
2017	700 MW (was 700)	2021
2018	700 MW (was 800)	2022
2019	700 MW (was 900)	2023
Total	**3,500 MW (was 3,450)**	

Land-based wind and wind-in-lake projects can be submitted in April for an effective basis tariff of 0.09 EUR (0.11 USD), in May for 0.10 EUR (0.12 USD), and June through November for 0.11 EUR (0.13 USD).

Since there is a cap on the number of full load hours per year and the wind regime can vary up to ~20% per year around the average, a serious disadvantage is that poor wind years cannot be compensated by windy years, because of the cap. Therefore, in 2014, an extra compensation system was built in: SDE can be paid over, at most, 80% of the maximum full load hours. The tariff will be paid at 125%, enabling poor wind years to be compensated by good years. As in previous years, the SDE+ subsidy is not only applicable for renewable electricity, but also for green gas and renewable heat including geothermal heat.

Land-based wind is split up in two categories by turbine size: <6 MW and ≥6 MW. The maximum full-load hours are limited to around 2,900 hours/year (land) and 2,560 hours/year (lake) for the 0.09 EUR (0.11 USD) basic tariff. Applications for more expensive electricity can only be granted for fewer full-load hours.

All wind applications in 2014 were done after June for a basic tariff of 0.11 EUR (0.13 USD), for a total budget claim of 717 million EUR (868 million USD) for 10.6 TWh. Approximately one third of this has been granted positively in February 2015, the rest has yet to be decided upon.

2.4 Issues affecting growth

In the first few years, the SDE+ incentive program made it difficult for wind energy to receive subsidies since there were many renewable energy projects applying for a lower basic tariff than the basic tariffs of the cheapest wind energy projects. In 2012, only 2.0 million EUR (2.4 million USD) was granted for only one wind project and most of the money went to other kinds of renewable energy projects. This was, up to 2012, a major factor limiting the growth of wind energy. But after three years of applying the principle of 'the cheapest renewable energy option first,' most of the low-hanging fruits have been plucked, and in 2014 land-based wind claimed approximately one eighth of the SDE+ budget.

Although there are, from a financial point of view, good arguments to limit the SDE+ subsidy to a maximum number of full-load hours per year, this discourages investors to place turbines with relatively oversized rotors. Discussions are ongoing to correlate this limit not to the size of the generator but to the size of the swept area.

With a characteristic price of around 150 EUR/MWh (182 USD/MWh), offshore wind energy is far out of the region of tariffs where it can get SDE+ subsidies. Therefore, no applications for offshore wind projects have been done. Special tenders for offshore wind SDE+ are expected to start in December 2015.

Bottlenecks on land are being monitored. Central bottlenecks are social acceptance, as well as hindrance and interferences with other land uses. With a surface of only 41,000 km^2 and a population of 17 million, the Netherlands is densely populated.

Noise and so called 'horizon pollution' (visual impact) are issues which come back on nearly every project. To broaden the basis of public support, a code of conduct has been drawn up. One of the more important tools in this code of conduct is the enhancement of the possibilities for people living in the neighborhood to participate financially in the wind energy projects. Public acceptance also plays a role concerning the illumination of wind turbines surrounding airports. Since the provinces of Noord Holland and Flevoland are provinces with high wind energy potential but also have landing corridors to Schiphol airport above their land, wind turbine illumination appears here often, having a serious visual impact. A pilot project began in mid-2014 to reduce this illumination.

The limited availability of good wind locations also affects growth. Several issues can contribute to this. Interferences with Natura 2000, an EU-established network of nature protection areas, might limit the size of some new, intended wind farms. The use of dikes and river foreland for wind energy has usually been forbidden in the past, but this is being reviewed in 2014. Less strict, but also clearer regulation can lead to more available spaces and also to faster decision making.

In a project to try to find more suitable locations a scan of the local options of wind energy has been made. In this scan, local governments, project developers, and utilities collaborate on finding locations that can be easily connected to grid. The starting point in this methodology is the grid, and this collaboration makes it easier for project developers to plan their project where the construction of the wind farm coincides with intended reinforcements of the grid.

Recently reduced fiscal advantages for private citizens on green savings accounts, green bonds, and green stocks resulted in reduced amounts of money available for banks to spend on green projects. In addition, the general tendency of banks, pension funds, and insurance companies is to act according to stricter rules on financing of projects (e.g., Basel III and Solvency II are obligatory) leading to less money being available to spend on green projects. Both effects result in the need for a higher financial participation of the project owner, making projects more difficult to be developed.

To avoid lengthy permit procedures the RijksCoordinatieRegeling (National Coordination Regulation) exists. This means for wind energy projects >100 MW, the national government automatically takes over procedures and deals with the permissions. This regulation coordinates and shortens procedures and is meant to speed up deployment.

Offshore wind deployment is in a phase of transition. As mentioned, the new policy is to have a new deployment system based on the SER agreement. To maximize cost reduction and time, the old issued permissions will no longer be used in the new SER planning. Another change due to new SER planning is that the project developers no longer choose their favorite locations, but instead the government chooses the locations and organizes tenders for projects of 350 MW, and project developers can offer bids. This new system will be implemented in 2015.

3.0 Implementation

3.1 Economic impact

The total investment in wind energy installations in the Netherlands for 2014 can be estimated at 227 million EUR (275 million USD), assuming an average investment cost for land-based wind of 1,376 EUR/kW (1,666 USD/kW) for the 165 MW installed. The total investment in wind energy installations built up to 2014 is estimated at approximately 4.5 billion EUR (5.5 billion USD).

In 2014, a report about the economic impact of the total wind sector on the Dutch economy was published. This was the result of extensive research covering 236 companies. Based on this research, the direct employment of the sector was estimated at 5,450, with 26% of this in the construction sector, 20% in the commercial service sector, 19% in the energy sector, 10% in industry, 10% in the financial service sector, and 8% in transport. The whole sector has a direct turnover of 2.57 billion EUR (3.11 billion USD), with a gross added value of 0.86 billion EUR (1.1 billion USD). Taking the (first order) indirect impact into account, these values are much higher and sum up to a total employment of 7,950 full time equivalent jobs, a total turnover of 3.06 billion EUR (3.71 billion USD) and an added value of 1.15 billion EUR (1.39 billion USD).

Although difficult to divide, an attempt has been made to split up the economic turnover in land-based versus offshore, as well as operation and maintenance (O&M) versus development. Most noticeable is the high turnover for offshore compared to land-based; although only 228 MW (~8%) of the installed wind capacity is offshore, the offshore sector takes up ~60% of the turnover. This indicates that wind offshore is a typical export product for the Netherlands, as most of this turnover is realized abroad.

Seventy five percent of the interviewed enterprises expect an increase in the turnover in the next five years. This will be caused by not only the expected end of the economic crisis, but also foreign policy and the renewed Dutch wind policy. Twenty five percent of the interviewed enterprises have serious difficulties in finding a work force. The research was carried out in 2013, during the lowest point of the economic situation and this percentage having difficulty finding workers is very high: the average throughout the whole economy in 2013 was around 6%.

3.2 Industry status

After years of near absence, Dutch turbine manufactures are gradually coming back. Lagerwey Company has its roots in the late 1970s and was the first developer of the DirectDrive. It is active in the 2.0–3.0 MW range and has developed its new 93-m 2.6-MW turbine. It has started taking orders from abroad. The turbine operates at variable speeds. Because it is high efficiency, natural airflow is sufficient for cooling and the generator does not need artificial cooling. Furthermore, by the end of 2014 the development of a new Lagerwey L136 had begun. This machine will have a 3.8-MW generator, and a 136-m rotor at a hub height of 133 m. A 150-m rotor version at a 150-m hub height is also being developed.

Emergya Wind Technologies (EWT) has doubled its production and is producing dozens of turbines in the 0.5–1.0 MW class, mainly for the UK, but also for Alaska in the United States. All EWT's turbines are meant for IEC61400 wind class IIA or IIIA.

The Dutch-Chinese enterprise XEMC-Darwind has sold the first two turbines of their flagship: the XD137, a 4-MW land-based turbine meant for the IEC wind class II-A. This turbine is completely designed and developed in the Netherlands and is optimized for low installation and low O&M costs.

Table 3. Overview of the Direct Turnover of Dutch Enterprises for Wind Energy Activities in 2013, (including activities abroad)

Category	Land-based		Offshore		Total	
Unknown						486 mil EUR; 589 mil USD
Development	3%	67 mil EUR 81 mil USD;	21%	429 mil EUR; 520 mil USD	24%	496 mil EUR; 601 mil USD;
O&M	38%	791 mil EUR; 958 mil USD	38%	797 mil EUR; 965 mil USD	76%	1,588 mil EUR; 1,923 mil USD
Total	41%	858 mil EUR; 1,139 mil USD	59%	1,226 mil EUR; 1,485 mil USD	100%	2,084 mil EUR; 2,524 mil USD

Besides these turbine manufactures, many supply companies or companies delivering transport, installing services, or delivering knowledge services (controlling, aerodynamics, strength calculations, etc) are present in the Netherlands. The large companies include Ballast Nedam/VanOord and Smulders. Smaller companies in the knowledge sector are less well-known, but the Netherlands has a strong position in this market as well.

Europe's largest commercial wind turbine test site is located in the Flevoland polder. This Lelystad test site has room for 12 separate positions, nine of which are available for prototypes with a maximum blade tip height of 200 m.

3.3 Operational status

The wind index (or windex) is a way to evaluate wind plant performance over the year. Although difficult to compare from year to year, and wind indices in the long term have a variable basis, 2014 was a poor year, and had a wind index of 89% (91% in 2013). Only three months had a windex > 100% (148%, 163%, and 161%), but seven months had a windex < 80% (68%, 72%, 40%, 49%, 74%, 35%, and 72%). Given these facts, the capacity factor on land in 2014 was 22.0%. This is, more or less, around the last ten-year average capacity factor of 21.4% and is similar to 2013 (22.3%). This indicates that newer turbines on land are constantly performing better than the older ones. Key factors to this are the increased average hub height and the increased swept area/power ratio. Offshore, the capacity factor in 2014 was 37.5% (2013: 38.6%). Since no modification on offshore wind turbines have been made, here we do see a decrease output in 2014 compared to 2013, because of the decreased windex.

3.4 Wind energy costs

Every year, the cost of wind energy is calculated to determine the SDE+ tariff. Because of initiatives to build wind farms in the Lake IJsselmeer (sea until 1932, 1,100 km^2, maximum depth of 9 m), a new wind category has been defined in 2012 in the SDE+ systematics: wind in lakes. Besides that, the land-based wind category is split up in the categories <6 MW and ≥6 MW. Land-based wind cannot receive more subsidy than 90 EUR/MWh (109 USD/MWh). Wind in lakes cannot receive more subsidy than 123 EUR/MWh (149 USD/MWh).

4.0 R, D&D Activities

4.1 National R, D&D efforts

Since 2012, R&D programs for wind energy are only focusing on offshore wind energy. These programs are coordinated by the TKI, the Topconsortia for Knowledge and Innovation. The TKI (actually TKI Wind Offshore) represents the R&D community and the involved industrial sector. One of the leading ideas behind this is to have the business sector, research centers, and universities directing R&D, instead of having R&D being directed from political and governmental organizations. Furthermore, the intention is to have much closer cooperation between these actors: the R&D community is encouraged to work more in line with requests from the industrial sector; while the industrial sector is encouraged make much more use of the knowledge available in the research centers and universities.

Besides coordinating the subsidy flows (according to EU legislation) for R&D, TKI itself as a foundation receives a basic subsidy for their coordinating tasks. In addition, TKI can receive a bonus subsidy depending on the extent the industrial sector and the R&D institutes are cooperating. In 2014, two R&D tenders were run with a total subsidy budget of 10 million EUR (12 million USD). These tenders had a low level of applications, only 30% of the budget has been allocated. On average the projects were subsidized at a rate of approximately 70%, because most of the awarded projects have a fundamental research or industrial research profile. The government is forcing this percentage down to around 50%.

The R&D vision describes the need for support in the field of six themes: supporting

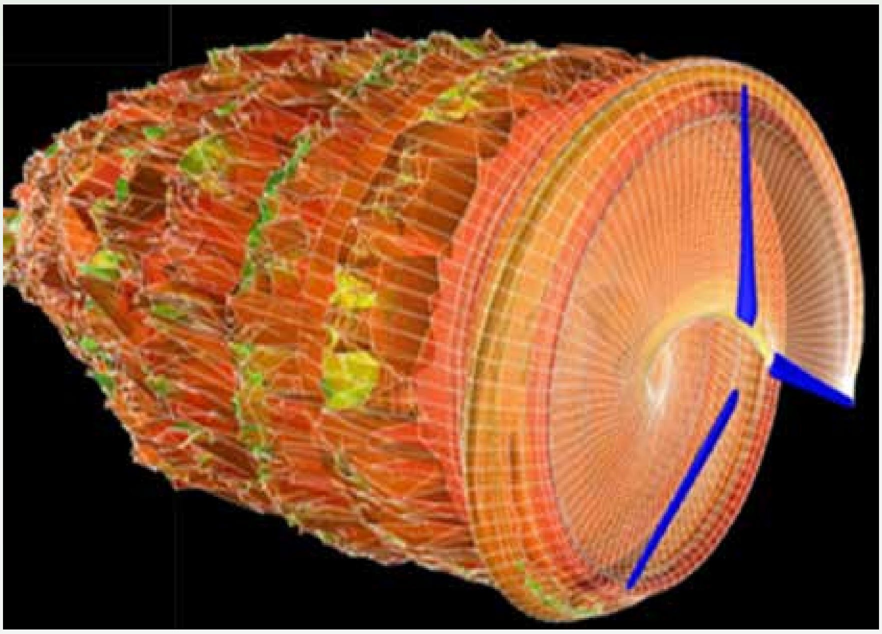

Figure 1. Computer simulation of wake behind a blade with an innovative tip

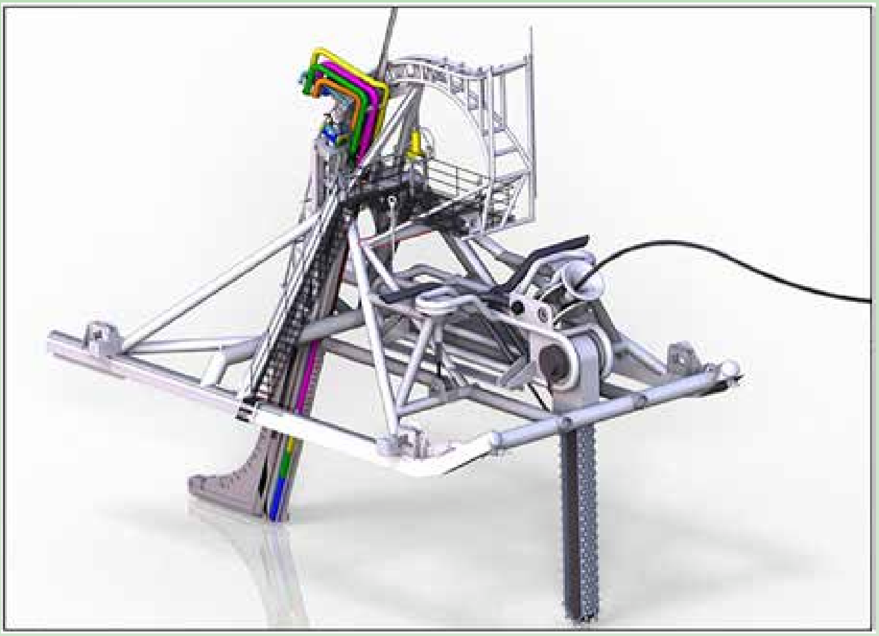

Figure 2. Subsea chain cutter being developed for installing offshore cables

structures, wind turbines and wind power plants, internal grid and connection to HV grid, transport installation and logistics, O&M, and wind farm development. Under the R&D tender, in 2014 effectively five projects are granted:

- Project "InnoTip—Innovative Offshore Tips to Improve Wind Farm Yield:" a project aiming at the development of new blade tips with milled edges. This new shape might lead to enhanced production for the individual wind turbine, and also to a more intensive interaction between the disturbed and undisturbed area wind the rotor, resulting in a faster disappearing wake and increasing the production of a whole wind farm. Finally—and this is relevant for land-based applications—milled edged can lead to reduction of noise (see Figure 1).
- Project "Subsea Chain Cutter:" a project in which a cutter will be developed that is able to trench deeply through complex layered soils (sand, clay, chalk). The cutter can trench up to 6 m below surface, following the trend to bury cables deeper, to have them more protected. Where water jetting is not an applicable technique, now expensive trench cutters are being used (see Figure 2).
- Project "Dynamic Asset Information System for Offshore Wind Farm Optimisation:" a project in which a system for asset management will be developed. The system obtains information from several sources (as SCADA, met-data, sensors for oil quality, displacement, vibration, acoustics) and based on these data, the characteristics of the turbines and by making use of the Fleet Leader (data from a limited number of turbines at widely spread key positions in the farm, estimate the load for all positions in the park) a forecast for wear and tear in the whole windfarm can be made on which a maintenance schema will be made.
- Project "Offshore Maintenance:" a project with the aim to decrease the O&M cost and risk for maintenance operations by developing improved knowledge and practical simulations tools for O&M cost analysis. This will be achieved by determining operational criteria for offshore maintenance and apply these criteria to select the most suitable maintenance logistics for each wind farm and maintenance activity. These operational criteria include human factors as well as limitations to the vessel and its equipment.
- Project "Wave Impacts on Fixed Wind Turbines II" a continuation of a project before on the same subject. The new project is further in detail than the preceding project and develops a validated, fully nonlinear wave load model for the industry.

4.2 Collaborative research

The Netherlands have continued to play an important role in several IEA Wind tasks. These include Task 26 Cost of Wind Energy with the representative of the offshore wind sector (TKI) participating. Participation in the IEA Wind tasks has proven to be a cost-effective

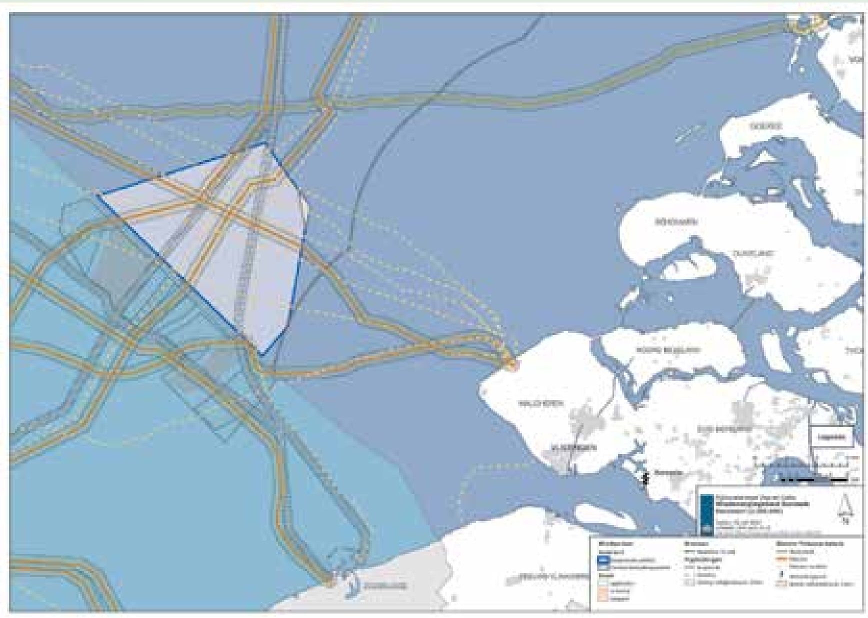

Figure 3. Map of the Borssele wind area

Figure 4. Arrival of the Luchterduinen cable at the beach near Noordwijk

way to conduct research. On average, 1 EUR (1.2 USD) spent in the Netherlands on research gives access to a value of 5 EUR (6 USD) of research spent in the other participating countries.

4.3 Offshore deployment

In 2014, preparations began for the deployment of the offshore wind programs (see SER agreement, section 1.0). Activities for this are on the field of legislation and in the fields of desk studies (geology and morphodynamics, wind resource assessment, assessment presence, unexploded ordnance, assessment archaeological, and historical value) and site investigations (geophysical survey, geotechnical survey). More about this will be written in the *IEA Wind 2015 Annual Report*. Meanwhile, reports about the site are constantly being updated [3].

5.0 The Next Term

5.1 Deployment

In 2015, the focus of offshore wind energy will be on activities for the development of the Borssele site. Expected milestones are the "Amendment of the Stimulation of Sustainable Energy Production" and the final reports of the many site investigations, resulting in a final "Technical Description" of the Borssele wind area. By the end of 2015 it is expected the call for tender for the first 700 MW will open.

For 2015 is foreseen that windfarm Luchterduinen (129 MW, west coast of the Netherlands, 23 km offshore) will be connected to the grid and produce its first power (see Figure 4). In addition, during 2015 construction is expected to begin for offshore wind farms Gemini—two farms of 300 MW each, on the north coast of the Netherlands, 85 km offshore.

In the beginning of 2015, 865 MW of land-based wind power will be in the construction phase, partly finished in 2015. Project NoordOostPolder is an important one in this series of projects with a total expected installed power of approximately 450 MW. The first turbines in this farm are expected to produce power in august 2015 (see Figure 5).

Figure 5. Enercon E-126 turbines being assembled along the dike at Noordoostpolder wind farm

5.2 Innovation Contract/TKI

In 2015, further continuation of the work under the guidance of TKI Offshore Wind is foreseen. A new set of tenders is expected, with criteria defined in close cooperation with the market but evaluated by independent experts. Central criteria for the tenders are the reduction of cost of energy and the economic impact on society.

5.3 SDE+ in 2015

The SDE+ 2015 will be further fine-tuned compared to 2014. The total budget will remain the same at 3.5 billion EUR (4.2 billion USD). On land there will be a specialization according to the wind regime: the subsidy will depend on the local wind speed and there will not be a limit on the number of full-load hours and no divide between <6 MW and ≥6 MW turbines. Furthermore, two new categories will be introduced: "wind on dikes" and "renewing/upgrading." In the last category the existing infrastructure will be taken into account, reducing the costs of new projects and therefore reducing the need for subsidies.

References:

Opening photo: View of the province of Flevoland from highway A27, the province with the highest penetration of wind energy (Photo credit: André de Boer, RVO)

[1] www.rvo.nl/onderwerpen/duurzaam-ondernemen/duurzame-energie-opwekken (Dutch)

[2] www.tki-windopzee.nl (Dutch)

[3] http://english.rvo.nl/topics/sustainability/offshore-wind-energy/borssele-wind-farm-zone

[4] www.rvo.nl

Author: André de Boer, Rijksdienst Voor Ondernemend Nederland, (Netherlands Enterprise Agency), The Netherlands.

31 Norway

1.0 Overview

In 2014, 45 MW of new wind power capacity were installed in Norway. Total installed capacity was 856 MW at the end of the year, and production of wind power in 2014 was 2,214 GWh, compared to 1,898 GWh in 2013. The calculated wind index for Norwegian wind farms in 2014 was 103%, corresponding to a production index of 102%. The average capacity factor for Norwegian wind farms in normal operation was 31%. Wind generation amounted to 1.5% of the total electric production in the country and offset 1.7% of total demand.

Electric energy in Norway is generated using a very high share of renewable energy. The primary source of electricity is hydropower, which in 2014 stood for approximately 96% of the country's electricity production. In recent years there has also been a keen interest in wind power as a commercial source of energy. Norway boasts some of the best wind resources in Europe, and the combination of technological advances and renewable energy support schemes mean that these resources will likely be tapped in the form of large amounts of new wind power installations in the coming years. The key statistics for 2014 are shown in Table 1 and Figure 1.

2.0 National Objectives and Progress

2.1 National targets

Renewable sources of electricity amounted to 97.6 % of the national electricity production in Norway in 2014 and 1.5 % of the electricity production came from wind power. With electricity consumption in the country totaling 126.7 TWh for the year, this meant a net electricity export of 15 TWh.

The already-high ratio of renewable energy production combined with concerns about wind power development's local environmental impacts has provided fuel for considerable public debate on the topic of wind power development in Norway in recent years.

As a member of the European Economic Area (EEA), Norway was obliged to accept the EU's renewable energy directive in 2011. The target for renewable energy was set to 67.5% of total energy consumption. This target is to be met through a combination of energy efficiency measures and increased renewable energy production.

The incentive mechanism for increasing renewable energy production in Norway is a joint support scheme with Sweden to finance 26.4 TWh/yr of new renewable energy production by 2020. This market-based electricity certificate scheme is unique in that the targets are both country- and technology-neutral, meaning that the policy does not dictate which country the new renewable energy production comes from or which type of renewable energy is produced. Rather, the objective of this policy is to allow the market to dictate what type

The technical availability of new wind turbines in Norway is usually in the range of 95% to 99%.

Table 1. Key National Statistics 2014: Norway	
Total (net) installed wind capacity	856 MW
New wind capacity installed	45 MW
Total electrical output from wind	2.2 TWh
Average capacity factor	31%
Wind generation as percent of national electric demand	1.7%
Target:	No target

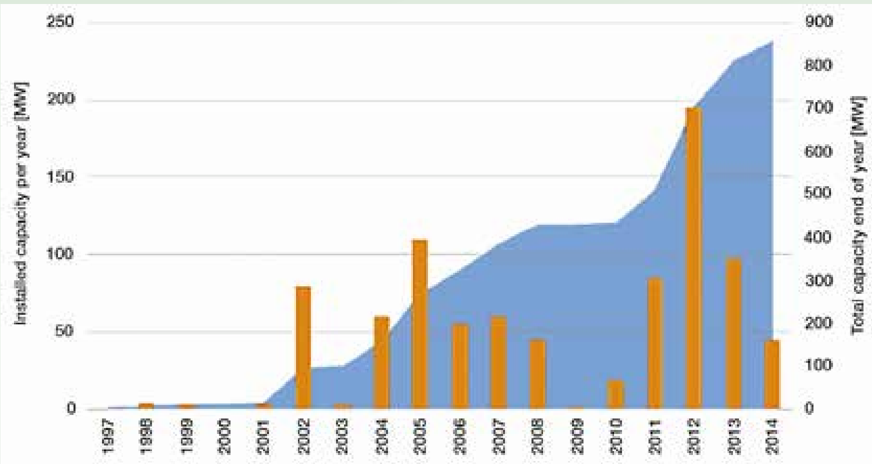

Figure 1. Installed wind capacity in Norway 1997–2014

of renewable energy production comes and where, thus ensuring a cost-effective increase in renewable energy production when seen from a macroeconomic standpoint. In practice this means that Norway has no explicit wind energy target, however considerable new wind energy installations in Norway are seen by analysts as implicitly necessary to reach the targets set forth for new renewable energy production through the joint agreement with Sweden.

2.2 Progress

Norway entered into the electricity certificate scheme with Sweden on 1 January 2012, and so far, the only large-scale Norwegian wind farms participating in the scheme are phase II of Midtfjellet wind farm and Raggovidda wind farm.

2.3 National incentive programs

Between 2001 and 2010, financial support for wind power projects in Norway was provided by the state-owned organization Enova SF, on a case-by-case basis with the goal to support projects just enough to make them commercially viable. This program was terminated in 2011 and from 1 January 2012, Norway and Sweden established a common electricity certificate market/scheme. The economic incentive is designed to stimulate the combined development of 26.4 TWh/yr of new renewable power production in the countries. Since 2012, Enova has focused on supporting technology development connected to wind power.

A key aspect of the certificate system is that it shifts the cost for supporting renewables from Enova to the electricity consumer. Approved power plants will receive one certificate for every generated MWh from renewable energy sources. Hence, owners of approved plants have two products on the market: electricity and certificates. They can be sold independently of each other. The demand for certificates is created by a requirement under the act that all electricity users purchase certificates equivalent to a certain proportion of their electricity use, known as their quota obligation. The price of certificates is determined in the market by supply and demand, and it can vary from one transaction to another.

All renewables are included in the certificate system; it is technology neutral. All technologies receive the same number of certificates per MWh, and there are no specific quotas for wind power. Nevertheless it is expected that these electricity certificates will primarily stimulate new production from wind- and hydropower in Norway and bioenergy and wind power in Sweden, since other renewables (e.g., power from ocean energy and solar energy) are still considerably more costly.

3.0 Implementation

3.1 Economic impact

Norwegian industry takes part in component production for wind energy systems, e.g., wind turbine blades and nacelles on a relatively small scale. Companies with experience from the offshore oil industry (e.g., OWEC Tower and Aker Solutions) have widened their scope of interest and engagement to the offshore wind industry. These companies offer offshore wind turbine substructure solutions like jacket quatropod and tripod. Increased construction of wind farms will generate engineering and construction jobs, and ultimately jobs for maintenance personnel.

3.2 Industry status

Production of wind power is dispersed among several energy companies, some of which are small local utilities. The largest wind power projects are operated by large national energy companies. Some Norwegian companies (Fred Olsen Renewables, Statkraft, and Statoil) are also engaged in projects in foreign countries, like offshore wind in the United Kingdom. So far, there is no significant wind turbine manufacturing industry in Norway.

3.3 Operational details

In 2014, the capacity factor of wind farms in normal operation varied between 10% and 41%. The average capacity factor was 31%. The technical availability of new wind turbines in Norway is usually in the range of 95% to 99%. Annual energy per swept area ranged from 385–2,119 kWh/m^2, with a national average of 1,189 kWh/m^2.

3.4 Wind energy costs

The total wind farm installation costs reported between 2012 and 2013 vary between approximately 10.5–13.5 million NOK/MW (1.2–1.5 million EUR/MW; 1.4–1.8 million USD/MW). Annual maintenance is reported to be between 0.12 and 0.16 NOK/kWh (0.013–0.018 EUR/kWh; 0.016–0.021 USD/kWh), with an average cost of 0.15 NOK/kWh (0.017 EUR/kWh; 0.02 USD/kWh). Estimates of production costs from sites with good wind conditions (35% capacity factor) suggest a production cost of about 450 NOK/MWh (50 EUR/MWh; 60 USD/MWh), including capital costs (discount rate 6%, 20-year period), operation, and maintenance.

4.0 R, D & D Activities

4.1 National R, D & D efforts

In Norway there are two research centers for offshore wind energy, the Research Center for Offshore Wind Technology (NOWITECH) at SINTEF Energy Research, and the Norwegian Center for Offshore Wind Energy (NORCOWE) at Christian Michelsen Research. Another center, the Center for Environmental Design of Renewable Energy (CEDREN) conducts research on environmental issues within wind energy and other renewable energy production. These centers receive half of their funding from the Research Council of Norway; the remainder is jointly funded by industry and the research institutions.

The Research Council of Norway also administers a public research program for sustainable energy, ENERGIX. This program covers renewable energy, energy efficiency, energy systems, and sustainable transport (hydrogen, fuel cells, biofuels, and batteries). Industry, research institutes, and universities may receive funding for their research based upon proposals to regular calls. The budget for 2014 was 400 million NOK (44 million EUR; 54 million USD). In total the Research Council granted 110 million NOK (12 million EUR; 15 million USD) to wind energy research in 2014. In December 2014 the following wind energy R&D projects were approved for funding:

- Reducing cost of offshore wind by integrated structural and geotechnical design, NGI
- Lidar and Advanced Simulation Methods for Evaluation of Complex Flow Features, MEVENTUS AS
- Optimize wind farm performance by delivering accurate shortest-term wind and power forecasts, WINDSIM AS

In total 11 R&D projects are funded by ENERGIX, and 15 industrial companies and five research institutes are involved in these projects.

The Norwegian energy agency, Enova, offers capital grants for full-scale demonstration projects of ocean renewable energy production including offshore wind. While up to 50% of eligible costs can be covered, Enova's funding measured in absolute figures is limited.

Innovation Norway runs a program supporting prototypes within environmental friendly technology. Wind energy is included in this definition. Projects are supported with up to 45% of eligible costs.

4.2 Collaborative research

In 2014, Norway participated in the following IEA Wind Tasks: Task 11 Base Technology Information Exchange; Task 25 Power Systems with Large Amounts of Wind Power; Task 26 The Cost of Wind Energy; Task 29 Mexnext Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models; Task 30 Offshore Code Comparison Collaboration Continuation with Correlation (OC5); Task 31 WAKEBENCH: Benchmarking Wind Farm Flow Models, Task 32 Lidar Systems for Wind Energy Deployment (LIDAR), Task 33 Reliability Data: Standardization of Data Collection for Wind Turbine Reliability and Maintenance Analyses, and Task 34 Assessing Environmental Effects and Monitoring Efforts for Offshore and Land-Based Wind Energy Systems.

5.0 The Next Term

The next term will be dominated by the impetus given to the wind power industry by the electricity certificate scheme. This scheme has also contributed to a trend toward to the development of wind farms in Norway by large international companies. In early 2015, one wind farm was under construction.

Opening photo: Raggovidda Wind Farm (Source:Varanger Kraft)

Authors: Harald Rikheim, Norwegian Research Council and David E. Weir, Norwegian Water Resources and Energy Directorate, Norway.

32 Portugal

1.0 Overview

In 2014, the wind energy sector achieved a maturity status within the Portuguese power system. While it still experienced some additional capacity deployment (222 MW), after 15 years of intense deployment Portugal reached 4, 953 MW of installed wind power capacity by the end of 2014. Wind power represents 25% (considering only mainland Portugal) of the total operational capacity and 42% of renewable energy capacity in the country [1, 2]. In 2014, Portuguese wind parks produced 12.1 TWh maintaining a wind energy contribution of 24% of the annually electricity consumption. This high wind penetration was influenced by the favorable wind conditions observed in the first three months of the year over central and northern regions of mainland Portugal that also correspond to the largest concentration of installed wind capacity [1].

The electricity generation from renewable energy sources in 2014 reached 65% of the national consumption, which is a new record in Portugal [1, 2]. The individual renewable contribution in Portugal was similar to the previous year, where hydropower production represented the highest contribution with 33% of the electrical demand. The high contribution from the endogenous resources enabled Portugal to reduce to 1.8% the dependency on foreign energy for meeting consumption, decreasing more than 4% when compared to the previous year [2].

Due to the energy efficiency measures implemented in the latest years and also to economic stalling, electricity consumption in Portugal was 50.3 TWh in Portugal, which corresponds to a slight reduction of 0.3% with respect to 2013 [1, 2]. Figure 1 depicts the yearly contribution of each technology in the Portuguese energy mix, the imports/exports and the consumption index in the period between 2008 and 2014. From Figure 1 it is possible to verify that the dependence on fossil fuels to balance the demand is less than 40% for the second consecutive year. This dependency is essentially supplied by the coal since it is the cheapest fossil fuel for generating electricity, although higher levels of pollutants are released into the atmosphere when compared to natural gas.

On 3 March 2014 the wind power generation reached the penetration of 64% on an average daily basis. The highest daily wind energy production was also registered on this day with 88.4 GWh. The highest wind instantaneous penetration was observed on 28 December with 89%—which is slightly below the previous instantaneous record of 93% observed on 13 November 2011. Despite these high values, no technical problems were reported during these periods by the Portuguese transmission system operator.

2.0 National Objectives and Progress

2.1 National targets

The targets for installed capacity currently in place were established in April 2013 by the Portuguese government through the National Renewable Energy Action Plan (NREAP) 2013–2020 [3]. Regarding wind power, this action plan sets the need to reach an installed minimum capacity of 5,300 MW by 2020. This value is divided into 5,273 MW installed on land (where 400 MW correspond to expanding the capacity of current wind parks—"overcapacity") and 27 MW offshore.

2.2 Progress

During 2014, a net capacity of 222 MW was added, which represents an installed capacity growth of 5% with respect to the

An instantaneous wind penetration on 28 December was 89%—with no technical problems by the Portuguese transmission system operator.

Table 1. Key National Statistics 2014: Portugal	
Total (net) installed wind capacity	4,953 MW
New wind capacity installed	222 MW
Total electrical output from wind	12.1 TWh
Wind generation as percent of national electric demand	24%
Average national capacity factor	28%
Target:	Land-based: 5,273 MW Offshore: 27 MW by 2020

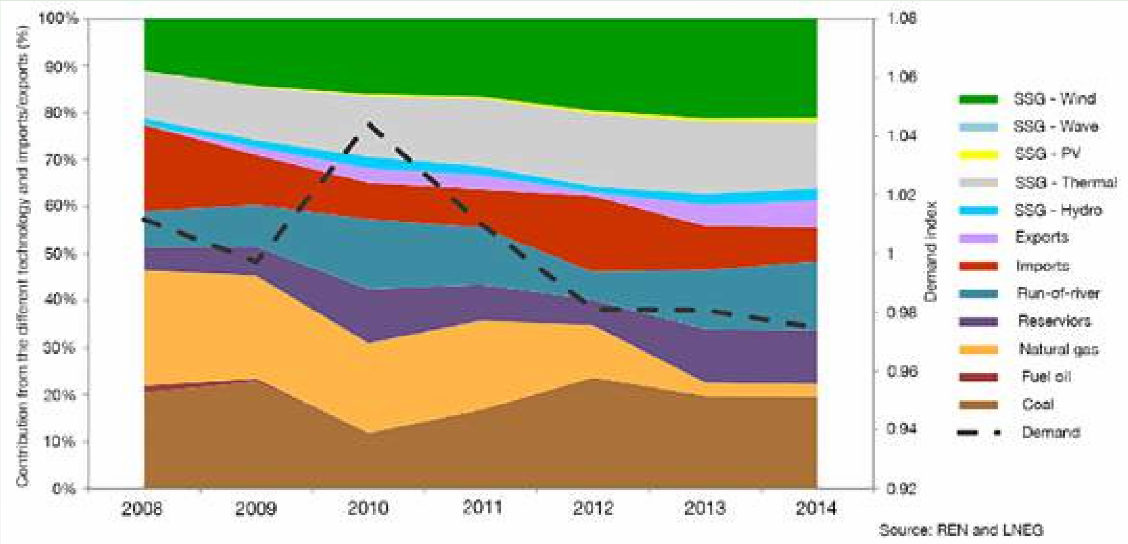

Figure 1. Yearly contribution from each technology to the energy consumption, imports/exports, and demand index considering the period between 2008 and 2014 (continent only) [2]

capacity of the previous year. For the first time in recent years, no new wind power capacity was installed in the Azores and Madeira archipelagos [1].

As shown in Figure 2, the added capacity is in line with that of 2013 demonstrating a slowing of newly installed wind capacity. Compared with the previous ten years, this value was the third lowest since 2004, when the strongest wind deployment began. Cumulative installed capacity until 2014 is distributed over 245 wind farms with 2,496 wind turbines operating across the country (mainland and islands), one of them being a floating offshore wind turbine (the number of operating wind turbines were recently corrected by the competent authority, which revised the values presented in 2013 report to 2476) [4].

The Portuguese wind power fleet in 2014 generated 12.1 TWh corresponding to 24% of the electricity demand. The wind share of total renewable production was 37.4%, a small decrease of 2% compared to 2013. The contribution from wind power was only surpassed by hydropower production that represented 50.8% of the total renewable production in 2014. The remaining mix of renewable sources maintained their share with the biomass sector representing 9.9% followed by PV (2.0 %) and geothermal (0.6%) [2]. In 2014, the average production at full capacity stood at 2,440 hours, which corresponds to a 4% decrease with respect to the same period of 2013 (2,540 hours). This result is mainly explained by the decreased wind energy index.

2.3 National incentive programs

In 2013, a review of the NREAP was issued, providing the structural context, strategy, and objectives for renewable

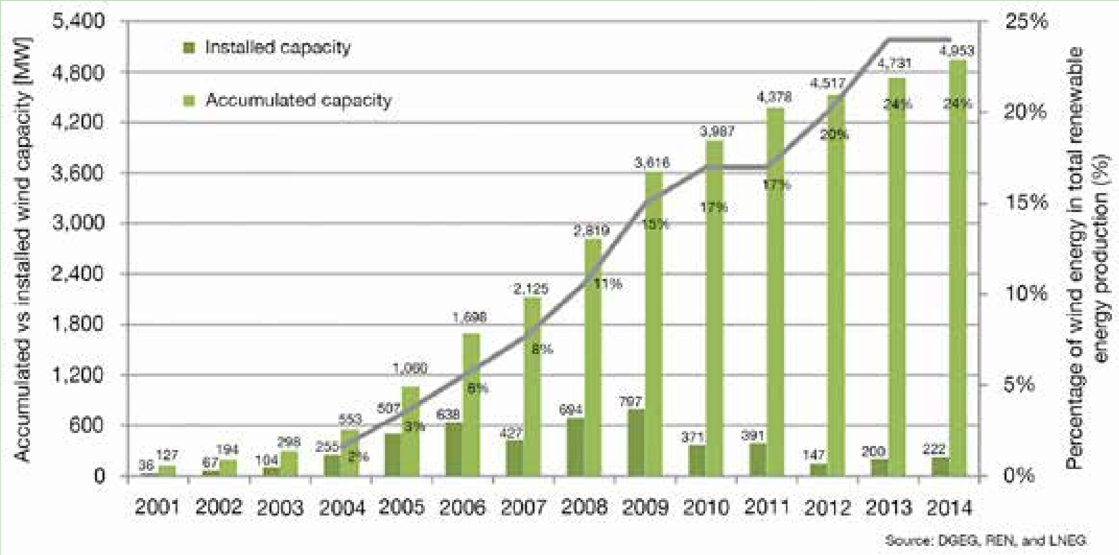

Figure 2. Installed versus accumulated wind capacity (bar graph) and percentage of wind energy production (line graph)

energy investments in Portugal. The targets defined in this plan are set to 2020 and took into consideration the current abundancy of electricity supply due to the reduction in demand in recent years, and the actual low growth economic context [3]. This new plan to support the promotion of renewable energies is based on the indicators from 2010 where the contributions from renewables were 5.5% in transportation, 34.5% in heating and cooling, and 41.1% in electricity. The targets for 2020 aim to raise those contributions to 10.0% in the transportation sector, 35.9 % in heating and cooling, and to 59.6% in electricity [3].

In order to reinforce the capacity of existing wind power plants, as foreseen in the NREAP 2013–2020, the Decree-Law 94/2014 [5] was published, on 24 June. This law amends the legal framework applicable to the overcapacity established in the Decree-Law 51/2010 [6]. Moreover, this law establishes the definition of additional power and energy with a guaranteed remuneration scheme of 60 EUR/MWh (73 USD/MWh). The additional energy is defined as the active energy provided from the use of the additional power. This corresponds to the maximum additional power value taking into consideration the difference between installed power and connection power. It is important to note that the energy generated under this decree-law, can be only delivered to the electrical grid when all the technical and safety conditions are met from the system operator point-of-view.

In Portugal, the renewable energy installations for micro-generation (up to 11 kW) and mini-generation (up to 250 kW) are mainly promoted through incentive programs based on a feed-in tariff (FIT). The micro-generation law was established by the Decree-law 118-A/2011 [7] that regulates the micro-production of electricity from renewable energy sources and provides a simplified framework and licensing regime for connecting renewable energy producers to the distribution grid. For 2014, the tariffs were set by the energy

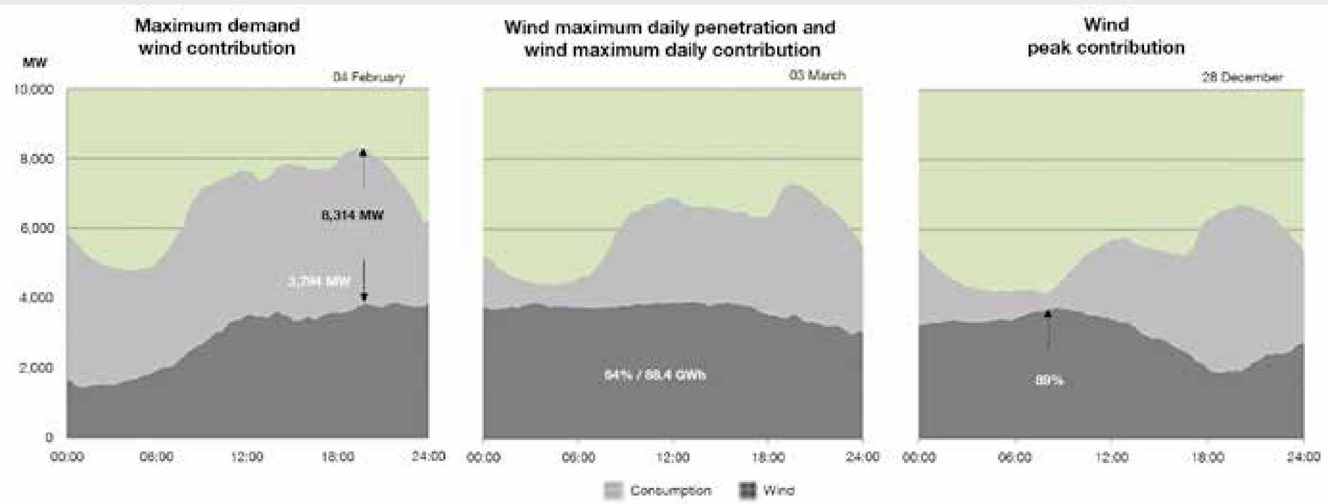

Figure 3. Record wind power penetration and energy generation during 2014 [2]

sector regulator—Direcção Geral de Energia e Geologia (DGEG)—to a value of 218 EUR/MWh (264 USD/MWh) for the first eight years of operation and 115 EUR/MWh (139 USD/MWh) for the second period of seven years with a limit of 11.45 MW for annual grid-connected power approved by ordinance number 431/2012 [8]. The mini-generation program established in Decree-law 34/2011 [9] enables small companies to install renewable-based production centers of up to 250 kW. During 2014, DGEG reduced the reference tariff by 14%, reducing the values from 185 EUR/MWh (224 USD/MWh) to 159 EUR/MWh (193 USD/MWh) with an annual maximum power injection of 30.35 MW.

During 2014, those national incentives for micro- and mini-generation were rectified and merged into a single category designated small production units (UPP) regulated by the Decree Law 153/2014 [10]. UPP enables the installation of renewable-based technology with a capacity of up to 250 kW, with an annual cap limit of 20 MW for grid-connected capacity. This new legal framework replaces the remuneration regime previously applicable to micro- and mini-generation units, contemplating the possibility of self-consumption and also to sell the energy to the public electricity grid. The new remuneration scheme is based on a bidding model where each producer bids discounts to a reference tariff, which is set annually by the government depending on the technology used. However, the previous FITs will remain valid for the existing installations during the statutory period.

2.4 Issues affecting growth

In 2012, the Portuguese government suspended the attribution of new capacity for grid connection to re-evaluate the legal framework for electricity generation [11]. Therefore, the deployment of land-based wind projects during 2014 (and in the next years) corresponds to the installation of the power previously licensed, but still not installed.

For the second consecutive year, Portugal reached a wind contribution of 24% of the annual consumed energy during 2014. This is a very high wind penetration value and the second highest in the world, only surpassed by Denmark. This high wind penetration, although without negative impacts in the Portuguese power system's operation, raises economic and technical challenges that lead to a more conservative approach for the deployment of variable renewables in the near future.

Portugal has installed and is operating a very high share of power production with a stochastic and non-dispatchable behavior as wind power, run-of-river hydropower plants, and also some photovoltaics (PV) plants. In light of the current power system's operation principles, this requires a certain amount of dispatchable sources in order to guarantee the balance between the electric generation and the demand. In power systems such as the Portuguese, the design parameter limit is the extreme penetration of renewable, non-dispatchable sources. The maximum demand instantaneous value was reached on the 4 February 2014 at 19:15 with a wind generation of 3,794 MW representing 77% of the wind power capacity. On 28 December 2014 at 8:00 AM, an instantaneous penetration of 89% from wind generation was recorded. The highest daily consumption supplied by wind energy generation occurred on the 3 March 2014 with 88.4 GWh, which accounted for 64% of the daily demand [2]. Despite the high wind penetration values recorded, it should be noted that no technical problems were reported during these occurrences by the Portuguese transmission system operator, Redes Energéticas Nacionais, S.A. (REN). Figure 3 depicts the wind generation profiles on: (i) the maximum demand day and the respective wind power contribution; (ii) maximum daily and also the maximum daily contribution from wind; and (iii) peak wind penetration.

3.0 Implementation

3.1 Economic impact

The wind industry in Portugal, together with the wind deployment activity (222 MW) supported an estimated 3,200 jobs. In 2014, the wind generated electricity produced an estimated income of 1,170 million EUR (1,417 million USD) and allowed the saving of 4.3 million tons of CO_2 emissions.

3.2 Industry status

During 2014, Enercon reinforced its leading position in Portugal as the most important supplier of turbines. In fact, from the wind turbines installed in 2014, the great majority corresponded to Enercon wind turbine models (Enercon E82 and E92 models) and the remaining wind turbines were manufactured by Senvion. As a consequence, Enercon increased its share of the overall Portuguese market to 56.6% of the installed capacity. In second place is Vestas with a 13.6% share, followed by Gamesa (8.9%), Nordex (8.3%), Senvion (former REpower) (4.0%), GEWE (2.2%), Ecotècnia (2.2%), Suzlon (2.1%), Bonus (1.5%), NEG-MICON (0.2%), and other manufacturers (0.7%), Figure 4 [4]. From the new wind turbines installed in 2014, 2% corresponded to wind parks capacity reinforcement (usually referred as "overcapacity"), a wind plant design principle that allows installation of more wind capacity than the maximum electric power allowed to be inject in the grid.

The offshore floating wind turbine installed in northern Portugal, the WindFloat prototype keeps its successful demonstration phase operating at Aguçadoura. This offshore wind system composed of

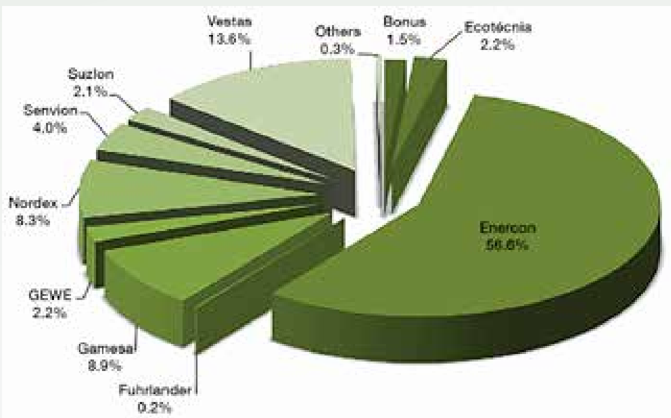

Figure 4. Distribution of installed wind capacity by manufacturer [4]

a semi-submersible structure and a Vestas V80 wind turbine with 2 MW capacity has proved to be an entirely technically viable solution for future floating deep offshore wind plants despite the adverse storm conditions observed in the open sea environment and already experienced in the Portuguese Coast, where the system already survived to 16 m waves with only minor requirements for maintenance. During 2014, the WindFloat reached another milestone; it passed the 10 GWh mark and at end of 2014 was already delivered 12.02 GWh of renewable electricity to the grid [12]. This project is being developed by WindPlus as a joint venture from EDP Inovação, Repsol, PPI, PPI Portugal, and A. Silva Matos. The performance achieved with this floating system has allowed this consortium to exploit the results of the ongoing R&D projects (e.g., FP7 DemoWFloat) and initiate the design of the first wind park with floating technology to be installed in the Portuguese Coast (foreseen for 2015 with a 25 MW capacity planned to be installed on the coast of Viana Do Castelo with EC NER300 co-funding) as well as in the United States coastal waters [12].

3.3 Operational details

In mainland Portugal seven new wind parks were connected to the grid in 2014.The overall installed capacity of the 245 wind parks in Portugal by the end of 2014 can be grouped into three categories; <10 MW, with 52% share; 10–50 MW, with 41% share and >50 MW with 7% share [4]. Figure 5 shows the wind and production indices since 1999. These values were achieved for two typical regions where wind turbines are operating in Portugal: coastal and mountainous. The wind and production indexes were computed based on reference wind data from anemometric stations installed in these two regions. After an atypical year in the mountainous regions in 2013, the Laboratório Nacional de Energia e Geologia (LNEG) indexes for wind and power production show a slight decrease with a wind availability of 1% above the average (1.01) and 4% above average on production (1.04). For the coastal region, the scenario reversed last year's tendency with the production growing 6% (index 1.04) reaching a wind index close to the average (0.98). In the coastal region, the scenario reversed the last year's tendency, with wind growing 7% (index 0.95) and production 12% (index 0.96).

Data from the Portuguese operation of power systems [2] is in the line with the results presented from LNEG, indicating a decrease of 7% in the annual wind generation index from to 1.11, when compared to the previous year. This result reveals the expected similarity to the typical mountains behavior, since the vast majority of the operating capacity in Portugal is installed in those regions.

3.4 Wind energy costs

The average cost per MW installed in 2014 was ***1.35 million EUR (1.64 million USD/MW)***. This amount includes associated costs of project installation and grid connection, among others. Turbine costs were around 80% of the total installation costs and corresponded to approximately 1.08 million EUR/MW (1.31 million USD/MW).

The mean tariff paid to the wind power plants in 2014 was 93.90 EUR/MWh (113.71 USD/MWh). It deserves to be noted that the Portuguese legislation assumes since the 1990s a period of approximately 12 years during which a green FIT (feed in tariff) applies to the retribution of wind generation. Since a representative number of wind plants is reaching the contractual maximum limit for access to green tariffs, the tendency in the near future is to verify an accentuated tendency of reduction on the wind energy mean tariff, as already observed from 2013 to 2014.

4.0 R, D&D Activities

4.1 National R, D&D efforts

The national R&D efforts during 2014 were mainly focused on offshore wind energy and development of tools and methodologies to maximize the penetration of renewable energy not only from a grid security operation point of view, but also from a market perspective. These activities are taking place at the main Portuguese institutes and universities, being financed through national or European programs. Some relevant R&D activities underway in Portugal include the following.

Project IRPWind: European-wide Measures and Structures for a Large-scale Wind Energy Integration: an FP7 European-funded project with the participation of LNEG. This project combines wind energy research projects and activities with the objective of fostering innovation, collaboration, and knowledge transfer between European researchers and leading R&D entities, with the participation of European energy Research Alliance (EERA) Joint Programme on Wind Energy partners.

Project TWENTIES: a project to deal with transmission system operation with large penetration of wind and other renewable electricity sources in networks by means of innovative tools and integrated energy solutions. It is funded by EC FP7 and has the participation of the Portuguese Institute INESC-Porto.

Project DREAM-GO: an international project that aims to contribute to a more sustainable and efficient energy system, based on intensive use of renewable energy and active management of consumers. This H2020 project is led by the GECAD group that belongs to Institute of Engineering - Polytechnic of Porto (ISEP/IPP).

Project MARINA: a project that brings together companies, technology centers, and universities from 12 EU countries. It is led by Acciona Energy and funded by EC FP7 with the Portuguese participation of University of Algarve. The objective is to develop deep-water structures that can exploit the energy from wind, waves, tidal, and ocean current energy sources.

Project FP7 DemoWFloat: a project to demonstrate the sustainability of the Wind Float technology deployed in Portuguese Atlantic waters. A consortium of European and North American partners will address the challenge of wind resource assessment in oceanic deep waters. It is funded by EC FP7 and has the participation of LNEG and several Portuguese and international partners involved in a consortium led by EDP.

Project ESFRI WindScanner: the project will establish a European network of innovative R&D for the acquisition of three-dimensional components of the atmospheric flow and characterization of wind turbulence. It is funded by EC FP7 and has the participation of the Portuguese entities LNEG and Porto University.

Project TROPOS: the project aims to develop a floating modular multi-use platform system for use in deep waters, with an initial geographic focus on the Mediterranean, tropical, and sub-tropical regions. It will be flexible enough so as to not be limited in geographic scope. It is funded by EC FP7 and has the Portuguese participation of WavEC.

Project Atlantic PC: the project seeks to develop cooperation and joint approaches to facilitate the identification of new market niches and redefine educational and training programs as per the needs of the offshore and marine energy sector in the Atlantic Area. It is funded through the European Regional Development Fund (ERDF) and has the Portuguese participation from WavEC.

Project OTEO: a Portugal-based project funded by the System Support for Collective Actions (SIAC) and has the participation of Instituto de Engenharia Mecânica e Gestão Industrial (INEGI), EnergyIN, Oceano XXI and WavEC. The project established a strategy to apply the Portuguese and international knowledge of offshore energy and to support technologies that increase competitiveness and entrepreneurship in this sector.

Project EERA-DTOC: the project combines expertise to design a tool for the optimized design of offshore wind farms and wind farm clusters. It is funded by EC FP7 and has the Portuguese participation from Porto University.

Project KIC-OTS: a technology project focused on the needs of the market, which was created under KIC-InnoEnergy, a company funded by the European Institute of Technology European Commission. The aim of the project OTS is developing a range of projects and services targeted to current and future needs for offshore renewable parks. This project has the Portuguese participation of WavEC.

Project WindMETER: the project was developed to fill a gap and meet a growing opportunity in the wind energy market, as fiber optic sensors play an increasing role in the structural health monitoring of wind turbines. The project is co-funded by the Portuguese National Strategic Reference Framework (QREN) and is led by the consortium INEGI (technological consultant) and Fibersensing (industrial partner).

Project OceanNET: an international project concerning floating offshore wind and wave energy funded from the PEOPLE Programme (Marie Curie Actions) of the EC FP7. The main goal of this project is to educate a new generation of engineers and scientists in the area of floating offshore wind and wave renewable energies to support the emerging offshore renewable energy sector. This project has the Portuguese participation of WavEC and Instituto Superior Técnico.

Project LEANWIND: an international project concerning the effectiveness and efficiency of the offshore wind farm lifecycle and supply funded by EC FP7. The main goal of this project is to develop innovate technical solutions and processes to optimize offshore wind park deployment, operation and maintenance as well as decommissioning procedures. This project has the Portuguese participation of EDP Inovação.

4.2 Collaborative research

In Portugal, LNEG and other Portuguese R&D entities are active partners in international research efforts. The country participates in IEA Wind Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power. Portugal also collaborates in the IEA Wind Task 30 Offshore Code Comparison Collaboration Continuation with Correlation (OC5) through Wavec, Instituto Superior Técnico/Centec with a participation co-sponsored by EDP-Inovação. In addition to the IEA Wind activities, LNEG is the Portuguese representative in the European Energy Research Alliance Wind Program (EERA-Wind) that is a European initiative that integrates the leading European research institutes in the energy sector that aims to strengthen, expand, and optimize EU energy research capabilities.

5.0 The Next Term

Due to the fact that Portugal is reaching the main goals for land-based wind capacity installation with few pending licensing procedures, and the wind penetration is already at the highest values in the world, 2015 is expected to be a stagnant year. Regarding offshore wind energy and with the NER300 program support, the implementation phase of the first floating offshore wind park on the Portuguese coast (and the world!) with an estimated capacity of 25 MW is expected to start [12]. In January 2015, the registration system for micro- and mini-generation units will open, and the reference tariff value for UPP units will be established by the energy sector regulator.

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Opening photo: Windfarm in Portugal (Credit: Vitor Andrade)

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33 Spain

1.0 Overview

According to the Spanish Wind Energy Association's (AEE) Wind Observatory, installed wind capacity in Spain reached 22,986.5 MW in 2014 with only 27.5 MW added, the lowest amount in twenty years. Compared to 2013 when 175 MW were installed, the market dropped by 84.3% in 2014.

According to the national transmission systems operator (TSO) (Red Eléctrica Española or REE), electrical energy demand decreased 1.2% from 2013 to 243.49 TWh. Wind energy produced approximately 51.1 TWh of electricity, equaling to 20.4% of the yearly energy electricity demand. Wind generation was the main source of electricity in the Spanish power system during the months of January, February, and November. Other big contributors to the system are shown in Figure 1.

The Energy Reform policy changes began in 2012. In January 2012, the Spanish government approved a decree (RDL 1-2012) halting the existing feed-in-tariff support scheme that allowed tariffs up to 0.082–0.087 EUR/kWh (0.099–0.105 USD/kWh) for a period of 20 years. At that time, all the renewable energy generation plants that were pre-registered in the feed-in-tariff (FIT) system still had the possibility move forward and carry out registered projects. Those projects (roughly 1.2 GW) were gradually completed during 2012 and 2013. The decree established a de-facto moratorium on new renewable energy generation receiving FITs.

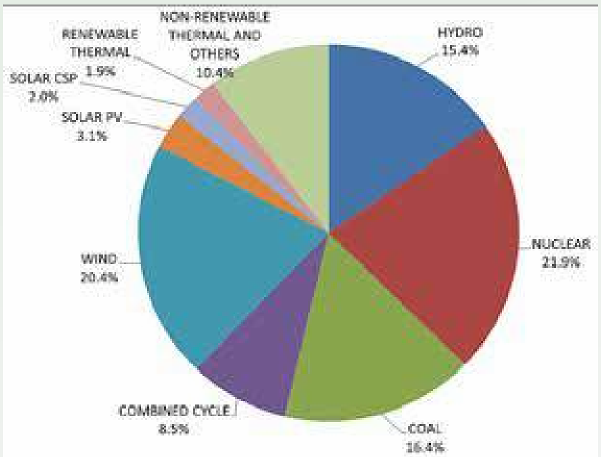

Figure 1. Percentages of the 2013 power supply mix in Spain (Source: REE, AEE)

The RDL 1-2012 was not the only problem for wind power promoters. The government has been dealing with the so-called "tariff deficit." In 2013, according to official data, Spain had accumulated a 26.0 billion EUR (31.5 billion USD) electricity tariff deficit (difference between the sector revenues and payments from final clients and the costs of exploiting the electrical system). In order to address this, the current government has taken several steps, among which is a reduction in the acknowledged FIT support scheme with retroactive effect and an increase in the taxation of current electricity generation of about 7% (Act 15/2012).

But this is not all. In February 2013, the Spanish government withdrew technically renewable energy from the spot market and established a mandatory regulated FIT which would no longer be updated by CPI (RDL 2/2013). Then in July 2013, the Spanish government changed the current renewable energy FIT payment system (RDL 9/2013). Instead of paying the established tariff for 20 years, the remuneration will be based on the so-called "reasonable profitability" for each project, depending on a wide variety of factors as age, cost, and amount of subsidies the project

Wind generation was the main supplier of electricity in the Spanish power system during January, February, and November.

Table 1. Key National Statistics 2014: Spain	
Total (net) installed wind capacity	22,986.5 MW
New wind capacity installed	27.5 MW
Total electrical output from wind	51.14 TWh
Wind generation as percent of national electric demand	20.4%
Average capacity factor	25.4%
Target 1. Official Network Planning Target 2. New National Renewable Energies Action Plan (NREAP)	29,000 MW by 2016 35,000 MW by 2020

has already received. This scheme still has to be approved, but it will likely further reduce the income of current renewable energy plants.

The new state regulation on renewable—that is shared among the Royal Decree-Law 9/2013, the Law 24/2013 and the renewable Royal Decree proposal—states that the remuneration shall be reviewed every three years based on investment market prices; every six years all of the compensation parameters may be reviewed as well, including the alleged reasonable profitability. This means that, investors have no guarantee for the entire regulatory life of the projects, which is 20 years.

But regulation is not the only insecurity in the Spanish power system: power demand has dropped some 8% since 2008. With more than 100 GW of total capacity, and a historical demand maximum of about 45 GW, there is currently an overcapacity of generation and some of the existing combined cycle gas plants are almost idle (working 20% of the time). This has led to a lack of interest for new energy developments in Spain.

In any case, the moratorium along with regulatory uncertainty and economic recession has resulted in the dramatic fall in new installed wind power in 2014. Not all the parks that were registered in the register of pre-allocation have been installed—approximately 150 MW have been out—and in that only 15 out of the expected 450 MW have applied to the call for proposals in the Canary Islands, where the government is very interested in installing new wind power to reduce the additional generation costs of conventional power stations.

Despite obstacles, new wind projects are under development without any subsidy as the 14-MW wind farm developed by the Spanish utility Gas Natural Fenosa (GNF) in the Galicia region.

2.0 National Objectives and Progress

2.1 National targets

On 11 November 2011, the new Renewable Energy Plan (REP 2011–2020) [1] was approved by the Spanish government for the years 2011–2020, establishing the development framework for the renewable energy sector. This plan aimed to fulfill and go beyond the EU objectives of covering 20% of total energy consumption by renewable sources by 2020. The REP 2011–2020 established Spanish objectives and suggested the measures to be implemented to reach the 20% goal. It included the Spanish vision for each type of renewable energy. The public entity in charge of implementing the REP 2011–2020 was the Institute for Energy Diversification and Savings (IDAE). For wind energy, the objective for 2020 was 35,000 MW. Offshore wind power is still in the early stages of development, with R&D projects being carried out. By the end of the REP 2011–2020, it was estimated that wind energy would continue to be the largest renewable energy contributor with 35,000 MW (71,540 GWh/yr) land-based and 750 MW (1,845 GWh/yr) offshore.

It seems impossible today that the necessary conditions provided by the government energy planning to meet the European 2020 consumption objectives through renewable energy sources can be met (Figure 2). According to new planning of the power transport networks started by the Ministry of Industry, Energy, and Tourism at the end of 2014, it would be necessary to install between 4,553 MW to 6,473 MW of wind power in the next six years. Only in 2015 and 2016, it is considered that 2,500 MW would have to be installed, which would mean a return to the growth rates of the years prior to the Energy Reform, but with much more restrictive conditions. Moreover, the Executive has not convened the auctions that would be required according to the new regulation to install new power.

2.2 Progress

The electrical generation capacity in the Spanish mainland system remained nearly constant in relation to previous years, ending 2014 with a total of 102,259 MW (a decrease of 122 MW or a 0.1%), according to the Spanish TSO REE [3]. Coal reduced its power by 159 MW as a consequence of a coal plant being dismantled. Renewable thermal experienced the largest increase within the RE technologies (35 MW). REE does not include in this register the installation of new wind power plants (27.5 MW, according to AEE, although 12 MW of these correspond to the Wind-Hydro-Pumped Station of El Hierro island, in the Canary Islands, which has been computed by REE as a new technology named "HydroWind" within the island new power plants).

With nearly 23,000 MW of wind power installed, around 20,200 turbines are operating in Spain, grouped among 1,077 wind farms. The average size of an installed wind farm in 2014 was 5.5 MW, whereas the overall wind farm size is 21 MW.

Wind energy is present in 15 of the 17 autonomous communities (Figure 3), though only three of them increased their wind capacity during 2014. Galicia had the biggest growth with 14.18 MW added in 2014, to a total of 3,328 MW that lead it to the fourth position, only behind Castilla y León which is the overall leader, with a total of 5,560 MW and Castilla–La Mancha, that remains in second place with 3,806 MW, and Andalucia

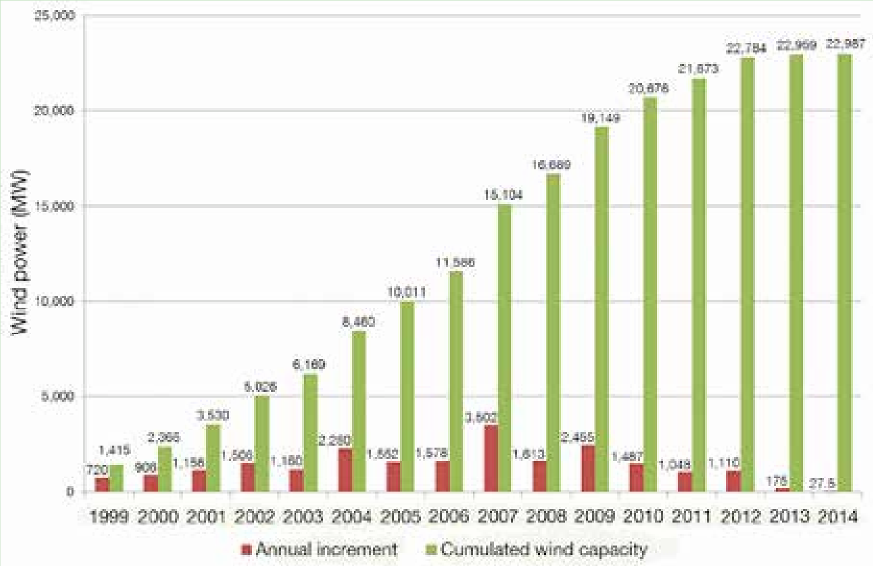

Figure 2. Annual and cumulative installed wind capacity in Spain

with 3,337 MW, all of them with no increase during this year.

The other additions were the Wind-Hydro-Pumped Station of El Hierro island (Canary Islands), an innovative project to increase the share of renewable energy. In addition, there was an increase of 1.8 MW in the capacity in a wind farm in Catalonia, but without any new proper installation. The rest of the traditional regions did not install any MW: Castilla y León, Castilla–La Mancha, Aragón, Comunidad Valenciana, Navarra, La Rioja, Murcia, País Vasco, Cantabria and Baleares. Only two autonomous regions, Extremadura and Madrid, have no wind power capacity.

The use of wind power has lowered carbon emissions by about 26.1 million tons during 2014. Regarding CO_2 emissions from the peninsular electricity sector, the increase in production from coal-fired power stations was offset by generation from renewable sources, resulting in an emissions balance of 60.4 million tons in 2014, a value similar to the 60.1 million tons registered in 2013. Furthermore, wind generation has saved up to 10.2 million tons of conventional fuels and has supplied the electrical consumption of more than 16.5 million Spanish households.

2.3 National incentive programs

To date, the promotion of renewable energies has been a stable national policy. All political parties have had similar policies regarding support of renewable energies. The main tools within this policy at a national level include the new NREAP (2011–2020), which included midterm objectives for each technology that could not be achieved due to new regulations. To facilitate the integration of wind energy into the grid, supplemental incentives are based on technical considerations (reactive power and voltage dips). These incentives apply only for existing wind farms (after January 2008), and it is mandatory to satisfy Grid Code P.O.12.3.

Payment for electricity generated by wind farms in Spain has been based on a FIT scheme. As stated earlier in this chapter, Royal Decree-Law 1/2012 temporarily suspended pre-allocation incentives for new energy production projects using, among others, renewable energy. So the situation at this point is that no renewable installation is allowed if the special regime is sought.

Finally, the approval of a net balance support scheme is expected to complement the existing technical regulation for the grid connection of small power production facilities (up to 100 kW), which is foreseen to be decisive for the development of small wind generation for the owners' use. Although some draft versions of the scheme have been proposed, the definitive royal decree was not yet published in 2014.

2.4 Issues affecting growth

The energy reform has been the main cause of this slowdown, due to the legal uncertainty that has been generated by the retroactive modification of the regulatory framework and by the adoption of a new payment system which allows changing the economic conditions every six years without knowing the methodology to be used beforehand. As a result, wind turbine production in Spain is declining and over the past five years the wind power sector has reduced the number of employments to less than half. In 2013 (the latest year for which data are available) the wind power sector employed 17,850 people. Compared to 2012, the sector registered a reduction of 5,458 people; the fifth consecutive year for 23,588 employments went down on aggregate. In 2013 the wind power sector generated 57% fewer jobs than in 2008, when the number of people employed in the sector was 41,438 [5].

3.0 Implementation

3.1 Economic impact

Given the regulatory situation in Spain, new wind capacity in 2014 was limited to 27.5 MW, reaching a total capacity of 22,986.5

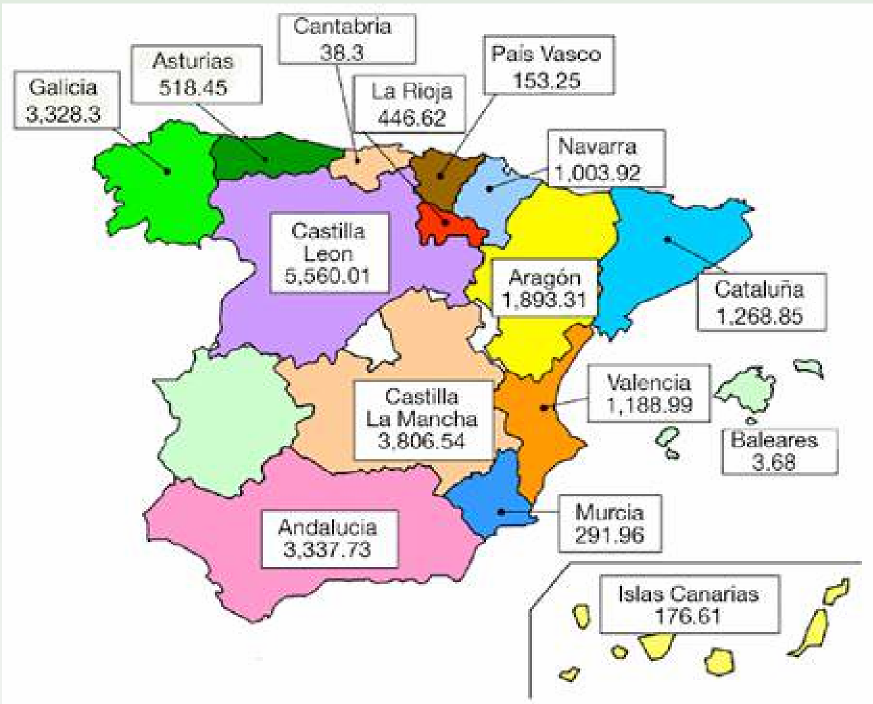

Figure 3. Wind energy capacity distributions by autonomous communities (MW)

MW. Installing and operating wind plants to cover 20.4% of the Spanish electrical demand implies a huge accomplishment by the developers and manufacturers. In 2013 (there are no data available for 2014 yet) the wind power sector reduced its contribution to GDP down to 1,928 million EUR (2,335 million USD), which means a 34.4% decline compared to the 2012 contribution of 2,898 million EUR (3,509 million USD) [5].

3.2 Industry status

Most of the world's main wind power manufacturers are present in the Spanish market, but only a few installed power during 2014; manufacturers that installed turbines in 2014 were Vestas Wind Power (14 MW), Enercon (11.5 MW in the Wind-Hydro-Pumped Station of El Hierro island), Nordex (1.80 MW though no new wind turbines, but an increase in the existing wind farm power output).

Gamesa is still the top manufacturer in Spain with 12,008 MW wind capacity installed (52.3% of the national total). In the second position is Vestas Wind Power with 4,091 MW wind capacity installed (17.8% of the national total), and Alstom Wind in third place with 1,739 MW (7.6% of the total). The Spanish manufacturer Acciona Windpower is in the fourth position with 1,728 MW (7.5% of the total) (Figure 4).

The companies Areva and Gamesa have entered into an agreement to form a 50/50 joint venture, named Adven. The joint-venture is responsible for the design, manufacturing, installation, commissioning, and services of offshore wind turbines. The first target of this new company is the development of a new 8-MW wind turbine. Combining both Gamesa and Areva wind expertise and extensive track-record, Adven is positioned to become a leading player in the offshore wind segment, with a 2.8-GW project pipeline and the objective of garnering a market share of close to 20% in Europe by 2020.

Regarding new technologies, the offshore wind turbine Gamesa G128-5.0 installed in Aguinaga port dock in Las Palmas de Gran Canaria Island has demonstrated a very high reliability, beating the monthly production record of a single wind turbine in Spain. In August 2014, the averaged output power was 4.27 MW, equivalent to a capacity factor of 85.4%. Gamesa has also presented two new platforms, the so-called Mainstream 2/2.5 MW which includes wind turbines with rotor diameter from 97–114 m (G97 to G114) and the Multi-MW 5/5.5 MW (on- and offshore), based on PMG and two stages planetary gear with two models, G132 and G144.

The second Spain-based manufacturer Acciona Windpower has developed a new wind turbine model for moderate wind sites (IEC class IIIb) AW 132/3000.

Several manufacturers are developing small wind turbines from 3–100 kW for grid-connected applications (Norvento connected one 100 kW wind turbine to the grid and a Lagerwey wind turbine LW 18/80 was also connected in a natural stone quarry, both in Galicia).

None of the four most important wind developers in Spain increased their capacity in 2014, remaining so in the same figures that in 2013: Iberdrola Renovables 5,513 MW, 24.0% of the whole wind market; Acciona Energy 4,268 MW, 18.6%; Portuguese company EDPR, with 2,099 MW total, 9.1%; and the Italian utility Enel Green Power Spain, with a total capacity installed of 1,403 MW, 6.5%. In fifth place is Gas Natural Fenosa, which had the biggest increase with 14 MW in 2014, accumulating that way a total of 982 MW (4.3%).

Under this discouraging situation almost all the Spanish companies which have not stopped their activity in this area have opted to internationalize their activity entering better markets. The Spanish wind sector exported 2.234 billion EUR (2.705 billion USD) worth of equipment in 2014, representing an increase of 57.4% compared to the previous year, according to provisional data from the Ministry of Economy and Competitiveness. Some of the world's largest developers like Iberdrola or Acciona Energy are working quite well abroad.

In 2014, Iberdrola installed 215 MW of onshore wind capacity (202 MW in the United States and 13 MW in the United Kingdom), whereas two installations with a total of 136 MW in Mexico and a third one with 38 MW in the United Kingdom are also under construction. In Brazil, on the other hand, 174 MW were awarded in two auction awards in June and November of 2014. In the offshore wind area, in the United Kingdom, the Iberdrola built the West of Duddon Sands project, located in the Irish Sea, with a capacity of 389 MW, to be jointly developed with Dong Energy on a 50% (194.5 MW) basis. Over the last 12 months, the installation has been completed and all 108 turbines are operative. Iberdrola continues with the development of the Wikinger offshore project, of up to 350 MW, in the Baltic Sea (Germany). During 2014, agreements have been signed with the main suppliers (foundations, electrical, installations, and electrical substation) and with AREVA, which was selected as the wind turbine supplier. Furthermore, Iberdrola is developing in the United Kingdom, the "East Anglia I, II, and III" project in the North Sea. Overall, Iberdrola manages directly or through investee companies 14,180 MW, of which 194 MW are offshore wind.

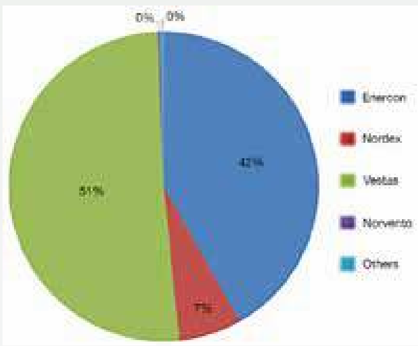

Figure 4. Installed wind capacity in 2013 by manufacturer (in percentages) (Source: AEE)

The net decrease of the consolidated Acciona Energy installed capacity from 7,140 MW to 7,087 MW in 2014 was due to the combined effect of the sale of 150 MW of wind power in Germany in Q1 2014 and the installation of 98 MW of new wind capacity (45 MW in Chile, 45 MW in South Africa, and 8 MW in Costa Rica). On the other hand, ACCIONA Wind Power installed 762 MW of wind power worldwide in 2014 versus 205 MW in 2013.

Similarly, the main Spanish manufacturer Gamesa Corporación Tecnológica seems to be getting off the ground. After some layoffs and an employment regulation process between 2010 and 2013 that involved some 600 employees, Gamesa Corporación Tecnológica regained sales growth in 2014 while steadily increasing profitability, enhancing cash flow and strengthening its balance sheet. Activity volume amounted to 2,623 MW, 34.3% more than in 2013 (1,953 MW), due to the strong contribution by the Indian (15% sales in 2014) and Brazilian markets to group sales, the recovery in the USA (15% sales in 2014), and the contribution of emerging markets, such as the Philippines, Turkey, and Sri Lanka. Growth in those markets was offset by the lower contribution to sales by Europe and RoW, although they improved in the second half of the year.

3.3 Operational details

The total number of turbines is more than 20,200 units. The average size of the total installed capacity is 1.1 MW. Wind turbines operating in Spain show important seasonal behavior. Annual electricity generated by wind farms was more than 51,140 GWh. During 2014, equivalent hours at rated power were approximately 2,223 hours for all of the wind farms. This shows that 2014 was a medium wind resource year overall, compared to, for example, 2013 when the equivalent hours where 2,350. In 2013, Spain was the first country in Europe in absolute energy production from wind technology with 53,930 GWh, surpassing Germany, with 51,700 GWh, even though the installed power ratio was 22,959 MW for Spain to 34,660 MW for Germany; and in 2013 Spain was also the third one in equivalent hours in Europe, only after UK and Portugal [6].

Because 2014 was not a very windy year, it saw a 6.1% drop in wind production in relation to 2013 and the historical power peaks of 2013 were not exceeded. Instantaneous wind power generation reached 17,056 MW; hourly production 16,918 MWh. Despite this decline, wind power made the largest contribution towards the total energy production in the Spanish Peninsula electricity system in the months of January, February, and November 2014.

3.4 Wind energy costs

Averaged specific cost of wind turbines manufactured in Spain decreased during 2014 to 700 EUR/kW (848 USD/kW) due mainly to supply chain optimization and reduction of labor cost. In terms of capital expenditures, the average installed costs are 1,100 EUR/kW (1,332 USD/kW) although some specific projects show installed costs around 1,000 EUR/kW (1,211 USD/kW).

4.0 R, D&D Activities

4.1 National R&D efforts

In 2014, the Spanish government continues the State Plan for Scientific and Technical Research and Innovation 2013–2016 following the Spanish Strategy for Science Technology and Innovation put in force in 2011. This Plan tries to align as much as possible the research and innovation lines with the lines defined in the European Strategic Energy Technology Plan SETPlan. The structure of action plan for 2014 is based on four state programs: Promotion of talent and employability in R&D&I; Promoting scientific and technical excellence; Impulse to corporate leadership in R&D&I; R&D&I focused on the challenges of the society.

The State R&D&I Programme was established to face the current challenges of society, and one of the most important challenges identified is to obtain safe, efficient, and clean energy. During 2014 one call for collaborative public and private proposals was deployed with five projects granted. The first project titled *"Design of a new generation of generator and auxiliary equipment for wind energy based on superconductors"* is coordinated by the company Gamesa Innovation and Technology S.L. This project has a total budget of 853,592 EUR (1,033,670 USD), grants of 256,062 EUR (310,091 USD), and loans of 268,875 EUR (325,608 USD). The second project titled *"Integration of wind turbines into the future electrical grids to achieve a sustainable economy and new markets"* is coordinated by a power electronics company called Ingeteam Power Technology S.A. This project has a total budget of 1,504,366 EUR (1,821,787 USD), grants of 372,256 EUR (450,802 USD), and loans of 905,687 EUR (1,096,787 USD).

The next project is focused on the improvement of wind turbine operation and maintenance activities. The project title is *"Autonomous inspection of operating wind turbines."* The coordinator is the company Diagnostiqa Consultoria Técnica, S.L. The total project budget is 1,487,597 EUR (1,801,480 USD) with grants of 346,683 EUR (419,833 USD) and loans of 778,455 EUR (942,709 USD). Another project is focused on the development of new floating platforms for offshore wind. The project title is *"Design, sea testing and validation of a semisumergible structure for floating offshore wind applications"* The coordinator is the company Widewall Investments S.L. and the total budget of the project is 1,535,160 EUR (1,859,079 USD) with grants of 262,700 EUR (318,130 USD) and loans of 999,991 EUR (1,210,989 USD). The last project funded under this call is focused on innovative drive train development. The project title is "*New drive train solutions and advanced control techniques for more efficient wind turbines*." The coordinator is the wind turbine manufacturer M.Torres Olvega Industrial S.L. The total Project Budget is 4,190,498 EUR (5,074,693 USD) with grants of 515,140 EUR (623,835 USD) and loans of 1,595,957.85 EUR (1,932,704.95 USD).

Another important initiative is ALINNE (Alliance for energetic research and innovation). ALINNE is a non-profit initiative created by the Ministry of Science and Innovation, with CIEMAT as leader, to bring together and coordinate efforts among all actors in the value chain of R&D in energy. This structure allows response to the major challenges that the policy of R&D&i have in the energy sector and contributes to the definition of working guidelines at the National and European level.

Finally, an important activity was developed by Spanish research centers in the European Energy Research Alliance (EERA). The Spanish team coordinated by CENER with the participation of CIEMAT, CIRCE, CTC, IC3, IREC, and TECNALIA is participating in most of the initiatives (EERA-DTOC, IRPWIND Project, NEWA ERA NET+, etc.)

Under the Seventh FP, the following Spanish project could be highlighted. The company Iberdrola has launched several projects that seek solutions to reduce the costs of offshore wind energy. These include the *TLPWind* project, whose goal is to design a model of floating wind turbine generation and associated innovative installation system to encourage the installation of offshore wind farms in areas where it is not feasible now by the depth of the sea. Other important projects are the *Low-Impact* project which is focused on the development of offshore gravity foundations, the European *LeanWind* project (Logistic Efficiencies and Naval Architecture for Wind Installations With Novel Developments) jointly with the Canary Islands Oceanic Platform (PLOCAN) and Applications Center numerical Engineering (CEANI) of the University of Las Palmas de Gran Canaria, which aimed the optimized development of all types of logistics in offshore technology and a new project to study the fatigue process in marine piles installed in soils with calcareous sediments, in order to optimize the design tools ensuring the stability and lifetime of the structure. Finally, Iberdrola has also launched the *Best Path* European project, whose goal is the demonstration of new technologies that facilitate the integration of renewables in the European networks, and *SmartWind* project, which investigates models for storage technology simulation suitable for wind parks applications.

CIRCE, the Castilla-La Mancha University, the Asociación Empresarial Eólica AEE and Ingeteam are participating in the European *AWESOME* project. The AWESOME project (Advanced Wind Energy Systems Operation and Maintenance Expertise) is a research program that tackles the main research challenges in the wind O&M field identified by the European wind academic and industrial community.

Most of the Spanish wind energy research centers (CENER, CIEMAT, CIRCE, CTC, IREC and TECNALIA) are involved in the IRPWIND Project. The *IRPWIND* is an European integrated research program that combines strategic research projects and support activities within the field of wind energy, with the aim of leveraging the long term European research potential fostering a better integration of European research activities in the field of wind energy research with the aim of accelerating the transition towards a low-carbon economy.

The *SWIP* project ("New innovative solutions, components and tools for the integration of wind energy in urban and peri-urban areas") aims to expand the market for small wind turbines in Europe. Several barriers currently stand in the way of the uptake of small wind turbines. SWIP will develop, implement, and test innovative solutions to overcome these barriers, aiming to reduce maintenance costs by 40%, increase performance by 9%, and mitigate or eliminate noise and vibrations. Such measures should help to reduce investment costs and increase the attractiveness of small wind turbines. To test the developed solutions, three pilot demonstrations will take place in Spain and Poland. This project is coordinated by CIRCE (Research Centre for Energy Resources and Consumption, Spain). The project consortium includes 13 members from ten different EU states: Belgium, France, Germany, Ireland, Lithuania, the Netherlands, Poland, Spain, Sweden, and the United Kingdom.

There is one project funded by the FP7 special instrument for SMES focused on the development of cost effective small wind turbines, the *WINDUR Project,* (Small wind turbine with vertical axis for urban environments). The aim is this project is to develop, design, test, and commercialize a small vertical axis wind turbine for urban areas. The partnership of this project includes nine partners from six different countries: Belgium (Ghent University), Denmark (DVE Technologies), Ireland (Gerriko), Spain (CENER, Machachi, Mastergas and Solute), Sweden (University of Uppsala) and United Kingdom (FuturEnergy).

4.1.1 Regional R&D&I Programs

Mainwind Project

The MainWind Project has as objective the development of innovative technologies to maximize the energy yield and economical profitability of land-based and offshore wind farms operation and maintenance activities. The leader is Ingeteam Group and the partners are Laulagun Bearings, Glual Hidráulica, Matz-Erreka, Aeroblade Structures, Xubi Engranajes, Renogear, Sisteplant and Fegemu Automatismos as well as other technological centers as CENER. The budget reaches 6.5 million EUR (7.9 million USD) (funded by the Basque Country R&D Regional Program Etorgai). The intention of this project is the integration of various advanced technologies such as on-line sensing, structural monitoring, failure forecasting, operational risk assessment, fault simulation in wind turbine control strategies and maintenance of wind farms, to automate and reduce the cost of maintenance of land-based and offshore wind farms

NAUTILUS Project

The Nautilus project is focused on the design and validation of a floating platform for offshore wind, for installation in deep water more than 60 m. Semi-submerged floating platforms are ideal for depths in excess of 60 m (of which there are many areas around the world). The first floating platform will be designed for 5-MW wind turbines, but the objective is to reach up to 10 MW. This is a market oriented project because it is based on development aspects as their manufacturing costs; its logistical requirements and installation are also addressed. The project is developed by an industrial and technological consortium called Nautilus Floating Solutions S.L. composed by local entities of Basque Country like the research center Tecnalia Research and Innovation, Murueta Shipyards, the engineering consulting Tamoin, Velatia group experts on electrical networks, electronics and communication networks, and Vicinay, world leader in the supply of chains and mooring systems for the offshore industry. During 2014, the first test prototype of the floating offshore wind turbine 1:35 scale has been developed and tested successfully in a wave test tank operated by the Hydraulic Institute of Cantabria.

4.2 Collaborative research

Spain is active in international research efforts and bilateral agreements. The government R&D program supports experts in Spain who lead IEA Wind Task 11 Base Technology Information Exchange, Task 27 Development and Deployment of Small Wind Turbine Labels for Consumers and Small Wind Turbines in High Turbulence Sites, and most recently Task 31 WAKEBENCH: Benchmarking Wind Farm Flow Models, a task led by Spanish experts in wind flow modeling in complex terrain.

5.0 The Next Term

The future of wind energy in Spain presents some hope. After the tough situation experienced in the recent times, 2015 is expected to be a more promising year. The new regulations to promote wind energy in the islands, because of their competitive cost and promise to set up auctions for new wind capacity in Spain during 2015, indicate a timid change in the government's position for wind energy. Besides increasing electricity interconnection capacity especially with the European power system through France but also with Africa through Morocco should gradually permit to increase the installed wind power capacity with guaranties.

Although the various changes made in the Spanish energy regulation by the current government have caused a stop in the development of wind farms in Spain, the Spanish wind sector is successfully opting for internationalization and is expected that in 2015, taking into account clear growth environment of the global wind demand, sales abroad will increase significantly especially in the market for onshore wind.

The new situation has meant that the priority in research and development is focused on the extension of the useful life time of the wind farms, the development of new techniques and innovative technologies to reduce costs of operation and maintenance of wind farms and the development of more accurate solutions for wind resources assessment and forecasting.

Finally, it is not expected that any commercial offshore facility will be deployed. However, research and development activities will probably take place aimed at achieving the development of prototypes of new wind turbines of up to 8 MW, as well as new support structure solutions such as cost competitive floating platforms.

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Opening photo: The increasingly clear wind in Spain (Photo Credit: Francisco Javier Preciado)

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34 Sweden

1.0 Overview

The new wind energy installations in 2014 had a capacity of 956 MW (862 MW were installed in 2013). At the end of 2014, the total installed wind generation was 5,425 MW from 3,048 wind turbines. A major part of wind power research financed by the Swedish Energy Agency is carried out in the research programs Vindforsk, Vindval, Swedish Wind Power Technology Center (SWPTC), and Wind Power in Cold Climate. Vindforsk focuses on wind resource and establishment, operation and maintenance, and wind power in the power system. Vindval is a knowledge program focused on studying the environmental effects of wind power. SWPTC's main objective is the design of an optimal wind turbine which takes the interaction among all components into account. The program Wind Power in Cold Climate focuses on removing barriers that arise for wind power in cold climates.

2.0 National Objectives and Progress

On the basis of the EU burden-sharing agreement, Sweden is required to achieve a renewable energy share of 49% by 2020. Sweden has further raised this goal so that its renewable energy share should be at least 50% of the total energy use.

The green electricity certificate system is the major policy measure in increasing the share of renewables in Sweden. Since 2011, a green electricity certificate system between Norway and Sweden has been in place.

2.1 National targets

In 2008, the Swedish government expressed a planning framework of 30 TWh wind power by 2020, comprised of 20 TWh land-based and 10 TWh offshore. Within the electricity certificate system the goal is to increase renewable electricity generation by 26.4 TWh until 2020, as compared to the level in 2012.

2.2 Progress

Electricity generation from wind power has increased from 9.9 TWh in 2013 to 11.6 TWh in 2014 (Figure 1).

The Swedish electricity end use in 2014 was 129.8 TWh. The wind power electricity generation share 2014 was 8.9%.

2.3 National incentive programs

There are two main incentive programs for the promotion of wind power: electricity certificates and support for technical development in coordination with market introduction for large-scale plants offshore and in arctic areas.

The work done in assessing areas of national interest for wind power can also be considered a sort of "soft incentive."

2.3.1 Electricity certificates

The electricity certificate system came into force on 1 May 2003, and it is intended to increase the production of renewable electricity in a cost-efficient way. The increased deployment of renewable electricity generation will be driven by stipulated quotas that are increased annually, as well as by a quota obligation fee. The principle is that there should be sellers and purchasers of certificates, and a market to bring them together. There are no specific quotas for wind power. Electricity producers receive a certificate from the state for each megawatt hour of renewable electricity that they produce. This certificate can be sold to provide additional revenue above the sale of the electricity, improve the economics of electricity production from renewable energy sources, and encourage the construction of new plants The demand for certificates is created by a requirement under the act that all electricity suppliers and certain electricity users purchase certificates equivalent to a certain proportion of their electricity sales or use, known as their quota obligation. The price of certificates is determined by supply and demand, and it can vary from one transaction to another.

Since 1 January 2012, Sweden and Norway have had a common electricity certificate market. This means that the electricity

Sweden generated 11.6 TWh in 2014, working toward a planning framework of 30 TWh from wind by 2020.

Table 1. Key National Statistics 2014: Sweden	
Total (net) installed wind capacity	5,425 MW
New wind capacity installed	956 MW
Total electrical output from wind	11.592 TWh
Wind generation as percent of national electric demand	8.9%
Average capacity factor	***26.7%***
Target:	Planning framework of 30 TWh wind power by 2020
Bold italic indicates estimates	

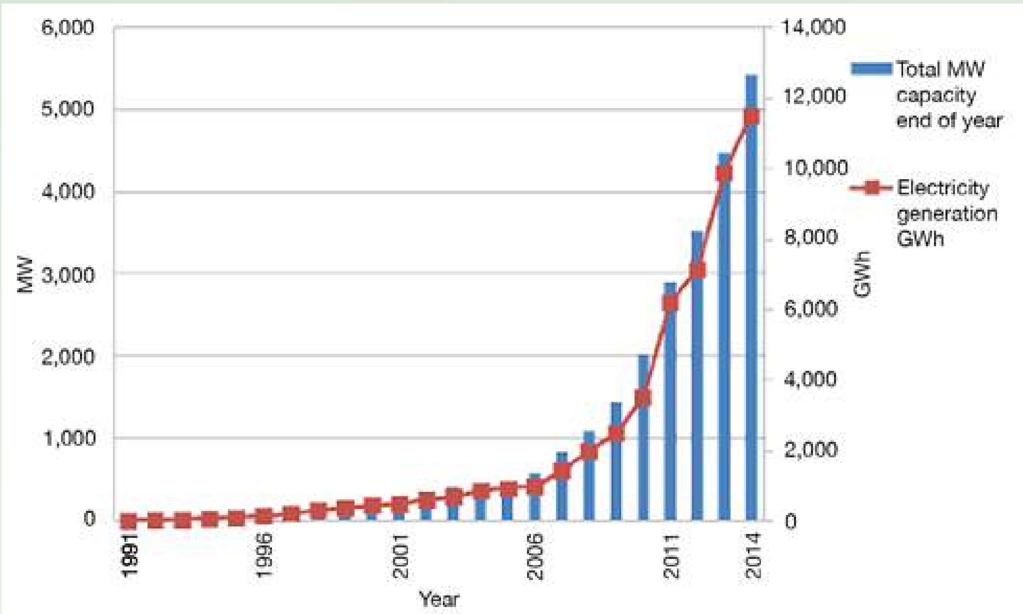

Figure 1. Installed wind power capacity in Sweden 1991–2014

certificate can take place across borders. The goal of the joint certificate market is to increase renewable electricity by 26.4 TWh from 2012 to 2020. This represents approximately 10% of electricity production in the two countries.

2.3.2 Support for technical development

In 2003, the Swedish Energy Agency launched a program to support technical development, in coordination with market introduction, for large-scale plants offshore and plants in arctic areas. The aim is to stimulate the market, achieve cost reduction, and gain knowledge about environmental effects. For the years 2003–2012, the budget was 700 million SEK (74.2 million EUR; 89.6 million USD). The market introduction program has been prolonged with an additional 10 million SEK per year (1.1 million EUR; 1.3 million USD).

2.3.3 Areas of national interest

According to the environmental code, land and water areas shall be used for the purposes for which the areas are best suited in view of their nature, the situation, and the existing needs. Priority shall be given to the use that promotes good management from the point of view of public interest. These are areas of national interest for fishery, mining, nature preservation, outdoor recreation, wind power, etc.

2.3.4 Network for wind utilization

The Swedish Energy Agency is the expert authority appointed by the government to promote the development of wind power, taking a holistic approach to encouraging the rapid expansion of wind power [1]. Therefore, the Swedish Energy Agency has started a national network for wind utilization. A national network is important for putting to use the opportunities offered by the expansion of wind power for local and regional development. The purpose of the network is to disseminate knowledge of the natural resource of wind, safeguard the availability of information for facilitating the expansion of wind power, and support regional initiatives of national importance. An essential part of the network is to strengthen existing initiatives and contribute to the formation of new regional nodes in the field of wind power. An important task is also to coordinate with other authorities on their work on wind power.

2.3.5 Vindlov.se

One of the key obstacles prolonging the permission process for wind power is the huge number of stakeholders in the process [2]. Hence, information a developer must consider is widespread, of different formats and quality, or simply is not accessible. Furthermore, staying up-to-date on this information requires considerable amounts of work. Also, during this process some stakeholders might be overlooked.

The website Vindlov.se (i.e. wind consent), takes a unique approach to target this bottleneck. The website follows the concept of a one-stop shop providing information on permitting issues from nearly twenty public authorities from a wide range of sectors—this includes permission information over the whole life cycle of wind power and features a dynamic web map application as well as contact tools to wind power handlers at all authorities. Further development is planned and an English version is in progress.

The dynamic web map application (www.vindlov.se/vindbrukskollen) enables the wind power developer, the authority and interested persons to view, share, and attach up-to-date public geographic information to a project without being a specialist in geographic information systems. The service is free of charge and shows localizations with public stakeholder interests, basic conditions for wind power, as well as all wind power in place and in planning. This includes detailed site and technical information for every single turbine and park/farm, a set of different administrative boundaries and a detailed base map as well as wind speed charts, weather radars and protection zones, restricted areas around military airports and training fields, national interest areas of different kinds, electricity trunk lines, valuable natural and cultural environments, and concession areas for mineral excavation.

In addition, the web maps application functions as a geographic based e-service tool between developer and authority. The developer forms his/her application in the web map application including all necessary information. Hereafter s/he sends it to the authority via the system. The authority handles the status of the application, which is visible on the map for the public to follow the process.

Figure 2. Wind turbines in Sweden (Photo credit: Per Westergård, Swedish Energy Agency)

2.4 Issues affecting growth

The expansion of wind power is mainly driven by the incentives within the electricity certificate system. Because of the last year's lower prices of both electricity and certificates, only the most profitable places are used for new wind farms/parks.

3.0 Implementation

Wind power in mountainous terrain and cold climates is gaining more and more interest. Northern Sweden exhibits many such areas, where the wind potential is high. Wind turbines in the northern part of Sweden are facing a number of challenges not seen in areas with warmer climates. One such challenge is the risk of ice on the wind turbine blades, which will reduce production and may result in falling ice. Experiences from operation of wind power in cold climates indicate that energy losses due to ice buildup on wind turbine blades can be substantial. It is a general understanding that wind turbines in such areas have to be equipped with special cold climate packages. Such packages may include special steel qualities in towers and nacelle structures, and special types of oil and grease. The most essential thing is to equip blades with equipment for de-icing or anti-icing. To support the deployment in cold areas the Swedish Energy Agency is supporting a number of projects financially.

3.1 Economic impact

No new data available.

3.2 Industry status

The expansion of wind power onshore is mostly driven by large utilities like Vattenfall and E.ON but also by others. A number of utilities, developers, real estate companies, and private persons are developing small and large projects.

The large, international manufacturers of turbines, including Enercon, Nordex, Vestas, and others have sales offices in Sweden. On the component side (supply chain), the value of manufactured goods is large. The market consists of subcontractors such as SKF (roller bearings and monitoring systems), and ABB (electrical components and cable). The subcontractors are mainly multinational companies, but smaller entities that find the wind power market relevant to their know-how are also established in Sweden.

4.0 R, D & D Activities

The publicly funded wind energy research in 2014 was mainly carried out within the research programs Vindforsk [3], Vindval [4], SWPTC [5], and Wind Power in Cold Climates [6].

The present period of Vindforsk (called Vindforsk IV) runs from 2013–2016, with a total budget of 60 million SEK (6.4 million EUR; 7.7 million USD). The program is financed 50% by the Swedish Energy Agency and 50% by industry. Vindforsk IV is organized in three project packages: wind resource and establishment; operation and maintenance; and wind power in the power system.

Vindval is a knowledge program focused on studying the environmental effects of wind power. The Vindval program is financed by the Swedish Energy Agency and is administrated by the Swedish Environmental Protection Agency. During 2014, the program was extended through 2018 with a new budget of 27 million SEK (2.9 million EUR; 3.5 million USD). The Vindval program has two research project supported by the Swedish Energy Agency in 2014, the two projects relate to wind power impact on reindeer and golden eagles.

The SWPTC was extended in 2014 and now runs from 2010 to 2017. The program is financed by the Swedish Energy Agency, by industry, and by Chalmers University and has a total budget of 196 million SEK (20.8 million EUR; 25.1 million USD). The center focuses on complete design of an optimal wind turbine which takes the interaction among all components into account. SWPTC is organized in six theme groups: power and control systems; turbine and wind load; mechanical power transmission and system optimization; structure and foundation; maintenance and reliability; and cold climate.

The program Wind Energy in Cold Climates runs from 2013 to 2016. The program is financed by the Swedish Energy Agency and has a total budget of 32 million SEK (3.4 million EUR; 4.1 million USD). The program focuses on removing barriers that arise for wind power in cold climates.

5.0 The Next Term

The research programs Wind Energy in Cold Climates, Vindval, Vindforsk, and SWPTC will continue during 2015. A lot of the expected growth in wind generation capacity will be in forest areas and also in the northern parts of Sweden in the "low-fields." The interest in those regions is prompted by the rather good wind potential as estimated by Swedish wind mapping. Substantial uncertainty, however, exists in the energy capture and loads of turbines in forested areas. The character of wind shear and turbulence is less explored in these areas and projects in the coming research program will be set up to increase the knowledge in this area. The SWPTC activities will continue developing wind turbines and to optimize maintenance and production costs.

References and notes:

Opening photo: Wind power at the south part of Öland Island. Photo credit: Per Westergård, Swedish Energy Agency.

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Author: Andreas Gustafsson, Swedish Energy Agency, Sweden.

35 Switzerland

1.0 Overview

By the end of 2014, 34 wind turbines of considerable size were operating in Switzerland with a total rated power of 60 MW. These turbines produced 101 GWh of electricity. Since 1 January 2009, a cost-covering feed-in-tariff (FIT) for renewable energy has been implemented in Switzerland [1]. This policy in promoting wind energy led to a boost of new wind energy projects. Financing is requested today for an additional 3,330 GWh under the FIT scheme. Due to continuous obstacles in the planning procedures and acceptance issues, no turbines were installed in 2014 (Table 1).

In Switzerland, an ancillary industry for wind turbine manufacturers and planners has been developed, which acts mainly on an international level. A recent study estimates that the total turnover in 2010 was about 38.9 million EUR (47.1 million USD) and the wind industry employs about 290 people [2]. Wind energy research is conducted by the public research institutions, such as the Swiss Federal Institute of Technology in Zurich (ETHZ), as well as by experienced private companies. Research activities are internationally cross-linked, mainly in the fields of cold climate, turbulent and remote sites, and social acceptance.

2.0 National Objectives and Progress

As a result of the devastating earthquake in Japan and the disaster at Fukushima, the Swiss government and parliament decided in autumn 2011 to decommission existing nuclear power plants at the end of their operational lifespan and to not replace them with new nuclear power plants. In order to ensure the security of electricity supply, the Federal Council, as part of its new Energy Strategy 2050, is placing emphasis on increased energy savings (energy efficiency) and—amongst other measures—the expansion of hydropower and new renewable energies [3].

Wind energy is an important element within this new strategy. Suisse Eole, the Swiss Wind Energy Association, is the leading institution on the use of wind energy in Switzerland and will play an even more important role in coordinating all activities in collaboration with the cantonal (state) authorities of energy, energy suppliers, and energy planners. A special focus will be on social acceptance issues [4].

2.1 National targets

Within the new energy strategy 2050, the additional energy yield from renewable energy is estimated to be 22.6 TWh/yr. Wind energy should contribute 4 TWh/yr to these targets. The Swiss wind energy concept (plan) also identifies the calculated wind energy potential for Switzerland, based on the real wind conditions at the sites, and on the possible number of plants to be installed. The potential is outlined by time horizons: time horizon 2020: 600 GWh; time horizon 2030: 1,500 GWh; time horizon 2050: 4,000 GWh [5]. By the end of 2014, the energy yield from operating wind turbines was 101 GWh; advanced projects may generate an additional 300 GWh in the near future.

Since the introduction of the FIT in 2009, projects with an estimated energy yield of 1,200 GWh are registered; additional projects with a potential energy yield of 2,135 GWh are on the waiting list. Projects with possible energy yield of 2,320 GWh have been submitted to planning bodies, and 445 GWh are already authorized.

2.2 Progress

Today, approximately 56% of Switzerland's overall electricity production comes from renewable sources, with hydropower by far the biggest contributor (95%). In 2014, no wind turbines were put in operation (including turbines for repowering). In total, 34 wind turbines of a considerable size are installed with a rated capacity of 60 MW. These turbines produced 101 GWh.

By the end of 2014, the energy yield from operating wind turbines was 101 GWh.

Table 1. Key National Statistics 2014: Switzerland	
Total (net) installed wind capacity	60 MW
New wind capacity installed	0 MW
Total electrical output from wind	***0.1 TWh***
Wind generation as percent of national electric demand	***0.2%***
Average national capacity factor	20%
Target:	4TWh/yr in 2050
Bold italic indicates estimates	

2.3 National incentive programs

The cost-covering FIT for renewable energy is the most significant measure. Renewable resources include hydropower (up to 10 MW), photovoltaics, wind energy, geothermal energy, biomass, and waste material from biomass. The additional cost of the FIT is financed by a levy on electricity consumption. By 1 January 2014, this levy is set to 0.083 EUR/kWh (0.101 USD/kWh), based on the current electricity consumption in Switzerland. This leads to more than 500 million CHF (416 million EUR; 503 million USD) annually of available funds. At the moment there is a debate in national parliament to raise this levy up to 0.124 EUR/kWh (0.150 USD/kWh), in order to be able to reduce the waiting list of the signed in projects.

The current FIT for wind energy is in a range of 0.13 to 0.18 EUR/ kWh (0.16 to 0.022 USD/kWh) [6]. Producers who decide in favor of the FIT option cannot simultaneously sell their green power on the free market for green electricity. Yet they can decide every year whether they will sell the electricity on the market or apply the FIT system.

2.4 Issues affecting growth

Besides the limited finances within the FIT system, there are other issues affecting growth. The substantial potential of wind energy in Switzerland can only be achieved if the existing widespread acceptance of this technology can be maintained. The activities of the IEA Wind Task 28 Social Acceptance of Wind Energy Projects continue to play an important role.

Planning procedures and construction permits in Switzerland are still very time- and cost-intensive and the outcomes are often uncertain. Here the intensified activities concerning spatial planning of the cantons (states) will lead to a higher realization grade of the planned projects.

Based on the important changes in the FIT, a dramatic rise in players on the Swiss market occurred. Establishing a high quality reference standard for future projects will be a major challenge for the Swiss Wind Energy Association.

3.0 Implementation

3.1 Economic impact

A study estimates that the total turnover in wind energy in Switzerland in 2010 was about 38.9 million EUR (47.1 million USD) and wind industry employs about 290 people [2]. Another study of McKinsey [7] from 2009 estimates the world-wide turnover of Swiss companies in the field of wind energy in the year 2020 of 8.6 billion EUR (10.4 billion USD) and 32,000 employees worldwide.

3.2 Industry status

The Swiss industry is active in several fields of wind energy: development and production of chemical products for rotor blades, like resins or adhesives (Gurit Heberlein, Huntsman, Clariant); grid connection (ABB); development and production of power electronics like inverters (ABB, Integral Drive Systems AG, Vivatec, VonRoll Isola); services in the field of site assessments and project development (Meteotest, Interwind, NEK, New Energy Scout, Kohle/Nussbaumer, etc.); and products like gearboxes (RUAG).

3.3 Operational details

Due to the specific wind regime in Switzerland (moderate wind speeds, turbulent sites, icing conditions, etc.) the average capacity factor for installations in Switzerland is below 20%. New projects with modern wind turbines are showing substantially higher performance, also thanks to lessons learned within research activities. The turbines in the lower Rhone Valley recorded over 2,500 full load hours, values known from locations in Northern Germany and Denmark.

3.4 Wind energy costs

The specific costs of existing large wind power plants is about 1,450 EUR/kW (1,756 USD/kW), including installation the figure rises to 2,070 EUR/kW (2,507 USD/kW). The regulation for the compensatory FIT scheme provides 0.13 to 0.18 EUR/ kWh (0.16 to 0.022 USD/kWh) for wind energy—based on the same mechanism as the German model. Swiss participation in the IEA Wind Task 26 Cost of Wind Energy did generate important information for this discussion.

4.0 R, D&D Activities

4.1 National R, D&D efforts

The Federal Energy Research Masterplan 2013–2016 [8] focuses in the field of wind energy on developing innovative turbine

Figure 1. Pilot wind turbine from Gries project, located 2,465 meters above sea level in the Swiss Alps (Source: SwissWinds Development GmbH)

components for specific application in harsh climates, increasing availability and energy yield at extreme sites, optimizing the integration of wind energy into the grid, and increasing the acceptance of wind energy. Implementation of pilot and demonstration projects is designed to increase market penetration of wind energy and close the gap between research activities and application in practice. In 2014, the budget for wind energy related R&D projects should have been around 391,000 EUR (473,500 USD). Within the national "SwissEnergy" program, approximately 620,000 CHF (515,840 EUR; 624,682 USD) were allocated to the wind energy sector for information activities, quality assurance measures, and for the support of regional and communal planning authorities. Several innovative research projects were underway in 2014.

Siting of Wind Turbines in Complex Terrain—Effects of Inclined Freestream Flow and Elevated Freestream Turbulence [9]: This project examines the effects of flow inclination and elevated freestream turbulence levels on the performance of wind turbines. As Switzerland's Energy Strategy 2050 requires, amongst other pillars, and expansion of electricity production from renewable energy sources, including wind, the work of this projects is practically relevant since Switzerland is characterized by complex terrain—that is changes in topography that have a profound impact on flow inclination and the freestream turbulence intensity.

The present work is carried out in the ETHZ School Wind Turbine Test Facility—this unique facility allows parameters to be specified under accurately controlled conditions. For this purpose, a flow inclination mechanism and integrated active turbulence generator—that can provide conditions representative of those in complex terrain—were designed, manufactured and implemented. The measurements show that output power of wind turbine with an incoming flow inclination of 15 degrees inclination decreases on average by 7%, relative to the output power of a turbine in non-inclined incoming flow. However, flowfield measurements show that the wake of the turbine in the inclined incoming flow is deflected by approximately 6 degrees for an incoming flow with 15 degrees inclination. Thus for wind farms that are in complex terrain, there is the possibility to more closely place wind turbines than in the case for flat terrain, The measurement also show that elevated freestream turbulence levels of 8% result in an increased output power of a turbine of up to 15% compared to a turbine that in low freestream turbulence flow of 2.5%.

Eole-Vaud [1]: Facing the observation that wind farm projects over the state of Vaud were triggering major protest movements, the state of Vaud has decided to launch in June 2014 an in-depth survey treating about how wind farms projects are introduced in the territory.

In order to do so, Vaud State Energy department gave to two representatives the mission of gathering and analyzing data about wind farm project process, and analyzing experience of the various actors concerned by the project. Two approaches were conducted in parallel: the goal of the first task was to reveal the point of view of the actors concerning the collaboration of the population with the wind farms, and identifying the needed conditions for improvement of dialogue.

The objective of the second task is to analyze the administrative process related to wind farm construction and the process requested by the state, towns, or project builders. Beside these two tasks, a participatory guide on wind power was developed, and a training guideline on participatory processes in renewable energy projects was carried out.

4.2 Collaborative research

In addition to IEA Wind Task 28 Social Acceptance of Wind Energy Projects, Switzerland participated in the IEA Wind Task 11 Base Technology Information Exchange, Task 19 Wind Energy in Cold Climates, Task 26 Cost of Wind Energy, and Task 31 WAKEBENCH, Benchmarking of Wind Farm Flow Models. In 2014, Switzerland integrated IEA Wind Task 34 Assessing Environmental Effects and Monitoring Efforts for Offshore and Land-Based Wind Energy Systems.

5.0 The Next Term

If significant economic effects of wind energy for the Swiss industry are to be realized, a substantial rise in research and promotional activities is crucial. In 2012, the energy research concept 2013 to 2016 was being elaborated by the Swiss Federal Office of Energy (SFOE). The following key issues were included:

- Quantifying production losses and downtimes due to icing; and implementation and evaluation of relevant measures, in collaboration with IEA Wind Task 19 Wind Energy in Cold Climates
- Reducing energy production costs by increasing the full-load hours and reliability of turbines in harsh conditions and on sites with low wind speeds
- Increasing the accuracy of energy yield estimates and improving the economics of wind parks
- Reducing planning and installation costs by speeding up planning procedures and considering important acceptance issues
- Maintaining the high degree of wind energy acceptance in Switzerland.

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Opening photo: View of the Gries pilot wind turbine, beside a Swiss pumped storage reservoir

(Source: SwissWinds Development GmbH)

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Author: Davy Marcel, Planair SA, Switzerland.

36 United Kingdom

1.0 Overview

The United Kingdom (UK) increased its land-based and offshore wind capacity throughout 2014. Land-based capacity increased by 11% to over 8 GW and offshore capacity increased by over 20% to over 4 GW. The higher rate of growth of offshore wind is expected to continue and is forecast to reach 10 GW of installed offshore wind capacity by 2020. Electricity generated from wind was approximately 9% of the total electricity generated in the UK, delivering 31 TWh of electricity onto the national grid in 2014.

The UK has approximately 40% of Europe's entire wind resource and has significant potential for both land-based and offshore wind. The 2009 Renewable Energy Directive sets a target for the UK to achieve 15% of its energy consumption from renewable sources by 2020. The renewable energy mix used to achieve this target is not defined but both offshore and land-based wind has already made a significant contribution to achieving this target.

In 2014 the UK government implemented the final stages of a significant new framework for the electricity generation sector with the first allocation of contracts under the Contract for Difference (CfD) scheme. Over 3 GW of offshore wind capacity were allocated and the first auctions for further contracts will take place in early 2015.

The Cost Reduction Monitoring Framework (CRMF) was also implemented in 2014 and the first report identified an 11% reduction in levelized cost of energy (LCOE) between 2011 and 2014. The CRMF reported that the average LCOE of projects with a successful financial investment decision (FID) between 2012 and 2014 was 121 Great Brittan Pound (GBP)/MWh (155 EUR/MWh; 189 USD/MWh). It concluded that the offshore wind sector was on target to reach an LCOE of 100 GBP/MWh (129 EUR/MWh; 156 USD/MWh) for projects reaching FID in 2020.

Progress is also being made in the supply chain. Siemens and Associated British Ports (ABP) committed to invest over 300 million GBP (386 million EUR; 468 million USD) to build a turbine blade factory and service operation center at Green Port Hull. This factory and operation center will provide around 1,000 jobs. MHI Vestas announced its intention for serial production of 80-m blades, safeguarding or creating up to 800 jobs, to commence on the Isle of Wight.

The UK continues to play a leading role in technology innovation and cost reduction of wind energy. The merger of the Offshore Renewable Energy Catapult in Glasgow and the National Renewable Energy Centre in Blyth has created a champion for the development and testing of technology innovation for the sector.

In terms of investment opportunities, the UK has held its place as the number one country for Offshore Wind in the Ernst Young Renewable Energy Renewable Energy Country Attractiveness Index.

2.0 National Objectives and Progress

In 2009, the UK signed up to a target of 15% of its primary energy from renewable sources as its contribution to the EU target of 20% of primary energy from renewables. In 2014 the EU was unable to agree on targets for 2030 [1].

Wind capacity on land increased 11% to over 8 GW and offshore capacity increased 22% in 2014 to over 4 GW. Offshore wind is forecast to reach 10 GW by 2020.

Table 1. Key National Statistics 2014: United Kingdom	
Total (net) installed wind capacity	12,808 MW
New wind capacity installed	1,599 MW
Total electrical output from wind	31.6 TWh
Wind generation as percent of national electric demand	9%
Average national capacity factor	30%
Target:	15% primary energy from renewables by 2020

2.1 National targets

The Climate Change Act 2008 established a target for the UK to reduce its carbon emissions by at least 80% from 1990 levels by 2050. To ensure that regular progress is made towards this long-term target, the Act also established a system of five-yearly carbon budgets. The first four carbon budgets, leading to 2027, have been set in law. The UK is currently in the second carbon budget period (2013–2017). The Committee on Climate Change (CCC) has recognized the progress that has been made in installed capacity of land-based and offshore wind generation and the further contribution that it needs to make to achieve future carbon emission reduction targets.

National targets for the energy mix are not defined in the carbon budgets but the Levy Control Framework provides an indication of capacity that is expected to be allocated. For offshore wind, the potential 2020 deployment is 8–16 GW dependent on a range of factors including industry cost reductions over time. For land-based wind, the potential 2020 deployment is 9–12 GW, but remains subject to future UK government policy.

2.2 Progress

The UK continued to increase its land-based and offshore wind capacity throughout 2014. Land-based capacity has increased by 11% to over 8 GW, and offshore capacity has increased by over 22% in the same period to over 4 GW (see Figure 1). The higher rate of growth of offshore wind is expected to continue and is forecast to reach 10 GW of installed offshore wind capacity by 2020 [2].

In the UK, electricity generation from wind increased by 11% in 2014 (+3.2 TWh) as a result of increased capacity. Wind was responsible for over 31 TWh of UK electricity generation, representing 9% of total electricity generation (see Figure 2). This is a three-fold increase in the last five years.

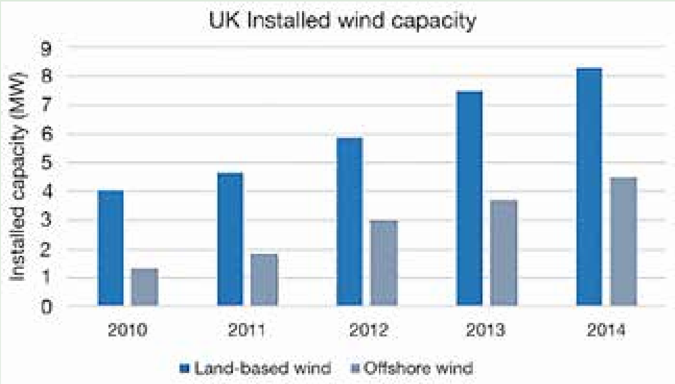

Figure 1. UK Installed wind capacity

2.3 National incentive programs

The UK government is committed to sourcing 15% of its energy from renewables by 2020 under the 2009 Renewable Energy Directive. The electricity generation contribution to this target will be driven by the Electricity Market Reform (EMR) program which was introduced as part of the Energy Act 2013. This implements a new support system for all forms of low carbon power beyond 2017. EMR changes the support for renewables from a fixed certificate price known as Renewable Obligation Certificates (ROCs) to a guaranteed strike price known

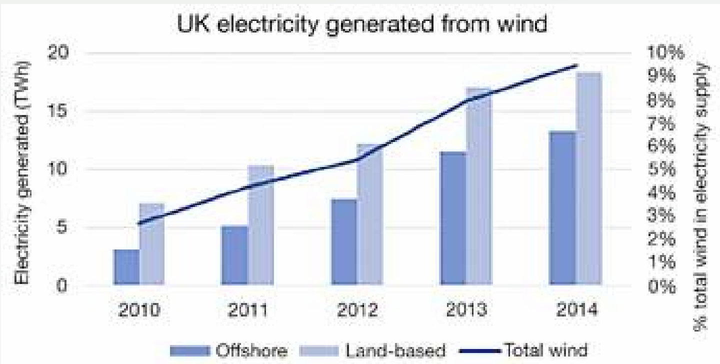

Figure 2. UK electricity generated from wind

as CfDs. A levy on energy bills will fund the difference payments from a day-ahead reference price.

2.3.1 Contracts for Difference (CfDs)

CfDs will support new investment in all forms of low-carbon generation (renewables, nuclear power, and Carbon Capture and Storage (CCS)) and the process has been designed to provide efficient and cost-effective revenue stabilization for new generation by reducing exposure to the volatile wholesale electricity price. A variable top-up from the market price to a pre-agreed 'strike price' is paid to generators. At times of high market prices, these payments reverse and the generator is required to pay back the difference between the market price and the strike price thus protecting consumers from over-payment. The strike price arrangements are higher for offshore wind compared with land-based wind power, as the government seeks to encourage developers to construct new offshore windfarms where they have less visual impact.

An auction process is used to award CfDs so as to provide best value to the electricity consumer. There is also a designated cap on the funding pot to provide control on the total cost of the program. Target strike prices have been set up to 2018/2019, but there are no commitments for projects that are commissioned beyond this date. For offshore wind, the potential 2020 deployment is 8–16 GW, dependent on a range of factors including industry cost reductions over time. For land-based wind the potential 2020 deployment is 9–12 GW but remains subject to future UK government policy. In early 2014 the government awarded over 3 GW of early CfDs to five offshore wind projects. The first auction round for contracts will take place in early 2015.

2.3.2 Capacity market

The government has introduced a capacity market allowing for capacity auctions from 2014 for delivery of capacity in the winter of 2018/2019 onwards to help ensure there is sufficient supply even at times of peak demand. A capacity market will provide an insurance policy against future supply shortages, helping to ensure that consumers continue to receive reliable electricity supplies at an affordable cost.

2.3.4 Renewables Obligation (RO)

The Renewables Obligation (RO) is the existing incentive mechanism for eligible renewable electricity generation and has been in operation since 2002 but will be replaced by CfDs from 2017 onwards. The RO requires power suppliers to derive a specified portion of the electricity they supply to customers from renewable sources. Eligible renewable generators receive Renewables Obligation Certificates (ROCs) for each MWh of electricity generated and these certificates can then be sold to power suppliers in order to meet their obligation.

2.3.5 Feed-In Tariff (FIT)

The FIT scheme was introduced on 1 April 2010, under powers in the Energy Act 2008. Through the use of FITs, the government aims to stimulate a significant increase in domestic and small-scale deployment of renewable energy systems by encouraging the deployment of additional small-scale (less than 5 MW) low-carbon electricity generation, particularly by organizations, businesses, communities, and individuals that have not traditionally engaged in the electricity market. The FITs, in the form of a premium to the power price, were set at 34.5 pence/KWh (0.444 EUR/kWh; 0.538 USD/kWh) for installations smaller than 1.5 kW, dropping to 4.5 pence (0.058 EUR/kWh; 0.070/kWh) for installations between 1.5 MW and 5 MW. This stimulated the installation of more than 17,000 small and medium wind systems across the UK.

2.4 Issues affecting growth

The energy trilemma of sustainability, security of supply, and cost continues to present policy makers with a difficult balancing act. This is compounded by the approaching general election in May 2015 and the constraints of a relatively short spending review period. Electricity Market Reform has brought some clarity up to 2020 but the lack of commitment beyond 2020 presents increased risk for project developers and is a threat to investment throughout the supply chain.

Land-based wind faces additional challenges at the consenting stage with an increasing number of planning applications being called in for a decision by the Department for Communities and local governments.

3.0 Implementation

The UK government published the Offshore Wind Industrial Strategy in July 2013 and this continues to provide the basis for industrial policy for the sector [3].

3.1 Economic impact

The Offshore Renewable Energy Catapult published an in-depth assessment of the economic impact of the offshore wind sector in early 2014. The report concluded that for an accelerated growth deployment scenario of 15 GW of installed capacity by 2020, where UK companies seize the opportunity and innovate collaboratively, gross value added can reach almost 6.7 billion GBP (8.6 billion EUR; 10.4 billion USD) in 2020, supporting 34,000 direct jobs and 150,000 jobs in total. With a gradual growth scenario to 8 GW installed in 2020, gross value added can reach 2.3 billion GBP (3.0 billion EUR; 3.6 billion USD) in 2020, with just under 12,000 direct jobs and 50,000 jobs supported in total [4].

3.2 Industry status

The Offshore Wind Industry Council (OWIC) commissioned Matthew Chinn to investigate the status of the UK offshore wind supply chain. The report "The UK Offshore Wind Supply Chain: A Review of Opportunities and Barriers" was published in November 2014 and concluded that 43% of the lifetime cost of a UK wind farm is spent in the UK. Whilst manufacturing related to the turbines themselves remains largely in Germany and Denmark, the resources required to project manage and install projects has grown extensively in the UK. The report also noted that as much as 60% to 70% of the workforce deployed on the latest projects has been UK based. It also concluded that over 6,800 people were directly employed in offshore wind in the UK [5].

The UK government introduced the requirement for supply chain plans within the CfD process to stimulate supply chain competition. It is hoped that the benefits of this approach will be realized in the next few years. Until recently, the UK did not have an established wind turbine manufacturer. Siemens has, confirmed that it is to invest 160 million GBP (206 million EUR; 250 million USD) in wind turbine production and installation facilities in the UK [6].

3.3 Operational details

For land-based wind, project sizes are declining overall, due partly to the growth of the sub-5-MW market under the FIT, with projects at this scale now making up two-thirds of new land-based submissions. Other factors include a reduction in the availability of larger sites, and developers' responses to changes in the planning system.

The overall trend for capacity factors of both land-based and offshore wind remains positive with the overall wind capacity factor at approximately 31% for 2014. This is slightly lower that 2013 but is likely to be a result of annual variations in the average wind speed (see Figure 3).

The size of offshore wind farm has continued to increase the West of Duddon Sands project contributing 389 MW of new capacity in 2014. Table 2 lists the projects that were operational by the end of 2014.

3.4 Wind energy costs

A major assessment of offshore wind costs was carried out in 2014 under the newly established CRMF. The analysis identified an 11% reduction in LCOE between 2011 and 2014. The CRMF reported that the average LCOE of projects with a successful financial investment decision (FID) between 2012 and 2014 was 121 GBP/MWh (156 EUR/MWh; 189 USD/MWh). It concluded that the offshore wind sector was on target to reach an LCOE of 100 GBP/MWh (129 EUR/MWh; 156 USD/MWh) for projects reaching FID in 2020 [7, 8].

Table 2. Offshore wind projects by end of 2014

Wind Farm Name	First Power	Total Capacity (MW)
Blyth	2000	4
North Hoyle	2003	60
Scroby Sands	2004	60
Kentish Flats	2005	90
Barrow	2006	90
Beatrice Demonstration	2007	10
Burbo Bank	2007	90
Inner Dowsing	2008	97
Lynn	2008	97
Rhyl Flats	2009	90
Gunfleet Sands I + II	2009	173
Robin Rigg	2009	180
Thanet	2010	300
Greater Gabbard	2010	504
Ormonde	2011	150
Walney Phase 1	2011	184
Walney Phase 2	2011	184
Sheringham Shoal	2011	317
Lincs	2012	270
London Array Phase 1	2012	630
Teesside	2013	62
Gwynt y Môr	2013	576
West of Duddon Sands	2014	389

4.0 R, D&D Activities

The UK continues to play a leading role in technology innovation and cost reduction of wind energy.

4.1 National R, D&D efforts

The merger of the Offshore Renewable Energy Catapult (ORE Catapult) in Glasgow and National Renewable Energy Centre in Blyth has created a champion for the development and testing of technology innovation for the sector.

4.1.1 The Offshore Renewable Energy Catapult

The ORE Catapult has world-leading test and research facilities. These include a 15-MW drive train test facility, 50-m and 100-m blade test facilities, a 3-MW tidal turbine drive train test facility, three dry dock facilities and a UKAS accredited electrical and materials laboratory. With the specialist skills and industry experience of the engineering team, ORE Catapult provides the necessary support to get new technologies ready for deployment. The facilities provide a controlled environment to perform accelerated life testing, improve reliability, and reduce costs of offshore renewable energy technologies in the UK.

In 2014, ORE Catapult managed the delivery of the CRMF and launched SPARTA (System performance, Availability and Reliability Trend Analysis). SPARTA was developed from a collaboration with The Crown Estate and offshore wind farm owner/operators and consists of a secure database of offshore wind farm performance data that will improve wind turbine operational performance by increasing safety, reliability and availability. Full roll-out of the database is scheduled for March 2015.

4.1.2 Research Councils UK Energy Programme

Each year the UK Research Councils invest around 3.0 billion GBP (3.8 billion EUR; 4.6 billion USD) in research covering the full spectrum of academic disciplines from the medical and biological sciences to astronomy, physics, chemistry and engineering, social sciences, economics, environmental sciences, and the arts and humanities. They support research that has an impact on the growth, prosperity, and wellbeing of the UK. To maintain the UK's global research position they offer a diverse range of funding opportunities, foster international collaborations, and provide access to the best facilities and infrastructure around the world. The research councils also support the training and career development of researchers and work with them to inspire young people and engage the wider public with research. To maximise the impact of research on economic growth and societal wellbeing the work in partnership with other research funders including the Technology Strategy Board, the UK Higher Education Funding Councils, business, government, and charitable organizations.

The Energy Programme has invested more than 625 million GBP (804 million EUR; 974 million USD) in research and skills to pioneer a low carbon future. This builds on an investment of 839 million GBP (1.1 billion EUR; 1.3 billion USD) over the past eight years. The Energy Programme is led by the Engineering and Physical Sciences Research Council (EPSRC). It brings together the work of EPSRC and that of the Biotechnology and Biological Sciences Research Council, the Economic and Social Research Council, the Natural Environment Research Council, and the Science and Technology Facilities Council. The EPSRC established the SUPERGEN Wind Energy Technologies Consortium (SUPERGEN Wind) in 2006 as part of the Sustainable Power Generation and Supply (SUPERGEN) programme. The SUPERGEN Wind Consortium is led by Strathclyde and Durham Universities and consists of seven research groups with

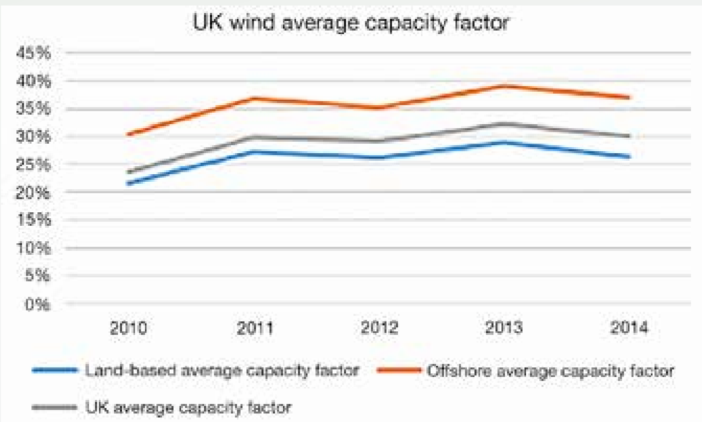

Figure 3. UK capacity factors

expertise in wind turbine technology, aerodynamics, hydrodynamics, materials, electrical machinery and control, and reliability and condition monitoring.

4.1.3 InnovateUK

InnovateUK is an executive, non-departmental public body established by the government in 2007 and sponsored by the Department for Business, Innovation, and Skills (BIS). InnovateUK activities are jointly supported and funded by BIS and other government departments, the devolved administrations, and research councils. InnovateUK aims to accelerate innovation by helping UK businesses to innovate faster and more effectively than would otherwise be possible, using its expertise, connections, and funding.

4.1.4 Energy Technologies Institute (ETI)

The Energy Technologies Institute (ETI) is a public-private partnership between global energy and engineering companies—BP, Caterpillar, EDF, E.ON, Rolls-Royce and Shell—and the UK government. The ETI carries out three key activities: firstly, modeling and analysis of the UK energy system to identify the key challenges and potential solutions to meeting the UK's 2020 and 2050 targets at the lowest cost to the UK; secondly, investing in engineering and technology development and demonstration projects which address these challenges with the aim of de-risking solutions—both in technology and in supply-chain development—for subsequent commercial investors; and thirdly providing deployment support to enable rapid commercialization of products.

4.1.4 GROW: Offshore Wind

GROW: Offshore Wind – is a 20 million GBP (26 million EUR; 31 million USD) program backed by the government's Regional Growth Fund to help support growth in the offshore wind manufacturing supply chain in England. The program offers English small and medium-sized enterprises a free upfront Business Capability Assessment and then funding of up to 50% for consultancy projects that will help them to become more competitive and increase the prospect of commercial growth and job creation. Beneficiary business can use this support to engage consultants they have previously worked with. A GROW-funded project can look at many aspects of the business, from bid writing, business strategy, technical consultancy, training, and capacity planning to product design, tooling, and financial metrics. In addition to this consultancy support, GROW offers Flexible Enabling Fund grant support of up to 500,000 GBP (643,500 EUR; 779,500 USD) toward the costs of tangible and intangible assets associated with businesses' investment plans, and toward the cost of jobs directly related to this investment. This support is available to SMEs and to large enterprises that fall within a European Commission-designated assisted area.

4.1.5 Offshore Wind Programme Board (OWPB)

The OWPB was established by the Secretary of State for Energy and Climate Change in November 2012 to build on extensive work on the cost reduction potential of the offshore wind sector. The OWPB aims to deliver cost reduction and enable growth of a competitive UK-based supply chain as the industry grows and matures. The Board's role is to identify and remove barriers to deployment of offshore wind generation, to share best practice across industry, and to bring forward innovative and collaborative solutions to build a competitive UK-based supply chain – supporting delivery of a LCOE of 100 GBP/MWh (129 EUR/MWh; 156 USD/MWh) for projects reaching the final investment decision in 2020.

4.1.6 The Industrial Doctorate Centre in Offshore Renewable Energy (IDCORE)

The Industrial Doctorate Centre in Offshore Renewable Energy (IDCORE) is a partnership of the Universities of Edinburgh, Strathclyde, and Exeter, the Scottish Association for Marine Science and HR-Wallingford. IDCORE was set up by the Energy Technologies Institute (ETI) and is funded by the ETI and the EPSRC RCUK Energy programme. The Centre will train up to 50 students in the research and skills needed to accelerate the development of renewable energy technologies. Each will spend part of their training with the three universities in the consortium. The students will spend most of their training time at ETI member companies, as well as in other renewable industry organizations and companies. The students will each gain an internationally-leading engineering doctorate. The drive to meet the UK's ambitious deployment targets for offshore renewable energy technologies requires a steady supply of highly trained engineers, scientists, and leaders.

4.1.7 Offshore Wind Accelerator (OWA)

The Offshore Wind Accelerator (OWA) is a collaborative R, D&D program bringing together nine offshore wind developers in a joint industry project to work towards reducing the cost of offshore wind by at least 10% by 2015. One third is funded by the UK government and two thirds from the industry. The OWA research development and demonstration program focuses on the following areas.

- Foundations: Developing new turbine foundation designs for 30–60 m water depths that are cheaper to fabricate and install
- Access systems: Developing improved access systems to transfer technicians and equipment onto turbines for operations and maintenance in heavier seas
- Wake effects: Improving the layout of large wind farms to reduce wake effects and optimise yields
- Electrical systems: Developing new electrical systems to reduce transmission losses and increase reliability
- Cable installation: Improving cable installation methods

4.1.8 The Low Carbon Innovation Co-ordination Group (LCICG)

The LCICG brings together the major public-sector backed funders of low carbon innovation in the UK. Its core members include the Department of Energy and Climate Change, the Department for Business, Innovation & Skills, the Carbon Trust, Energy Technologies Institute, the Technology Strategy Board, the Engineering and Physical Sciences Research Council, the Scottish government, the Scottish Enterprise. Several other organizations including the other devolved administrations have recently joined as associate members. The group's aims are to maximize the impact of UK public sector funding for low carbon energy, in order to:

- Deliver affordable, secure, sustainable energy for the UK;
- Deliver UK economic growth; and
- Develop UK's capabilities, knowledge and skills.

In 2014, the LCICG commissioned an update of the Technology Innovation Needs Assessment (TINA) of a range of low carbon technologies including offshore wind.

4.2 Collaborative research

There are a number of major collaborative EU research projects that the UK is participating in. These include LEANWIND, HiPRwind, and OPTIMUS.

LEANWIND (Logistic Efficiencies and Naval architecture for Wind Installations with Novel Developments) is a four-year project that started in December 2013. It is led by a 31-partner consortium and has been awarded 10 million EUR (12 million USD) by the European Commission, but its total value amounts to 15 million EUR (18 million USD). The primary LEANWIND objective is to provide cost reductions across the offshore wind farm lifecycle and supply chain through the application of lean principles and the development of state of the art technologies and tools.

HiPRWind is dedicated to creating and testing at the megawatt scale novel, cost effective approaches to floating offshore wind turbines. In order to gain real sea experience and data, a fully functional floating MW-scale wind turbine will be deployed within the five-year scope of the project at a European ocean test site. This research and testing installation is approximately 1:10 scale of the future commercial systems anticipated. Following a philosophy of "open architecture, shared access," results of general interest will be shared within the broader R&D community working on future wind energy solutions. As a world's first large scale real sea research and testing facility offering shared access, the installation will allow to address critical issues of deep offshore wind technology such as innovative floater designs, efficient installation methods, advanced control engineering solutions, and grid integration aspects of floating wind turbines. At the same time, R&D in the project will address the need for extreme reliability in particular of the power electronic components, new concepts for large rotors, and condition and structural health monitoring.

The Demonstration of Methods and Tools for the Optimisation of Operational Reliability of Large-Scale Industrial Wind Turbines (OPTIMUS), is a large collaborative FP7 research project being led by ORE Catapult to develop and demonstrate novel strategies to enable the prognosis of the remaining lifetime of key wind turbine components.

ORE Catapult is working with GnoSys, a Guildford-based technology innovation company, and power cable manufacturers and users, on a project to further develop a new generation of polymer blend-based cables to provide greater insulation, improving electrical connection reliability and increasing energy to power conversion. This follows a successful Innovate UK-funded project led by GnoSys Global and the University of Southampton called SUSCABLE.

The MAterials and REliability in offshore WINd Turbines technology (MAREWINT) is an FP7-funded project. Its Initial Training Network will provide a structured, integrated and multidisciplinary training program for the future offshore wind turbine technology experts. The consortium is composed of public and private organizations and based on a common research program; it aims to increase the skills exchange between the public and private sector.

The Regional Growth Fund Wind Innovation Project provides technical support and administration of 11 million GBP (14 million EUR; 17 million USD) fund for developing offshore wind supply chain in the UK. Delivering a total of six major technology projects (Romax Technology Ltd, University of Sheffield, TWI, HVPD, David Brown Gear Systems Ltd, and Siemens Transmission and Distribution Ltd) that are addressing key technical challenges associated with the offshore wind supply chain. To date the project has created 153 jobs and safeguarded 405 jobs in industry.

5.0 The Next Term

With a forecast installed base of over 20 GW the wind sector has established itself as a significant contributor to sustainable and secure energy and has demonstrated that with the right investment in innovation, costs can be reduced further. The first report from the CRMF provided strong evidence that the offshore wind sector in the UK is on track to reach 100 GBP/MWh (129 EUR/MWh; 156 USD/MWh) by 2020 and showed that there is a continued path for further cost reductions beyond that.

Electricity Market Reform has helped to reduce financial risk up to 2020 but the lower-than-forecast capacity allocation and the lack of certainty beyond 2020 could impact investment in new technology and slow down further technology development that will lead to cost reduction. The United Kingdom remains a world-leader in the wind sector, and 2014 has seen progress being made in terms of growth of installed capacity and electricity generated. The potential for the sector to deliver economic growth and significant employment has been demonstrated. The sector must work closely with policy makers in 2015 to ensure the benefits will be realized.

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Opening photo: Offshore windfarm in the United Kingdom.

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37 United States

1.0 Overview

The United States installed 4,854 MW of new capacity in 2014—more than four times the capacity installed by the wind industry in 2013. The nation's cumulative wind energy capacity now stands at 65,877 MW and provides 4.4% of the nation's electrical demand [1]. The United States led the world in wind energy generation in 2014 by generating more than 182 million megawatt-hours (MWh) of electricity. The 2014 generation avoided approximately 125 million metric tons of carbon dioxide emissions and the consumption of more than 68 billion gallons of water [1].

There are 18 offshore wind projects in 10 states under various stages of development. The U.S. offshore industry passed a major hurdle when Deepwater Wind secured project financing for its Block Island Wind Farm (BIWF). Construction on the BIWF, the nation's first offshore wind plant, will begin in 2015.

U.S. distributed wind capacity is nearing the 1 GW milestone. Distributed wind applications refer to wind power plants or turbines that are connected either physically or virtually on the customer side of the meter. With new capacity additions of 64 MW, in 2014 the cumulative installed of capacity of distributed wind systems in the United States reached a total of 906 MW from nearly 74,000 wind turbines. Though 64 MW in 2014 is more than twice the new capacity additions of 30 MW in 2013, it lags behind the 2008–2012 average of 120 MW of new capacity additions.

2.0 National Objectives and Progress

Although the U.S. government has no official targets for wind energy, a new *Wind Vision* study recently released by the U.S. Department of Energy (DOE), quantifies the benefits and economic impacts of current and potential future wind energy and examines the potential for wind to provide 35% of the nation's end use electricity by 2050. The analysis concludes that with continued investment in technology innovations and transmission system expansions, the study's ambitious deployment scenarios are viable.

2.1 National targets

The administration is working to achieve 100 MW of renewable capacity across federally subsidized housing by 2020, complete permits for 10 GW of renewable projects on public lands by 2020, deploy 3 GW of renewable energy on military installations by 2025, and double wind and solar electricity generation in the United States by 2025. The current administration also supports increasing the use of renewable energy technologies indirectly through proposed carbon pollution reduction rules that direct the U.S. Environmental Protection Agency (EPA) to work closely with states, industry, and other stakeholders to establish carbon pollution standards for both new and existing power plants (the Clean Power Plan).

2.2 Progress

Total U.S. wind capacity at the close of 2014 was 65,877 MW, generating a total of 181,791 GWh of electricity—enough to power nearly 17 million average U.S. homes. Wind grew by 7.7% in 2014 and generated 4.4% of all electricity, maintaining its position as the country's fifth largest electricity source. Approximately 2,500 turbines were installed in 19 different states in 2014, bringing the total fleet to more than 48,000 turbines.

In 2014, wind generation avoided approximately 125 million metric tons of carbon dioxide emissions and the consumption of more than 68 billion gallons of water.

Table 1. Key National Statistics 2014: United States	
Total (net) installed wind capacity	65,877 MW
New wind capacity installed	4,854 MW
Total electrical output from wind	182 TWh
Wind generation as percent of national electric demand	4.4%
Average national capacity factor	32.3%
Target:	Double wind and solar electricity generation in the United States by 2025
Bold italic indicates estimates	

The distributed wind market sector experienced mixed results in 2014. Sales of distributed wind systems using small wind turbines (<100 kW) continued to slide since coming off of highs in 2012, while systems using turbines greater than 100 kW in size showed signs of recovery. In 2014, exports continued to buoy U.S. small wind turbine manufacturers. The market value of exports from U.S.-based small wind turbine manufacturers in 2014 accounted for 75% of total sales, staying relatively stable at 11.2 MW compared to 13.6 MW in 2013.

There are 18 offshore wind energy projects comprising 1,500 MW of capacity in various stages of development. A 30-MW offshore wind project by Deepwater Wind passed a major milestone when it secured the funding needed to begin construction. Deepwater's offshore wind project, off the coast of Block Island, Rhode Island, is expected to go online in late 2016.

2.3 National incentive programs

Although federal and state level incentives have both helped stimulate the growth of the wind industry, one of the most impactful federal incentives for utility-scale development in the past has been the renewable energy production tax credit (PTC). Originally enacted in 1992, the PTC is an inflation-adjusted per-kilowatt-hour tax credit for electricity generated by qualified facilities. The PTC expired at the end of 2013. Although it was not extended until just a few weeks before it expired again at the end of December 2014, the effective date was 1 January 2014, meaning any qualifying project that commenced construction at any point in 2014 is eligible to claim the tax credit.

The investment tax credit (ITC) currently allows for a 30% credit on the cost of development for small and residential wind turbines with capacity ratings of less than 100 kilowatts with no maximum credit for small wind turbines placed in service after 31 December 2008.

Other federal incentives include the Tribal Energy Grant Program that supports renewable energy efforts on Native American lands, the High Energy Cost Grant Program that has funded the installation of wind turbines in rural areas, and the Rural Energy for America Program, which provides both grants and loans to agricultural producers and small businesses in rural areas.

On the local level, states and other municipal authorities may institute renewable portfolio standards (RPS), which require utilities to purchase some percentage of their power from renewable sources. This has been a major driver of wind energy deployment. As of September 2014, 29 states, the District of Columbia, Puerto Rico, and the Northern Marianas Islands have RPS. Another nine states, Guam, and the U. S. Virgin Islands have renewable portfolio goals. Other policies that encourage wind deployment include carbon-reduction policies, customer demand for renewable power, utility requirements, and local funding.

2.4 Issues affecting growth

Factors affecting the growth of the U.S. wind industry include federal and state energy policies, the cost of wind energy, access to transmission, and siting challenges.

2.4.1 Federal and state policies

Inconsistent policy for wind energy has slowed the growth of the wind industry in recent years, as exemplified by the expirations of the PTC and the Advanced Energy Manufacturing Tax Credit Program. The PTC was allowed to expire in 2013, was extended for a couple of weeks at the end of 2014, and then expired again in January 2015. The decrease in annual installed capacity in 2013 and 2014 compared to recent years coincide with these expirations. Short-term extensions of the PTC have proven insufficient for sustaining the long-term growth of the wind industry because the planning and permitting process for a wind plant can take up to two years or longer to complete.

2.4.2 Cost of wind energy

Risk and uncertainty associated with wind technology present a barrier to industry and manufacturing. Low natural gas and wholesale electricity prices combined with a reduced demand for electricity since 2008 have impacted investments for all new electric generation. Annual U.S. wind capacity additions vary as a function of these factors as well as trends in wind power costs and policy.

2.4.3 Transmission and integration

The growth of wind deployment has been impeded in some areas by a lack of access to transmission. An example of one effort to address this issue is the Competitive Renewable Energy Zones Plan in Texas that expanded transmission lines between the wind-rich areas of the state and its population centers. By early 2014, interconnection agreements had been signed for proposed projects totaling 7 GW and applications had been submitted for 24 GW of wind power.

The variable nature of wind generation and whether high penetration of wind or other renewable sources would cause cycling impacts on current fossil-fuel power plants has been another area of concern for the nation's utilities industry. To identify ways to address this, the U.S. DOE is funding large-scale, multiyear studies into the impacts of high renewable integration in utility systems.

2.4.4 Siting challenges

Siting challenges include social resistance to wind installations because of perceived or actual visual or acoustic impacts, interactions of wildlife with wind technology, and radar interference. DOE continues to support efforts to identify and mitigate such issues.

2.4.5 Factors affecting distributed wind growth

Factors that affect the growth of distributed wind include inconsistent zoning regulations and permitting processes, difficulty in financing, lower cost electricity from other distributed generation power sources, and technology certification.

3.0 Implementation

There are now 16 states with more than 1,000 MW of installed wind project capacity. Three states generated more than 20% of their electricity from wind energy in 2014, seven states generated more than 15%, and nine states produced more than 10%.

In November 2014, the Bureau of Ocean Energy Management (BOEM) offered the first right-of-way grant in federal waters off the Atlantic Coast to the Deepwater Wind Block Island Transmission System, LLC, for the installation of a bi-directional submerged transmission cable between Block Island and the Rhode Island mainland. The cable will connect the nation's first 30-MW Block Island offshore wind farm to the Rhode Island mainland and transmit power from the existing land-based transmission grid on the mainland to Block Island.

3.1 Economic impact

According to the American Wind Energy Association, since 2008 the U.S. wind industry has generated more than 100 billion USD (82.6 billion EUR) in private investments, 8.0 billion USD (6.6 billion EUR) was invested into new wind energy projects in 2014, and by the end of the year, more than 12,700 MW of wind energy capacity was under construction across 98 projects. The wind energy industry brought 26,700 new jobs to the American workforce in 2014 bringing the total number of people employed to 73,000 with 19,200 in the manufacturing sector.

3.2 Industry status

At the end of 2014, there were more than 500 wind-related manufacturing facilities across 43 states, producing everything from major components like blades, nacelles, and towers down to bearings, fasteners, and sensors. GE Energy led the wind turbine manufacturing sector in 2014, capturing 42% of the cumulative market, followed by Vestas with 18%, and Siemens with 15%.

More than 3,300 MW of new wind power purchase agreements were announced in 2014, bringing the total long-term power purchase agreements signed in the 2013–2014 timeframe to more than 11,000 MW. More than 60 non-utility entities have invested in wind energy, including Amazon, Yahoo!, Walmart, Google, Microsoft, IKEA, and Mars.

3.3 Operational details

By the end of 2014, the U.S. fleet had more than 956 projects comprising more than 48,000 wind turbines—2,500 of those were installed in 2014. The average project size was 118 MW (excluding wind projects with a single wind turbine) and the average turbine size was 1.94 MW. The average rotor diameter of the turbines installed in 2014 was 99.7 m and the average hub height was 82.4 m.

3.4 Wind energy costs

According to the Lawrence Berkeley National Laboratory, data based on a limited sample of recently announced U.S. turbine transactions shows the current wind turbine price per kilowatt in the 850–1,250 USD (702–1,033 EUR) range.

4.0 Research, Development, and Demonstration Activities

The DOE Wind Program works with industry partners, national laboratories, universities, and other federal agencies to conduct R&D activities through competitively selected, directly funded, and cost-shared projects that produce innovative technologies for land-based, offshore, and distributed wind applications. The total budget for wind energy R, D&D in 2014 through the DOE Wind Program was 88 million USD (73 million EUR) [2].

In 2014, the Wind Program launched a new initiative to develop a renewed vision for long-term U.S. wind power R, D&D. The new *Wind Vision Report*, published in 2015, includes a roadmap addressing the challenges to achieving 35% wind energy by 2050, which will inform the DOE Wind Program's R&D future investments.

Wind Program representatives also worked with industry stakeholders in 2014 to develop a research plan for its multi-year Atmosphere to Electrons (A2e) initiative. The main objective of A2e is to gain a better understanding of the underlying physical processes and causal effects driving wind plant underperformance. The goals of the research plan are to optimize existing wind plant performance, facilitate seamless grid integration at high penetrations, and improve wind plant performance through the development of next-generation technology.

4.1 U.S. R, D&D efforts

4.1.1 Offshore wind

Three offshore wind demonstration projects will receive up to 47 million USD (38.8 million EUR) each over the next four years to deploy innovative, grid-connected systems in federal and state waters. Fishermen's Energy will deploy up to six wind turbines with a total capacity of at least 20 MW with twisted-jacket foundations off the coast of New Jersey. Principle Power will install a wind plant that will have a capacity of up to 30 MW on semi-submersible floating foundations in deep water off the coast of Oregon. Dominion Virginia Power will install two 6-MW direct-drive wind turbines off the coast of Virginia that utilize a twisted jacket foundation. Two other DOE demonstration projects, University of Maine and Lake Erie Energy Development Corporation (LEEDCo), received additional funding to pursue design and engineering work of their innovative floating and icebreaking foundations, respectively.

Two new offshore reports published in 2014 provide a detailed analysis of the current U.S. offshore wind market and examine the impacts of offshore wind energy on the national transmission system; *Offshore Wind Market and Economic Analysis* [3] and *National Offshore Wind Energy Grid Interconnection Study (NOWEGIS)* [4].

DOE's Pacific Northwest National Laboratory deployed one of two specialized research buoys near Virginia Beach, Virginia. The buoys are equipped with lidar and other advanced instruments that measure wind speed and direction throughout the rotor swept area while recording air and sea surface temperature, barometric pressure, relative humidity, wave height and period, water conductivity, and subsurface ocean currents.

DOE is also working with the National Oceanic and Atmospheric Administration (NOAA) to collect data that will help the wind industry better understand the extreme hurricane conditions that turbines installed on the Atlantic and Gulf Coasts will need to withstand. NOAA is using high-tech airplanes equipped with Doppler to drop sensors into developing storms that measure temperature, pressure, wind speed, and direction.

4.1.2 Wind research and test facilities

Commissioning activities continued at the Clemson University's Drivetrain Test Facility. The Clemson facility has two dynamometers capable of testing wind turbine drivetrains up to 7.5 MW or up to 15 MW. The facility is also equipped with a grid simulator that mimics real-world circumstances such as wide-area power disruptions and frequency fluctuations to determine the effects of wind turbines on utility grids and of grids on wind turbines. A 5-MW dynamometer test facility at the National Renewable Energy Laboratory (NREL) in Colorado can test drivetrains with capacity ratings up to 5 MW and can be connected directly to the grid or to a controllable grid interface (CGI) to give engineers a better understanding of how wind turbines react to grid disturbances. NREL's CGI can also be connected either to wind turbines in the field or to electronic and mechanical storage devices undergoing a test. The SWiFT facility at Texas Tech University is the first U.S. facility specifically designed to tackle the challenges of DOE's wind plant optimization R&D efforts, which aim to increase the performance and reliability of wind technologies. When complete three highly modified and upgraded wind turbines constructed on the SWiFT site will serve as the first phase of DOE's work to understand the complex wind flow and wakes within a wind plant.

4.1.3 Emerging technology applications

DOE's NREL worked with industry partners to complete the fabrication of a new gearbox and power converter software as a part an ongoing project to create an innovative drivetrain. The new drivetrain can increase reliability, improve efficiency, and significantly reduce the cost of wind energy and can be scaled up to ratings as high as 10 MW.

DOE's Argonne National Laboratory is working with AML Superconductivity and Magnetics to develop a superconducting generator for large-scale, high efficiency offshore wind turbines. The direct-drive generator will make a magnetic field using superconducting windings that are more powerful and compact than copper-based alternatives. They are also constructed of more readily available and lower-cost materials than permanent-magnet-based generators, and AML estimates the new generator will weigh up to 50% less.

To better understand the characteristics of wind at turbine hub height and improve short-term forecasting skills, DOE is working with NOAA, national labs, and private companies to collect wind speed, direction, and duration data at turbine hub heights using radar and other experimental wind profiling equipment [6].

4.1.4 Manufacturing and supply chain

DOE supported an NREL study titled *Analysis of Transportation and Logistics Challenges Affecting the Deployment of Larger Wind Turbines*. Pursuant to these findings, DOE awarded funding to several projects in 2014 to advance the manufacturing processes and reduce the costs and logistical constraints associated with transporting the larger towers required for the latest utility-scale wind turbine configurations.

Two projects were awarded a total of 2.0 million USD (1.6 million EUR) to advance the manufacturing of taller wind turbine towers. Keystone Tower of Boston, Massachusetts, is adapting a spiral welding system commonly used for pipe manufacturing in the oil and gas industries to roll raw materials into tapered tower sections on-site, requiring as little as 10% of the labor used by the current tower manufacturing process and enabling use of wider, thinner base sections. Iowa State University is developing a modular hexagonal-shaped tower approach that combines high-strength concrete with pre-stressed steel reinforcements to assemble individual tower modules and wall segments that can be easily transported and joined together on-site.

Wetzel Engineering, Inc., of Lawrence, Kansas, received a Small Business Innovation Research Phase 2 grant of 1 million USD (826,000 EUR) to commercialize its process for manufacturing longer blades. Wetzel is combining two technologies—sectional component-based assembly and in-field assembly—to produce turbine blades that can be transported in smaller sections and assembled on site.

4.1.5 Distributed wind applications

DOE announced several new projects to be funded under its Competitiveness Improvement Project (CIP) in 2014. The CIP helps U.S. manufacturers of small and mid-sized wind turbines improve their design and manufacturing processes to reduce costs, improve performance, and obtain certification.

Northern Power Systems of Barre, Vermont, is developing an innovative blade designed for low wind speed applications and will model and test an advanced control method to increase the amount of energy produced by its turbine. Urban Green Energy of New York City, New York, will subject its 1-kW vertical-axis wind turbine to extensive third-party testing by a regional test center. Pika Energy, of Westbrook, Maine, is upgrading its manufacturing processes and improving core wind turbine components. Endurance Wind Power, of Spanish Forks, Utah, will conduct testing on its prototype turbine with an expanded rotor that allows for a larger wind-swept area.

DOE has made significant investments to establish a framework for small wind turbine certification in the United States. Certification and quality assurance requirements promote safe, reliable products that can be adopted by local planning officials, utilities, banks, state energy offices, and federal agencies to ensure consumer protection and industry credibility. By 2020, DOE's goal is to increase the number of certified small and medium wind turbine designs to 40.

4.1.6 Grid system integrations, planning, and operations

NREL completed the third and final phase of the Western Wind Integration Study (WWSIS) [7]. The WWSIS is one of the largest regional solar and wind integration studies to date. It explores whether large amounts of wind and solar energy can be integrated into the western electric power system. The third phase of the study specifically found that the Western grid could weather disturbances under high renewable penetrations.

NREL, the Electric Power Research Institute, and the University of Colorado published a report on Active Power Controls from Wind Power [8]. The studies detailed in this report show that careful design of the ancillary services markets will result in increased revenue when wind plants provide these services, and careful design of control systems will result in responses that have negligible impacts on turbine loading and will improve power system reliability.

The National Offshore Wind Energy Grid Interconnection Study (NOWEGIS) was also published in 2014. The report considered the availability and potential impacts of interconnecting large amounts of offshore wind energy into the transmission system of the lower 48 contiguous United States and found that deployment and integration of 50+ GW of offshore wind was feasible with existing integration technologies and practices, though significant market and institutional challenges remain to offshore deployment [4].

4.1.7 Workforce development and stakeholder engagement

DOE held its first Collegiate Wind Competition in 2014 to challenge interdisciplinary teams of undergraduate students to develop a solution to a complex wind energy project. More than 150 students from ten universities across the nation participated to design, build, and test model wind turbines to perform according to market data-derived business plans. They demonstrated their knowledge of key market drivers and deployment acceleration challenges and opportunities. Pennsylvania State University won the competition. The next competition will be held in 2016. Twelve universities have already been selected to compete.

DOE also supported the formation of six new Wind Energy Regional Resource Centers. The centers provide region-specific wind energy information to communities and decision makers to help them evaluate wind energy in their areas. The centers impacted more than 10,000 key stakeholders in 2014.

4.1.8 Siting, radar, and environmental studies

DOE, in conjunction with the Department of Defense, Department of Homeland Security, Federal Aviation Administration, and National Oceanic and Atmospheric Administration, released the final results of the 8 million USD (6.6 million EUR) Integrated Field Test and Evaluation Campaign (IFT&E), a set of field studies evaluating technologies to mitigate the impact of wind energy facilities on long-range surveillance and air terminal radars. The IFT&E reports show that a number of mitigation measures have promise in reducing or eliminating wind turbine radar interference but that further work is needed to validate their long-term performance at operating wind facilities.

DOE, NREL, and AWS Truepower LLC released maps that illustrate the potential for wind energy development using more advanced wind turbine technologies (Figure 1).

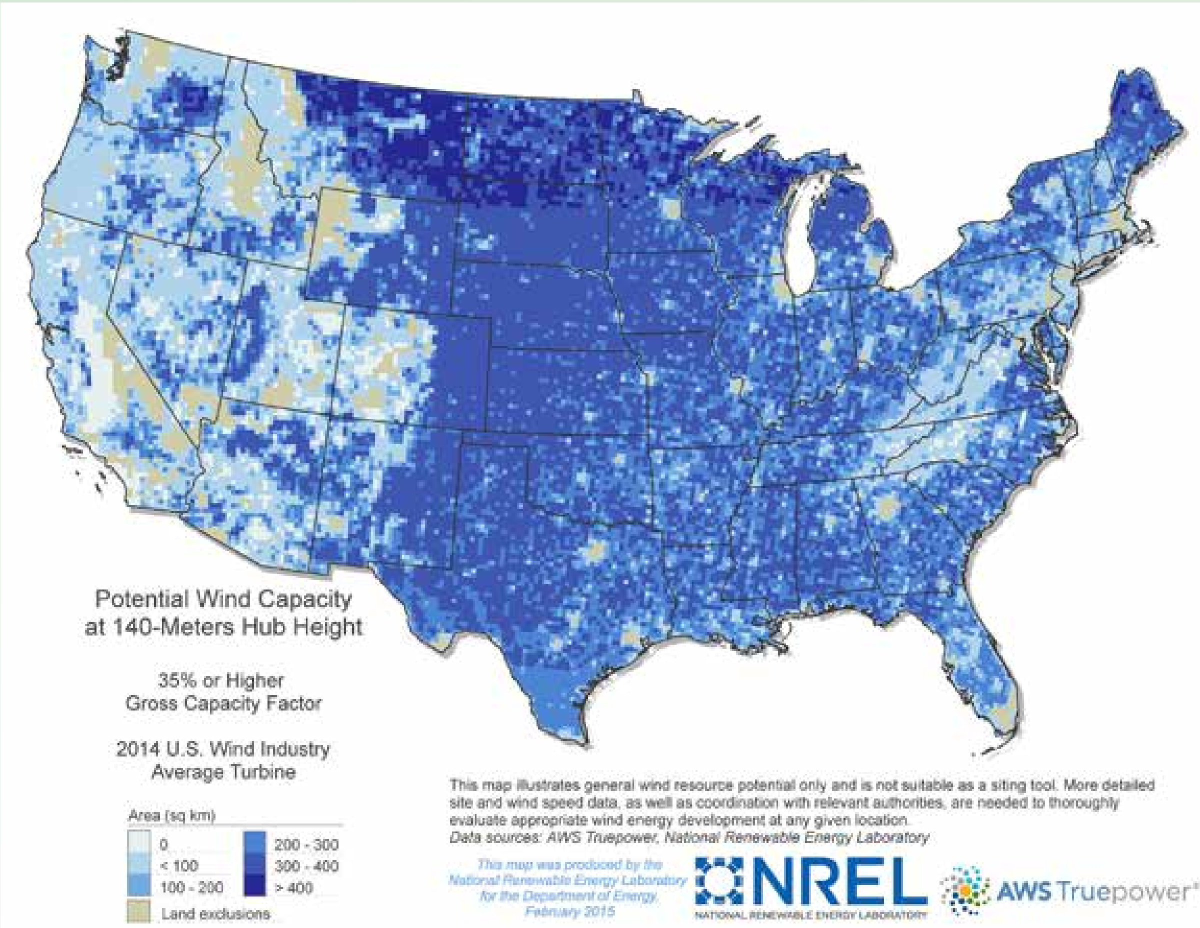

Figure 1. New map showing U.S. wind capacity potentials for turbines with 140-m hub height or greater

Because stronger and more consistent winds are typically found at higher heights, these new maps show the concentration of land areas with gross capacity factors over 35% at turbine hub heights of 110 and 140 meters (361 and 459 feet), representing recent and planned turbine advancements. DOE estimates that enabling the cost-effective deployment of wind turbines with hub heights up to 140 meters will unlock additional wind power resource potential across 1,137,565 square miles of the United States.

The American Wind and Wildlife Institute hosted a Wind Wildlife Research Meeting in 2014 that drew more than 330 participants from around the world. The meeting focused on relevant wind-wildlife topics being addressed by industry, policy-makers, conservation groups, and scientists.

DOE is leading an international effort to address the environmental effects of wind energy technology. The International Energy Agency (IEA) Wind Task 34, also known as WREN (Working together to Resolve Environmental effects of wind eNergy), focuses on two key activities: develop an online platform to facilitate the broad sharing of information about the impacts of wind energy deployment and expedite collaboration; and develop white papers on environmental topics important to the large-scale deployment of wind energy.

4.2 International collaborations

The DOE Wind Program supported many research efforts conducted under international collaborations in 2014. These efforts included work with:

- Bats and Wind Energy Cooperative
- International Electrotechnical Commission (IEC)
- Institute of Electrical and Electronics Engineers (IEEE); Underwriters Laboratory (UL)
- International Measuring Network of Wind Energy Institutes
- Technical University of Delft (Netherlands)
- Det Norske Veritas-Germanischer Lloyd (DNV-GL)
- Nanyang Technological University (Singapore)
- Norwegian Research Centre for Offshore Wind Technology
- National Renewable Energy Centre (United Kingdom)
- National Renewable Energy Centre (CENER) of Spain

U.S. representatives also participated in research conducted for most of the IEA Wind tasks in 2014 and serve as operating agents for Task 26 Cost of Wind Energy; Task 30 Offshore Code Comparison Collaboration Continuation with Correlation (OC5) Project; and Task 34 Assessing Environmental Effects and Monitoring Efforts for Offshore and Land-Based Wind Energy Systems (WREN).

5.0 The Next Term

DOE's new *Wind Vision Report* published in April 2015 provides a roadmap for future R&D activities that will focus on three themes: reducing the cost of wind energy, expanding developable areas, and increasing the economic value for the nation. The roadmap—which was developed through a collaborative effort led by DOE, with contributions and rigorous peer review from industry, the electric power sector, environmental stewardship organizations, academia, national labs, and participants at various levels of government—sets the stage for the future collaborative efforts required to achieve the industry growth outlined by the study's scenario: wind energy supplying 10% of the country's electricity in 2020, 20% in 2030, and 35% in 2050. The Wind Vision roadmap provides a portfolio of actions for achieving the scenario that covers the major domestic wind applications on land and offshore and a framework that defines specific activities at greater levels of detail.

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Opening photo: Cedar Creek Wind Farm, Grover, Colorado (Photo credit: Dennis Schroeder, NREL 3120)

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Author: United States Department of Energy.

Appendix A

ExCo 74 Meeting in Charlottetown, Canada (Credit: Rick Hinrichs)

Appendix B

IEA WIND EXECUTIVE COMMITTEE 2014

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Appendix C

Currency Conversion Rates for IEA Wind 2014 Annual Report			
Country	Currency	1 EUR	1 USD
Austria	EUR	1.000	1.211
Canada	CAD	0.712	0.863
China	Yuan	0.133	0.161
Denmark	DKK	0.134	0.163
Finland	EUR	1.000	1.211
France	EUR	1.000	1.211
Germany	EUR	1.000	1.211
Greece	EUR	1.000	1.211
Ireland	EUR	1.000	1.211
Italy	EUR	1.000	1.211
Japan	JPY	0.0069	0.0084
Korea	KRW	0.0007	0.00092
México	MXP	0.056	0.068
Netherlands	EUR	1.000	1.211
Norway	NOK	0.111	0.134
Portugal	EUR	1.000	1.211
Spain	EUR	1.000	1.211
Sweden	SEK	0.106	0.128
Switzerland	CHF	0.832	1.007
United Kingdom	GBP	1.287	1.559
United States	USD	0.826	1.000
Source: Federal Reserve Bank of New York (www.x-rates.com) 31 December 2014			

Appendix D

Appendix D Abbreviations and Terminology

availability: the percentage of time that a wind plant is ready to generate (that is, not out of service for maintenance or repairs)

balancing cost: system operating cost increases arising from wind variability and uncertainty

capacity factor: a measure of the productivity of a wind plant that is the amount of energy the plant produces over a set time period, divided by the amount of energy that would have been produced if the plant had been running at full capacity during that same time interval. For wind turbines, capacity factor is dependent on the quality of the wind resource, the availability of the machine (reliability) to generate when there is enough wind, the availability of the utility distribution system (no curtailment), and the accuracy of nameplate rating. Most wind power plants operate at a capacity factor of 25% to 40%.

CCGT: combined cycle gas turbines

CCS: carbon capture and sequestration (or storage)

CHP: combined heating and power or cogeneration of heat and power

CIGRE: International Council on Large Electric Systems

CO_2e: carbon dioxide equivalent

COE: cost of energy

CSP: concentrating solar power

DFIG: doubly-fed induction generator

DSM: demand side management

EC: European Commission

EIA: environmental impact assessment

ENARD: Electricity Networks Analysis, Research and Development an IEA Implementing Agreement

EU: European Union

ExCo: Executive Committee (of IEA Wind)

feed-in tariffs (FIT): mandates for utilities to buy the electricity fed into the grid by system owners at a fixed price over the long term. The cost is then redistributed over all electricity customers.

flicker: when the operating turbine blades cast shadows on the observer

full load hours: the (calculated) amount of time the generators would have run at full capacity to produce the electricity they actually generated in the year. A year has 365 days, hence 8,760 potential full load hours.

full-time equivalent (FTE)

FY: fiscal year

GEF: Global Environment Facility

GHG: greenhouse gas

GIS: geographical information system

GL: Germanischer Lloyd certification body

GW: gigawatt (1 billion Watts)

GWh: gigawatt hour = 3.6 Terajoules

h/a: hours annual

HAWT: horizontal axis wind turbine

hydro: hydroelectric power

IEA: International Energy Agency

IEC: International Electro-Technical Commission

IEEE: Institute of Electrical and Electronics Engineers

IPP: independent power producer

ISO: international standards organization

IT: information technology

kW: kilowatt (one thousand Watts)

kWh: kilowatt hour

LCOE: levelized cost of electricity; the present value of total costs divided by the present value of energy production over a defined duration

lidar: a combined term from "light" and "radar." Uses atmospheric scattering of beams of laser light to measure profiles of the wind at a distance.

LVRT: low-voltage ride-through

m: meter

m a.g.: meters above ground

m.a.s.l.: meters above sea level

MDAO: Multi-disciplinary design, analysis, and optimization

Mtoe: million tonnes of oil equivalent

MW: megawatt (one million Watts)

MWh: megawatt hour

m/s: meters per second

NA: not applicable (or not available)

NGO: non-governmental organizations

OA: operating agent that manages the work of a research task

OEM: original equipment manufacturer

O&M: operations and maintenance

penetration rate: the share of total wind generation relative to total end-use energy demand, expressed as a percentage

PJ: peta joule

PPA: power purchase agreement

PSO: public service obligation

PV: photovoltaics or solar electric cells

R&D: research and development

R, D&D: research, development, and deployment

RE: renewable energy

RES: renewable energy systems (or sources)

repowering: taking down old turbines at a site and installing newer ones with more generating capacity

RO: renewables obligation

rotor: the blades attached to the hub

RPS: renewables portfolio standard

SCADA: supervisory control and data acquisition

semi-offshore projects: projects in the tidal zone or in very shallow water

SME: small- and medium-sized enterprises

specific power: the ratio of generator nameplate capacity (in watts) to the rotor-swept area (in m^2)

tCO_2-e per capita: metric tonne of carbon dioxide emissions per person

TNO: transmission network operator

Toe: metric tonne of oil equivalent

TSO: transmission system operators

TWh: terawatt hour (one trillion watt hours)

UN: United Nations

UNDP: United Nations Development Programme

VAT: value added tax

VAWT: vertical axis wind turbine

wind index: the energy in the wind for the year, compared to a normal year.

wind farm: also referred to as wind park or wind plant, a group of wind turbines interconnected to a common utility system.

WT: wind turbine

Yr: year

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Front cover photo: Tugliq Énergie Enercon 3-MW turbine at Raglan Mine, Quebec, Canada with aurora borealis (Credit: Justin Bulota)

Back cover photo: Offshore wind farm and meteorological tower in the United Kingdom.

Notes

Notes