IEA WIND
2013 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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Message from the Chair

Welcome to the IEA Wind 2013 Annual Report of the cooperative research, development, and deployment (R, D&D) efforts of our member governments and organizations. IEA Wind helps advance wind energy in member countries, which together represent nearly 85% of the world's wind generating capacity. In 2013, the members voted to continue this successful co-operation for another five-year term. To support this extension, they worked to report the accomplishments of the last term and developed a strategic plan for the coming period.

Data from the IEA Wind member countries in 2013 illustrate key effects of improved wind plant design. Wind capacity (in gigawatts) increased a modest 12% but electrical production from wind (in terawatt-hours) increased a full 21%. The 270 gigawatts of wind capacity met 3.86% of the total electrical demand represented by these countries, up from 3.3% in 2012.

In 2013, IEA Wind held Topical Experts Meetings focused on advances in forecasting techniques and on overcoming the challenges of deploying wind projects in hilly or forested environments. Both of these topics are important to continued expansion of wind energy. The IEA Wind members also approved Recommended Practices about social acceptance of wind energy projects, remote sensing for wind resource assessment, and on conducting wind integration studies.

Looking forward, IEA Wind approved a new research task to develop recommended procedures for ground-based testing of full-size wind turbines and their components. Supporting the increased use of ground-based testing will reduce the costs of developing advanced technologies ready for the expanding market on land and offshore. The 13 co-operative research tasks of IEA wind offer members many options to gain access to research results many times greater than could be accomplished in any one country.

With market challenges and ever-evolving research issues to address, IEA Wind co-operative efforts continue to advance wind energy's role in the world's energy supply.

JMAhlgrimm

Jim Ahlgrimm
Chair of the Executive Committee, 2013–2014

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1 Executive Summary

While wind power installed capacity increased 12% over the 2012 level, electricity production from wind increased 21% in IEA Wind member countries.

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Total installed capacity	268.84 GW
Total offshore wind capacity*	6.59 GW
Total (net) new wind capacity installed 2013 On land 27.20 GW Offshore 2.01 GW	Total new 29.21 GW
Total annual output from wind	541.7 TWh
Wind generation as a percent of IEA Wind members' national electric demand	3.86%

* 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.

1.0 Introduction

At the close of 2013, wind generation was meeting nearly 4% of the world's electricity demand (WWEA 2014) with 318.1 GW of wind power operating in 103 countries (GWEC 2014). Nearly 85% of the world's wind generating capacity resides in the 21 countries participating in the International Energy Agency (IEA) Wind Implementing Agreement (IEA Wind), an international co-operation that shares information and research activities to advance wind energy deployment. These IEA Wind member countries added nearly 30 GW of capacity in 2013, which is almost 83% of the worldwide market for the year. With approximately 270 GW of wind generating capacity, electrical production from wind met 3.86% of the total electrical demand in the IEA Wind member countries (Tables 1–4).

This *IEA Wind 2013 Annual Report* contains chapters from each member country and from the Chinese Wind Energy Association (reporting on the People's Republic of China) and the European Wind Energy Association (EWEA) and European Commission reporting on activity in European Union (EU) countries. 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 IEA Wind active 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 from the past 16 years, as reported in

Table 2. National Statistics of the IEA Wind Member Countries 2013								
Country	Total installed wind capacity (MW)	Total offshore installed wind capacity* (MW)	Annual net increase in capacity (MW)	Total number of turbines	Average capacity of new turbines (kW)	Wind-generated electricity (TWh/yr)	National electricity demand (TWh/yr)	National electricity demand from wind** (%)
Australia***	3,239	0	655	1,651	---	9.2	***226.0***	***4.1%***
Austria	1,684	0	309	113	2,730	3.6	62.0	5.8%
Canada	***7,803***	0	1,599	4,377	2,000	***17.5***	560.0	3.1%
China	91,413	428	16,089	63,120	1,719	137.1	5,245.1	2.6%
Denmark	4,808	1,271	644	5,194	3,132	11.1	34.0	32.7%
Finland	448	26	190	210	3,200	0.8	83.9	0.9%
Germany	34,660	903	3,356	23,864	on land 2,598 offshore 4,485	53.4	600.1	8.9%
Greece***	1,865	0	116	1,357	1,145	3.3	57.0	5.8%
Ireland	1,896	25	133	---	---	***4.5***	***27.9***	***16.3%***
Italy	8,554	0	434	6,391	2,014	***14.9***	***317.1***	***4.7%***
Japan	2,670	50	***56***	1,925	1,474	4.0	845.5	0.5%
Korea	561	2	74	326	1,721	0.9	532.2	***0.2%***
México	1,551	0	426	***1,071***	2,000	***3.9***	***249.0***	***1.5%***
Netherlands	2,709	228	281	***2,160***	2,729	5.6	120.3	4.7%
Norway	811	2	98	356	2,500	1.9	129.2	1.4%
Portugal	4,709	2	192	2,739	***2,000***	11.9	50.6	23.5%
Spain	22,959	0	175	20,252	1,980	54.3	260.0	20.9%
Sweden	4,469	0	862	2,681	2,912	9.9	139.0	***7.0%***
Switzerland	60	0	11	***34***	***2,216***	***0.1***	***63.7***	***0.2%***
United Kingdom	10,861	3,653	2,422	5,413	---	26.1	375.9	***6.0%***
United States	61,110	0	1,087	46,044	1,870	167.7	4,058.2	***4.1%***
Totals/Average	268,840	6,590	29,209	***189,278***		541.7	14,036.7	3.86%****

Bold italic indicates estimates
* A subset of total capacity
** Total TWh from Wind/TWh total national electric demand x 100
*** (GWEC 2014)
**** Overall contribution to IEA Wind Member countries (total wind generated electricity/total electricity demand) x 100

Table 3. Worldwide Installed Wind Capacity for 2013

IEA Wind members*		Rest of world**	
Country	MW	Country	MW
China	91,413	India	20,150
United States	61,110	France	8,254
Germany	34,660	Other countries***	4,820
Spain	22,959	Brazil	3,461
United Kingdom	10,861	Poland	3,390
Italy	8,554	Turkey	2,959
Canada	***7,803***	Romania	2,600
Denmark	4,808	New Zealand	623
Portugal	4,709	Taiwan	614
Sweden	4,469	Egypt	550
Australia**	3,239	Chile	335
Netherlands	2,709	Morocco	291
Japan	2,670	Thailand	223
Ireland	1,896	Argentina	218
Greece**	1,865	Ethiopia	171
Austria	1,684	Costa Rica	148
México	1,551	Nicaragua	146
Norway	811	Pakistan	106
Korea	561	Tunisia	104
Finland	448	Honduras	102
Switzerland	60	**Total Rest of World**	**49,265**
Total IEA Wind	**268,840**	**Grand Total**	**318,105**
* Numbers reported by IEA Wind member countries ***Bold Italic*** indicates estimate		** Numbers reported by GWEC (2014) *** Countries not in this list or in IEA Wind	

previous IEA Wind documents (IEA Wind 1995–2012), are included as background for discussions of 2013 events.

2.0 National Objectives and Progress

IEA's updated Technology Roadmap for Wind Energy (IEA 2013) 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 2013, wind energy supplied 4% of global electricity. IEA Wind member governments and industries establish national targets for 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 16). 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 (Table 4). Some of these countries also have specific goals or targets for generation capacity of wind energy or wind energy contributions to electricity supply as part of their long-term energy strategies. National targets in several countries include separate goals for wind on land and offshore.

In response to European Union (EU) Directive 2009/28/EC, all EU member states have submitted National Renewable Energy Action Plans (NREAPs) detailing sectoral- and technology-specific targets and policy measures to reach the renewable energy systems target of 20% by 2020. As shown in Table 4, each country has goals adapted to its domestic situation.

Outside of Europe, planning is underway to increase wind power development. Canada set the goal to reduce GHG emissions by 17% below 2005 levels by 2020. The Chinese Plan of Action for Prevention and Control of Atmospheric Pollution proposed a 13% increase in non-fossil energy consumption by 2017. In Japan, a draft Basic Energy Plan published in 2013 and an industry roadmap confirm goals for renewable energy and identify issues to be solved. The Republic of Korea is shifting attention to wind and solar photovoltaics (PV) as alternatives to biomass as the main renewable resource. México is on track for wind generation to supply approximately 5% of electric consumption by 2024. In the United States, the President's Climate Action Plan was released in 2013 to reduce greenhouse gas emissions and an update of the 2008 report, 20% Wind Energy by 2030, will be published in 2014 to describe progress and lay out a roadmap for an expanded U.S. Wind Vision.

2.2 Progress

2.2.1 Capacity increases

In 2013, IEA Wind member countries added 29.21 GW of net wind capacity, which is less than the 36.76 GW added in 2012 and the smallest capacity increase since 2009 (Table 5). As shown in Table 6, despite this overall decline in new deployments, nine countries increased capacity by more than 20% in 2013: Finland (67%), México (35%), United Kingdom (29%), Canada (26%), Australia (25%), Sweden (24%), Austria (22%), Switzerland (22%), and China (21%).

Eleven countries installed more capacity in 2013 than in 2012: Australia, Austria, Canada, Denmark, Finland, Germany, the Netherlands, Portugal, Sweden, Switzerland, and the United Kingdom. Five countries installed more than 1 GW: China (16.09 GW), Germany (3.36 GW), the United Kingdom (2.42 GW), Canada (1.60 GW), and the United States (1.09 GW) (Table 2). Australia, Denmark, Italy, México, and Sweden added more than 400 MW each. In all, 17 countries added more than 100 MW of new capacity. However, these additions to the total of new deployments in 2013 were more than offset by the dramatic *decline* in new installations in four countries: the United States, China, Spain, and Italy. Explanation for these declines can be found in the country chapters.

As a whole, capacity has increased in the IEA Wind member countries from less than 5 GW in 1995 to more than 268.8 GW in 2013 (Figure 1).

2.2.2 Electrical production

Although wind generation *capacity* only increased 12% in 2013, electrical *production* from wind increased 21%. These data suggest that new wind turbines are more productive per megawatt of rated capacity. Countries report that some of this increased productivity is due to better grid connection (reduced curtailment), as well as improved hardware and better wind plant siting and design.

Total wind energy electrical production from all IEA Wind member countries increased by 94.6 TWh in 2013. National electrical output from wind energy increased in all member countries except Japan. Meanwhile, total electrical demand from these countries increased by 339.2 TWh in 2013. Total electrical demand *increased* in Austria, China, Germany, Ireland, Korea, Portugal, Spain, Switzerland, the United Kingdom, and the United States; *stayed the same* in the Netherlands; and *decreased* in Canada, Denmark, Finland, Italy, Japan, México, Norway, and Sweden.

Electrical production is influenced by the quality of the wind resource for the year, the operating availability of the wind plants, and the consistency of the transmission grid availability. Regarding the wind resource, correcting annual production to wind indexes is becoming more common as wind capacity increases and the effects of variations across years are experienced. These indexes are based on a long-term average wind resource, typically five to fifteen years. Table 7 compares the wind resource levels reported by some IEA Wind member countries in 2013.

The penetration level, or the percent contribution of wind generation to total electrical demand, increased in 2013 in all countries except the United Kingdom, Japan, and Korea, where it remained constant. Some countries set records in 2013 for wind penetration (Table 8). Denmark set the new world record by meeting nearly 33% of annual national electric demand from wind energy in 2013. Wind energy met nearly 27% of Spanish electricity demand in 2013 and was the largest single contributor to electricity generation for the entire year, surpassing nuclear, coal, and hydropower. Portugal met 23.5% of its 2013 electric demand from wind—on one day in December, instantaneous wind contribution to demand reached 90%, and 69% of the day's consumption was supplied by wind energy. Table 9 shows wind penetration and national electrical demand for 2013.

Table 4. Renewable Energy and Wind Targets Reported by IEA Wind Member Countries in 2013

Country	Renewable energy sources (RES) target	Wind energy target
Austria	4,400 MW increase from 2010–2020	2,000 MW increase from 2010–2020
Canada	---	---
China	15% of primary energy consumption from non-fossil energy by 2020	200 GW (30 GW offshore) by 2020
Denmark	100% by 2050; more than 35% renewable by 2020	50% by 2020
European Commission	20% by 2020	---
Finland	38% of gross energy consumption by 2020	6 TWh/yr (2.5 GW) in 2020
Germany	35% of electrical energy consumption by 2020	6.5 GW offshore by 2020 (formerly 10 GW offshore)
Greece	40% of electricity by 2020	---
Ireland	40% by 2020	---
Italy	17% by 2020	12 GW on land, 0.68 GW offshore by 2020
Japan	25% to 35% by 2030	5 GW by 2020
Korea, Republic of	11% of consumption by 2035	18.2% of Renewable Energy by 2035
México	---	12 GW by 2020
The Netherlands	14% by 2020; 16% by 2023; 20% reduction CO_2 in 2020 as compared to 1990 level	6,000 MW on land installed in 2020 2,050 MW offshore installed in 2020 4,450 MW offshore installed in 2023
Norway	67.5% of total energy consumption by 2020	---
Portugal	31% of gross energy consumption by 2020	5.273 GW on land, 27 MW offshore by 2020
Spain	20% of overall energy consumption by 2020	35 GW on land; 0.75 GW offshore by 2020
Sweden	50% of overall energy consumption by 2020.	30 TWh by 2020: 20 TWh on land, 10 TWh offshore
Switzerland	22.6 TWh/yr by 2050	4.0 TWh/yr by 2050 (0.6 TWh by 2020, 1.5 TWh by 2035)
United Kingdom	15% increase by 2020	---
United States	80% of electricity from clean sources by 2035	---

--- = No data available

2.2.3 Offshore wind progress and plans

Among the IEA Wind member countries, offshore wind systems totaling more than 6.59 GW were operating in 11 countries at the close of 2013 (Table 10). During 2013, more than 2.01 GW were added in the following countries: China (38 MW), Denmark (351 MW), Germany (623 MW), Japan (25

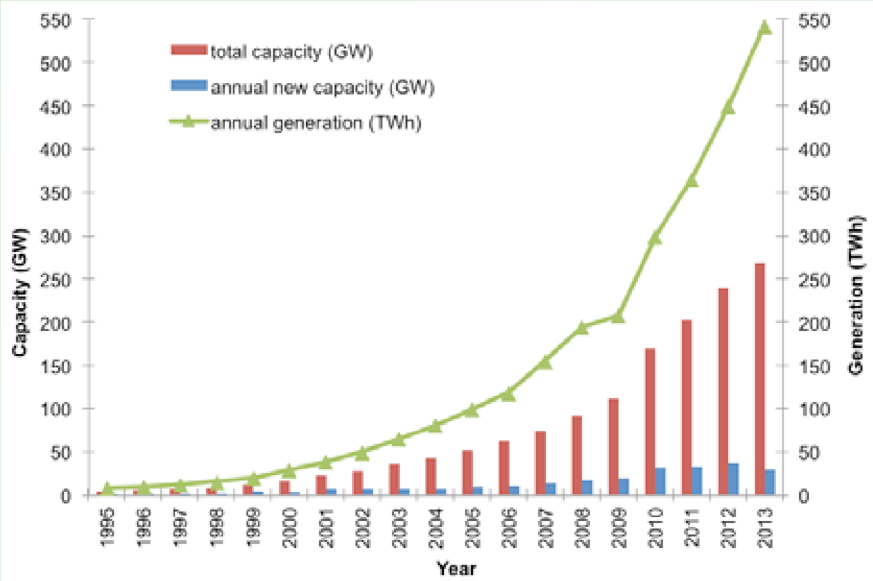

Figure 1. Annual new capacity (net), cumulative capacity, and electricity generation for IEA Wind member countries, 1995–2013 (Note: China is first represented in 2010.)

MW), and the United Kingdom (974 MW). The UK offshore wind capacity grew 79% and the country now has more than 1,000 wind turbines operating offshore.

In the EU, 2013 was a record year for offshore wind energy installations, with 1.57 GW of new capacity connected to the grid. Offshore wind power installations represented 14% of the annual EU wind energy market, up from 10% in 2012. The EWEA documented 22 GW of consented offshore wind farms in Europe and identified plans for offshore wind farms totaling more than 133 GW.

Outside of Europe, many countries are planning to expand capacity with offshore wind. In Japan, half of the new capacity installed for the year was located offshore. In Korea, construction is underway for the 100-MW first phase of a 2.5-GW offshore wind farm designed to demonstrate the technology and the quality of the site. In the United States, 14 offshore wind projects representing more than 5 GW of capacity were in various stages of development in 2013.

Several countries have set targets for offshore wind deployment: China, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, and the United States (Table 4). Finland issued a tender for an offshore demonstration wind power plant in 2013 that should be awarded in 2014.

China is active in offshore wind deployment worldwide. In 2013, a Chinese entity designed and built a set of jack-up installation vessels for a Danish wind turbine company. The vessel integrates the functions of transport, crane lifting, and installation of wind turbine components and can be used to install ten sets of wind turbines from 5 MW to 7 MW capacities.

In Denmark, the Megawind partnership released a roadmap in 2013 for the country to supply competitive offshore wind solutions.

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 cooperative research and development efforts are being focused on technology for this application (Section 4 and Table 16).

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

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 cap on carbon dioxide emissions will encourage the move to renewables, including wind energy (Carbon Trust 2014). Feed-in tariffs were used by 14 of the IEA Wind member countries to encourage wind development. They are reported to be very effective tools in that regard. Also popular with the IEA Wind member countries are programs that mandate utilities to supply a portion of electricity from renewables. Eleven countries use these utility obligations, renewable obligations, or renewable portfolio standards.

Some countries report that changes to existing incentive programs reduced wind deployment in 2013: Italy, Portugal, Spain, and the United States. In other countries, stable policies and new incentives are encouraging deployment: Austria, Canada, China, Denmark, Germany, Korea, México, Norway, Sweden, and the United Kingdom.

2.4 Issues affecting growth

At the end of 2013, an estimated 184.6 GW in new wind plants were planned and/or under construction in the 14 reporting IEA Wind member countries (Table 12). The actual increases in capacity for 2014 and beyond will depend on resolution of the issues in the following paragraphs, reported by the IEA Wind member countries as limiting growth. Many of these issues are being addressed through national research projects, incentive programs, and 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 feed-in tariffs, increase tax benefits, and provide targeted grants are mentioned as ways to reduce the effects of policy uncertainty. In Italy, Portugal, Spain, Switzerland, the United Kingdom, and the United States; government cost-cutting measures have targeted funds allocated for incentive programs. In Italy, establishment of a low quota of wind capacity that can benefit from incentives resulted in a 66% drop in annual wind installations for 2013. In the United Kingdom, two planned offshore projects were withdrawn in response to incentive scheme changes. In the United States, incentive changes resulted in a 92% drop in annual wind installations for 2013.

Economic climate:

Reduced 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 in countries including Portugal, Spain, and the United States.

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. In the Netherlands, wind sites on land are shifting from stand-alone turbines to wind farms. Many provinces forbid the installation of stand-alone turbines and even upgrading existing ones. Due to the high population density, space for wind farms is limited.

Grid integration and capacity issues:

In many countries, the electrical grids are adapted to the needs of centralized, large-scale power plants. Their capacity is limited to existing generation and demand. Some of these systems must absorb large amounts of wind power. Curtailment occurs when grid operators shut down wind farms to balance generation and demand. Improved forecasting and grid upgrades are addressing this problem. Additionally, requirements imposed by grid operators are reported to increase project costs.

Several countries made progress in upgrading or adding transmission lines to carry wind capacity. In Italy, wind production curtailments in 2013 were less than 1% compared to more than 5% in 2010. In China, the average curtailment rate for wind power decreased by 11% in 2013. In Japan, wind power development will be enhanced by a 50% subsidy to reinforce the grid system in high-wind areas with limited grid capacity. In México, a new transmission line has been commissioned to an area where annual wind capacity factors could reach 40%. In the United States, a large new transmission project capable of transmitting more than 18 GW of wind energy was completed in Texas.

Permitting process:

Permitting requirements for wind development in several countries can be lengthy. In

Table 6. Wind Energy Capacity Increases in IEA Wind Member Countries

Country	2012 capacity (MW)	2013 new capacity (MW)	Increase (%)*
Finland	288	190	67
México	1,212	426	35
United Kingdom	8,292	2,422	29
Canada	***6,201***	1,599	26
Australia	2,584	655	25
Sweden	3,524	862	24
Austria	1,378	309	22
Switzerland	49	11	22
China	75,324	16,089	21
Denmark	4,162	644	16
Korea	487	74	15
Norway	704	98	14
Netherlands	***2,431***	281	12
Germany	31,315	3,356	11
Greece	1,749	116	7
Ireland	1,827	133	7
Italy	8,144	434	5
Portugal	***4,517***	192	4
Japan	2,614	56	2
United States	60,007	1,087	2
Spain	22,785	175	1

* % increase = (new capacity 2013/ capacity in 2012) x 100
Bold italic = indicates estimate

Table 7. Reported Wind Resource Levels (2013)

High wind Country (index %)	Average wind Country (index %)	Low wind Country (index %)
Italy (103%) Portugal Spain	Austria China Finland (102%) Norway United States*	Denmark Germany (97.8%) the Netherlands (91%)

The average wind year = 100%
* Regional resources vary across the continent in any year

Table 8. Percent Contribution of Wind to National Electricity Demand 2010–2013*				
Country	2010 (%)	2011 (%)	2012 (%)	2013 (%)
Denmark	21.9	28.0	29.9	32.7
Portugal	17.0	18.0	20.0	23.5
Spain	16.4	16.3	17.8	20.9
Ireland	10.5	15.6	14.5	***16.3***
Germany	6.0	7.6	7.7	8.9
Sweden	2.6	4.4	5.0	***7.0***
United Kingdom	2.6	4.2	6.0	***6.0***
Austria	3.0	3.6	5.0	5.8
Greece**	4.0	5.8	5.8	***5.8***
Italy	2.6	3.0	4.0	***4.7***
Netherlands	4.0	4.2	4.1	4.7
Australia**	2.0	2.4	3.4	***4.1***
United States	2.3	2.9	3.5	***4.1***
Canada	1.8	2.3	2.8	3.1
China	1.2	1.6	2.0	2.6
México	0.6	0.6	1.2	***1.5***
Norway	0.7	1.0	1.1	1.5
Finland	0.3	0.6	0.6	0.9
Japan	0.4	0.5	0.54	0.5
Korea	0.2	0.2	0.2	***0.2***
Switzerland	0.05	0.1	0.1	***0.2***
Overall of IEA Wind Member Countries	2.3	2.8	3.3	3.86

*Percent of national electricity demand from wind = (wind generated electricity / national electricity demand) × 100
** (GWEC 2014)
Bold italic = indicates estimate

Finland, local and regional planning to designate areas for wind development is helping to shorten the permitting process. Conflicts with aviation, radar, and railways are being addressed with procedures and modeling tools that identify cost-effective solutions, such as updating radar or television hardware. Environmental impact assessments can take months or years to complete. In Japan, the environmental impact assessment (EIA) process required since 2012 can take two to three years to complete and has delayed several projects. However, five wind farm projects with total capacity of 174 MW have finished the EIA procedure, and the impact assessment of more than 80 projects with about 4,700 MW are now in progress. In the Netherlands, a National Coordination Regulation stipulates that for wind energy projects of greater than 100 MW, the national government will automatically take over procedures and deal with the permissions. This regulation coordinates and shortens procedures and is meant to speed up employment.

Environmental impacts:
Concerns about environmental impact were also mentioned as issues affecting the permitting of new wind projects. Research projects on environmental impact are underway in most countries. The new IEA Wind Task 34 Environmental Impacts and Assessment will leverage the findings of these projects for the task participants.

In Finland, noise is being addressed by increased measurement programs, curtailed operation, and hardware replacement where necessary. Noise and shadow flicker (when the operating turbine blades cast shadows on the observer) have been addressed in Ireland with draft revised guidelines.

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. The Sustainable Energy Authority of Ireland published the "Methodology for Local Authority Renewable Energy Strategies" in 2013 that provides a methodology for identifying areas suitable for wind energy development. It has been adopted by several local authorities in preparing their renewable energy strategies.

Table 9. National Electricity Demand and Percent Contribution from Wind in 2013*		
Country	National electricity demand (TWH/yr)	National electricity demand from wind* (%)
China	5,245.1	2.6%
United States	4,058.2	***4.1%***
Japan	845.5	0.5%
Germany	600.1	8.9%
Canada	560.0	3.1%
Korea	532.2	***0.2%***
United Kingdom	375.9	***6.0%***
Italy	***317.1***	***4.7%***
Spain	260.0	20.9%
México	***249.0***	***1.5%***
Australia**	***226.0***	***4.1%***
Sweden	139.0	7.0%
Norway	129.2	1.5%
Netherlands	120.3	4.7%
Finland	83.9	0.9%
Switzerland	***63.7***	***0.2%***
Austria	62.0	5.8%
Greece**	57.0	5.8%
Portugal	50.6	23.5%
Denmark	34.0	32.7%
Ireland	***27.9***	***16.3%***
Totals/ Average	14,037.5	3.86%

*Percent of national electricity demand from wind = (wind generated electricity / national electricity demand) × 100
** (GWEC 2014)
Bold italic indicates estimate

Equitable distribution regarding the export of wind project electricity has been an issue in Ireland. In México equitable treatment of wind land-owners needs to be addressed. Canadian provinces have addressed this distribution issue with community funds set up by developers, administered by foundations, and distributed to affected communities for projects to improve the community, health, youth education, and other causes.

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 export of wind turbines, components, and consulting expertise. Even countries with no domestic turbine manufacturers have export markets attributed to wind energy.

Table 13 shows reported labor and economic turnover effects for 2013 in the reporting IEA Wind member countries. The United States reported fewer jobs in 2013, while nine countries reported an increase in jobs in 2013: Austria, China, Finland, Germany, Japan, Korea, the Netherlands, Spain, and the United Kingdom. Five countries reported no change in employment in 2013: Denmark, Ireland, Italy, México, and Portugal.

In Ireland, a model of the Irish economy has been developed to assess the economic impacts of investment in renewable energy and energy efficiency. In a scenario where 32% of electricity is supplied by wind energy by 2020, gross domestic product would increase by 314 million EUR (433 million USD) (2012 prices) with 2,969 net new jobs that year.

One of the positive effects of wind generation is displacing fossil fuel consumption by the power sector and the related economic and environmental costs. Most countries calculate the avoided emissions attributable to wind energy and the number of households supplied with electricity generated by wind turbines. These calculations are based on the generation mix and usage patterns of each country reporting. In the United States, the highest producer of wind-generated electricity, the 167.7 GWh produced meant that nearly 96 million tons of carbon dioxide were not emitted into the atmosphere; this was equivalent to reducing power system emissions by 4.4%. In China, the 137.1 TWh produced could satisfy the electrical needs of 62.75 million Chinese households.

3.2 Industry status

Wind projects are owned by utilities, cooperatives, 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). Many details are presented in the country chapters of this report. A few examples are included here.

In Canada, a wind turbine owned and operated by a labor union began production after nine years of planning, preparation, construction, and testing. The 500-kW turbine on the grounds of the union's Family Education Centre will generate the equivalent of 50%–60% of the center's current energy needs.

In México, several wind energy projects share electricity with both big- and medium-sized electricity consumers under self-supply consortiums. CEMEX, a global leader in the building materials industry, is using wind energy to supply its activities. Another 10-MW wind energy project is supplying electricity for public municipal lighting in México.

The economic downturn has had widely publicized effects on wind turbine suppliers. For example, in the United States, the number of wind turbine suppliers fell from 28 in 2012 to 7 in 2013.

3.3 Operational details

Wind plants composed of many individual wind turbines are becoming more productive by several measures, one of which 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 availability of the machine to generate when there is enough wind (i.e., its reliability), and the size of the generator. The capacity factor is reduced if the utility curtails production due to load management needs. Most wind power plants operate at a capacity factor of 25%–40%. 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 2013 are in Table 14.

The IEA Wind member countries report a trend of installing low-wind-speed turbines that have taller towers, longer blades, and comparatively smaller generators. These turbines allow wind development in more areas, including those with lower wind speeds or forests, resulting in better performance.

In the Netherlands, despite the low wind index of 91% (compared to average index of 100%) in 2013, average turbines on land are currently performing better than before. Key reasons are the increased average hub height and the increased area swept by the rotor, resulting in a better

Table 10. Offshore Wind Energy Capacity in IEA Wind Member Countries 2011–2013

Country	2011 Capacity (MW)	2012 Capacity (MW)	2013 Capacity (MW)
United Kingdom	1,838	2,679	3,653
Denmark	871	920	1,271
Germany	200	280	903
China	108	390	428
Netherlands	228	228	228
Japan	25	25	50
Finland	26	26	26
Ireland	25	25	25
Korea	0	2	2
Norway	2	2	2
Portugal	2	2	2
Total	3,325	4,579	6,590

Table 11. Incentive Programs in IEA Wind Member Countries for 2013 into 2014		
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 emissions trading system (EU ETS) - international system for trading GHG emission allowances, covers more than 11,000 power stations, industrial plants, and airlines in 31 countries.
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, Japan (until June 2012), Korea, Norway, Portugal, Sweden, United Kingdom, United States (10 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.	Austria, Canada, Denmark, Finland, Netherlands, Norway, Sweden, Switzerland, United States (9 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, Ireland, Italy, Japan (from July 2012), Portugal, United States (7 countries)
Electric utility activities	Activities include green power schemes, allowing customers to purchase green electricity, wind farms, various wind generation ownership and financing options with select customers, and wind electricity power purchase models.	Canada, Denmark, Finland, Ireland (Including voluntary supplier tariff for domestic micro-wind), Sweden, Switzerland, United States (7 countries)
Spatial planning activities	Areas of national interest that are officially considered for wind energy development.	China, Denmark, Korea, México, the Netherlands, Norway, Sweden, Switzerland (8 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, Netherlands (small wind only), Portugal (micro-generation only), United States (6 countries)
Income tax credits	Some or all expenses associated with wind installation that may be deducted from taxable income streams.	Canada, Ireland, México, Netherlands, United States (5 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, Netherlands, Switzerland, United Kingdom (5 countries)
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, geothermal). Existing buildings can qualify for financial incentives to retrofit renewable technologies.	Denmark (solar), Ireland, Korea, Portugal (4 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.	Norway, Sweden, and United Kingdom (3 countries)
Capital subsidies	Direct financial subsidies aimed at the up-front cost barrier, either for specific equipment or total installed wind system cost.	Canada, China, Korea (3 countries)

Type of program	Description	Countries implementing
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
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.	Switzerland
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

ratio of large wind capture area to the generator rating.

In Finland, new projects with towers up to 140 m high are seen in forested inland locations. High towers and new designs with larger rotors provide considerably higher capacity factors than previously experienced in Finland, increasing from 20%–23% to 26%–35%. For the 33 turbines with a hub height of 100 m or more, the average capacity factor was 31% and the maximum capacity factor was 48%.

In Germany, the rather weak wind resource year was partially compensated by installations of larger turbines and above-average rotor diameters for wind energy generators on land and new capacity offshore. This combination led to an average capacity factor that is only slightly below the long-term average. Tall turbines with very large rotor diameters and relatively small generators have been installed primarily in southern German states to better exploit lower wind speeds.

In Japan, Hitachi developed a new 2-MW, downwind wind turbine, the HTW2.0-86. It is a low-wind-speed version of HTW2.0-80 with longer rotor blades.

In Switzerland, new projects with modern wind turbines are showing substantially higher performance. The average capacity factor for installations in Switzerland has increased to about 20%.

In the United States, of the 582 turbines installed in 2013, 437 had rotors with diameters of 100 m or larger.

The move to offshore deployment, replacing older, smaller machines and developing large wind plants, led to a higher average power rating of new wind turbines installed in 2013 in 13 countries: Canada, China, Denmark, Finland, Italy, Korea, México, the Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland. The average power rating of new turbines was lower in 2013 than in 2012 in Austria, Japan, and the United States.

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

Country	Planning approval* (MW)	Under construction** (MW)	Total planned and/or under construction (MW)
Australia	---	---	---
Austria	400	483	883
Canada (by 2016)	4,500	---	4,500
China	18,000	60,230	78,230
Denmark (Anholt)	---	---	3,300
Finland	224	195	419
Germany (offshore)	6,800	2,300	9,100
Greece	---	---	---
Ireland	---	---	---
Italy	---	---	---
Japan	174	---	4,719
Korea	---	---	---
México	3,022	316	3,438
Netherlands	---	---	On land: 1,064 Offshore: 745
Norway	3,064	45	3,109
Portugal	---	---	---
Spain	---	---	177
Sweden	6,426	1,434	7,860
Switzerland	0	0	0
United Kingdom	37,191	17,890	55,081
United States	---	12,000+	12,000+
Total			184,625

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

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 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

Table 13. Capacity in Relation to Estimated Jobs and Economic Impact 2013			
Country	Capacity (MW)	Estimated number of jobs	Economic impact (million EUR)
China	91,413	360,000	13,100
United States	61,110	50,500	86,000
Germany	34,660	137,800	8,500
Spain	22,959	>20,000	2,623
United Kingdom	10,861	16,500	---
Italy	8,554	30,000	1,000
Canada	7,803	---	---
Denmark	4,808	23,000	7,400
Portugal	4,709	3,200	---
Sweden	4,469	---	---
Australia	3,239	---	---
Netherlands	2,709	2,200	800
Japan	2,670	3,300	1,297
Ireland	1,896	2,200	---
Greece	1,865	---	---
Austria	1,684	4,500	1,180
México	1,551	1,500	435
Norway	811	---	---
Korea	561	2,366	1,010
Finland	448	3,000	930
Switzerland	60	---	48
Total	268,840		

* Applicable conversion rate EUR to USD: 1.378
--- = No data available

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 15 shows reported *turbine* and project costs in 2013 currency. Figure 2 shows trends of project costs since 2003 as reported by IEA Wind member countries. Please note that the historic cost numbers (2003 to 2012) have not been corrected to 2013 currency.

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 2013, 13 active research tasks sponsored by IEA Wind were advancing wind energy technology and deployment. To guide these activities, the Executive Committee of 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 3 lists the 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 cooperation. For example, a new task was added in 2013 for ground-based testing, Task 35.

4.1 National R, D&D efforts

The major research areas discussed in the individual country chapters are listed in Table 16. The country chapters contain references to recent reports and databases resulting from this research. One clear trend is that most countries with shorelines are placing a high priority on research to support offshore wind technology (Denmark, China, Finland, Germany, Italy, Japan, Korea, the Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom, and the United States).

Government research support contributes to the advancement of wind technology and deployment. It is difficult to calculate the total funds for research supporting wind energy technology. However, Table 17 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.

Another effective approach in R&D planning is to develop or update a national or industry wind technology roadmap. Roadmaps summarize the status, assesses needs, sets priorities, and call out key actions needed to increase the contribution of wind energy to electricity generation (Austria, Japan, Portugal, and the United States.)

The European Commission is a significant source of funding for wind energy research projects proposed by EU countries. In 2013, 18 wind R&D projects were started with the support of the EU's Seventh Framework Programme (FP7). Framework Programmes are the main EU-wide tool to support strategic research areas. These projects run from two to four years.

Outside of Europe, IEA Wind member countries establish their research priorities and benefit from cooperation in the IEA Wind research tasks. 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.

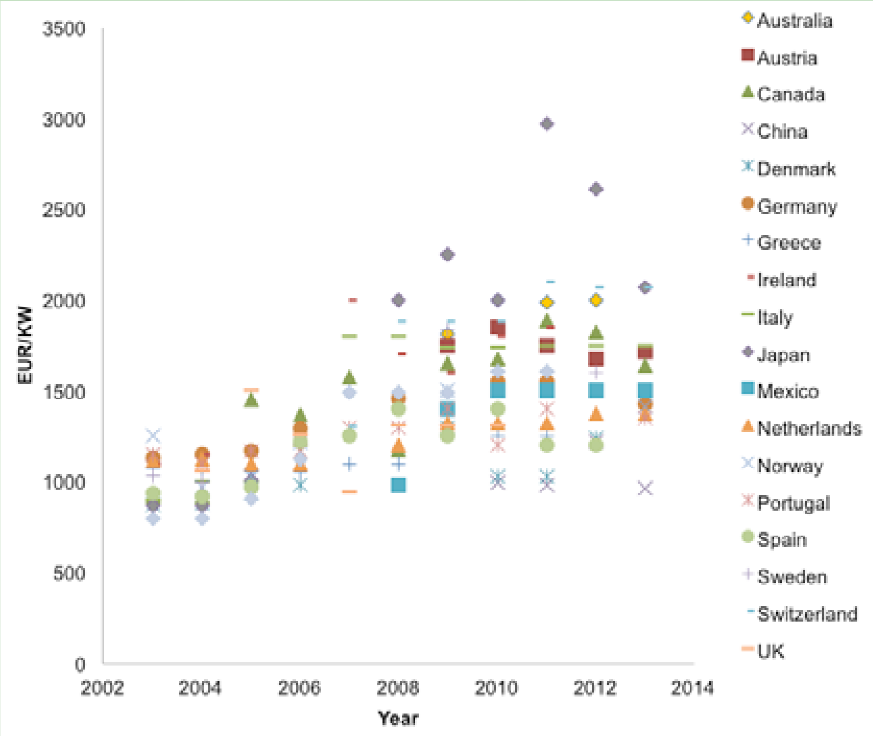

Figure 2. Average project cost of wind turbines *on land* 2003–2013 as reported by IEA Wind member countries. Prior-year costs are not adjusted to 2013 values.

4.1.1 New test, research, and demonstration facilities

Several important new research centers were opened, under construction, or being planned in 2013.

In Canada, the Wind Energy Institute commissioned a new Wind R&D Park in April 2013 that will be able to demonstrate the benefit of energy storage under various scenarios. The Wind Park features generating capacity of 10 MW and incorporates a battery energy storage system.

A Canadian company is working with the utility Hydro One to provide up to ten 500-kW flywheels for frequency regulation on a feeder that is connected to two 10-MW wind farms in southwest Ontario. The 9,000-pound solid-steel flywheel will provide about three to fifteen minutes of storage and millisecond-level responses to balance wind ramping, starting in 2014. Ontario's Independent Electricity System Operator will also gain 2 MW of regulation service by integrating flywheel technology into the province's grid.

In China, an icing wind tunnel (3m x 2m) in China's Aerodynamics Research & Development Center began operation and completed the NACA0012 airfoil iced model tests. Designed for aircraft component testing, it can also be used for wind turbine blade materials and provides the variable pressure icing cloud environment of low and high temperature for icing tests.

In Denmark, at the Lindoe Offshore Renewables Center, planning continues, and funding is now guaranteed. There will be two test beds for nacelle assemblies of up to 10 MW.

Aercoustics, an engineering firm based in Ontario, Canada, received accreditation to perform testing to IEC 61400-11, Wind Turbine Generator Systems–Acoustic Noise Measurement Techniques. Construction of the German facilities for testing nacelles in Bremerhaven, support structures in Hanover, and power drives in Aachen continued in 2013 with operations to begin in 2014.

In Italy, the KiteGen Research and Sequoia Automation companies set up a 3-MW kite wind generator in southern Piedmont for testing.

In Japan, several offshore demonstration turbines were installed in 2013. A JSW 2-MW gearless offshore wind turbine with a hybrid between gravity and jacket substructure was installed in the Kitakyusu offshore site. A Hitachi 2-MW downwind turbine on a hybrid (steel and concrete) spar type floater was installed 1 km offshore in Nagasaki Prefecture and began operation in 2013. At this offshore site, the water depth is about 100 m, and the extreme significant wave height is 7.7 m. Several offshore technologies were installed in the Pacific Ocean more than 20 km offshore of Fukushima prefecture. A Hitachi 2-MW, downwind turbine with a 4-column, semi-submersible floater and a 66-kV floating offshore electrical substation with a measurement platform began operation. 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 been estimated at 7.0 m/s or more.

The Méxican Wind Energy Innovation Center (CEMIE-Eólico) is a consortium that integrates six public research centers, 14 universities, and ten private companies. It will start operations in 2014 to develop 13 projects that will be carried out over the next four years.

The Swedish Wind Power Technology Center focuses on the complete design of an optimal wind turbine, which takes the interaction among all components into account. It is split into 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 climates.

In the United Kingdom, the National Renewable Energy Centre (Narec), opened a 15-MW drive train test facility for offshore wind turbines in 2013. Once final commissioning is complete, it will test Samsung Heavy Industries' 7-MW nacelle assembly. In 2013, Narec was granted planning consents for a 99-MW offshore wind demonstration site in deep water and for an onshore substation on the coast of Blyth, Northumberland. Samsung Heavy Industries erected its 7-MW demonstrator turbine, as part of the Methil Offshore Wind Demonstration Farm in Scotland.

The United States opened three new research and testing facilities in 2013: a 7.5-MW and a 15-MW dynamometer capable of testing wind turbine drive trains up to 15 MW; a 5-MW dynamometer test facility that can test drivetrains up to 5 MW; and the first U.S. test facility specifically designed to understand the complex wind flow and wakes within a wind plant. This third new test facility has three research-scale wind turbines spaced and oriented to study turbine-to-turbine interactions.

In the United States, a concrete-composite floating platform wind turbine (1:8th-scale 20-kW) was installed off the coast of Maine to validate coupled aero-elastic/hydrodynamic computer models for floating offshore wind turbines and to better understand the dynamic response behavior of floating offshore wind systems.

Table 14. Reported Average Capacity Factors 2011–2013 (%)*

Country	Average capacity factor 2011 (%)	Average capacity factor 2012 (%)	Average capacity factor 2013 (%)
Australia	---	35.0	---
Austria	---	30.0	24.0
Canada	31.0	31.0	31.0
China	---	18.4	23.7
Denmark	28.4	22.6	27.1
Finland	28.0	24.0	26.0
Germany	19.0	---	18.5
Greece	---	---	27.5
Ireland	31.6	28.4	30.5
Italy	18.0	---	21.0
Japan	19.0	19.9	17.0
Korea	---	---	---
México	30.0	30.0	30.0
Netherlands	---	On land 20.0 Offshore 39.5	Onland 22.0 Offshore 38.6
Norway	31.3	31.2	29.2
Portugal	26.0	28.0	29.0
Spain	---	24.1	26.9
Sweden	---	26.0	28.3
Switzerland	20.0	<20.0	20.0
United Kingdom	Onshore 27.4 Offshore 36.7	On land 27.4 Offshore 36.7	---
United States	33.0	33.0	32.1

* 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. These are all estimated numbers.
--- = No data available

Table 15. Estimated Average Turbine Cost and Total Project Cost for 2013

Country	Turbine cost (EUR/kW**)	Total installed project cost* (EUR/kW**)
Austria	1,390	1,715
Canada	---	1,639
China	480	960
Denmark	---	---
Finland	---	---
Germany (onshore)	1,053	1,427
Greece	---	---
Ireland	---	---
Italy	1,200	1,750
Japan	1,380	2,070
Korea	---	---
México	1,200	1,500
Netherlands	---	on land: 1,376 offshore: 3,200
Norway	912	1,412
Portugal	1,080	1,350
Spain	---	---
Sweden	---	---
Switzerland	1,450	2,070
United Kingdom	---	---
United States	653.40 to 943.80	---

* Total Installed Project Cost includes: costs for turbines, roads, electrical equipment, installation, development, and grid connection.
** Applicable conversion rate EUR to USD: 1.378
--- = No data available

4.1.2 Highlights of research results

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

In Canada, TechnoCentre éolien collaborated with VTT Technical Research Centre of Finland to gather data on vibrations and ice from wind turbines at the Canadian research site and from wind turbines in Finland. The data showed that vibrations were more pronounced during ice events. Applying this result, the IEC is revising the guidelines for wind turbine design (IEC 61400-1) for cases involving loads associated with ice.

TechnoCentre éolien participated in the first market study dedicated to wind energy in cold climates. According to the report, 11.5 GW of the world's wind energy capacity is installed in areas where moderate to heavy icing conditions occur—66% of which are in North America, 14% of which are in Quebec.

The first phase of a demonstration project in China completed in 2011 includes 100 MW of wind power, 40 MW of photovoltaic power, and 20 MW of energy storage. By 2013, the results show that smooth and controllable power output can be achieved and the voltage fluctuation rate in ten minutes can be controlled within 5%.

Research in China analyzed and calculated GHG emissions during the life cycle of electricity generation from coal power, nuclear power, hydropower, wind power, and photovoltaic power. Results showed that the normalized amount of GHG emission during the life cycle of the wind power supply chain is 15.9 to 18.7 CO_2 eg/kWh. Of this total, 75% was emitted during manufacture and 25% during construction and operations and maintenance.

In Germany, the "StUKplus conference" by the Federal Maritime and Hydrographic Agency in 2013 dealt with lessons learned from five years of environmental monitoring and research on ecological effects at the offshore wind farm Alpha Ventus. The lessons of dealing with effects of offshore wind energy development to fish, benthos, birds, and marine mammals were also discussed. In that context, the standard for the "Investigation of

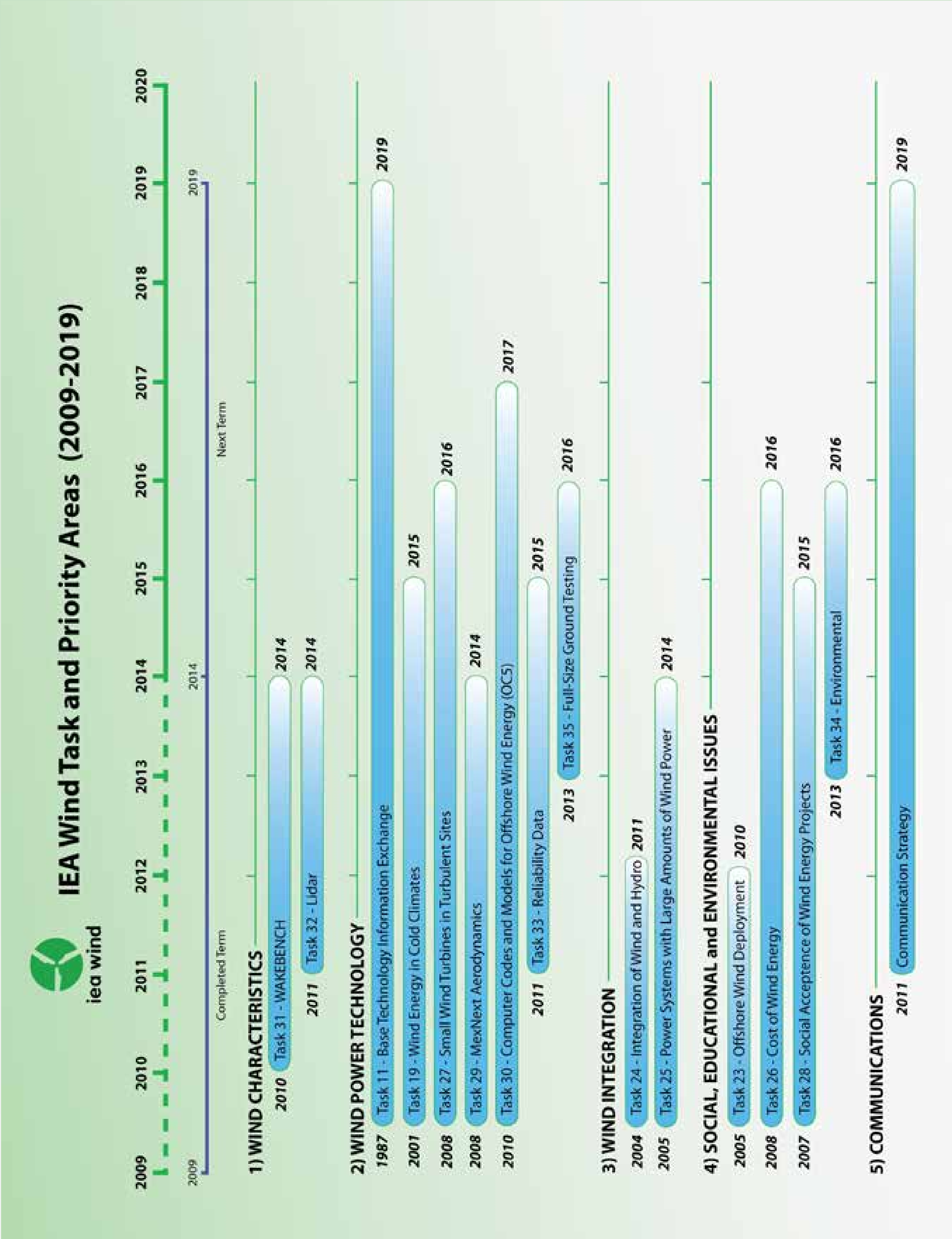

Figure 3. Priority areas from IEA Wind Strategic Plan

Table 16. Reported Research Activities in IEA Wind Member Countries

Type of program	Country activities reported	IEA Wind co-operative activities in 2013
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	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.	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

Type of program	Country activities reported	IEA Wind co-operative activities in 2013
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	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.	

the Impacts of Offshore Wind Turbines on the Marine Environment (StUK4)" was presented as an update and published.

In Italy, several joint studies were published that define guidelines for the design of off-shore wind parks; assess the more promising solutions for floating platform design; and design an advanced system for floating platform stability.

In Spain, several major research projects completed the work of four years in 2013. The Azimut project concluded applied research on the development of world's largest capacity wind turbine by 2020. Eleven Spanish companies and 22 research centers, coordinated by Gamesa, identified new materials, such as a resin with improved properties for the manufacture of blades and a blade coating with anti-icing properties and high resistance to erosion. They identified technologies to detect the advancing front of resin flow in molds and developed key design and calculation tools for improving generator, blade, and gearbox designs.

The Ocean Leader project, carried out by a consortium consisting of 20 companies and 25 research centers in Spain, set up a smart system capable of placing offshore installations in the most suitable locations. It used three tools to analyze and assess marine resources: the Wave Rider buoy to measure wave motion; the Flotante tower to measure waves, and the Awac to measure currents. It designed new marine technologies including a system of floating wind turbines for deep water and a new turbine for generating energy from currents. It designed a semi-submersible floating substation with specially adapted connectors and dynamic power lines. The project also created a ship that enables this infrastructure to be installed and an operating system managed from a control center designed especially for this type of energy infrastructure.

In Switzerland, research projects about social acceptance of wind plants focused on local acceptance during planning and during operation of the plant. The work shows that acceptance was higher during the operational phase than during the planning phase.

In the United Kingdom, the Offshore Renewable Energy (ORE) Catapult completed pilot projects on industry standardization, offshore cables, and performance and reliability. Under work of the Energy Technologies Institute, the design phase was completed in 2013 of the Very Long Blades Project and a prototype 80-m long blade will be assembled and tested in 2014. Another project completed in 2013 developed an intelligent, integrated, predictive package, which has shown improvements in the capability to holistically monitor wind turbines.

The United States published studies on the nation's offshore manufacturing and supply chain, manufacturing capability for next-generation drive trains, transportation and logistics for large wind turbines, integration with the electric power system, mitigating radar interference, and impacts on property values.

4.2 Collaborative research

The collaborative research conducted by organizations in the IEA Wind member countries made significant progress in 2013. A key report was published, Recommended Practice 16: Wind Integration Studies, that will help guide the conduct of these important studies assessing the impact of wind power on the power system. In addition, Recommended Practices are under development in Task 27 Small Wind Turbines in High Turbulence and Task 33 Standardizing Data Collection for Wind Turbine Reliability Studies.

Task 11 Base Technology Information Exchange held two Topical Expert Meetings: Forecasting Techniques and Wind Energy in Complex Terrain. Proceedings from these meetings of invited experts are posted in the IEA Wind website. For 2014, four high-priority topics were selected for Topical Expert Meetings: Floating offshore wind plants, Meso-scale to micro-scale model coupling, Field test instrumentation and measurement best practices, and Best practices for wind turbine and plant end of life. In 2013, Task 11 also managed the approval process for the new Recommended Practice from IEA Wind Task 25 on the conduct of wind integration studies. IEA Wind Recommended Practices serve as pre-normative guidelines in advance of formal standards to promote best practices available for wind technology and deployment. They are often used as input to the more lengthy full standards process.

Task 19 Wind Energy in Cold Climates task participants contributed to a landmark 2013 market study of cold climate wind energy. The study used sophisticated analysis and global coverage to conclude that the wind energy market potential in cold climate areas is huge; 20% of all installed capacity in

Table 17. National R&D Budgets 2010–2013 for Reporting Countries

Country	R&D budget 2010 (million EUR)	R&D budget 2011 (million EUR)	R&D budget 2012 (million EUR)	R&D budget 2013** (million EUR)
Austria	---	---	---	---
Canada	---	6.00	4.23	3.62
China	---	---	7.63	6.37
Denmark	18.00	23.40	7.80	17.51
Finland	4.00	10.00	2.00	3.50
Germany	53.00	77.00	93.20	37.30
Greece	---	---	---	---
Ireland	0.30	0.30	---	---
Italy	3.00	3.00	3.00	3.00
Japan	17.85	31.17	40.14	34.50
Korea	28.36	29.10	33.91	35.60
México	---	---	---	---
Netherlands	38.00	7.08	8.1	5.07
Norway	12.60	14.87	17.14	13.2
Portugal	---	---	---	---
Spain	150.00	150.00	120.00	85.50
Sweden	10.80	10.80	10.80	10.80
Switzerland	0.41	0.41	0.41	0.41
United Kingdom	---	---	---	---
United States	59.52	59.52	70.9	68.20

* Applicable conversion rate EUR to USD: 1.378 (2013)
** Please refer to country chapters for explanations
--- = No data available

the world is installed in areas classified as cold climates, experiencing either icing or low temperatures or both. In 2014, participants will update the Recommended Practices on wind energy in cold climates published in 2012. Key topics will be site classification, methods for energy yield estimation, harmonizing health and safety recommendations with respect to icing conditions.

Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power participants drafted Recommended Practice 16: Wind Integration Studies that were approved in 2013. This is the first publication aiming to capture current best practice when estimating impacts of wind power on power systems. A summary report was also published highlighting results from 13 national case studies of integration. These case studies address impacts related to incremental increases in reserve requirements, balancing the power system on different short-term time scales: grid congestion, reinforcement, and stability, as well as power adequacy (i.e., capacity value of wind).

Task 26 Cost of Wind Energy continued work to identify elements associated with quantifying the value of wind energy and assess data and methodologies for estimating the cost of wind energy on land. Updated cost of energy estimates on land for participating countries will be produced in 2014.

Task 27 Development and Deployment of Small Wind Turbine Labels for Consumers drafted the IEA Wind Recommended Practice 12 Consumer Label for Small Wind Turbines (2011). This document has been included as an appendix to the IEC TC 88 standard on wind system testing. The task also created the "Small Wind Association of Testers" (SWAT) an international peer network of small wind test experts. The topic and future of labelling will be undertaken by the IEC TC88 Certification Advisory Council Small Wind Turbine subcommittee that now has purview over the important labelling task.

Task 27 Small Wind Turbines at Turbulent Sites is an extension of the original Task 27 to conduct 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. Changes in power performance for small wind turbines in highly turbulent sites will be noted. This work will produce a Recommended Practice on micro-siting of small turbines at turbulent sites.

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 Practice 14 Social Acceptance of Wind Energy Projects to guide good practices by developers and local authorities. In 2013 through 2015 participants will address how 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 will be published in 2014. The test plan for a new wind tunnel experiment using the MEXICO scale model turbine was designed; the New MEXICO experiment will be conducted in 2014.

Task 30 Offshore Code Comparison Collaboration Continuation (OC4) is coordinating the work of 15 countries and 61 organizations to improve the design of offshore wind turbines using verified and improved codes. Analysis of a wind turbine on an offshore floating semisubmersible was completed and several papers were presented. A final report is in preparation. To advance the quality of the models, Task 30 was extended for an additional four years as the Offshore Code Comparison Collaboration Continuation, with Correlation (OC5) project.

Task 31 Wakebench: Benchmarking Wind Farm Flow Models manages the work of 13 countries and 30 organizations to improve atmospheric boundary layer and wind turbine wake models by developing and defining quality-check procedures. In 2013, six active benchmarks were conducted and a standardized fit-to-purpose metric to evaluate models was developed based on the variables of interest for the wind turbine siting process. This will be integrated in Windbench, the web platform that is evolving to accommodate this protocol by implementing online tools for visualizing and quantifying model performance.

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.

Task 33 Reliability Data: Standardization of Data Collection for Wind Turbine Reliability and Operation & Maintenance Analyses will apply 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 was approved in 2012 to share information from completed and on-going environmental assessment and monitoring efforts on land and offshore, both pre- and post-construction. A survey of participants was used to refine the work plan in 2013.

An important new IEA wind research task began work in 2013, Task 35 Full-Size Ground Testing of Wind Turbines and their Components (blades and drive trains). Ground-based testing is a less costly alternative to full-scale field testing of prototype wind turbines. Ground-based test benches offer the opportunity to evaluate wind turbine components under repeatable, accelerated life conditions and are an important tool for development and certification of new wind turbines. 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 International Energy Agency approved the extension request of IEA Wind and work will continue through 2019 following the strategic plan.

After assessing the accomplishments of the previous five years and developing a new strategic plan the members concluded that significant cost reductions are possible with R&D in the strategic areas of wind characteristics, wind power technology, wind integration, and social, environmental and educational issues.

5.0 The Next Term

Increasing performance of the world's wind generation fleet will continue to expand its role in the electricity generation portfolio. 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.

Expanding membership in IEA Wind will enhance the benefits of co-operation. At press, France became a new member and invitations to Belgium and Israel are expected be accepted in 2014. 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.

References and notes:

Opening photo: The Hall of Supreme Harmony; Forbidden City, Beijing, China (ExCo 72 was held in Beijing in 2013) (Credit: Rick Hinrichs, PWT Communications LLC)

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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 2013. For the latest information, visit www.ieawind.org.

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2 Implementing Agreement

1.0 Introduction

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-sixth *IEA Wind Annual Report*, lists accomplishments by the close of 2013. The Executive Summary (Chapter 1) compiles information from all countries and tasks to highlight important statistics and trends. Activities completed in 2013 and planned for 2014 are reported for the overall agreement (Chapter 2) and for the research tasks (Chapters 3 through 15). Member country chapters (Chapters 16 through 36) describe activities in the research, development, and deployment of wind energy in their countries during the year just ended. The *IEA Wind 2013 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

* 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 34 OECD member countries, non-member countries, and international organizations may participate. For more information, visit www.iea.org.

† The IEA Wind implementing agreement 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.

are most relevant to their current national research and development programs. A lead organization in each country must agree to 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 Ex-Co 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.

At the close of 2013, IEA Wind had 13 active research tasks exploring key issues of wind energy technology and deployment. Additional tasks are planned when new areas for co-operative research are identified by

Table 1. Participants in IEA Wind in 2013

Country/Organization	Contracting Party to Agreement
Australia	Clean Energy Council*
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)
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	The Netherlands Agency
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	National Renewable Energy Centre (Narec)
United States	U.S. Department of Energy
Sponsor Participants	
CWEA	Chinese Wind Energy Association
EWEA	European Wind Energy Association

* Clean Energy Council withdrew effective December 31, 2013.

Table 2. Member Participation in Research Tasks During 2013

Participant *	Research Task Number												
	11	19	25	26	27	28	29	30	31	32	33	34	35
Australia													
Austria													
Canada													
CWEA, China													
Denmark													
European Commission													
EWEA													
Finland		OA**	OA										
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	16	7	8	6	9	12	13	6	9	6	4

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

members. In 2013, member countries continued work on 12 tasks and approved the start of one new research task: Task 35 Full-Size Ground Testing for Wind Turbines and Their Components. Discussion began for a task to be proposed in 2014 on forecasting wind energy production.

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 2013, 20 IEA Wind research tasks had been successfully completed,

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/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

*Labour 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 (140hr) valued at 10 800 Euro

two tasks had been deferred indefinitely, and 13 were working on solving issues of wind energy technology and deployment, (Table 4).

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 Web site: www.ieawind.org. Table 2 shows participation by members in active research tasks in 2013.

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 2013, Jim Ahlgrimm (United States) served as chair; Tetsuya Kogaki (Japan), Joachim Kutscher (Germany), and Brian Smith (United States) served as Vice Chairs.

Beginning in 2014, Jim Ahlgrimm will serve as Chair and Ignacio Marti (United Kingdom), John McCann, Ireland, and Brian Smith (United States) will serve as vice chairs.

Participants

In 2013, there were several personnel changes among the members and alternate members representing their organizations (See Appendix B IEA Wind Executive Committee 2013). For the latest and most complete ExCo member contact information, please click the IEA Wind Members tab at www.ieawind.org.

At ExCo 71 in 2013, the ExCo voted to invite the government of Israel and the government of France to join the IEA Wind Implementing Agreement as a Contracting Party. At press time for this Annual Report, France had completed the process and became the newest member of IEA Wind.

Meetings

The ExCo met twice in 2013 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 71st ExCo meeting was hosted by the Austrian Government and the European Wind Energy Association in Vienna, Austria, February 5 through February 7, 2013. Twenty-four representatives from 17 of the contracting parties attended, along with thirteen operating agent representatives of the tasks. The Common Fund audit report for 2012 was approved. The meeting included attendance at the European Wind Energy Association 2013 Conference and Exhibition.

The 72nd ExCo meeting was hosted in Beijing, China, 13–16 October 2013 by the Chinese Wind Energy Association and Goldwind Science & Technology Co. LTD. On October 13, ExCo members participated in a technical exchange with Goldwind engineers. On October 14, twenty-four participants from 13 contracting parties were present at the ExCo meeting. OA representatives from 11 of the active tasks gave reports. And observers from the IEA Secretariat and from China were present. Budgets were approved for the ongoing tasks and for the Common Fund for 2014. Members requested an email ballot to increase the fee and budget for 2014. The ExCo elected officers for 2014. On 16 October, ExCo members attended the China Windpower Conference and Exhibition.

Table 4. Active Cooperative Research Tasks (OA indicates operating agent that manages the task)	
Task 11	Base Technology Information Exchange OA: Vattenfall, Sweden (1987 to 2008) changed to CENER, Spain (2013-2014)
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)
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)
Task 30	Offshore Code Comparison Collaborative Continuation (OC4) OA: NREL, the United States and Fraunhofer IWES, Germany (2010-2013)
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 (2011-2014)
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), 2012-2014)
Task 34	Environmental Assessment and Monitoring for Wind Energy Systems 2013-2016 OA: NREL, United States
Task 35	Full-Size, Ground Testing for Wind Turbines and Their Components OA: RWTH Aachen University, Germany and NREL, United States

4.0 Decisions, Publications, and Outreach

The IEA Wind ExCo requested the IEA CERT to extend the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems for another five years through February 2019. The members developed, reviewed, and unanimously approved supporting documents including an End-of-Term report and Strategic Plan (See Section 5). These documents were recommended for approval by the Renewable Energy Working Party and will be voted by the IEA Committee on Energy Research and Technology (CERT) in February 2014.

In 2013, IEA Wind approved publication of five important documents:

- Long-Term R&D Needs for Wind Energy for the Time Frame 2012-2030
- IEA Wind End-of-Term Report 2009–2013 and Strategic Plan 2014–2019
- Recommended Practice 14: Social Acceptance of Wind Energy Projects
- Recommended Practices 15: Ground-Based Vertically-profiling Remote Sensing for Wind Resource Assessment
- Recommended Practice 16: Wind Integration Studies

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 30 Offshore Code Comparison Collaborative Continuation (OC4) to improve the design of support structures for offshore wind turbines.

An important new research task was approved: Task 35 on full-size ground testing of wind turbines and components (blades and drive trains).

The IEA Wind 2012 Annual Report was published in July 2013; 2,200 copies were printed and distributed to member organizations; and press releases were issued with links to the electronic version on the website.

The website, www.ieawind.org, continued to expand coverage of IEA Wind activities. Three Task 11 Proceedings of Experts Meetings from 2012 were posted on the public website. 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

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	
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

perform communication and outreach activities between ExCo meetings. One of these activities is providing support for IEA Paris initiatives. For example, the Chair attended the IEA REWP meeting in Paris and ExCo members reviewed the Mid-term Market Report (MRMR) and the update of IEA's Wind Technology Roadmap.

Invitations to attend ExCo meetings were extended to Argentina, Belgium, France, India, Israel, Malaysia, Poland, Russia, and Turkey. 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

Assessing the accomplishments of the previous five years and developing a new strategic plan were major activities of IEA Wind in 2013. The work concluded that significant cost reductions are possible with R&D in the strategic areas of wind characteristics, wind power technology, wind integration, and social, environmental and educational issues, (Table 5). R&D should characterise the wind resource to support reliable and cost-optimised technology. R&D should develop wind turbine technology for future applications such as large, highly reliable machines for offshore applications in shallow or deep waters. R&D should develop technology that facilitates the integration of this variable energy source into energy systems. R&D should 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 R&D should address challenges related to implementation uncertainties such as physical planning to optimise land use and minimise negative effects to people and nature. The overall aim of future research is to support development of cost-effective wind turbine systems that can be connected to an optimised and efficient grid or be used as nongrid-connected turbines.

The issues identified for long- term R&D were basic research topics, adding intelligence to the complete wind sector. According to the experts, major R&D issues with results expected in the long-term time frame are:

- Aerodynamic experiments on model wind turbines in large wind tunnels and on a full-scale multi-MW wind turbines at test sites
- Terrain and rotor flow interaction and topology optimisation for siting wind power plants with respect to loads, power, and cost
- Standardisation of micro-sitting methodologies based on state-of-the-art models and measurement techniques
- New and cost-effective materials for wind energy systems; smart materials and structures
- Minimisation of environmental impact and securing social acceptance; offshore-specific environmental impact studies

The overall aim of future IEA Wind research is to support development of cost-effective wind turbine systems that can be connected to an optimised and efficient grid or be used to supply electricity without being connected to the grid.

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

2013 IEA Wind Task and Country Reports

Vienna, Austria

3 Task 11 Base Technology Information Exchange

1.0 Introduction

Task 11 of the IEA Wind Agreement has the objective to promote and disseminate knowledge through cooperative activities and information exchange on R&D topics of common interest to the Task members. These cooperative activities have been part of the IEA Wind Implementing Agreement since 1978.

Table 1 lists the countries participating in this Task in 2013. 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 can react quickly to new technical and scientific developments and information needs. It brings the latest knowledge to wind energy players in the member countries and collects information and recommendations for the work of the IEA Wind Agreement. Task 11 is also an important catalyst for starting new tasks within IEA Wind. Documents produced are available immediately following the meetings 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).

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. The main activity is to arrange Topical Expert Meetings (TEMs) focused on priority issues. A meeting is hosted by an organization

Table 1. Countries and Organizations Participating in Task 11 During 2013

	Country	Institution
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	NL Agency, Ministry of Economic Affairs
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	National Renewable Energy Centre (Narec)
16	United States	U.S. Department of Energy (DOE)

No.	Meeting Title	Year
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

Table 2. Topical Expert Meetings (2008–2013)

*Meetings are sometimes cancelled if confirmed participants are fewer than five.

within one of the countries participating in the task. An introductory note on the topic frames the discussion. Experts attend by invitation of the country contracting parties. All attendees give a presentation on their area of expertise.

Four meetings are arranged every year on topics are selected by the IEA Wind Executive Committee. Topical Expert Meetings (TEMs) have been addressing the most important topics in wind energy since 1978. TEMs can also begin the process of organizing new co-operative research tasks within the IEA Wind Agreement. Table 2 lists the TEMs arranged in the last six years (2008–2013).

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 (Table 3). Many of the IEA Wind Recommended Practices documents have served as the basis for both international and national standards.

3.0 Progress in 2013

3.1 Topical Expert Meetings

Topical Expert Meetings are small workshops (<30 people) where information is presented and discussed in an open manner. Usually the meetings cover two days. A presentation is expected each participant and these are assembled into a meeting report. The agenda usually covers the following items:

- Collecting proposals for presentations
- Introduction, host
- Introduction by OA, recognition of participants
- Presentation of introductory note
- Individual presentations
- Discussion
- Summary of meeting

Four TEMs were organized in 2013; however two were cancelled due to lack of confirmed participants. Proceedings were published on the ftp-server for country members. Proceedings are available to the public after one year at (www.ieawind.org). Meeting topics for 2014 have been selected by the IEA Wind Executive Committee.

TEM #72: Forecasting Techniques

The meeting took place in April 2013 in Milan, Italy and was attended by 23 participants from ten countries (China, Denmark, Finland, Germany, Ireland, Italy, Norway, Spain, United Kingdom and the United States). The participants represented stakeholders related to the topic, including consultants, manufacturers, research organizations, universities, and wind farm operators. Following the two days of presentations, a short discussion took place on topics of general interest, which included:

- Probabilistic forecasts—application and evaluation
- Data quality, availability, and assimilation
- Link to market and grid reliability
- Extreme events forecasting

It was proposed that information exchange among the participants should continue. However, most participants suggested that more development was needed before proposing a specific IEA Wind task covering the priorities selected. However, after the meeting, several of the attendees expressed interest in establishing an IEA Wind Task on Wind Power Forecasting to further international collaboration on R&D.

Table 3. IEA Wind Recommended Practices						
	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

TEM #73: Noise Reduction Technologies

First call for attendees, 1–2 June; second call 24–25 September. Due to the low number of experts registered, the meeting was cancelled.

TEM #74: Operation and Maintenance Challenges

This meeting was also cancelled due to the low number of experts registered. The main reason for this is that in 2013 there were a large number of workshops, seminars, courses, and conferences dealing with this issue. Also, the high cost of travel to China for many attendees could reduce attendance.

TEM #75: Wind Energy in Complex Terrain

The University of Stuttgart hosted the meeting that was organized together with the IEA Wind Task 31 Wakebench annual meeting. The meeting was attended by 28 experts from eight countries (Canada, Denmark, Finland, Germany, Japan, Spain, the United Kingdom, and the United States). The primary goal of the meeting was to give the participants an overview of the challenges faced by wind energy deployment in complex terrains. Twenty two presentations were given. Following the presentations, the floor was opened and a general discussion took place among the participants. The following topics were selected for discussion:

- Challenges associated with the wind resource assessment in complex terrain
- Use of remote sensors in complex terrain
- Application of computational fluid dynamics models in complex terrain
- Prediction of power performance and annual energy production in complex terrain

The discussion focused on establishing a new IEA Wind task on challenges of wind energy in complex terrain. The consensus was that it would be better to launch a task with a more narrow focus, for instance "Uncertainty Analysis of Computational Fluid Dynamics Models in Complex Terrain," rather than launch a task covering several issues of wind energy in complex terrain. Several of the attendees suggested that instead of starting a new IEA Wind Task specific to complex terrain, this topic could be considered as a working group inside an extension of Task 31 Wakebench. The Task 31 OA agreed to circulate a questionnaire to potential participants in an extension about the areas of interest. Based on these inputs, a draft proposal will be presented preliminary at the IEA Wind ExCo73 in spring 2014. After gaining expressions of interest, a full proposal for extension will be presented for a vote at ExCo74 in autumn 2014.

3.2 Future Meetings

The process for selection of topics for 2014 meetings started in August 2013. The OA sent a mail to IEA Wind members, alternate members, Task 11 members, and alternate members, soliciting topics of their interest for future challenging Topical Experts Meetings. The OA prepared a list with all the topics proposed that was distributed to the members for priority rating (1 to 5). The four high-priority topics selected for 2014 TEM are:

- Floating offshore wind plants
- Meso-scale to micro-scale model coupling
- Field test instrumentation and measurement best practices
- Best practices for wind turbine and plant end of life

3.3 Recommended Practices

IEA Wind approved procedures have strict requirements for the development, review, and approval for publication of IEA Wind Recommended Practices. First, the task participants or experts groups develop a draft document to address needed practices on a topic relevant to wind energy. Then the research task Operating Agent (OA) works with task participants, the OA of Task 11, and relevant external experts to develop a recommended practice document following the format of previously issued IEA Wind Recommended Practices. The draft Recommended Practices must be approved by the majority of official task participants. Next, the OA of Task 11 and the Secretary send the draft Recommended Practices to the IEA Wind ExCo for a 30-day final comment and review period. ExCo members are asked to circulate the document for comment within their countries. ExCo members send any comments to the Secretary on the Excel comment sheet provided. These comments and the responses of the task OA and participants are maintained to document the review process. Finally, after all comments are integrated or addressed, a ballot version of the Recommended Practice is presented to the ExCo for a vote. A majority vote approves the document for publication.

Three Recommended Practices were drafted, peer-reviewed, and approved in 2013:

RP 14: Social Acceptance of Wind Energy Projects was coordinated by the OA and participants in IEA Wind Task 28 Social Acceptance of Wind Energy Projects.

RP 15: Ground-Based Vertically-Profiling Remote Sensing for Wind Resource Assessment was coordinated by participants in IEA Wind Task 32 Wind Lidar Systems for Wind Energy Deployment.

RP 16: Wind Integration Studies was developed by the OA and participants in IEA Wind Task 25 Design and Operation of Power Systems with large Amounts of Wind Power.

The OAs of following tasks are working to develop additional IEA Wind Recommended Practices:

- Task 26 Cost of Wind Energy
- Task 33 Standardizing Wind Data Collection for Wind Turbine Reliability and O&M, and
- Task 34 Environmental Assessment and Monitoring for Wind Energy Systems

3.4 Other Actions

To encourage and support the technological development and global deployment of wind energy technology, a new document *Long-Term Research and Development Needs for Wind Energy for the Time Frame 2012 to 2030* was elaborated (http://www.ieawind.org). This report presents the R&D priorities identified by the IEA Wind ExCo members and the OAs of research tasks. More than 94 research priorities were proposed. Experts were asked when research results should be expected and the topics were divided according to short-term (0–5 years), mid-term (5–10 years), or long-term (10–20 years).

4.0 Plans for 2014 and Beyond

Task 11 Base Technology Information Exchange can be defined as an ongoing task. Started in 1987, every two years the Task is extended. The latest extension covers the period 2013–2014.

Topical Experts Meetings for 2014 will be held as follows:

- TEM #76: Floating Offshore Wind Plants, 28–29 April, PLOCAN, Canary Islands, Spain
- TEM #77: Best Practices for Wind Turbine and Plant End of Life, date TBD, the Netherlands
- TEM #78: Meso-scale to Micro-scale Model Coupling, date TBD, tentative host is México
- TEM #79: Field Test Instrumentation and Measurement Best Practices, host and date TBD.

The OA will collaborate with the OAs of Tasks 19 and 26 to begin development of new IEA Wind Recommended Practices: Performance and Load Conditions of Wind Turbines in Cold Climates and Cost of Wind Energy.

References:

Opening Photo: Experts attending meeting on wind energy deployment in complex terrain.

Author: Félix Avia Aranda, Centro Nacional de Energías Renovables (CENER), Spain.

4 Task 19 Wind Energy in Cold Climates

1.0 Introduction

IEA Wind Task 19 Wind Energy in Cold Climates began work in 2002 to address the special issues for wind turbines operating in cold environments. Areas where icing events (Icing Climate) or periods with temperatures below the operational limits (Low Temperature Climate) of standard wind turbines occur, may impact project implementation, economics, and safety. In some areas, wind turbines are only exposed to either icing or low temperature events. In some regions both low temperatures and icing events may take place. Although theoretically possible, active icing rarely occurs at temperatures below minus 25°C.

Wind resources in cold climate areas are typically good, making them attractive for wind development. However, icing and low ambient temperatures pose special challenges for wind energy projects. Icing of wind turbine rotor blades reduces energy yield, shortens mechanical life time of turbines, and increases safety risk due to potential ice throw. Low temperatures can affect a turbine's mechanical lifetime if they are not taken into account in turbine design by using appropriate materials. Cold climate areas have gained more focus recently in attempts to reach higher wind energy targets. Also, increased experience, knowledge, and improvements in cold climate technologies have made projects in cold climates more competitive with standard wind projects.

The current wind capacity operating in cold climates in Scandinavia, North America, Europe, and Asia is approximately 60 GW; however, only a small portion of this wind turbine fleet is designed for icing and low temperature conditions. The potential to install new capacity in cold climate areas is vast and it is estimated that the capacity will increase, especially in Canada, the northern United States, China, and in northern Scandinavia. IEA Wind Task 19 estimated in 2013 that a capacity of nearly 10 GW is being installed annually at cold climate sites. This means that the stimulus for further development of wind power projects and technology in cold climate areas is strong.

To meet the demand for cold climate installations, turbine manufacturers have developed technical solutions for low temperatures of their standard turbines. In addition, first-generation commercial solutions for de-icing of wind turbine blades have entered the marketplace. R&D activities have been conducted in a number of countries to master the difficulties that atmospheric icing and low temperatures create. These research activities aim to improve the economics of wind power at new areas around the globe. The coming years are important to validate the fresh information and knowledge, and to analyze the performance of the adapted technologies arising from the wind energy projects going on, as well to gather more information to be publicly available.

Table 1 shows the countries and organizations participating in Task 19 during 2013. The group collects, evaluates, and creates information covering all aspects of wind energy in cold climates. For example, the group is working on site assessment 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 are as follows:

- Determine the current state of cold climate solutions for wind turbines,

Table 1. Countries and Organizations Participating in Task 19 During 2013

	Country	Institution(s)
1	Austria	Energiewerkstatt
2	Canada	TechnoCentre éolien
3	China	CWEA
4	Denmark	DTU Wind Energy
5	Finland	VTT Technical Research Centre of Finland
6	Germany	Fraunhofer IWES
7	Sweden	Swedish Energy Agency/WindREN/ Vattenfall
8	Switzerland	Meteotest

especially anti-icing and de-icing solutions that are available or are entering the market

- Review current standards and recommendations from the cold climate point of view and identify possible needs for updates
- Find and recommend a method for estimating the effects of atmospheric icing on energy production, because the commonly used standard tools do not address issues specific to cold climates
- Clarify the significance of extra loading that ice and cold climate induce on wind turbine components
- Perform a market survey for cold climate wind technology, including wind farms, remote grid systems, and stand-alone systems
- Define recommended limits for the use of standard technology (site classification)
- Create and update the Task 19 state-of-the-art report and expert group study on guidelines for applying wind energy in cold climates.

The items above have been identified as key topics that are slowing wind power development in cold climates. The ongoing national R&D activities in task participant countries contribute to tackling these challenges and provide new information and know-how on the subject. The results of national activities will improve the overall economy of wind energy projects in cold climates and thus significantly lower the risks of developing in areas where low temperatures and atmospheric icing occurs.

The collaboration actively disseminates results through speakers at conferences, seminars, and workshops as well as through the Task 19 website at (www.ieawind.org). During 2013, members of Task 19 were invited as speakers and chairs in numerous seminars, conferences, and workshops dealing with wind energy in cold climates.

3.0 Progress in 2013

In 2013, the task gained valuable participants when China (represented by the Chinese Wind Energy Association) and Denmark joined and began contributing to the work plan. Also in 2013, Task 19 contributed to a landmark market study of cold climate wind energy. The study used sophisticated analysis and global coverage to make its projections. The study was published as a special chapter in the 18th edition of the annual market analysis, World Market Update 2012 (Navigant 2013). The results and conclusions have been referred to in numerous articles, presentations, and publications. The market study concluded that the wind energy market potential in cold climate areas is huge; 20% of all installed capacity in the world is installed in areas classified as cold climates, experiencing either icing or low temperatures or both. Table 2, copied here from the Navigant 2013, presents the total installed and forecasted capacity in cold climates and Figure 1 shows how the capacity is distributed around the world.

Table 2. Total installed and forecasted capacity in cold climates (Source: Navigant 2013)

Cumulative installed capacity by end of 2012 (MW)			Forecasted capacity 2013–2017 (MW)		
Low temperature	Light icing: safety risk, some economic risk	Moderate to heavy icing: economic and safety risk	Low temperature	Light icing: safety risk, some economic risk	Moderate to heavy icing: economic and safety risk
18,945	41,079	11,478	20,025	22,083	8,003
Total 69,000*			Total 45,000–50,000		

*The total capacity is less than the sum of individual capacities because some of the sites have both low temperatures and icing conditions.

4.0 Plans for 2014 and beyond

The main goals for 2014 and 2015 are to update the Recommended Practices by verifying the recommendations based on accumulating experience and data collection. Key topics will be cold climate site classification, methods for energy yield estimation, harmonizing health and safety recommendations with respect to icing conditions. The task will also update the State-of-the-Art report on cold climate wind energy. Task 19 will have two meetings in 2014, the first one in Canada in June and the second one in Europe in fall. New results, publications, and reports can be found online at www.ieawind.org Task 19 Wind Energy in Cold Climates.

Reference:

Navigant Consulting, Inc. (2013). "Section 9 Special Theme: Cold Climate Turbines," World Market Update 2012. ISBN: 978-87-994438-4-0. www.navigantresearch.com/wp.../WWMU-13-Executive-Summary.pdf

Author: Tomas Wallenius, VTT Technical Research Centre of Finland, Finland.

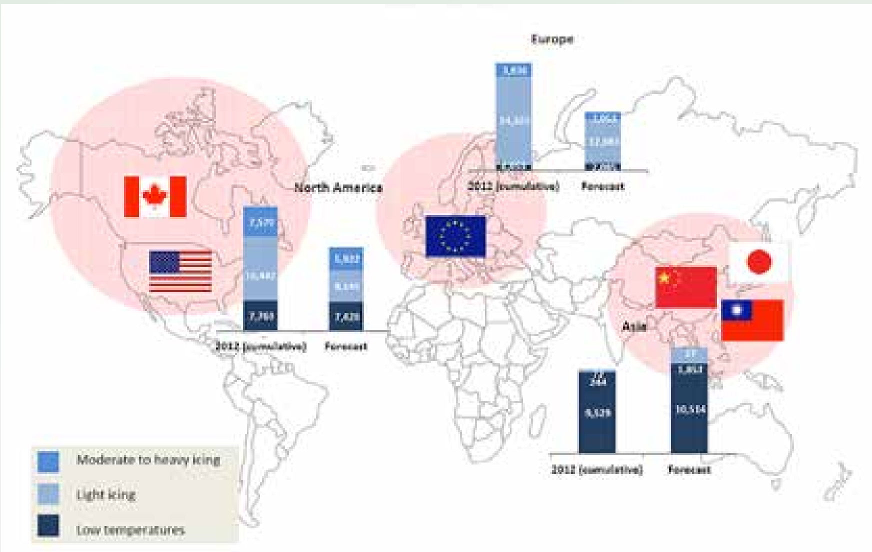
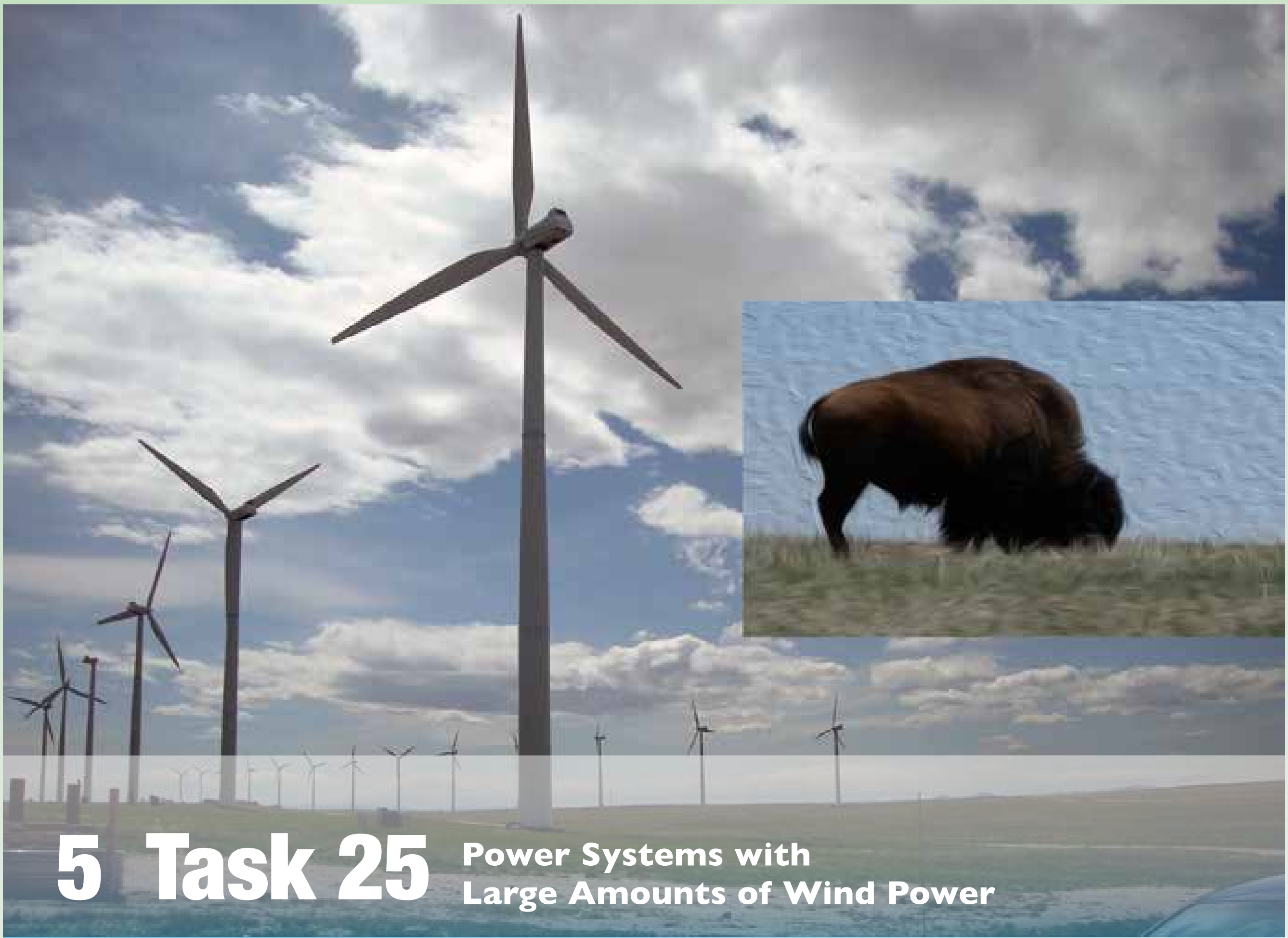


Figure 1. Worldwide capacity in cold climate through 2012 and forecast (2013 to 2017) (Source: Navigant 2013)



5 Task 25 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 partly unpredictable. To meet this challenge, there is need for more flexibility in the power system. How much extra flexibility is needed depends on how much wind power there is and on how much flexibility exists in the power system.

The existing targets for wind power anticipate a quite high contribution from wind to national electricity demand in many countries. It is technically possible to integrate very large amounts of wind capacity in power systems; the limits arise from how much can be integrated at socially and economically acceptable costs. So far, the integration of wind power into regional power systems has mainly been studied on a theoretical basis, because wind power penetration is still rather limited in most countries and power systems. However, already some countries, e.g., Denmark, Ireland, and the Iberian Peninsula (Spain and Portugal) show a high contribution of 15–30% of yearly electricity consumption coming from wind power and have significant practical experience with wind integration.

In recent years, several reports have been published investigating the power system impacts of wind power. However, results on the costs of integration differ substantially among reports and comparisons are difficult to make. This is due to using 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 conducting integration studies. Because system impact studies are often the first steps taken towards defining wind penetration targets within each country, it is important that commonly accepted standard methodologies are applied in system impact studies.

The Task 25 website is available under Task Web Sites from the IEA Wind Web Site (www.ieawind.org). The public portion of the site contains the Task 25 publications as well as a literature bibliography. 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 within 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 exchange of knowledge and experiences related to power system operation with large amounts of wind power. A key factor has been the participation in meetings of transmission system operators (TSOs).

The participants are collecting and sharing information on their experiences with wind integration 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 and requirements for new network investments, bottlenecks, cross-border trade, and system stability issues. The main emphasis is on technical operation. Costs will be assessed when necessary as a basis for comparison. Also, technology that supports enhanced penetration will be addressed: wind power plant controls and operating procedures, dynamic line ratings, storage, demand side management, etc.

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. A new report summarizing 2009–2012 work was published in January 2013. Best practice recommendations were formulated into an IEA Wind Recommended Practice that was reviewed extensively and approved in October 2013 as *IEA Wind RP 16 Wind Integration Studies*.

Task 25 of the IEA Wind Implementing Agreement was approved at Executive Committee meeting 56 in September 2005 for three years, 2006–2008. The work was granted a second term 2009–2011 at ExCo 62 in 2008, and a third term 2012–2014 was approved at ExCo 68 in 2011. Table 1 shows the participants in the task. During the first term, 11 countries plus the European Wind Energy Association participated in the Task. For the second term, Canada, Japan, and Italy also joined. For the third term, a Chinese participant from SGERI has joined.

Table 1. Countries and Organizations Participating in IEA Wind Task 25 (third term 2012–2014)

	Country	Institutions coordinating work in countries (TSO participating in some meetings in brackets)*
1	Canada	Hydro Quebec
2	CWEA	SGERI
3	Denmark	DTU Wind; [TSO Energinet.dk]
4	EWEA	European Wind Energy Association
5	Finland	VTT Technical Research Centre of Finland
6	Germany	Fraunhofer IWES; [Amprion]
7	Ireland	SEIA [ECR; Eirgrid]
8	Italy	TSO Terna
9	Japan	AIST, Kansai University
10	Netherlands	ECN, TUDelft
11	Norway	SINTEF Energy Research;
12	Portugal	LNEG; [REN Rede Electrica Nacional]
13	Spain	Universidad de Castilla-La Mancha; [REE]
14	Sweden	KTH [Kungliga Tekniska Högskolan]
15	United Kingdom	DG & SEE (Centre for Distributed Generation & Sustainable Electrical Energy); [National Grid]
16	United States	NREL (National Renewable Energy Laboratory); UVIG (Utility Variable Generation Integration Group)

* CIGRE JWG C1,3,6/18, IEA Secretariat in Paris, and European TSO consortium EWIS have sent observers to meetings.

3.0 Progress in 2013

The meetings organized by Task 25 have established an international forum for exchange of knowledge and experiences. The spring task meeting in 2013 was organized in Finland and hosted by operating agent VTT. The autumn meeting was hosted by SGERI in Beijing and included a workshop on wind integration where Task 25 experience on wind integration was presented.

Coordination with other relevant activities is an important part of the Task 25 effort. Task 25 organized workshop sessions for TSO organizations in Europe (ENTSO-E in September 2013) and America (UVIG workshop in April 2013). The system operators of Denmark, Italy, and Quebec (Canada) have been active in Task 25 work in 2013. The Task 25 OA has joined the Advisory board of the IEA Secretariat project on integrating renewable energies (GIVAR) and the leader of that project has joined Task 25 meetings as an observer.

Publication of the work is a key goal of Task 25 cooperative research. The highlights have been the Task 25 sessions organized in several conferences. In 2013, a session in the London Wind Integration Workshop was organized, together with the IEA Paris GIVAR project. Collaborative papers were presented in the Wind Integration workshop on curtailments of wind energy; flexibility assessment of power systems; integration cost assessment; wind power forecast errors, and a general summary paper. Two papers were written for the 2014 IEEE PES summer conference, on stability issues and Recommended Practices.

The main efforts in 2013 went toward developing and gaining approval for the IEA Wind Recommended Practices for conducting wind integration studies. This IEA Wind RP 16 Wind Integration Studies is the first publication aiming to capture current best practice when estimating impacts of wind power on power systems. In addition, the latest summary report highlighting results from case studies was published in early 2013.

3.1 Summary of recent wind integration studies

The national case studies of participants in Task 25 address impacts related to balancing the power system on different short-term time scales: grid congestion, reinforcement, and stability, as well as power adequacy (i.e., capacity value of wind).

Incremental increase in reserve requirements:

There is a large range of results for estimates of increases in reserve requirements. This is mainly due to different time scales of uncertainty taken into account in different studies.

- If only hourly variability of wind is taken into account when estimating the increase in short-term reserve requirement, 3% of installed wind capacity or less are estimated as needed, with wind penetrations below 20% of gross electric demand.
- When four-hour forecast errors of wind power are taken into account, an increase in short-term reserve requirement of up to 9–10% of installed wind capacity has been reported for penetration levels of 7–20% of gross demand.

Increasing reserve requirement is usually calculated for the worst case. However, this does not necessarily mean that new investments are required for reserve capacity—rather, generators that were formerly used to provide energy could now be used to provide reserves. The experience so far is that wind power has not caused investments for new reserve capacity. However, some new pumped hydro schemes are planned in the Iberian Peninsula to manage more than 20% wind penetration levels in the future.

Because wind power output varies, it is now widely recognized that wind-induced reserves should be calculated dynamically. If allocation is estimated once per day for the next day instead of using the same reserve requirement for all days, the low-wind days will make smaller requirements on the system. Avoiding allocation of unnecessary reserve is cost-effective and can be needed in higher penetration levels of wind power.

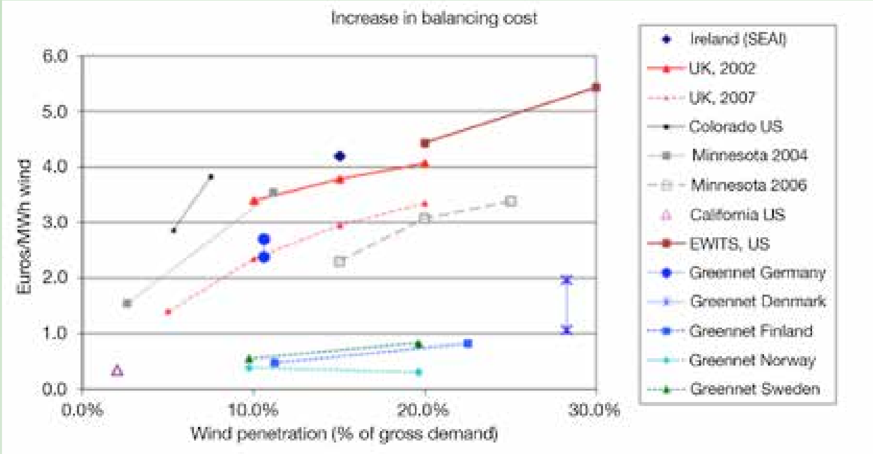


Figure 1. Results from estimates for the increase in balancing and operating costs due to wind power. (The currency conversion used here is 1 EUR= 0.7 GBP and 1 EUR = 1.3 USD). For the UK, 2007 study, the average cost is presented here.

Balancing costs:

At wind penetrations of up to 20% of gross demand (energy), system operating cost increases, arising from wind variability and uncertainty amount to approximately 1.0–4.5 EUR/MWh (1.4–6.2 USD/MWh). This is 10% or less of the wholesale value of the wind energy. In addition to estimates, there is some experience with actual balancing costs for existing wind power from electricity markets. For 16% wind penetration (Spain): 1.3–1.5 EUR/MWh (1.8–2.0 USD/MWh), and for 24% wind penetration (West Denmark): 1.4–2.6 EUR/MWh (1.9–3.6 USD/MWh).

When estimating balancing costs, a general conclusion is that if interconnection capacity is allowed to be used for balancing purposes, then the balancing costs are lower compared to the case where they are not allowed to be used (Figure 1). Other important factors that were identified as reducing integration costs were: aggregating wind plant output over large geographical regions and scheduling the power system operation closer to the delivery hour.

Impacts to transmission grid:

Grid studies involve a more detailed simulation of power flows in the transmission grid to confirm the steady-state adequacy and utilization of the transmission system and to assess if the grid is sufficiently strong to cope with added wind power plants during significant failures. Dynamic system stability analyses are usually not performed at lower penetration levels of wind power unless particular stability issues are foreseen in the system. Wind turbine capabilities are still evolving and may mitigate some potential impacts of wind power on the utility system.

There is also a trend towards regional planning efforts around the world. The allocation of grid investments to wind power is challenging, in a similar manner to balancing costs. System operators rarely make allocation of grid infrastructure because new infrastructure usually benefits all users. The investments are made to improve electricity market operation, to increase the security of the system, and to bring about strategic transitions in the long-term sustainability of electricity supply. Even in cases where wind power would be the main reason for investing, after the grid is built, it is not possible to allocate the benefits to any single user.

Capacity value of wind power:

The capacity value of wind will decrease as wind penetration increases (Figure 2). The results summarized in this report show a range from 40% of installed wind power capacity (in situations with low wind penetration and a high-capacity factor at times of peak load) to 5% in higher wind penetrations, or if regional wind power output profiles correlate negatively with the system load profile (i.e., low capacity factor at times of peak load). Aggregation benefits apply to capacity credit calculations—for larger geographical areas, the capacity credit will be higher.

3.2 Recommended practices for wind integration studies

The methods to perform wind integration studies are evolving, using the experiences of previous studies, more data on system-wide wind power production, and improved models. Task 25 participants wrote a recommendation report to compile the best practices and instructions on how to perform an integration study. Participants started by making a flow chart of all phases of an integration study. A complete integration study will include several parts, and this usually means an iterative process, as

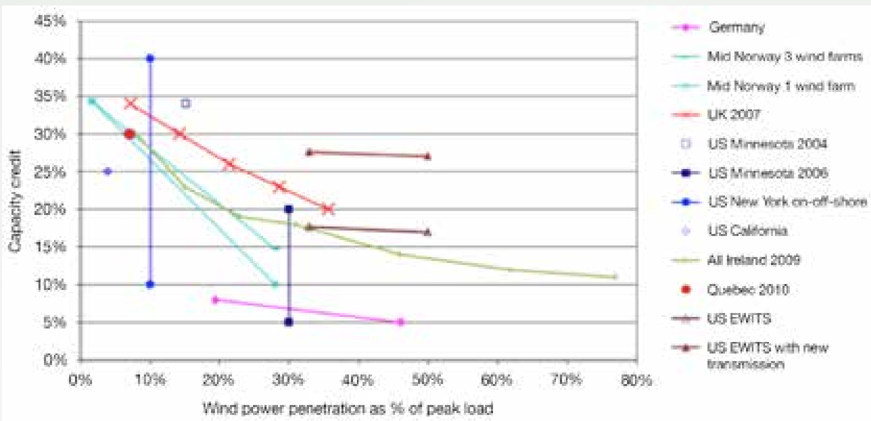


Figure 2. Capacity credit of wind power. Results from ten studies show reduction of capacity value as penetration level increases. New York on- and offshore shows the range of capacity value for wind, when calculated only for onshore sites (10%) or only offshore sites (40%).

described in the flow chart in Figure 3. 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, as well as interconnection options to neighboring areas. The basic setup assumptions will have a crucial impact on the results of the study. How is the wind power added—replacing something else or with the remaining generation staying the same? For lower penetration levels, the assumption of keeping the remaining system the same can be used as a starting point. However, to reach higher penetration levels usually also means a future system where the conventional generation portfolio may change.

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). More detailed levels include also dynamic simulations and flexibility assessment—these are necessary when studying higher penetration levels of wind power. Reliability constraints from transmission or 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. Integration impacts depend crucially on the assumptions made and especially the set-up of the study, like investments in the remaining system. Larger wind shares in the power system usually mean 10–30 years in the future, and the question is, which other investments are to be performed in the power system during these years?

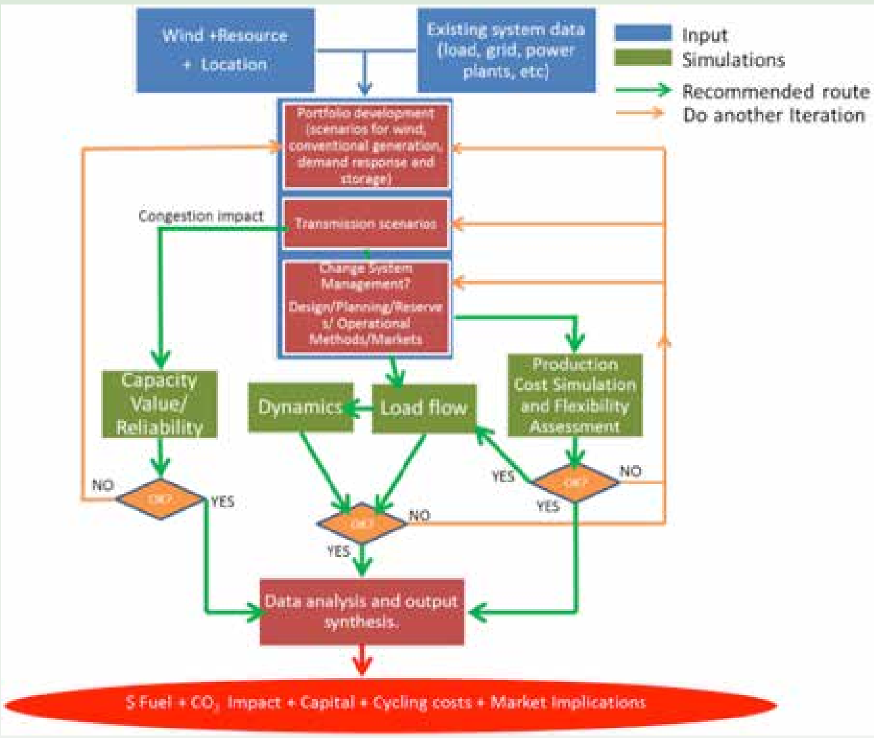


Figure 3. Flow chart of a complete wind integration study, showing relevant iteration loops from simulations to set-up and portfolio development

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 because 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 when adding wind power to power systems is reducing the total operating costs and emissions as wind replaces fossil fuels.

4.0 Plans for 2014

Task 25 will continue its work as discussed in the planned meetings of participants. The first meeting in 2014 will take place in April in Golden, Colorado, United States, hosted by NREL. The fall meeting is planned for Münich, Germany, hosted by Fraunhofer IWES and Research Institute for Energy Economy. Task 25 work and results will be presented also at several meetings in 2014 including the IEEE Power Engineering Society summer conference in Washington D.C., United States, July, 2014 and the 14th Wind Integration Workshop in Berlin, 2014.

Journal articles and conference presentations will be made about critical modeling issues in wind integration studies: integration costs, electricity market design, curtailments, wind-hydro integration, forecast error modeling, and variability. Fact sheets of wind integration issues will be published. Work on collecting a time series of large-scale wind power relevant for integration studies as the basis for a database is also planned during 2014.

The topic being addressed by Task 25 is growing exponentially in importance within the member countries and more broadly. The end of the third term (2012–2014), will likely see a proposal to continue work to address design and operation of power systems with large amounts of wind power.

Opening photo: PWT Communications LLC

Author: Hannele Holttinen, 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 MW 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). 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 this task 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 an 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 this task 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 is to provide information on the cost of wind energy in order to understand past and present trends and anticipate future trends using consistent, transparent methodologies. Another aspect is to understand how wind technology compares to other generation options within the broader electric sector. Task 26 participants (Table 1) will continue to add data and analysis, develop methodologies, and enhance collaboration.

Expected results include:

- Enhanced international collaboration and coordination in the field of the cost of wind energy
- Updated data, analysis, and understanding of cost trends for land-based wind energy and comparison among countries
- Identification of the primary cost drivers for offshore wind energy and the variation of these costs among participating countries
- Collaborative journal articles summarizing and further analyzing work conducted to understand trends in 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 2013

In 2013, efforts were focused in two areas: identifying elements associated with quantifying the value of wind energy and assessing data and methodologies for estimating the cost of wind energy on land.

Value of Wind Energy:

Assessing the value of wind energy to society is important for making informed decisions about electricity generation options. Impacts to society are found in economic, wind technology, electric sector, social and environmental systems, and many impacts are inter-related. A system-based approach to assessing the value of wind energy is warranted.

A workshop was held to create a comprehensive list of social, environmental, and economic elements that should or could be included in any analysis of the value of wind energy to society. Hosted by the Joint Research Centre of the European Commission, the workshop was titled "System Approach to Assessing the Value of Wind for the Society"

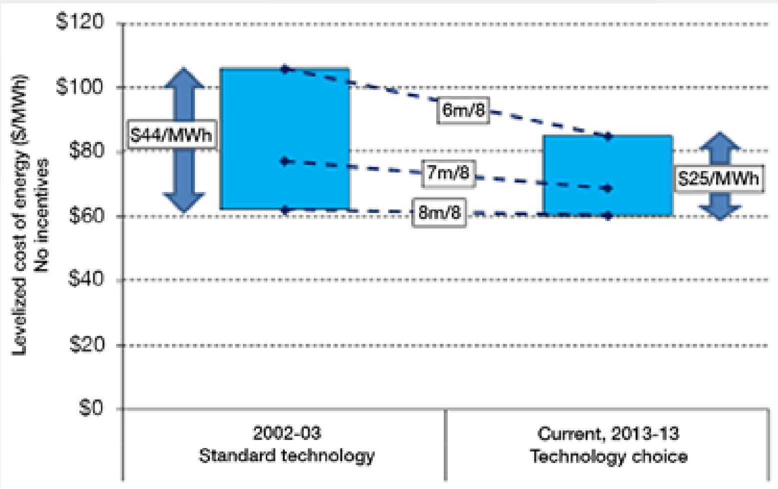


Figure 1. Estimated wind plant cost of energy in the U.S. for single turbine technology prevalent in 2002–2003 compared to the multiple turbine technology offerings available in 2012–2013 (1)

Table 1. Countries and Organizations Participating in Task 26 During 2013

	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 IWES
4	Ireland	Dublin Institute of Technology (DIT)
5	Netherlands	Energy Center of the Netherlands (ECN), TKI - Wind op Zee
6	Norway	SINTEF, Norwegian Energy Agency
7	U.S.	National Renewable Energy Laboratory (NREL), Lawrence Berkeley National Laboratory (LBNL)

and was held in Petten, Netherlands, 13–14 November 2013. The participants represented expertise in economics, electric system operation, wind technology, environmental analysis, and social aspects. Together, through a series of small group exercises, elements required to assess the value of wind were identified and knowledge or data gaps were elicited. A document summarizing the resulting insights from the meeting is forthcoming.

Considering a systems approach to assessing the value of wind is quite challenging due to the broad application of topics, the analytic approaches and available data utilized today, and the type and magnitude of impacts. The system boundary definition is critical because it affects the analytic approach as well as the results. Some elements associated with the value of wind energy are quantifiable with the models and data available today, however improved data or analytic tools are required to assess other elements, and some aspects may never be fully quantified. Many impacts are largely localized around the vicinity of a wind plant while the societal benefits are broadly distributed. By identifying the elements associated with assessing the value of wind energy, an initial framework for understanding the interactions, boundaries, and extent of analysis could be developed.

Cost of Energy for Land-based Wind:

Building from the work conducted in the first phase of the task (2), updated estimates of cost of wind energy for land-based wind plants will be made. 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 the countries. This work will be updated by participants continuing in the task as well as expanded to include Norway and Ireland due to new task participation.

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 over time to identify changes in wind technology and its associated impact on cost of energy is anticipated to be a valuable addition to understanding cost of wind energy in each country. In this first year of the continuation of Task 26, best practices for obtaining and analyzing wind project data were shared among the participants.

Semi-annual meetings provide a valuable forum for exchanging ideas among the participants as well as engaging with other industry or research organizations. For example, a meeting held in Trondheim, Norway, in May 2013 included presentations and discussion from a range of Norwegian industry, government, and academic perspectives. This informal information exchange is highly valuable to the task overall as well as for the participating national organizations.

4.0 Plans for 2014 and beyond

In 2012, a task extension proposal was approved by the IEA Wind Executive Committee. The task extension includes the following activities over the subsequent three years (October 2012–September 2015).

Land-based cost of energy estimates will be updated by each of the participants to include a record of project cost estimates from 2008 through the present. In addition, new participants representing Ireland and Norway will expand the countries represented in the analysis. Examination of trends within countries and among countries will also be conducted. Exploring trends in technology as well as wind plant resource conditions over this period will enable the participants to refine cost of energy estimates based on recent technology trends.

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 will be devised. This approach will allow analysis of cost drivers based on information provided from the various participants and will represent offshore wind project costs generically—rather than specific to those countries where projects are in operation. In addition, analysis of the primary differences among countries, both technical and policy-based will be conducted.

A second workshop will be held to assemble experts in order to engage a broad range of perspectives. Potential topics include continuing exploration of methodologies to estimate the value of wind and investigation of methods and approaches to estimating the future cost of wind energy. The workshop format provides an opportunity for experts to actively engage in a topic area of interest as well as for industry participants to engage with Task 26 researchers.

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.

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

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) 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.

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

Task 27 has evolved through two major focuses: Development and Deployment of Small Wind Turbine Consumer Labels (2008–2011) and Task 27 Small Wind Turbines in High Turbulence Sites (2012–2016). In 2008, the IEA Wind Executive Committee approved the launch of a task on small wind turbines with two main objectives:

1. Develop and deploy a Small Wind Turbine Consumer Label. This subtask developed IEA Wind Recommended Practice: Consumer Label for Small Wind Turbines.
2. Develop an association for testing organizations. This subtask established the Small Wind Association of Testers (SWAT) to promote standardized testing of small wind turbines.

Since 2008, IEA Wind Task 27 has held ten liaison meetings with the International Electrotechnical Commission (IEC) MT2 at locations in Madrid (Spain), London (United Kingdom), Wisconsin (United States), Toronto (Canada), Tokyo (Japan), Kaiser-Wilhelm-Koog (Germany), Glasgow (United Kingdom), Colorado (United States), Perth (Australia), and in 2013, in Madrid (Spain). As a result of the collaborative work between IEC MT2 and IEA Wind Task 27 experts, the third revision of IEC 61400-2 standard includes an informative annex with the same consumer label requirements.

Task 27 hosted two international SWAT conferences, one in 2012 in Ithaca, NY (U.S.) and another in 2013 in Soria (Spain) (Figure 1). In 2014, the topic and future of small wind turbine labeling may be undertaken by the new IEC RE group which has replaced the TC88 Certification Advisory Council (CAC). Under the CAC there is a small wind turbine subcommittee that will likely continue under the IEC RE structure. Part of the role of IEC RE is to develop consumer information about renewables so it is likely that IEC RE will have the purview of the important labeling task. Proposals have also been presented to host the label system through the World Wind Energy Association (WWEA) or the International Renewable Energy Association (IRENA) web pages.

By 2011, participants were interested in expanding the scope of IEA Wind Task 27 to conduct research to improve the IEC standard on small wind turbine design. One research topic was to gain a better understanding of the special wind conditions found in areas of complex terrain where small wind turbines are typically sited. One of the areas of complex terrain is in the urban environment or on a roof. A better understanding of the wind resource in areas of high turbulence and its impact on turbine design and performance would be used as the basis for consideration of changes to the small wind turbine design requirements per IEC 61400-2. In 2012, the Task 27 extension was approved with a new work plan covering research on small wind turbines in turbulent sites.

2.0 Objectives and Strategy

The Task 27 extension through 2016 has three main objectives:

1. Develop a Recommended Practice that provides guidelines and information on micro-siting of small turbines in highly turbulent sites (urban/suburban setting, on rooftops, in forested areas) and also provides general information on energy production for these turbulent sites.
2. Prepare for the fourth revision of IEC 61400-2 by recommending new design classification for urban turbines, considering whether there is a better metric for turbulence than I15, defining new external conditions (normal turbulence model and extreme direction change), and considering the normal turbulence model.
3. Compare existing, accredited power performance test results to field data on power performance taken in highly

Table 1. Countries and Organizations Participating in Task 27 During 2013

	Country	Institution(s)
1	Australia	Australian National Small Wind Turbine Centre (RISE) Murdoch University
2	China	Chinese Wind Energy Association (CWEA)
3	Denmark	Technical University of Denmark (DTU)
4	Ireland	Dundalk Institute of Technology (DKIT)
5	Japan	National Institute of Advanced Industrial Science and Technology (AIST)
6	Korea, Republic of	Korean Institute of Energy Research (KIER)
7	Spain	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)
8	United States	National Renewable Energy Laboratory (NREL)
	France (Observer)	Centre Scientifique et Technique du Bâtiment; (CSTB)
	Argentina (Observer)	Instituto Nacional de Tecnología Industrial (INTI)

turbulent sites to learn about trends in power production.

Four Work Packages were defined: WP 1: SWAT/ Label deployment, WP 2: Analyze and model highly turbulent wind resource, WP3: Collect "new" wind resource and turbine power performance data from rooftop and other complex terrain test sites, and WP4: Develop a Recommended Practice on micro-siting of small turbines in highly turbulent sites. Since the Task extension was approved, progress has been made in WP1, WP2, and WP3.

3.0 Progress in 2013

3.1 Meetings of participants

Two physical meetings and three virtual (via Internet connection) meetings were held during 2013. IEA Wind Task 27 country members are from certification bodies, test labs, national research and university organizations, and the small wind turbine industry. Participants report on relevant research in their countries and then discuss task activities and plans for cooperation.

The first virtual meeting was held in two parts to accommodate participants in widely separated time zones. The first part had nine participants from Ireland, Spain, the United States, and Israel (Observer). The second part had 15 experts from Australia, China, Japan, Spain, and the United States.

The second virtual meeting of the year was held in two parts in March. The first part had 8 participants from China, Ireland, Spain, and the United States, and the second part had 11 participants from Australia, China, Japan, Korea, Spain, and the United States.

The third face-to-face meeting was held in Soria, Spain (Figure 1), and was attended by 19 experts from 10 countries: Argentina (Observer), Australia, China, France (Observer), Ireland, Japan, Korea, Peru (Observer), Spain, and the United States. The participants represent research organizations, test labs, manufacturers, and universities; 20 presentations were given.

The fourth meeting of the year, was virtual; 13 experts from certification bodies, scientific institutions, and the small wind turbine industry attended from Australia, China, France (observer), Ireland, Korea, Spain, and the United States.

The fifth meeting, held on Jeju Island, Republic of Korea, was attended by 15 experts from Australia, China, Ireland, Korea, Spain, and the United States. Participants from research organizations, manufacturers, and universities made 14 presentations.

3.2 Reports, conferences and decisions

In addition to presentations given for task participants at meetings, participants have presented the task work at several conferences. The Second International Conference of Small Wind Associations of Testers Conference had 31 presentations. "Development and Deployment of Consumer Label for Small Wind Turbines" was presented at the Small Wind Turbine International Workshop PUCRS Porto Alegre (Brazil) 2013.

The following industry organizations have participated in Task 27 meetings: HyEnergy (China), Zhejiang Huaying Wind Power Generator Co (China), Zephyr Co (Japan), and Baiwind (Spain), and Kliux (Spain).

At the task meetings several conclusions were reached. All information related to the small wind turbine consumer label will remain accessible only to IEA Wind Task 27 participants for at least one year. Participants agree that management of the labeling

Figure 1. Experts at the Second International SWAT Conference, hosted by CEDER (CIEMAT) in Soria, Spain

Figure 2. IEA Wind Task 27 team photo from CEDER in Soria, Spain

process will pass to another organization. The IEC RE Small Wind Turbine subcommittee, the World Wind Energy Association, or the International Renewable Energy Agency are possibilities. It was agreed that labels with information from unaccredited test organizations should use some codes or explanations for consumers to make it clear that the results are not accredited.

The group decided to develop a draft procedure for rooftop testing of small wind turbines. A new proposal was considered to conduct R&D and tests to develop simplified loads methodology (SLM) for the IEC 61400-2 standard for vertical axis wind turbines (VAWT). Currently there is no simplified loads methodology for VAWTs within IEC 61400-2, yet many small wind turbines being sold use VAWT technology.

Some Task 27 members have specifically asked for global research on this topic to be developed under the task to develop a new VAWT simplified loads methodology for consideration under the fourth revision of IEC 61400-2. Task activities are needed in measuring, modeling (computational fluid dynamics (CFD), aeroelastic, etc.), and validation. Japan is already doing some research that includes CFD modeling and measurements for VAWTs.

4.0 Plans for 2014 and Beyond

The labeling activity will be transferred to one of three possible organizations: to the new IEC RE Small Wind Turbine subcommittee, to the World Wind Energy Association, or to the International Renewable Energy Agency. Once a host is identified, it is likely that the deployment of SWAT will be completed.

Rooftop testing at several sites with different conditions (especially high turbulence intensity conditions) is on-going. Standardization of measurements from roof-top wind monitoring will be discussed. Analysis and data collection methodology discussion for rooftop/complex terrain testing and analysis is needed. Development of CFD models of these sites are ongoing with discussion of possible model validation.

Data sets of wind turbine performance in areas of complex terrain is being analyzed. Participants are helping to develop a proposed methodology for rooftop small wind turbine power performance tests.

A general procedure for annual energy prediction of small wind turbines operating in highly turbulent wind sites is under development. A new IEC 61400-2 wind class definition is under consideration. A new VAWT simplified load equations method is also under consideration. The possibility to collaborate with the SWIP Project team (funded by the European Union the FP7) is also under consideration. New countries will be integrated into the IEA Wind Task 27 team.

References:

Opening photo: PEGASUS Wind Turbine (Credit: HYE Energy)

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

Many national or regional surveys include aspects of social acceptance of wind power, and studies have been conducted on the acceptance of specific wind power projects. Task 28 has been working to answer questions that go beyond these surveys and studies. For example, could it be possible to derive some indicators based on this knowledge, on a national-, regional-, or project-specific basis to visualize the status of social acceptance and/or to show its development over time?

Many actors involved in the development of wind energy projects have acknowledged the particular role of acceptance issues in the planning and communication process. If no effort is dedicated to addressing the different views, fears, and expectations of residents, non-governmental organizations, and others to wind energy projects, a lot of the work invested in preparations can be wasted.

Many national wind associations, national or regional planning authorities, and research institutions have developed guidelines and recommendations to help their partners in the development of projects that have a chance to find the necessary acceptance. Additionally, the industry has learned the hard lesson that a few black sheep among them can spoil projects when negative opinions multiply within a region. There are not many studies, however, on how those guidelines are used and what their benefit is.

Wind energy projects often include first-time encounters for responsible parties involved such as municipalities that have to decide on a project. How can the flow of information be secured and the acceptance issues be brought to the attention of the decision makers?

All those questions describe aspects of monitoring the status of social acceptance and the description of its development. Monitoring social acceptance is one of the issues that IEA Wind Task 28 is dedicated to discuss in its current project period with the aim of (1) helping IEA Wind countries to document the social acceptance developments in their countries as a support to their national policies and supporting instruments, and (2) supporting actors evaluate acceptance measures or to identify key issues.

2.0 Objectives and Strategy

IEA Wind Task 28 will support participating countries to address social acceptance issues. It will provide up-to-date information on social acceptance of wind energy in each of the participating countries. It will identify and document successful policy strategies anticipated to be applicable. It will enable sharing among participants of practical information, learning from each other, complementing each other's approaches.

Task 28 stimulates discussion of the complex issues around social acceptance and contributes to additional insights from the broad transnational and interdisciplinary experience of the participant network. Participants work together on open issues and research gaps, including opportunities for joint research. Task 28 has enlarged the network and knowledge on good practice of institutions, organizations, experts and practitioners. These participants contribute to 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 better projects.

The intended means to provide these inputs are:

- Working group meetings, national expert meetings, Topical Expert Meetings
- Good Practice Recommendations and other publications
- Reports to IEA Wind Executive Committee and Annual Reports
- Participation in conferences, e.g., the annual European Wind Energy Association conference
- Articles in industry journals and branch magazines
- Task 28 website homepage

At each working group meeting, Task 28 participants focus on an issue to develop more detailed recommendations. The main areas of proposed work for the next period include the following:

- Monitor social acceptance
- Document existing policies and standards that have been demonstrated to increase social acceptance
- Discuss current and new issues influencing social acceptance that are being debated in the participating countries, stressing research gaps and discovering opportunities for joint research
- Determine, document, and disseminate the lessons learned, good practices, and successful strategies, to improve

Table 1. Countries and Organizations Participating in Task 28 During 2013

	Country	Institution(s)
1	Germany	Federal Ministry for Economic Affairs and Energy; Martin Luther University; University of the Saarland
2	Ireland	Sustainable Energy Authority; Queen's University Belfast
3	Italy	RSE Ricerca sul Sistema Energetico
4	Japan	National Institute of Advanced Industrial Science and Technology; Nagoya University
5	Switzerland	Swiss Federal Office of Energy; ENCO Energie-Consulting AG
6	United States	U.S. Department of Energy; National Renewable Energy Laboratory Wind Technology Center; Lawrence Berkeley Lab

projects and their implementation and to support the definition of the common understanding of "sustainable, acceptable projects"

- Elaborate on the role of intermediary persons or organizations in the management of controversial projects
- Explain the importance of a "guichet unique" for developers or public authorities in the approval of a wind energy project.

The contact and exchange with further projects in the area of social acceptance of renewable energies will also be sought.

3.0 Progress in 2013

As a highlight of 2013, IEA Wind Task 28 met for a working group meeting in Japan, which was connected to a Japanese national expert meeting. The meeting was hosted by the Japan Electric Manufacturers Association (JEMA) and organized by the Japanese working group members. Japanese experts from various institutes, community organizations and associations met to exchange information on acceptance issues of wind power. The developments in Japan since the Fukushima events of 2011, the community power movement, and the Japanese progress on the prevention of bird strikes were especially interesting for the Task 28 members from abroad.

At the Japan meeting, the working group tackled the issue of monitoring social acceptance. The issue was first described as an assessment of the "magnitude" of social acceptance" and as the quantification of the phenomenon and the impact of social acceptance especially in places where it has been ignored. The discussion focused on how to track developments in the area of social acceptance of wind energy projects, development of methods, and possible indicators to illustrate those trends.

The working group discussed the reasons for monitoring social acceptance as well as possible benefits to various target groups for the results of such studies. Criteria for "social acceptance indicators" were defined and possible indicators assembled. The working group conclusions were circulated to IEA Wind members in a "flash note" (not yet published). What is missing from the surveys on acceptance of renewable energy technologies or specific projects, in the view of Task 28 participants, are lead indicators to summarize developments in social acceptance. Such lead indicators should represent more detailed measurements and social research. Task 28 participants recognize the complexity of the issue and the difficulties in establishing relevant indicators. However, such *lead indicators* could serve as a valuable tool to make the dimension of social acceptance visible to administrations and politicians as well as to citizens. Measureable indicators could also help evaluate policies, policy instruments, and the degree to which guidelines or recommendations are being implemented. The Task 28 working group will continue discussion of the issue in 2014 and will eventually elaborate some proposals to the countries involved in IEA Wind.

The meeting in Japan was prepared by means of a web meeting giving the Operating Agent a chance to work out the structure of the discussions beforehand and to help the working group prepare for the meeting. After the Japan meeting, another web meeting was held to discuss the results that should be presented to the IEA Wind Executive Committee.

The website was updated on a regular basis and new projects were inserted into the data base. In 2013, the exchange with interested partners from Australia was intensified and a representative from the Clean Energy Council was present at the Japan meeting. This gave the working group a chance to have an insight into the situation on social acceptance in Australia.

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

4.0 Plans for 2014 and beyond

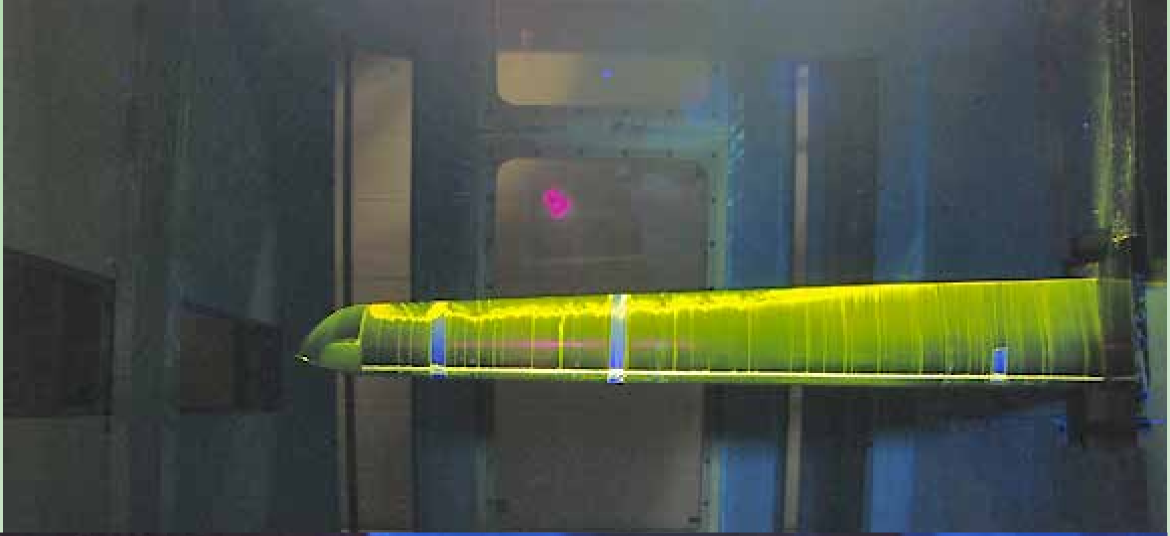
Apart from the issue of monitoring social acceptance, the working group has decided to tackle the role of the intermediary in social acceptance projects in 2014. In many of the IEA Wind countries, individual persons, private enterprises, or public agencies have acted as intermediaries by bringing together the various interests involved. This role has helped move projects forward to the benefit of all parties. The working group will reflect on the various models available. It will summarize lessons learned and make recommendations for organizations aiming to establish such an intermediary function.

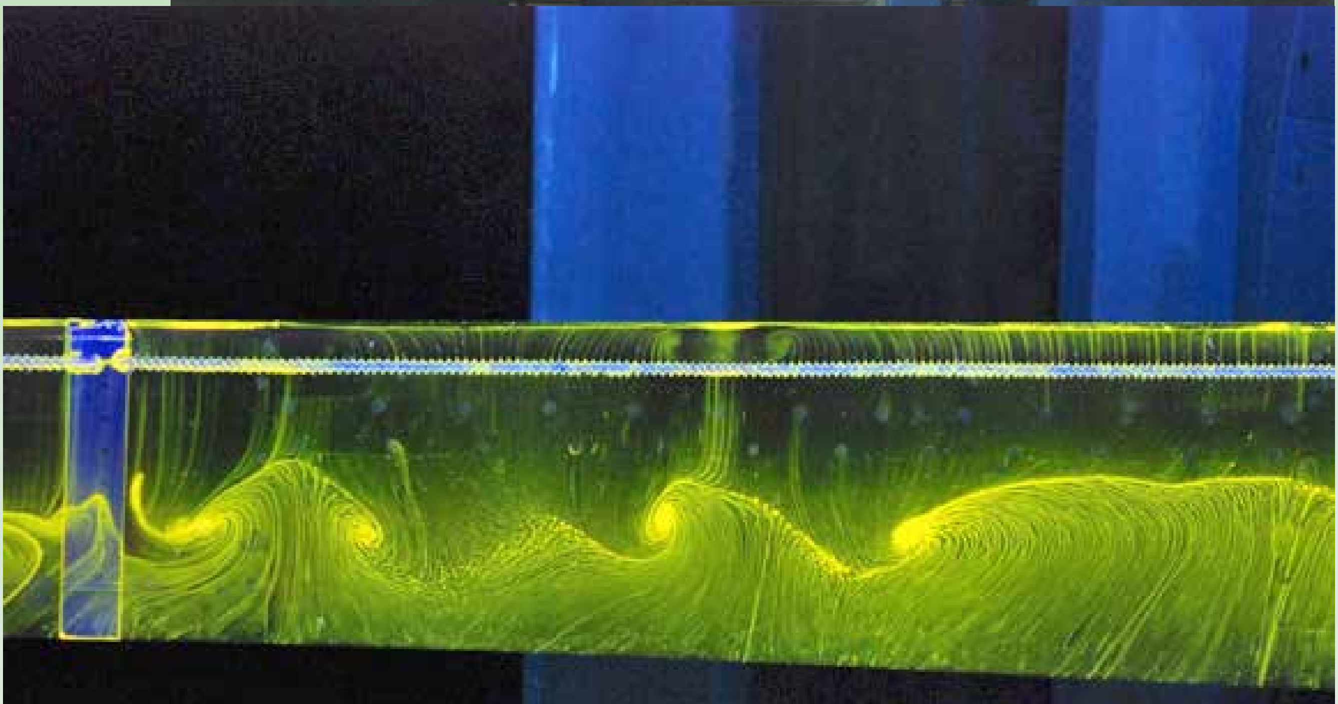
The highlight of 2014 will be the working group meeting in March in Milano, Italy, at the premises of RSE, the Italian partner. The meeting will be connected to an Italian expert day, bringing together for the first time Italian stakeholders involved in the social acceptance issues surrounding wind farms. The title of the experience exchange is to be "Building and Measuring Public Acceptance of Wind Energy Projects."

References:

Opening photo: National expert meeting of IEA Wind Task 28 in Japan in May 2014

Authors: Markus Geissmann, Swiss Federal Office of Energy and Stefanie Huber, ENCO AG, Switzerland.





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

1.0 Introduction

In the past, the accuracy of wind turbine design models has been assessed in several validation projects (1). They all showed that the modeling of a wind turbine response (i.e., the power or the loads) is subject to large uncertainties. These uncertainties mainly find their origin in the aerodynamic modeling where several phenomena such as 3-D geometric and rotational effects, instationary effects, yaw effects, stall, and tower effects, among others, contribute to unknown responses, particularly at off-design conditions.

The availability of high-quality measurements is the most important prerequisite to gain insight into these uncertainties and to validate and improve aerodynamic wind turbine models. For this reason, IEA Wind Task 29 Mexnext is carried out. Mexnext is being performed in two phases. The first phase, Mexnext-I, ran for three years starting in June 2008. The main aim of Mexnext-I was to analyze the measurements from the European Union project *Mexico* (Model Rotor Experiments In Controlled Conditions) (2). In that project, ten institutes from six countries cooperated in doing experiments on an instrumented, three-bladed wind turbine of 4.5 m diameter placed in the 9.5 by 9.5 m^2 open section of the Large Low-speed Facility (LLF) of German-Dutch Wind Tunnels (DNW) in the Netherlands. The measurements were performed in December 2006 and resulted in a database of combined blade pressure distributions, loads, and flow field measurements, which can be used for aerodynamic model validation and improvement. In Mexnext-I, 20 participants from 11 countries participated. On 1 June 2011, Mexnext-I officially ended and a final report was issued (3). Thereafter, Mexnext-II was approved, which runs from 1 January 2012 until 31 December 2014.

In general terms the work plan of Mexnext-II is very similar to the work plan of Mexnext-I. The main difference lies in the fact that the analyses will include an inventory and further analysis of all historical aerodynamic wind turbine measurements (where history ranges from long past to very recent and includes the Mexico experiment). It is believed that these analyses will lead to the maximum possible understanding of wind turbine aerodynamics. Originally no new measurements were foreseen.

However in 2012, the EU Aerospace program ESWIRP approved a *New Mexico* project in which additional measurements are performed on the Mexico model wind turbine in the DNW-LLF. This project funds the (very expensive) tunnel time where the instrumented model wind turbine is still available from the Mexico project. Person hours are funded from the EU FP7 project 'INNWIND.EU.' The 'New Mexico' measurements are scheduled for mid-2014.

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

2.0 Objectives and Strategy

The objective of 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 carries out an inventory of 'unexplored' experiments, those data are available but have not been analyzed. Mexnext-I used the Mexico measurements so this inventory was not needed. Apart from that difference, both Mexnext-I and Mexnext-II are carried out along the following WP.

- WP2: Processing/presentation of data, uncertainties. The aim of this work package is to provide high-quality measurement data to facilitate and compare calculations. To that end, the quality of the data is assessed and the data are reprocessed. Moreover, in the case of wind tunnel measurements, the tunnel effects are assessed.
- WP3: Comparison of calculational results from different types of codes with various measurement data. In this work package, the calculational results from the codes used by the task participants are compared with the data from the various experiments.
- WP4: Deeper investigation into phenomena. In this work package, phenomena are investigated with isolated sub-models, simple analytical tools, or by physical rules. The phenomena investigated include 3-D effects, instationary effects, yawed flow, 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 2013

In 2013, a calculation round on the National Renewable Energy Laboratory (NREL) Phase VI (NASA-Ames) experiment was defined, which consists of four cases in axial flow. Emphasis was put on measurements at a rotational speed of 90 rpm. Such rotational speed is higher than the commonly featured rotor speed of 72 rpm. This makes it interesting because it is expected to lead to different induction effects. When preparing these cases some improvements to the existing computer-assisted design (CAD) file of the NREL Phase VI blade surface geometry turned out to be necessary in order to provide a reliable input to the computational fluid dynamics (CFD) codes. The results of the calculations in comparison with the measurements will be presented at the next European Wind Energy Association conference from in March 2014 in Barcelona (4).

Another focus of Mexnext II has been the preparation of the New Mexico experiment. A large number of 'lessons learned' were summarized and presented to the Mexnext group in September 2013 at a plenary meeting. These lessons learned are now included in the preparation of the experiment and/or the test matrix. The preliminary test matrix includes pressure measurements, particle image velocimetry (PIV) measurements, load measurements (including the measurement of torque from the generator), microphone array measurements, and application of several flow visualization techniques. These measurements will be taken at several conditions including yaw and dynamic pitch. In addition to that, a test run is added where the blades will be equipped with Guerney flaps.

In order to prepare the New Mexico experiment, the instrumented Mexico turbine blades have been placed in the Low Speed Tunnel (LST) of the TU Delft, i.e., at quasi 2-D conditions. In the LST, the aerodynamic characteristics of the blades at standstill have been measured (including a flow visualization) where moreover the blade instrumentation and data acquisition could be tested and recalibrated. A first test in LST was done in November 2013 followed by a second experiment in January 2014. The experiments in the LST were very successful. The pressure sensors and data acquisition systems have been reactivated and several improvements have been made to both the instrumentation and data acquisition system. The analysis of aerodynamic characteristics at standstill is currently taking place. Some first results of this analysis will be reported in (4). In the opening photo, some representative oil flow visualizations from the LST experiment are shown.

Several analyses took place on measurements other than NREL Phase VI or Mexico. Amongst other things, measurements from FFA/CARDC (as performed at the end of 1980s) have been used to derive a 3-D correction model on the drag coefficients. Also measurements on transition from

Table 1. Countries and Organizations Participating in Task 29 during 2013

	Country	Institution(s)*
1	China	Chinese Wind Energy Association (CWEA)
2	Denmark	Danish Technical University (DTU; Vestas
3	Germany	Fraunhofer IWES; University of Stuttgart (IAG); University of Applied Sciences at Kiel; ForWind; Windnovation; 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; Germanischer Loyd/Garrad Hassan (GL-GH)
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	United States	National Renewable Energy Laboratory (NREL)

* Technion in Israel is a subcontractor to Task 29.

Danaero, UAS-Kiel and TU Delft/ECN were found useful. The same holds for the very well documented IEA Wind Task 18 measurements from the 1990s which could be used to assess tip effects and 3-D drag effects (5). However, in some of the old experiments the information on quality and precise airfoil shape was found difficult to retrieve. It should be realized that the statement 'everyone believes the measurements except the experimentalist' is not very true within the Mexnext-II project team.

All of the above mentioned results and actions were discussed at the third meeting of Mexnext-II (i.e., the eighth meeting of the overall Mexnext project). From 25–28 September 2013 at CENER in Spain, several technical results were presented, together with the test plan for the New Mexico experiment. The last day was devoted to 'aerodynamic free wheeling,' i.e., presentations on aerodynamic subjects not related to Mexnext. This included presentations on related EU projects like AVATAR (www.eera-avatar.eu/), OFFWINDTECH and IEA Wind Task 31 Wakebench. Several of these presentations have been uploaded to the public part of the Mexnext site (www.mexnext.org/).

Through early 2014, results have been published and presented in at least 29 papers and articles, (see references 3, 4, 6, 7, 8, 9), and they formed the basis for two PhD theses (10) and (11).

4.0 Plans for 2014 and beyond

The most important activity in 2014 will be the New Mexico experiment, which is scheduled for mid-July 2014 in the DNW-LLF. The analysis of these data may require an extension of Mexnext II or a follow-up IEA Wind Task.

A new calculation round on yawed flow will be defined. It will be based on NREL Phase VI measurements at limited yaw (smaller than 10 degrees) in order to comply with the standards. Moreover a calculational round at large yaw will be defined, which is expected to have a large scientific value.

The next plenary meeting of Mexnext II will most likely be held in autumn 2014 in Asia. If possible, the meeting will be combined with a meeting from IEA Wind Task 31 Wakebench.

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Opening Photo: Flow visualizations of Mexico blade in LST wind tunnel of TUDelft

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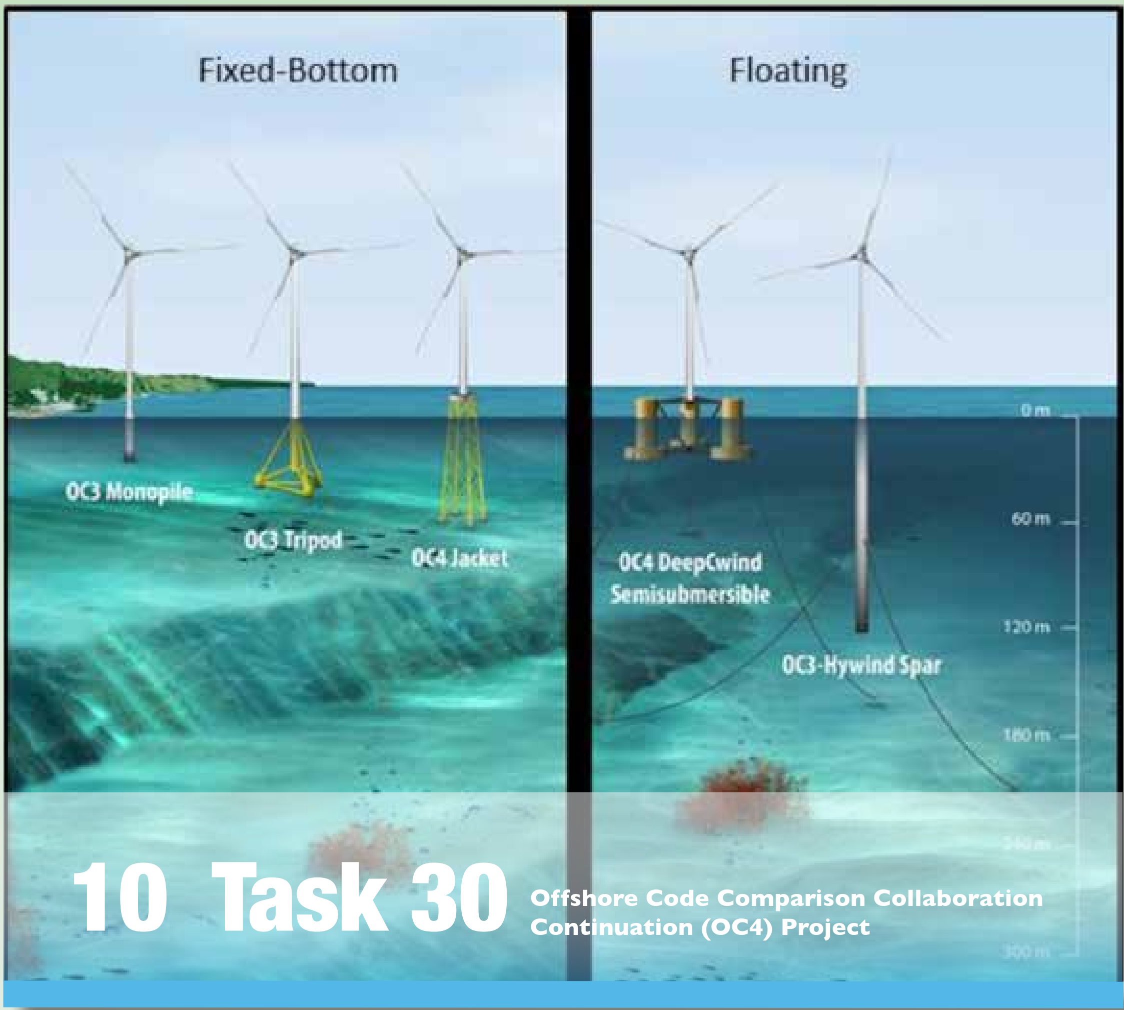


10 Task 30 Offshore Code Comparison Collaboration Continuation (OC4) Project

1.0 Introduction

The vast offshore wind resource represents a potential to use wind turbines installed offshore to make a significant contribution to the world's energy supply. Design of offshore wind turbines can be complicated because offshore sites vary significantly through differences in water depth, soil type, and wind and wave severity, which requires the use of a variety of support structure types. These types include 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, aerodynamic (aero), 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 foundation dynamics of the support structure. The sophistication of these aero-hydro-servo-elastic codes and the limited data available that is available to validate them with underscores the need to verify their accuracy and correctness.

The Offshore Code Comparison Collaboration (OC3), which operated under Subtask 2 of the IEA Wind Task 23, was established to meet this need. Task 23 was completed in 2009; in 2010, a new project (OC4) was established to continue the work. OC4 is led cooperatively by the National Renewable Energy Laboratory (NREL), United States and the Fraunhofer Institute for Wind Energy and Energy Systems Technology (IWES), Germany.

Since the project began, 154 participants from 61 organizations in 18 countries have participated in the task. Many more have participated via e-mail communication, but have not been able to attend physical meetings.

2.0 Objectives and Strategy

The purpose of the OC4 project is to perform a benchmarking exercise of offshore wind turbine dynamics computer codes. To test the codes, the main activities of OC4 are to (a) discuss modeling strategies, (b) develop a suite of benchmark models and simulations, (c) run the simulations and process the simulation results, and (d) compare and discuss the results. 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 and verifying the capabilities and limitations of implemented theories
- Investigating and refining applied analysis methodologies
- Identifying further research and development (R&D) needs.

Such verification work, in the past, led to dramatic improvements in model accuracy as

Table 1. Countries and Organizations Participating in Task 30 During 2013

	Country	Institution(s)
1	China	China General Certification Center, Goldwind, Chinese Wind Energy Assoc., China Ship Industry Corporation
2	Denmark	DTU Wind Energy (campus Risø), DHI, Rambøll
3	Finland	VTT Technical Research Centre of Finland
4	Germany	Fraunhofer IWES, Germanischer Lloyd, Leibniz Universität Hannover, REpower, University of Stuttgart, SKI
5	Greece	Aristotle University of Thessaloniki, National Technical University of Athens
6	Japan	University of Tokyo, National Marine Research Institute, WEIT
7	Korea	Pohang University of Science and Technology, University of Ulsan, KAIST
8	The Netherlands	Energy Research Centre of the Netherlands (ECN), The Knowledge Centre WMC, GustoMSC, TU Delft, MARIN
9	Norway	Norwegian University of Science and Technology (NTNU), FEDEM Technology, Institute for Energy Technology, Marintek, 4subsea, University of Stavanger, Simis
10	Portugal	Wave Energy Centre, Instituto Superior Tecnico, CENTEC
11	Spain	Acciona Energia, ALSTOM Wind, CENER, LMS, IREC, SAMTECH
12	United States	ABS, National Renewable Energy Laboratory, Principle Power, MSC Software, Texas A&M University, Clear Path Energy, Penn State University, University of Maine, Department of Energy
Observers		LMS (Belgium); McGill (Canada); Principia (France); Polytechnico Di Milano, Ricerca Sistema Energetico (RSE), University of Florence (Italy); GE Wind, Teknikgruppen (Sweden); GL Garrad Hassan, Lloyd's Register (UK)

the code-to-code comparisons and lessons learned helped identify model deficiencies and needed improvements.

In OC3 and now again in OC4, the "NREL 5-MW offshore baseline turbine" (1) is used as the turbine model. Emphasis is given to the verification of the offshore support-structure dynamics as part of the dynamics of the complete offshore wind turbine system. This emphasis distinguishes OC3 and OC4 from previous wind turbine code-to-code verification activities. To encompass the variety of support structures required for cost effectiveness at varying offshore sites, different support structures (for the same wind turbine) are investigated in separate phases of the projects. In OC3, four phases were used to consider (I) a fixed-bottom monopile with rigid foundation, (II) a fixed-bottom monopile with flexible foundation, (III) a fixed-bottom tripod, and (IV) floating spar buoy. The results of the OC3 project are summarized in its final report (2).

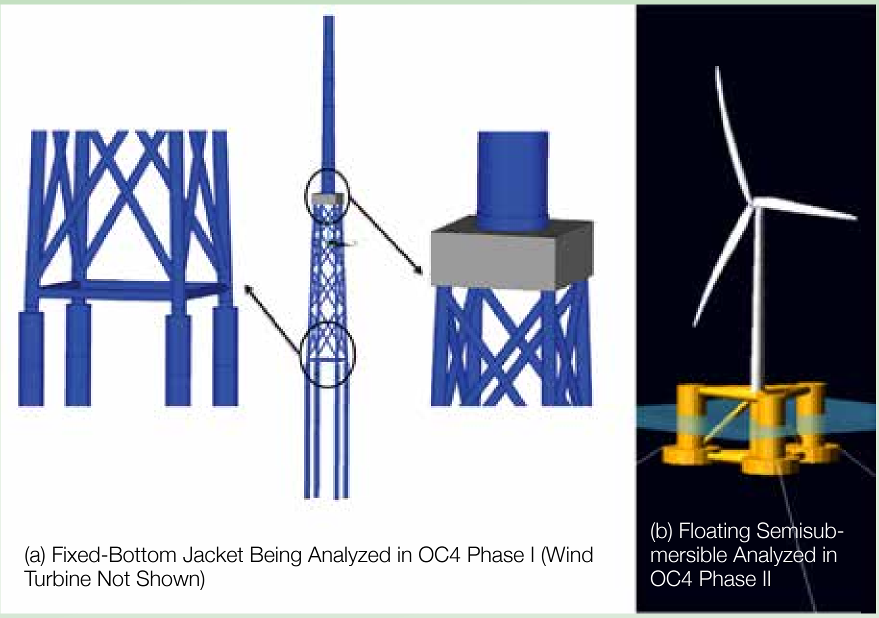
OC4 consists of two phases that were not considered in OC3: (I) analysis of a wind turbine on an offshore fixed-bottom jacket support structure and (II) analysis of a wind turbine on an offshore floating semisubmersible support structure (see Figure 1). Phase I of the OC4 project was completed in the summer of 2012, with a conference paper presented at the International Offshore and Polar Engineering Conference (ISOPE) conference in June 2012 in Rhodes, Greece (3). Phase II of the project was completed in December 2013, and a summary paper was presented at the European Wind Energy Association (EWEA) Offshore conference in Frankfurt, Germany (4) with more technical details being written in an upcoming International Conference on Ocean, Offshore and Arctic Engineering (OMAE) 2014 conference paper (5). Additionally, an experts meeting on the topic of test methods, data availability, and code validation was held as a standalone meeting in Boulder, CO in 2012. The conclusions from the meeting were summarized in a report.

3.0 Progress in 2013

The project had three physical meetings in 2013: the first in conjunction with the EWEA conference in Vienna, Austria in February; the second in conjunction with the OMAE conference in Nantes, France in June; and the third in conjunction with the EWEA Offshore conference in Frankfurt, Germany in November. In between physical meetings, progress was made through e-mail communication and Internet-meetings scheduled every one to two months.

At the end of December, 2013, Phase II was completed, and the project came to a close. A number of tasks were accomplished during the project. The list below identifies the major accomplishments in 2013:

- Twenty-one organizations from ten countries submitted results using 24 different simulation tools for Phase II of the OC4 project. Some institutions provided multiple results, examining the influence of varying modeling approaches within their tool. Multiple institutions also used the same tool, which provided insight into the differences that could be obtained from a given simulation tool based on the user's choice of modeling parameters.
- To compare the response behavior achieved by the different modeling approaches, 21 different load cases (simulations) were performed. In addition to traditional wind/wave load cases, this phase included the computation of response amplitude operators, which were shown to be a good way to examine offshore structure response characteristics across a range of wave conditions, an approach traditionally used in the offshore structural community, but new to the wind community. Damage cases were also modeled, which included the loss of a mooring line and the flooding of one column, to check the simulation tools' capabilities in assessing system behavior in a variety of design conditions. Several findings were made in the project regarding the influence of hydrodynamic and mooring models on the response behavior of a floating semisubmersible.
- A high-level summary paper of Phase II was written and presented at the EWEA Offshore conference in Frankfurt, Germany in November, 2013 (4). In addition, an abstract for a paper providing a more technical summary of Phase II was accepted for presentation at the OMAE conference in June, 2014.
- A proposal for the extension of Task 30 for an additional four years was presented at the IEA Wind Executive Committee meeting in October 2013.



(a) Fixed-Bottom Jacket Being Analyzed in OC4 Phase I (Wind Turbine Not Shown)

(b) Floating Semisubmersible Analyzed in OC4 Phase II

Figure 1. Offshore wind system designs analyzed in OC4

The committee approved this new extension, for the project that will officially be called the Offshore Code Comparison Collaboration Continuation, with Correlation (OC5) project.

4.0 Plans for 2014 and Beyond

In addition to the individual reports from each of the phases, a final report encompassing the entire project will be completed at the beginning of 2014.

Following the enthusiasm expressed by committee members, NREL and Fraunhofer IWES pursued the idea of extending the OC4 project for another four years. A proposal for this extension was presented to and approved by the IEA Executive Committee in October, 2013. The focus of the extension (OC5) will be on the validation of offshore wind modeling tools through the comparison of participant simulations to experimental data from actual offshore wind systems. The project will have three different phases, associated with the validation of three different offshore wind systems. The tentative list of systems include: a monopile, the DeepCwind semisubmersible, and the a full-scale offshore wind turbine.

The last physical meeting for the project will be held in San Francisco, California, United States in June of 2014 in conjunction with the OMAE Conference.

The verification activities that were performed in OC3 and are continuing in OC4 and OC5 are important because the advancement of the offshore wind industry is closely tied to the development and accuracy of dynamics models. 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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Authors: 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 Wind Atlas Analysis and Application Program (WAsP) with its Wind Atlas Methodology. The alternative to linear models like WAsP, is to retain the non-linearity 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 an option 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 from the user due to the extended degrees 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. Research CFD models in contrast are either based on generic commercial CFD solvers or on in-house or open-source codes and are used by researchers due to 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 between RANS and LES), and even full large eddy simulations (LES) of rotating blades.

Common to 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 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 verification, validation, and uncertainty quantification procedures is an unresolved issue in wind resource assessment due to the inherent complexity of the system to model.

As stated in the COST 732 Action (2009) report on microscale model evaluation (4), there is not a distinct definition of the requirements of a validation test case dataset or a 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 since 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 in order 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 new strategy for verification, validation, and uncertainty quantification 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 and some others will come from experimental facilities and operational wind farms. These inter-comparison case studies will produce enough background information for the discussion of the verification, validation, and uncertainty quantification strategies.

2.0 Objectives and Strategy

Task 31 provides a forum for industrial, governmental, and academic partners to develop and define quality-check procedures, as well as to improve the atmospheric boundary layer and wind turbine wake models for use in wind energy. The working methodology (Figure 1) will be based on the benchmarking of different wind and wake modeling techniques in order to identify and quantify

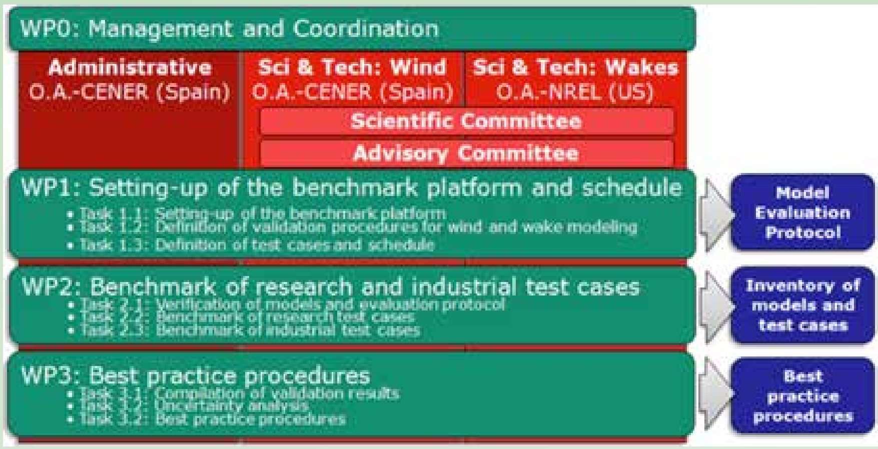

Figure 1. Structure of Task 31 and deliverables

best practices for using these models under a range of conditions, both onshore and offshore, from flat to very complex terrain. These benchmarks will involve model inter-comparison versus experimental data. The best practices will cover the wide range of tools currently used by the industry and will attempt to quantify the uncertainty bounds for each type of model.

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 web platform (www.windbench.net) 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. An evaluation protocol will be agreed to by the participants and a scientific committee will be designated to supervise the correct implementation of each test case.

3.0 Progress in 2013

During 2013 the following active benchmarks were conducted:

- Monin-Obukhov and Leipzig for surface layer and ABL models in flat terrain
- Askervein and Bolund for flow over hilly terrain
- Alaiz for flow over complex terrain
- Axisymmetric wake for verification of self-similar behavior of a single wake
- Sexbierum single-wake and double-wake
- Horns Rev and Lillgrund multiple-wake under various inflow conditions

Most of the benchmarks are based on neutral stratification since this assumption is adopted by a majority of models. An example of a benchmark result in anonymous format is shown in Figure 2 for the Horns Rev test case.

The Windbench.net portal was released online in May 2013. It now has more than 80 registered participants, 21 models in the catalog, 15 test cases, and 24 benchmarks.

Table 1. Countries and Organizations Participating in Task 31 During 2013		
	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, CNR-INSEAN, Sorgenia S.p.A., Karalit
7	Japan	University of Tokio, Wind Energy Institute of Tokyo
8	Norway	Windsim, Statkraft, Agder Energy, Institute for Energy Technology, Sintef, CMR Gexcon
9	Spain	National Renewable Energy Centre (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

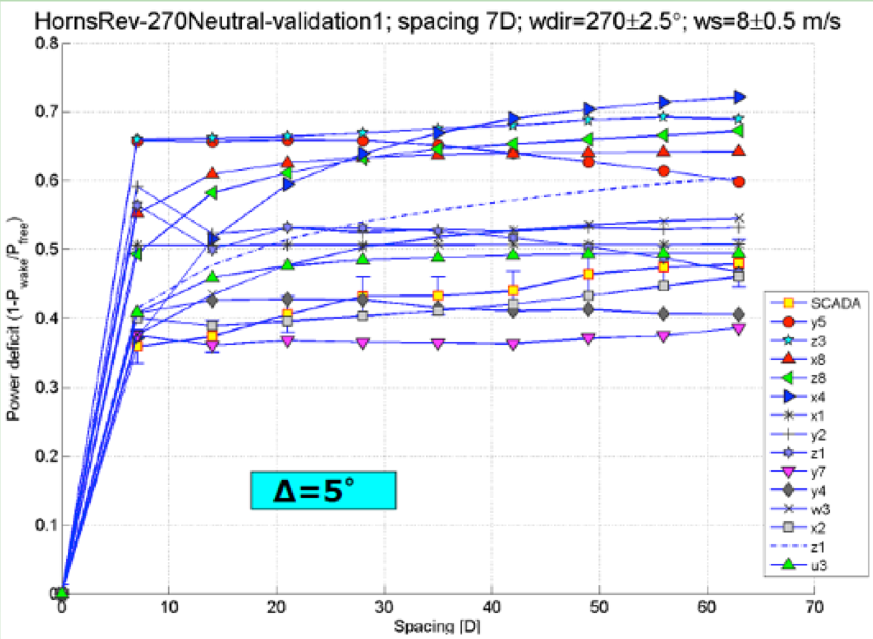

Figure 2. Example of Horns Rev benchmark results presented in anonymous format

An interim meeting in June 2013 was organized together with the ICOWES-2013 Conference, hosted by the Technical University of Denmark (DTU). The meeting was focused on benchmarking activities for wake models. The final meeting took place in November 2013 at the University of Stuttgart, Germany, jointly organized with an IEA Wind Task 11 Topical Expert Meeting on complex terrain.

The key outcome of these two meetings is the definition of a standardized fit-to-purpose metric to evaluate models based on the variables of interest for the wind turbine siting process. This is the core aspect of the model evaluation protocol that will be delivered by the task and will be integrated into the Windbench.net portal. The Windbench.net platform is evolving to accommodate this protocol by implementing online tools for visualizing and quantifying model performance. As usual, IEA Wind meetings are a good opportunity for participants to show their R&D activities related to the task scope in relation to national and international projects. It is worth mentioning the collaboration with the European project EERA-DTOC on developing joint benchmarking activities around wake models for the cases of Horns Rev and Lillgrund wind farms.

4.0 Plans for 2014 and Beyond

The last year of Task 31 is focused on delivering the reports about the model evaluation protocol and the Best Practice guidelines for wind farm flow models. These reports are based on the results from the benchmarking activities of the task.

New benchmarks will be launched in 2014, notably: the GEWEX Atmospheric Boundary Layer Study (GABLS) benchmarks will be used to study idealized atmospheric boundary layer flows in flat terrain under various stability; the Norrekaer Enge (Denmark) wind farm supervisory control and data acquisition (SCADA) data will be used to evaluate data analysis for the generation of validation data for wake models; the San Gregorio wind farm (opening photo) in very complex terrain in Italy will be used to analyze most of the complexities that a wind farm model can face (steep terrain, wake-terrain coupling, wakes from neighboring wind farm, etc); the Infinite Wind Farm benchmark will be used to study the development of the wind farm equilibrium boundary layer; the RisøWakeLidar experiment at the Risø campus (Denmark) makes use of a nacelle-mounted lidar to scan the wake from a single wind turbine in flat terrain under different stability conditions; the Higashiizu complex terrain site in Japan will be used to validate flow-over-terrain models using wind tunnel and field data; and the UMN-EPFL wind tunnel experiments on model wind turbines will be used to study wakes under control environment with high quality measurements.

An interim meeting will be hosted by DTU in connection with the European Academy of Wind Energy (EAWE) conference “The Science of Making Torque from Wind” in June 2014. The final meeting will take place at the North China Electric Power University (Beijing, China) in September 2013 to summarize the outcome of the Task 31 and make plans for a new follow-up task. The new task shall extend the scope to mesoscale as well as near-wake models and develop a basis for multi-scale model-chain validation and uncertainty quantification.

References:

Opening photo: San Gregorio wind farm in Italy illustrates effects of steep terrain, a neighboring wind farm and upstream topographic wakes.

(1) Troen I., Petersen E.L. (1989) European Wind Atlas, Risø National Laboratory, Roskilde. ISBN 87-550-1482-8. 656 pp.

(2) Ainslie, J. F. (1988) Calculating the flowfield in the wake of wind turbines, Journal of Wind Engineering and Industrial Aerodynamics vol. 27; 213-224.

(3) Oberkampf W.L. (2010) Verification, Validation and Uncertainty Quantification of Simulation Results, NAFEMS WWW Virtual Conference, November 15-16.

(4) Britter R. and Schatzmann M. (2007) Model Evaluation Guidance and Protocol Document, COST Action 732, © COST Office, distributed by University of Hamburg, ISBN: 3-00-018312-4.

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

Traditionally, wind data for siting and operation of wind turbines have been collected using cup anemometers and vanes on meteorological towers. Lidar for wind energy deployment uses atmospheric scattering of beams of laser light to measure profiles of the wind at a distance. Task 32 addresses the rapid development of wind lidar technologies and their applicability for more accurate measurement of wind characteristics relevant for reliable deployment of wind energy power systems.

The purpose of Task 32 is to bring together the present actors in the industry and research community to create synergies in the many research and development (R&D) activities already on-going in this very promising and new remote sensing-based measurement technology. The task was approved by the IEA Wind Executive Committee (ExCo) in autumn 2011 and began work in May 2012. In 2013, 42 institutions from 15 countries were involved in the task activity.

2.0 Objectives and Strategy

The main objective of the task is the publication of experimentally-tested recommended practices and expert group 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. Task 32 is only considering lidar systems even though sodar is another promising remote sensing technique that was considered as well in the above-mentioned IEA Wind Topical Expert Meetings.

IEA Wind Task 11 developed and approved the publication in 2013 of *Recommended Practice RP: 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. The 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.

The expert group reports from Task 32 will provide guidance for accurate calibration of ground- and nacelle-based lidar. They will include information for a better understanding of lidar-measured wind and turbulence and they will also give indication about the application of lidar in flat terrain and complex flow conditions. Some reports will also be dedicated to the application of lidar more connected to wind turbines, such as the application of the rotor equivalent wind speed or nacelle-based lidar for power curve assessment.

The scientific and technological content of the Task 32 deliverables is subdivided in three subtasks, which are tailored as well in smaller work packages (WPs) as presented in Table 2. The coordination of the three subtasks is delegated to the Operating Agent's partners, i.e., DTU-Wind Energy, the National Renewable Energy Laboratory (NREL), and WindForS-University of Stuttgart. One additional subtask is dedicated to the data management.

3.0 Progress in 2013

During 2013, all work packages (listed under subtasks I, II, and III) were begun and the task activity proceeded mainly over telephone meetings and exchange of documents, papers, and technical reports on a virtual workingspace. The third plenary meeting was held in May at the NREL National Wind Technology Center in Boulder, Colorado, United States. This meeting was attended with enthusiasm by 33 participants. The progress of each subtask is presented separately in the next sections and then some technology highlights are given for relevant topics of the task.

3.1 Subtask I

Calibration of wind lidars is addressed in this subtask in particular for ground as well as nacelle-based devices and for floating units too. Concerning ground-based vertical profilers, the issue of calibration repeatability of the same device has been studied. In particular two aspects have been considered: different statistical approaches (vector and scalar average) have been compared, as well as the combined effect of the vertical shear, the spatial average along the line of sight, and the accuracy in the sensing range has been investigated (WP 1.1).

For nacelle-mounted lidars, a procedure for their calibration has been proposed (WP 1.3). For floating lidars, experience and information have been collected and an RP is in preparation (WP 1.5).

3.2 Subtask II

RP 15 was presented to the audience during the third plenary meeting and since then feedback has been collected (WP 2.1). During the same meeting the challenges of applying lidar in inhomogeneous flows were addressed. From the discussion, a draft state-of-the-art document has been compiled and is currently under revision (WP 2.2). Within this document, particular attention is given to application of lidar vertical profilers in complex terrain and to application of scanning lidars. An extensive bibliography about the evaluation of turbulence from vertical-profiler's measurements has been collected and reviewed. An outline has been prepared for a group of experts' report which summarizes the collected documents (WP 2.3).

Table 1. Countries and Organizations Participating in Task 32 During 2013

	Country	Institution(s)
1	Canada	AXYS, Technocenter Eolien
2	Denmark	DONG Energy, DTU Wind Energy (Alpha Wind Energy, Vestas Technology R&D, Windar)
3	Germany	Deutsche WindGuard, DEWI, ForWind – Oldenburg, Fraunhofer IWES, GL Garrad Hassan, GWU, Senvion SE, Stuttgart Wind Energy (SWE) – University of Stuttgart, (Kenersys, KIT, Vaisala, WIND-consult)
4	Japan	ITOCHU Techno-Solutions Corp., Mitsubishi Electric Corp., (Mie University)
5	Norway	Meventus, NORCOWE, University of Bergen
6	U.S.	AWS TrueWind, University of Colorado, Indiana University, NCAR, NOAA – ESNL, National Renewable Energy Laboratory (NREL), Pacific Northwest National Laboratory
Participants in progress		
7	Austria	Energiewerkstatt
8	Belgium	3E
9	China	CWEA, Goldwind
10	France	Avent, IFP Energies nouvelles, Leosphere
11	Italy	Pentalum
12	Netherlands	ECN
13	Sweden	Windvector
14	Switzerland	Meteotest
15	UK	Fazer Nash, Narec, RES, Sgurr Energy, Zephir

3.3 Subtask III

The indications included in the IEC 61400-12-1 standard concerning the power performance of wind turbines by means of ground-based remote sensing have been applied on the same datasets by different participants. The results provided do not always agree due to ambiguity in the norm, which can lead to different interpretation (WP 3.1).

Knowledge and experience about power curve measurements have been collected and reviewed. This information was used to write the outline for a group of experts' report that includes the application of different type of nacelle-based lidars as well as different strategies for the evaluation of the power performance of a wind turbine (WP 3.3).

3.4 Technology highlights

The task activity supports diffusion to industry of the advanced applications mainly implemented in the research. In this section, current developments in lidar applications are presented for three different cases.

3.4.1 Offshore met-masts

Floating lidar systems represent a cost-effective alternative to an offshore met mast (opening photo: right). Met masts not only require a significant capital investment but are also limited to smaller heights than those captured by a standard lidar device. Floating lidar also require a shorter process of permitting than met masts because they have lower requirements for a corresponding marine license application, a significantly smaller disturbance of the environment, and a greater flexibility of the system enabling deployment at different locations.

A floating lidar system is here defined as a lidar device integrated in or installed on top of a buoy. The offshore environment presents major challenges to the lidar instrument but also to the complete system. The harshness of the environment sets requirements on all system components; its non-stability (with changing water depths, wave conditions, and ocean currents) requires certain adaptability; and the limited access by technicians affects the availability and the reliability of the system. Power supply may also be a critical issue, and needs to be ensured by a technically mature approach—similarly as data storage and communication.

Furthermore, the quality of the lidar measurements—in terms of accuracy and precision—is affected by the motion of the buoy. Platform-typical motions, including up to six degrees of freedom, may cause systematic measurement errors, appearing e.g., as a wrong projection of the wind velocity vector, a confused wind direction measurement, added velocity components, increased lidar turbulence intensity, or a wrong measurement height. The development of suitable and optimized floating-lidar systems for an application in the offshore wind industry has made considerable progress during the last few years. There have been adaptations in lidar and buoy technologies but also in the concepts used for installation or data handling, and in particular the consideration of motion effects on the recorded data.

Several floating lidar systems are meanwhile considered as pre-commercial. The first commercial contracts were signed but the absence of agreed upon standard procedures for their application still prevents the deployment of a large number of devices. The WP 1.5 of the IEA Wind Task 32, comprising system providers as well as independent measurement institutes and consultancies, has now formed to draft a corresponding guideline document aimed to be accepted as an RP in the near future.

3.4.2 Scanning lidars

While the application of wind lidar vertical profilers is getting widely adopted in both industry and research, scanning wind lidars are

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 (WindForS)
WP 1.1 Ground-based lidar calibration (includes former 1.2)	WP 2.1 RP 15 Ground-based, vertically-profiling remote sensing for wind resource assessment	WP 3.1 Exchange of experience in power performance testing according to IEC 61400-12-1 ed. 2
WP 1.3 Calibrating nacelle lidar	WP 2.2 Wind field reconstruction methods in complex flow with wind lidars (includes former 1.2)	WP 3.2 Wind field reconstruction from nacelle based lidar measurements
WP 1.5 Calibrating floating lidar	WP 2.3 Measurement of wind characteristics	WP 3.3 Nacelle-based power performance testing
	WP 2.4 Using lidar as part of a wind resource assessment	WP 3.4 Load estimation using a lidar system

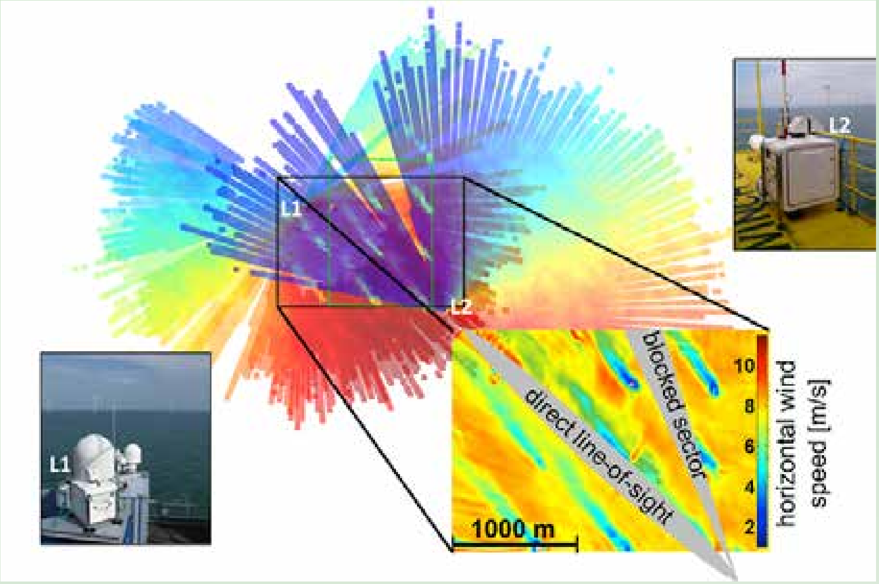

Figure 1. Multi-lidar measurements using two long-range scanning lidars L1 and L2 in the wind farm Alpha Ventus

now in the phase of gathering experience. Different from a vertical profiler, scanning lidars do not provide the horizontal wind speed and wind direction as output ready to use; they just provide the line of sight wind component. This, combined with the possibility to steer the laser beam in the desired direction, offers a lot possibilities of measurement and analysis. Some applications have already been developed, e.g., shear mapping, wake measurements, and gust detection.

More sophisticated applications involving two or three scanning lidars are also starting to be implemented in order to combine the line of sight data measured by the available units. With this kind of application, depending on the installation layout and the number of the units of scanning lidars available, it is possible to retrieve the horizontal wind vector over the scanned area. It is also possible to retrieve the flow inclination over complex terrain, or to have a so-called virtual met mast, which can be easily moved over a site. The upper part of Figure 1 shows the measured line of sight of the individual devices. The detail shows the magnitude of the horizontal wind vector evaluated from the measurements at hub height. Spurious and blocked sectors are blanked in gray.

Research is still required to increase the confidence in these new applications, to optimize the strategy of the measurements, and to enhance the related methods of analysis. Nevertheless, technological aspects such as the pointing accuracy also have to be addressed in the future. These points are going to be addressed in WP 2.2, where scanning lidars are included in a list of applications, the so-called "use cases," next to other wind-lidar devices. Their applications are classified accordingly to their scope, an explanation about their limitations is included, and further guidance is provided.

3.4.3 Nacelle-based lidars

Lidar technology is becoming more and more popular for site assessment purposes (opening photo: left). However, wind not only provides the energy source for wind turbines but also causes disturbances to the control system. Advances in nacelle- and rotor-based lidar technology provide new opportunities to rethink conventional control strategies. Traditional feedback controllers are only able to react to impacts of wind changes on the turbine dynamics after these impacts have already occurred. With the new nacelle-based lidar systems, the information about incoming disturbances can be made available ahead of time. This allows a fundamental reformulation of the control problem. A previously unknown and unpredictable disturbance is partially unveiled and thus can be used for preview control algorithms that incorporate this knowledge to optimize energy production and reduce structural loads.

However, with the lidar technology the incoming wind disturbance cannot be measured exactly. This requires research to address two coupled aspects. On the one hand, the complex wind field can be reduced to wind characteristics such as speed, direction, or shears, and a control problem can be formulated to address changes in the disturbances. In high wind speeds, feed-forward control based on the rotor effective wind speed can assist the blade pitch controller in regulating the rotor speed as well as mitigating structural loads. This can lead to lower operational and manufacturing costs. Approaches improving yaw control and preventing shutdowns due to over-speed are promising for energy optimization.

On the other hand, the performance of the preview controller depends on how well the wind characteristics measured by the lidar correlate with the effective disturbances acting on the turbine. A thorough understanding of the nature of the wind, as well as signal processing and estimation principles, are mandatory for developing accurate measurement techniques that enable successful preview control algorithms.

Pioneering work in this field has been done by scientists from SWE at the University of Stuttgart together with engineers from NREL in Boulder, CO, U.S. In the world's first test of lidar-assisted control of a wind turbine, they proved the concept and lowered the rotor speed variation of two mid-scale research wind turbines equipped with a nacelle-based lidar systems. However, further investigations are necessary to bring the technology forward to a future, where all wind turbines are able to see and react to the incoming wind changes. Part of this complex matter is discussed within WP 3.2, where different approaches to model the wind are proposed in order to evaluate the wind field characteristic from lidar measurements. Possibly a group of experts' report will provide indications for the further implementation of nacelle-based lidar measurements for control application.

4.0 Plans for 2014 and beyond

In the upcoming year, two plenary meetings are scheduled. The first one will take place in Stuttgart at SWE-University of Stuttgart in March. The second one is planned to be in autumn in the U.K. During these meetings, results from the WPs will be presented as well as the progress of the expected deliverables. Official information about the task can be found at www.ieawind.org Task 32. The activity of the WPs can be followed at (https://sites.google.com/site/ieawindannex32/home).

References:

Opening photo: Left: Nacelle-mounted lidar (Credit: Wolker-Möhlmann); Right: Floating lidar (Credit: Fraunhofer IWES)

Authors: Martin Kühn and Davide Trabucchi, ForWind-University of Oldenburg; Mike Courtney, DTU Wind Energy, Denmark; Andreas Rettenmeier, WindForS; Julia Gottschall, Fraunhofer IWES; David Schlipf, University of Stuttgart, Germany; and Andrew Clifton, NREL, United States.

13 Task 33 Reliability Data: Standardizing Data Collection for Wind Turbine Reliability and Operation & Maintenance Analyses

1.0 Introduction

IEA Wind Task 33 aims to support reliability improvement and the optimization of operation and maintenance (O&M) procedures of wind turbines through the use of reliability data. It addresses developments of data collection and failure statistics in the wind energy sector to agree on standards and overall structures for collecting and reporting this information. Task 33 brings together the present actors in the industry and research community to create synergies and agreements in the many R&D activities already on-going in the field of statistical failure and O&M analysis (Table 1).

2.0 Objectives and Strategy

Task 33 is dealing with standardized, well-structured databases of statistics for use in optimizing reliability and maintenance procedures. The aim is to address the different developments of data collection and failure statistics to agree on standards and overall structures. Standardized reliability data will facilitate effective analysis and the wide applicability of results.

Task 33 aims to:

- Provide an open forum on failure and maintenance statistics on wind turbines for exchange of experience from individual research projects
- Develop IEA Wind Recommended Practices for collecting and reporting reliability data
- Identify research, development, and standardization needs for collecting and reporting reliability data.

The drivers for Task 33 based on wind turbine reliability are:

- Extensive national research projects dedicated to reliability analyses on wind turbine failures have been performed over the past several years, e.g., Denmark, Finland, Germany, the Netherlands, Sweden, United Kingdom, and the United States. However, a consolidated multi-lateral and international exchange has, to date, just partially taken place.
- The increasing future demands on reliability and profitability of wind energy use, especially offshore, require the optimization of wind-turbine maintenance. For this in turn, appropriate data management and sophisticated decision-support tools are prerequisites.
- Several working groups on appropriate standards for O&M of wind power

Table 1. Countries and Organizations Participating in Task 33 Duing 2013

	Country	Institution(s)
1	China	Chinese Wind Energy Association (CWEA); Goldwind Science Technology Co., Ltd
2	Denmark	Aalborg University; DTU Wind Energy
3	Finland	Technical Research Centre of Finland (VTT)
4	Germany	Fraunhofer 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; KTH Royal Institute of Technology; Vattenfall
9	United States	Sandia National Laboratories

plants have been launched on national levels for land-based wind energy applications, e.g., joint activities on standardizing O&M measures, documentation, and data structure.

Task 33 has three subtasks, which have currently been selected as the most relevant. They reflect the experience of reliability analyses and failure statistics in the last decade not only in the wind industry, but they also reflect the determination of data collection and analysis based on defined structures and standards, which are shown in Figure 1. Each subtask group reports their results in a state-of-the-art report.

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 times between failure (MTBF), mean time to repair (MTTR), etc.), based on international standards, aims to:

- Establish an international forum for exchange of knowledge and information related to reliability data and failure statistics of wind turbines
- Bring available knowledge together and use experience for improvements
- Develop and define an internationally accepted data structure that can be used by IEA groups 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 the financial and technical reporting and to ease cooperation with similarly oriented businesses
- Provide a basis for sound conclusions out of operational experience in terms of reliability characteristics such as failure rates, repair times, etc.

The competences gained in the IEA Wind Task 33 will be collected and summarized in an IEA Wind "Recommended Practices for Reliability Data."

3.0 Progress in 2013

Work in 2013 was focused on the first of three planned state-of-the-art reports about current initiatives dedicated to reliability in the member countries. A survey was started in late 2012 and finished in spring 2013. Twenty-eight initiatives had been identified and assessed regarding relevance for Task 33. Thirteen of these initiatives gather reliability data and feed it into databases for analyses. Only five of these databases contain cost data. The survey produced the following conclusions:

- There is an extensive interest in having valid, trusted reliability data
- A variety of databases already exist
- The surveys and databases differ in terms of data gathered and continuity of samples, in terms of structure and format of data, and in terms of duration period and wind turbine types considered
- There is a general lack of data on events and costs
- International standards concerning terminology and communication are not yet considered

Countries		Germany				China		F	IRL	S	USA		
Databases		WMEP	LWK	Windstats (Ger.)	WInD-Pool	60-database	PI	VTT	ServusNet	RCM	BRC	CREW	GRC
Initiatives		12	13	14	10 11	7	8	9	17	21	24	25	26
Additional information	Kind of survey												
	Information on individual wind turbines	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	Information on wind power plant in total	no	no	no	yes	no	yes	no	yes	yes	no	no	no
	Reports an fixed sample of turbines / varying sample	v	v	v	v	v	v	f, (v)	v	v	v	f	v
	Who is / was reporting (expert, technician, operator,	op	-	-	op	t	t	(op), ow	op / all	op/ow	t, isp, op	e - SCADA - automated flow	t, op
	Obligatory or voluntary reporting?	o, v	v	v	v	v	o, v	v	o	o	v	v	v
	Time period gathering data												
	Start-up of survey	1989	1993	1995	2011	2011	-	1996	-	1997	2010	2011	2007
	Closing of survey	2008	2006	2004	On-going	On-going	On-going	-	-	-	2012	On-going	On-going
	Database size												
	Number of different turbine types	30	-	-	35	4	-	~13	4	-	-	6	3
	Number of individual turbines	1500	643	4285	2000	>2000	-	64	>350	>600	>600	700-800	-
	Wind turbine size												
	Nominal power of the smallest turbine (kW)	10	-	-	10	750	750	200	600	<500	1000	1000	-
	Nominal power of the biggest turbine (kW)	1500	-	-	6000	2500	3000	3000	2300	2000	-	-	-
	Average size (kW)	320	493	589	-	1625	2000	1734	2300	-	2500	1760	-

Figure 1. General information on databases: kind of survey, time period of data gathering, and sizes

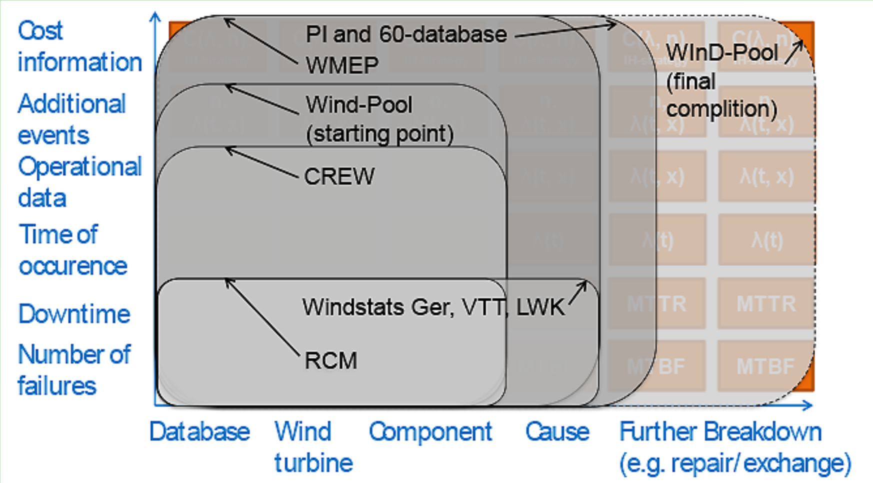

Figure 2. Capability of the data bases for more or less complex analyses

- Results are difficult to compare to each other

Figure 1 illustrates the variety of data sets gathered as well as the different sizes of data pools. Because the contents of the databases are so different, it is hardly possible to compare analyses results. Figure 2 shows the different capabilities needed to gain detailed results and data out of the databases. In October, the first state-of-the-art report "Initiatives Concerning Reliability Data" was released. It is an internal report, which is not meant to get published.

Working groups were set up for working out the next tasks, i.e., which kind of analyses are suited for assessing reliability of wind turbines and which data have to be gathered. One of the first steps the working groups have taken is to define and synchronize their goals between groups. This process will be completed in 2014. The groups will compile their results in an IEA Wind Recommended Practice report.

Two meetings were held in 2013. The first one was held in Trondheim, Norway, 6–7 March. During this meeting, the results of the survey on reliability initiatives as well as the first draft of the first state-of-the-art report were discussed. The setup of working groups was agreed to. The second meeting was held on 15–16 August in Albuquerque, New Mexico, the United States, following Sandia's "Wind Plant Reliability Workshop 2013." The first state-of-the-art report was finalized and group work was started on the second state-of-the-art report. One continuing issue has been the integration of all interested participants. Finally, the team of twelve institutions/companies from nine countries has been settled. However, CWEA announced more companies may be participating in the future.

4.0 Plans for 2014 and beyond

The groups will continue their work and uncover key issues of Task 33. The groups will work out the second and third state-of-the-art reports in 2014. The results of these reports will be the main subjects of the recommended practices, which will be worked on in the coming year. The groups will work independently on their topics, while group leaders will discuss contents and results in phone or Web meetings. Two meetings are planned for 2014—the first one will be held in the springtime in Sweden, the second will follow dependent on progress of Task 33.

References:

Opening photo credit: Paavo Blåfield

Authors: Berthold Hahn, Fraunhofer Institute for Wind Energy and Energy System Technology, Germany; Lina Tjernberg, KTH Royal Institute of Technology, Sweden; and Valerie Hines, Sandia National Laboratories, the United States.

14 Task 34 Assessing Environmental Effects and Monitoring Efforts for Offshore and Land-Based Wind Energy Systems

1.0 Introduction

Concerns over environmental effects of wind energy continue to challenge the wide-scale deployment of both offshore and land-based wind 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 across 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 selected provide the highest value to the member countries.

2.0 Objectives and Strategy

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

3.0 Progress in 2013

Efforts during 2013 were focused on refining the work package activities contained in the original approved task proposal and identifying countries interested in contributing to the work effort. Initial discussions were conducted via conference calls. In January, conference calls were held with representatives from six countries: Australia, China, Germany, Ireland, Switzerland, and the United States. From these calls, the participants agreed to provide detailed information via a follow-up survey. The survey was conducted during the June/July timeframe and results were used to begin to identify key areas of interest and research gaps. This information was used to refine the Task 34 objectives, develop vision and goal statements, and to plan the in-person kickoff meeting.

A webinar focused on a set of databases that could be useful for Task 34 was

Table 1. Countries and Organizations Participating in Task 34 During 2013

	Country	Institution(s)
1	Germany	Berlin Institute of Technology
2	Netherlands	Rijkswaterstaat—Department of Water Quality
3	Norway	Norwegian Institute for Nature Research; Statkraft AS; UniResearch
4	Sweden	Vindval
5	Switzerland	Federal Department of the Environment, Transport, Energy and Communication DETEC; Nateco AG
6	United States	National Renewable Energy Laboratory (NREL); Pacific Northwest National Laboratory; U.S. Department of Energy

Figure 1. Participants of the Task 34 kickoff meeting in Trondheim, Norway, December 2013

conducted in April 2013. This webinar featured presentations on three U.S. databases—American Wind Wildlife Institute's Research Information System, NREL's Wind-Wildlife Impacts Literature Database, and Pacific Northwest National Laboratory's Tethys database.

Twelve participants representing six countries traveled to Trondheim, Norway, to attend a three-day kickoff meeting in December 2013. Discussions during this meeting led to the development of a revised work package, with specific objectives and activities outlined for the next three years. Meeting materials, including presentations, minutes, member contact information, and key resource links, as well as other information, are available on the IEA Wind Task 34 website, which was designed and became available in 2013 (www.ieawind.org/task_34.html). Task 34 materials will continue to reside on this website until such time as the Hub (see below) is developed. Thereafter, all materials will be accessible through a link to the new platform.

4.0 Plans for 2014 and beyond

Over the next three years, Task 34 will seek to achieve its goals as described above through two primary sets of activities. The first is to serve as a "Hub" to facilitate collaboration within the international community on wind environmental issues. This includes both conducting information-sharing activities (web meetings/webinars, annual seminars, and workshops) as well as the development of an online platform for the wind community to more easily find information on completed and ongoing research, tools for communication, and collaboration. The Hub will:

- Foster international community through a variety of channels
- Expand knowledge of land-based and offshore wind energy environmental effects, impact reduction, monitoring methods, and research being conducted around the world
- Identify effective monitoring practices and strategies for impact avoidance, minimization, mitigation, and compensation
- Increase accessibility of information on these topics through aggregation and active dissemination.

The second set of activities is to develop white papers to focus on and advance the state of understanding on issues of global concern within the wind community. Potential topics identified during the kickoff meeting include: adaptive management, cumulative impacts, transboundary collaboration, "green vs. green" (i.e., balancing the local effects of a wind facility on sensitive species against its global benefits such as CO_2 emissions), and individual vs. population effects. In order to ensure that the white paper topics selected meet the needs of the member countries, each country will conduct a stakeholder survey internally then share the results with the full collaborative. The survey will be used to assess challenges and high priority environmental topics to enable sustainable development of wind energy.

Information on the regulatory context for environmental research will be identified within each participating country and submitted to the Operating Agent for inclusion on the Task 34 website (later within the Hub). This information may be used to develop a comparison across countries, and could potentially be the basis of an international standard.

Task 34 members will engage in planned activities and product development using a variety of communication strategies, including virtual meetings, conference calls, webinars, the Hub (once it is available), or other communication formats deemed appropriate. A webinar series will be launched, with the first year focusing on research and monitoring efforts. The webinar will offer multinational perspectives on specific topics and allow time for discussion. The members will meet at least twice a year in person. These meetings are tentatively scheduled for the spring and fall seasons each year. Topic-specific workshops will be scheduled if needed to expedite the development of the white papers.

Success of Task 34 will require all participating countries to be actively engaged over the next three years. The United States will support administrative and operating costs of the Operating Agent; no membership fees will be required to participate in Task 34. 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 six member countries, representatives from several other countries have expressed interest in participating in Task 34 and will be encouraged to submit commitment letters.

For 2014, two in-person meetings are planned. Members will meet 15-16 May in Newcastle, UK. Details are still being developed for this spring meeting. The fall meeting is planned for December. This meeting will be hosted by the United States, and held in conjunction with the National Wind Coordinating Collaborative Research Meeting X scheduled for 2-5 December near Broomfield, Colorado.

The spring 2015 in-person meeting will be held concurrent with the Conference on Wind Energy and Wildlife Impacts scheduled for March 2015 in Berlin, Germany. The fall meeting will be hosted by Switzerland, with details still under development.

References:

Opening photo: Research is being conducted at the Smøla wind farm, located in Norway, to assess whether painted blades or ultraviolet light will make the wind turbines more visible to birds and reduce the number of bird fatalities at wind facilities. Impacts to white-tailed eagles at Smøla are of particular concern. (Source: Espen Lie Dahl)

Author: Karin Sinclair, National Renewable Energy Laboratory, the United States.

15 Task 35 Full-Size, Ground Testing for Wind Turbines and Their Components

1.0 Introduction

As wind turbines 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 down time and development costs of wind turbines 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 predictability of site-specific load cases. As an alternative, ground-based test benches offer the opportunity to evaluate wind turbine components under repeatable accelerated life conditions and become an important tool for development and certification of new wind turbines. The test pyramid in Figure 1 shows the benefits and advantages of ground-based system testing in comparison to field tests and component testing. While full-size testing provides the most realistic system behavior and load characteristics, subsystem testing is much more independent from wind and grid states than field tests and therefore is a promising alternative.

For several years, numerous test facilities have been operating to test multi-MW wind turbine components, but there are much larger facilities currently in planning or under construction. These facilities utilize a variety of different test bench configurations for blade, drivetrain, and other subcomponent testing. These test facilities are purposely built by the test bench users (original equipment manufacturers (OEMs), researchers, component designer/suppliers) pursuing different objectives, such as:

- Functionality tests of the overall wind turbine systems and their components
- Design validation, acceptance testing, or certification testing
- Performance in controlled environments (e.g., cold climate conditions)
- Durability tests to determine the

Table 1. Countries and Organizations Participating in Task 35 During 2013

	Country	Institution(s)
1	Denmark	DTU Wind Energy; Lindoe Offshore Renewables Center (LORC); Vestas Wind Systems A/S
2	Germany	Center for Wind Power Drives RWTH Aachen University (CWD); GE Energy Power Conversion GmbH; Fraunhofer Institute for Wind Energy and Energy System Technology (IWES); MTS Systems GmbH; Renewable Energy Technology Center (RETC) GmbH; Technical University of Berlin; TÜV Rheinland AG; Windtest Grevenbroich GmbH
3	United Kingdom	National Renewable Energy Centre (Narec)
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

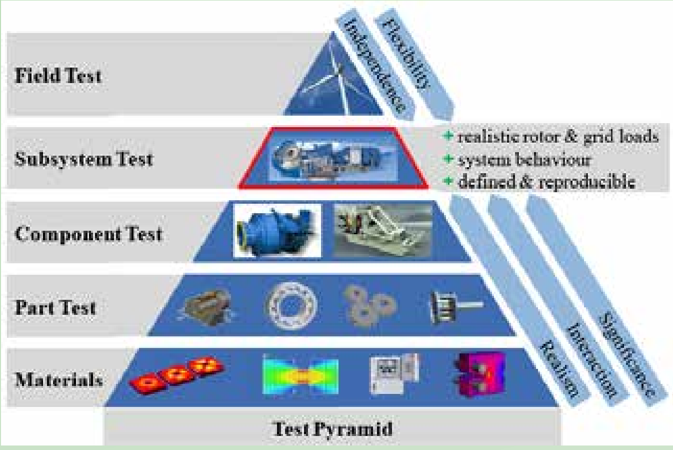

Figure 1. Test pyramid for wind turbines

safety and lifetime of components (e.g., blades, gearboxes, yaw drives, pitch systems, etc.)
• Determination of component interaction and loads during wind turbine operation as the key implement for validation of design models.

Although there are some test methods for wind turbines defined in the International Electrotechnical Commission (IEC) TC88 standards, it is recognized by many of the wind industry stakeholders that system reliability could be improved by further defining new testing procedures and refining existing methods (1). The IEA Wind framework offers the opportunity to get the key stakeholders in the wind industry at one table and to discuss the requirements for the development and use of system test benches for wind turbines and their components. All these key stakeholders represent their interest and are able to influence and determine the focus and orientation of Task 35. Sharing the experiences of all competences in Task 35 helps to improve development of wind turbines along the value chain and ensures sustainable competitiveness.

2.0 Objectives and Strategy

IEA Wind Task 35 intends to face the emerging demand for reliable and cost-effective full-scale ground testing. Since the use of full-scale ground test facilities for validating wind turbine designs has become an attractive option to the component manufactures, wind turbine OEMs, and wind turbine owner/operators (2), (3) the challenge is to find ways to exploit the potential of each facility and combine all specific capabilities.

Therefore Task 35 aims and seeks to:
• Improve the quality and reliability of ground-based component testing of wind turbine nacelle assemblies and blades in order to evaluate the in-field performance and possible failure modes under accelerated life test conditions
• Specify requirements and boundary conditions of test bench configurations
• Refine the standardization and certification procedures of the entire wind turbine and components
• Emphasize the use of test facilities as a reliable alternative or as a 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 test load calculations and to standardize these across multiple laboratories with various capabilities. The more particular objective of Task 35 is to develop guidelines for test facilities and methods that support the verification of design assumptions as well as validation of function, safety, and durability of systems or components. Recommended practices for uniform test and measurements procedures will be provided for the interfaces and subsystems of wind turbines required for a realistic investigation on nacelle- and blade-specific test benches. The Task 35 strategy focuses on:

1) Detection of the structural component loads
• Definition of reference load collectives for test bench investigations including requirements for wind load and grid load calculations
• Clarify the dynamic interaction between the different components (system and subsystems) of a wind turbine and describe the influences

2) Function test procedures
• Replace or extend conventional field test procedures with test bench investigations (comparison between IEC field tests and ground tests)

3) Durability test procedures
• Increase the quality of prediction for the prognosticated durability of components in the overall wind turbine system through the development and refinement of new test procedures

Depending on the recommended configuration, most test benches should 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 wind turbines and their components. The exchange of ideas from different perspectives will eventually advance the use of test facilities.

3.0 Progress in 2013

After developing the task idea at the 68th Topical Experts Meeting in 2012, the first draft proposal for Task 35 was created. It was revised at the pre-kickoff meeting in March 2013 and finally approved by the Executive Committee in October 2013. The general approach and task assignment as well as the work schedule were discussed during the first Web-based meeting in December 2013. Beside the introduction of Task 35 and its new participants, the discussion of the work program came to fundamental statements and conclusions.

Primarily Task 35 needs consistent technical wording and methodologies as well as clear definition of interfaces. While the technical wording will avoid ambiguity and misunderstandings, consistent methodologies and defined interfaces will ensure a unitized approach and independent workflows. These agreements might be crucial for the further Task 35 progress. The first project phase is about to determine the scope of Task 35. By considering industry demands and wind turbine manufacturer concerns, Task 35 is able to identify relevant types of testing for both nacelle subsystems and blades as well as to estimate their future prospects. Because the wind industry is largely unaware of the full potential of ground testing, all participants emphasize the capabilities and benefits of full-scale ground testing. Since Task 35 was approved, the wind industry and various research institutions have expressed their interest and become more and more attracted by the significance and importance of the work.

4.0 Plans for 2014 and Beyond

In 2014, the more detailed and concrete aspects of Phase I will be considered in the design analysis of the technical system wind turbine described below. The purpose is to analyze and benchmark the interaction effects between rotor, tower, nacelle, and further subsystems and components. To improve test facilities and procedures for wind turbines, it is necessary to identify and understand weak spots of the technical system. With an analysis of the critical operating conditions, it is possible to consider design uncertainties, design limiting, and design load cases as well as design assumptions with high sensitivities to operational success of different drive train concepts. The critical load conditions of a wind turbine will be investigated to develop reasonable load cases for test procedures.

The results of the first analysis phase will be used as the basis for further Task 35 activities. The Phase II is divided into the subtasks "Blade Test" and "Nacelle Test." Each subtask will have a manager with expertise in that type of test (Table 2). The topics covered in each subtask will be similar but adapted to the respective systems and test specifications. With the knowledge of the critical components, load situations, and common test investigations it is possible to define new or augmented requirements for test bench configurations.

Blade test group

With increasing blade production and increases in size of turbine blades, new advancements in testing are needed to keep pace with the scale and technology. The blade test group focuses on improvements in testing that can lead to harmonization of test methods, improved accuracy, and reduce the time needed to validate blade designs. Work packages for 2014 include the evaluation of fatigue test methods to provide consistency between results of single axis and biaxial test methods. The next steps are about to develop and evaluate test procedures for subcomponent test methods as well as best-practice recommendations for uncertainty estimation in full-scale blade testing.

Table 2. Subtasks of Task 35 and Responsible People

Test Group	Head and Contact Person
Blade	Scott Hughes, National Renewable Energy Laboratory (NREL), United States
Nacelle	Stefan Franzen, Center for Wind Power Drives (CWD), Germany

Nacelle test group

The first approach of the nacelle subtask focuses on the definition of interfaces between the test bench and the test item as well as the determination of load application for different nacelle test procedures. After defining different test levels, the subtask aims to develop and compile a test repertory for basic nacelle test procedures. The various test levels range from 1 degree of freedom rotational subcomponent tests to 6 degrees of freedom full nacelle tests, providing realistic wind and grid load emulation within a hardware in the loop environment.

Figure 2 shows the planned schedule and work program of 2014. Narec will host the next Task 35 meeting in April 2014. Each participant will present its results of the assigned topic which regards one aspect of Phase I. The purpose of this meeting will be to evaluate the overall outcome of Phase I and to launch both subtasks.

References:

Opening photos: Full-size testing of wind turbine components (Images courtesy of MTS Systems Corporation, NREL, Clemson, IWES, and LORC)

(1) Félix Avia (Operating Agent, Task 11); IEA Wind Topical Expert Meeting TEM #68 "Advances in Wind Turbine and Component Testing"; Aachen, Germany, February 2012.

(2) Areva; www.areva.com/EN/news-9108/offshore-wind-turbines-arevas-5-megawatt-full-load-test-benchin-operationsinceoctober2011.html. November 2011.

(3) Vestas; http://worldofwind.vestas.com/en/verification-testing; July 2013.

Authors: Stefan Franzen, Simon Serowy, Dennis Bosse, Ralf Schelenz, and Georg Jacobs, Center for Wind Power Drives at RWTH Aachen University, Germany; in cooperation with Christian Berggreen, DTU, Denmark; Martin Pilas, IWES, and Sven Sagner, RETC, Germany; Brian McNiff, McNiff Light Industry, and Nathan Post, Derek Berry and Scott Hughes, NREL, the United States.

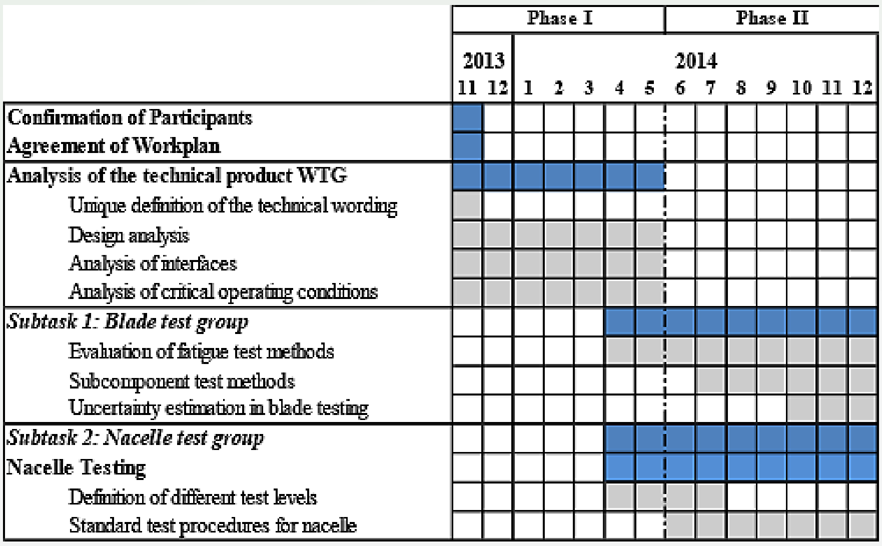

Figure 2. Work Schedule of 2014

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 second year in a row, wind energy in Austria increased by around 300 MW (Table 1).

By the end of 2013, nearly 1,700 MW of wind power were operating in Austria. An additional 380 MW of wind power will be constructed in Austria in 2014. 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. For the first time, tariffs for two years were fixed by the ministries, bringing some certainty for investors. The FIT for 2014 is fixed at 0.0935 EUR/kWh (0.1288 USD/kWh), for 2015 it is fixed at 0.0927 EUR/kWh (0.1277 USD/kWh).

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 (a rise 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 2007 study, the Austrian Wind Energy Association estimated that by 2020 an annual wind power potential of 3,450 MW (production of 7.3 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, for an annual production of around 3.6 TWh of electricity production. This is equivalent to more than 5.8% of the Austrian electricity demand (end energy consumption of households). Wind electricity avoids more than 2.2 million tons of CO_2 emissions every year. With an estimated 2,064 MW in 2014, the annual production of all Austrian wind turbines counts for an equivalent of more than 7% of the Austrian electricity demand and avoids approximately 3 million tons of CO_2.

Most wind turbines (796.7 MW) are still installed in Lower Austria, followed closely by Burgenland (770.4 MW), Styria (82.6 MW), Upper Austria (26.4 MW), Vienna (7.4 MW), and Carinthia (0.5 MW), as shown in Figure 2.

2.3 National incentive programs

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

The Austrian federal state of Burgenland now generates enough electricity from wind power to cover more than the state's annual usage.

Table 1. Key National Statistics 2013: Austria	
Total installed wind capacity	1,684 MW
New wind capacity installed	309 MW
Total electrical output from wind	3.6 TWh
Wind generation as % of national electric demand	5.8%
Average national capacity factor*	24%
Target:	3,000 MW wind power by 2020
Bold italic indicates an estimate.	

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; 0.134 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 (69 million USD/yr) for new projects. This is enough for approximately 120 MW to 350 MW of new wind capacity per year depending on the market price for electricity and the applications from Photovoltaics (PV) and small hydro power plants. For the first ten years the law is in action, this budget decreases by 1 million EUR (1.378 million USD) per year. 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.

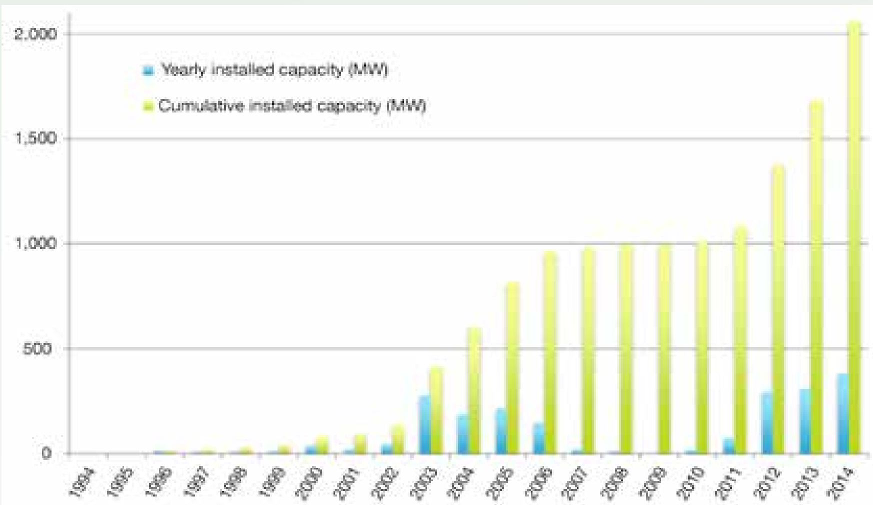

Figure 1. Cumulative installation of wind power in Austria

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 (0.1289 USD/kWh), for 2015 it is fixed at 0.0927 EUR/kWh (0.1277 USD/kWh).

2.4 Issues affecting growth

Crucial for the growth of wind power capacity are the amount 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

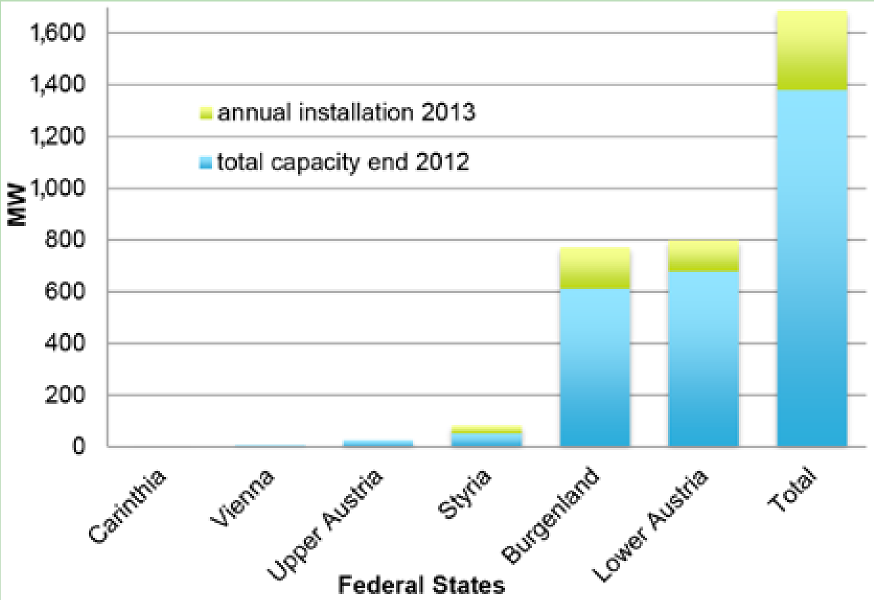

Figure 2. Wind power capacity of the federal states

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.

3.0 Implementation

3.1 Economic impact

The Austrian wind power market is made up of wind turbine operators and planning offices on the one hand and component suppliers for international wind turbine manufacturers on the other hand. In 2010, the annual turnover of operators of existing wind parks was over 150 million EUR (206.7 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 committed successfully both in the onshore 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. More than 120 companies of the Austrian wind energy supplier industry obtain an export volume of more than 500 million EUR (689 million USD). This is backed by strong growth rates between 20–25% of the wind industry sector during the last years.

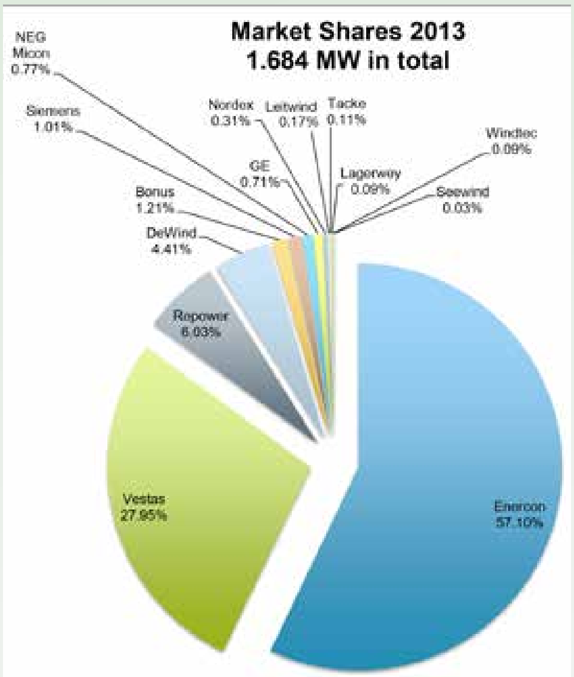

Figure 3. Market shares of suppliers in Austria

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 neighbouring countries of central and Eastern Europe, and some independent companies have also started businesses outside Europe. The one domestic manufacturer of large turbines, Leitwind, began the manufacture of wind turbines in Telfs in Tyrolia in 2008. Apart from Leitwind, 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.

Fostered by the growth of the domestic market, the number of small and medium enterprises 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 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).

3.4 Wind energy costs

Table 2 shows estimated costs for wind energy project elements (price basis for 2013).

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 an Energy Fund (4 million EUR; 5.5 million USD). One 2.5-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 into site-specific parameters into account. In another effort, funds from 2013 have been allocated to compile a Wind Energy Technology Roadmap (end 2014).

National Research funds have also been applied to investigate the usability and economics of small wind turbines to accommodate growing demand in this field. This project is funded by the Austrian Research and Development Program "Neue Energien 2020" of the Austrian Climate and Energy Fund.

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 three research aspects:

1. 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.

2. Evaluation of the operational performance of a stand-alone power supply unit for an intelligent, demand-oriented energy supply of heated wind measurement sensors.

3. Evaluation of operational data of a wind farm in Sweden in terms of performance and vulnerability of a Siemens rotor blade heating system.

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

The Austrian company 'Energiewerkstatt' (energiewerkstatt.org) is the coordinator of the South Eastern European Wind Energy Project (SEEWIND), one of the largest Research and Demonstration Projects carried out under the Sixth Framework Programme (FP6) of the European Commission. SEEWIND is a research and demonstration project with ten partners from six European countries. SEEWIND has a total budget of 9.6 million EUR (13.2 million USD) to install one pilot wind turbine each in Bosnia, Croatia, Herzegovina, 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.

5.0 The Next Term

The GEA 2012 and the FIT for 2014 and 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.

Opening Photo: Windfarm in Lower Austria. Credit: IG Windkraft/Jürgen Pletterbauer

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

Table 2. Cost of New Wind Energy Projects

	EUR/kW	USD/kW
Total investment costs	1,715	2,363
Turbine costs	1,390	1,915
Incidental costs (planning, connection to grid and grid reinforcement, etc.)	325	448
O&M costs average	0.023	0.032
O&M costs years 16–20	0.028	0.0369

17 Canada

1.0 Overview

Canada is the ninth largest producer of wind energy in the world. It has over 7.8 GW of installed wind energy capacity, which produces enough power to meet about 3.1% of the country's total electricity demand. Canada has more than 180 wind farms, spread across ten provinces and two territories.

In 2013, Canada placed fifth globally in terms of new wind energy capacity installed. Nearly 1,600 MW of new wind capacity were installed in six provinces. The province of Quebec led the way, with just over 1 GW of new installations. The first wind-storage facility on First Nations land was commissioned in Saskatchewan. In Nova Scotia, the first community feed-in tariff (COMFIT) projects came on-line.

The government of Canada continues to fund the growth of Canada's wind power sector through its ecoENERGY programs. Provinces across Canada continue to offer a range of incentives for renewable power, including wind. In some cases, existing programs have undergone changes.

Wind farms in Canada are giving back to the community. Wind farm developers have created innovative programs and processes to give back to the community in exchange for their involvement and support for wind energy, and to share in the benefits that come from producing wind energy.

Canada's federal departments and research organizations are working together in R, D&D areas that are particularly relevant to Canada, including quantifying the impact of icing and cold temperatures on wind turbine performance, and using energy storage systems for managing variability.

2.0 National Objectives and Progress

2.1 National targets

Although there are no national wind energy deployment targets, Canada's federal government has set a goal to reduce greenhouse gas emissions by 17% by 2020, compared to the level in 2005.

2.2 Progress

In British Columbia, the new 99-MW Cape Scott wind farm on the northern tip of Vancouver Island entered commercial operation. Cape Scott joined three other wind operations in the province that now deliver a total of 500 MW of power to residents of British Columbia. The 325 million CAD (222 million EUR; 306 million UD) wind farm was jointly developed by GDF SUEZ Canada and partners Mitsui & Co., Ltd. and Fiera Axium Infrastructure. The province's utility, BC Hydro, will purchase the estimated 290 GWh/yr from the owner and operators, under a 20-year power purchase agreement (PPA).

In Saskatchewan, the Cowessess First Nation powered-up their 800-kW turbine to supply energy into the provincial grid. The turbine, erected on Cowessess First Nation land near Regina, is connected to a lithium-ion battery with 740 kWh of electrical storage capacity—a first in Canada. The combined wind-storage system received funding and support from Natural Resources Canada (NRCan) through its Clean Energy Fund, from Aboriginal Affairs, and Northern Development Canada, and from the Saskatchewan government through its Go Green Fund.

In Ontario, wind energy facilities are playing an increasingly important role in meeting the province's demand for electricity. They supplied 5.2 TWh in 2013, which represented 3.4% of all the electricity generated in the province. Ontario's electricity system will continue to evolve over the next year and beyond as wind generation develops critical mass.

The first union-owned and operated turbine in Canada began operation in Port

Canada has more than 180 wind farms, spread across ten provinces and two territories.

Table 1. Key National Statistics 2013: Canada	
Total installed wind capacity	7,803 MW
New wind capacity installed	1,599 MW
Total electrical output from wind	***17.5*** TWh
Wind generation as % of national electric demand	3.1%
Average national capacity factor	31%
Target:	N/A
Bold italic indicates estimates.	

Elgin, Ontario. Commissioning of the turbine came after nine years of planning, preparation, construction, and testing. The 500-kW turbine was erected on the grounds of the Unifor's Family Education Centre, in March 2013. It is estimated that the turbine will generate the equivalent of 50–60% of the center's current energy needs. Unifor is a new union formed by the coming together of the Canadian Auto Workers union (CAW) and the Communications, Energy, and Paperworkers Union of Canada (CEP).

In Québec, EDF EN Canada's 350-MW Rivière-du-Moulin wind project received approval for construction and operation. When commissioned, the project will be the largest wind energy facility in Canada with a single PPA. The wind farm will be developed in two phases: the first 150-MW phase is expected to be commissioned in December 2014, and the remaining 200-MW phase is scheduled to be commissioned in December 2015.

In May 2013, the province of Québec announced its intention to secure a new block of wind power capacity. The 800-MW block was allocated as follows:

- 150 MW for a project currently being developed by the Mi'gmawei Mawiomi, in the Gaspésie
- 150 MW for projects throughout Québec
- 200 MW for Hydro-Québec Production, and
- 300 MW for projects in the Gaspésie or Bas-Saint-Laurent regions.

In December 2013, Hydro-Québec Distribution followed through with a call for tenders: 300 MW in the Gaspésie or Bas-Saint-Laurent regions and another 150 MW for projects throughout the rest of the province. The proposed projects will have to satisfy content and price requirements, such as:

- A minimum of 60% of total project costs must be spent in Québec, including costs for the installation of wind turbines
- A minimum of 35% of wind turbine costs must be allocated to the regional county municipality of La Matanie and the administrative region of Gaspésie—Îles-de-la-Madeleine
- The energy price, which must be added the cost of transmission and the cost of balancing service and firming capacity, must not exceed 0.09 CAD/kWh (0.06 EUR/kWh; (0.08 USD/kWh)

In Nova Scotia, the first COMFIT projects came on-line. Six 50-kW turbines, in three communities, started generating electricity for the province's grid. Furthermore, the province announced the approval of new COMFIT projects in two rounds—the first in March of 2013, and the second in December. Projects approved varied in size from 0.05 MW of small wind near the town of Pictou, to 7.2 MW in the Regional Municipality of Halifax.

2.3 National incentive programs

The government of Canada, through the Wind Power Production Incentive (WPPI) and the ecoENERGY for Renewable Power (ecoERP) programs, has committed about 1.3 billion CAD (8.9 million EUR; 1.2 billion USD) toward wind energy projects. A total of 89 projects, representing 4,442 MW of installed capacity, qualify 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 one under ecoERP will end in fiscal year 2020–2021.

The ecoENERGY for Aboriginal and Northern Communities Program is focused exclusively on providing Aboriginal and northern communities with funding support for clean energy projects. In the fiscal year 2012–2013, the program provided 323,000 CAD (220,609 EUR; 303,943 USD) to five wind projects for pre-feasibility and feasibility studies.

Provinces across Canada continue to offer a range of incentives for renewable power, including wind. In some cases, existing programs have or will undergo reviews and changes. Ontario, for example, is developing a competitive process for large renewable energy projects (over 500 kW), to replace the existing FIT. In 2014, the Ontario Power Authority will be hosting regional community meetings to obtain feedback and input on interim recommendations and proposed Large Renewable Procurement programs.

Ontario also introduced legislation in December 2013 that would eliminate domestic content requirements for construction of future renewable energy projects. The requirements were initially put in place to help spur the growth of Ontario manufacturers and service firms in the renewable energy industry. According to Ontario's Ministry of Energy, the measure is no longer required. If the legislation is passed, domestic content requirements will no longer need to be met under the province's FIT program. The changes would help ensure Ontario is in line with decisions made by the World Trade Organization.

Moreover, the Ontario Ministry of Energy released its 2013 Long-Term Energy Plan. The Plan balances five principles that will guide future decisions: cost-effectiveness, reliability, clean energy, community engagement, and an emphasis on conservation and demand management before building new generation. One of the commitments laid out in the plan is the phasing-in of wind, solar and bioenergy for three more years than estimated in the 2010 Long-Term Energy Plan, with 10,700 MW online by 2021. It is anticipated that by 2025, about half of Ontario's installed generating capacity will come from renewable sources.

In Nova Scotia, the government recently passed Bill No. 1 The Electricity Reform Act. The bill delivers on the government's commitment to begin opening the market to renewable energy producers and create local investment opportunities for renewable electricity providers. If passed into law, the Bill will end the monopoly of Nova Scotia Power Incorporated and the municipal electric utilities over the retail electricity market in the province, and open it to limited competition. Licensed suppliers will be allowed to sell locally generated, renewable, low-impact electricity (such as wind-generated electricity) directly to end users.

3.0 Implementation

3.1 Economic impact

Wind farms across Canada are giving back to the community. Wind farm developers have created innovative programs and processes to give back to the community for their involvement and support for wind energy, and to share in the benefits that come from producing wind energy. For example, Pattern Energy Group and Samsung C&T established the South Kent Wind (SKW) Community Fund for the communities in the Municipality of Chatham-Kent. The SKW Community Fund will be administered by the Chatham Kent Community Foundation. An initial 1 million CAD (683,000 EUR; 941,000 USD) will establish the fund endowment, and an additional 10 million CAD (6.83 million EUR; 9.41 million USD) will carry the fund over the next twenty years. A portion of the annual contribution will go into the endowment and a portion will go directly to fund grants. Funds will be distributed among five areas of giving (community, environment, health and wellness, youth education, and First Nations and Métis) through a granting process.

In western Canada, Zero Emission Energy Developments (ZED), Penticton Indian Band (PIB), and Westbank First Nation (WFN) signed a wind power Impact Benefit Agreement (IBA) in June 2013— the first to be signed with these First Nations. The IBA will enhance opportunities for the PIB and WFN through training, employment and revenue sharing. PIB and WFN are members of the Okanagan Nation Alliance. ZED is developing two separate 15-MW projects within the Okanagan Nation's traditional territory. Scheduled to come on-line in 2014, these projects will be the first wind farms in the interior of British Columbia.

3.2 Industry status

Ownership:

In Canada, wind farms are typically owned by independent power producers, utilities, or income funds (CanWEA maintains a list of wind farm owners/operators at www.canwea.ca). However, in the last decade, the provinces of Nova Scotia, Ontario, and Quebec have introduced policies to encourage community ownership.

In March 2013, the first kilowatt-hour from Nova Scotia's COMFIT program was generated using Nova Scotian wind turbine technology. Seaforth Energy's AOC 15/50 50-kW wind turbines were commissioned in the towns of New Glasgow, Tatamagouche, and Goldboro. Seaforth Energy is a commercial-grade wind turbine manufacturer based in Dartmouth, Nova Scotia. The company manufactures AOC 15/50 turbines—one of the most proven and reliable 50-kW wind turbines, with installations around the world.

In November 2013, the first project from Quebec's 2009 community call for power was put into operation. Innergex Renewable Energy Inc. and the Rivière-du-Loup Regional County Municipality (RCM) brought their 24.6-MW Viger-Denonville wind farm on line. It is expected that the wind farm will generate approximately 22 million CAD (15 million EUR; 20 million USD) over 20 years for the benefit of twelve shareholder municipalities. The wind farm is owned by both Innergex and the Rivière-du-Loup RCM, in a 50/50 split. All of the wind farm's twelve turbines are located on private lands in the municipalities of Saint-Paul-de-la-Croix and Saint-Épiphane.

Manufacturing:

Canada continues to attract wind power equipment manufacturers. The country's manufacturing capacity is primarily based in Ontario and Quebec.

Senvion (renamed from REpower Systems) announced in April 2013 that it will establish its first North American blade production facility in Welland, Ontario. A 300,000 square-foot former steel pipe factory will be retrofitted at a cost of about 6.0 million CAD (4.1 million EUR; 5.6 million USD). The new plant will have access to good transportation links via road, rail, and water. In fact, a rail line runs right through the site, which is located on the Welland Canal between lakes Ontario and Erie. Initially, the facility will employ 125 employees to manufacture 45-meter-long turbine blades for the MM92 2-MW turbine. In the months following, its manufacturing line will be expanded to include 59-meter blades for 3-MW turbines, and hire an additional 75 workers. The facility will be owned and operated by PowerBlades Inc., a wholly owned subsidiary of Senvion.

Siemens shipped its first "Made in Canada" wind turbine blade in July 2013. The 49-meter, B49 blade left the manufacturing facility in Tillsonburg, Ontario, and made its way to the SKW project. This first blade, produced and cast in one, is one of 372 blades to be employed in the commissioning of 124 SWT-2.3-101 wind turbines at SKW. All of the remaining 371 blades will be manufactured in Tillsonburg. The 253,000-square-foot blade manufacturing facility is located on 49 acres, and currently employs nearly 300 people in manufacturing, service operations, and associated back-office activities.

Figure 1. Annemometer and wind vane boom for wind farm studies (credit: NRCan)

3.3 Operational details

Twenty-two wind farms were commissioned across six provinces in 2013 (Table 2).

4.0 R, D&D Activities

4.1 National R, D&D efforts

The focus of Canada's wind energy R&D activities is the integration of wind energy technologies into the electrical grid and into remote community applications, as well as the advancement and development of safe, reliable, and cost-effective wind turbine technology. Several departments of the federal government are active in wind energy R&D:

- NRCan's R&D priority areas include: reducing the cost and increasing the penetration of large wind turbines, and improving the performance and reliability of turbines in Canada's north.
- Environment Canada conducts research on the environmental impacts of wind development, including potential impacts on migratory birds, bats, and other wildlife. The department also conducts research on wind resource assessment and on wind and ice forecasting.
- Health Canada is collaborating with Statistics Canada on an epidemiological study on the health impacts of wind turbines. The research study will support the Government of Canada and other stakeholders by strengthening the evidence base that supports decisions, advice, and policies regarding wind turbine development in Canada. For more information, go to (http://www.hc-sc.gc.ca/ewh-semt/consult/_2013/wind_turbine-eoliennes/research_recherche-eng.php).

NRCan's CanmetENERGY is collaborating with the Caribou Wind Park in New Brunswick to instrument a tower and collect atmospheric information on icing and clouds (Figure 2). The purpose of the project is to determine with relative accuracy the amount of 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 by the Numerical Research Group at Environment Canada to validate a meso-scale icing model currently under development.

On 3 May 2013, the government of Canada announced support of more than 82 million CAD (56 million EUR; 77 million USD) through NRCan's ecoENERGY Innovation Initiative (ecoEII). Three wind-related initiatives are among the 55 projects that have received funding:

- A Front End Engineering and Design (FEED) study to determine the technical and economic requirements of a proposed wind hybrid power plant in Whapmagoostui, northern Quebec. The hybrid plant would combine wind, biomass, and battery to replace all or part of the existing diesel plant.
- A FEED study to determine the requirements of a proposed wind/storage/diesel hybrid system in Nunavik, northern Quebec. The hybrid system

Figure 2. Ice detectors and fog sensors (credit: NRCan)

Table 2. Statistics for new wind farms commissioned in 2013 in Canada

Smallest wind farm	0.5 MW – Unifor, Ontario
Largest wind farm	300 MW – Lac Alfred, Quebec (commissioned in 2 phases)
Wind farm locations	British Columbia, Saskatchewan, Ontario, Quebec, Nova Scotia, Prince Edward Island
Turbine manufacturers	Enercon, Siemens, Repower (Senvion), Vestas, DeWind
Turbine sizes (range)	0.5–2.3 MW
Average turbine size	2 MW

would generate energy from wind, and store surplus wind energy through hydrogen. This system would be part of Xstrata Nickel's Raglan Renewable Electricity Micro-Grid and Smart-Grid Pilot Demonstration Project.

• An assessment of whether Virtual Blade Wind Power's novel configuration of turbine blades can achieve an increase in energy production over conventional blades, when operating in the field. Further research and development needs that address technical risks associated with moving to a new wind turbine blade technology will also be identified.

NSERC Wind Energy Strategic Network (WESNet) is a Canada-wide multi-institutional (16 universities) and multi-disciplinary research network. WESNet's research program spans the entire value chain of wind energy. The network focuses on developing innovative solutions to critical technical issues confronting the Canadian wind sector, strengthening broad-based partnerships among researchers and with industry, and training highly qualified personnel. The original five-year program was scheduled to be completed by 31 March 2013, but was extended to 31 March 2014. During the final year (2013–2014), WESNet has focused on moving the technology solutions developed by researchers down the innovation chain, towards demonstration and commercialization. WESNet researchers continue to actively seek opportunities for technology transfer to the Canadian wind industry, and disseminate research results to the wind energy community at large. For more information see (www.wesnet.ca).

TechnoCentre éolien (TCE) is a non-profit institution whose mission is to conduct research into cold climate issues and contribute to the development of an industrial wind energy network in Quebec (www.eolien.qc.ca). TCE owns an experimental cold climate wind energy site in Rivière-au-Renard where there are two REpower MM92 CCV wind turbines, each with a capacity of 2.05 MW.

TechnoCentre éolien collaborated with VTT Technical Research Centre of Finland on a research project to determine if wind turbine vibrations could be caused by ice. Data was gathered from wind turbines at the TechnoCentre éolien research site located in Québec and from wind turbines in Finland. An analysis of the data showed that the measured vibrations were more pronounced during ice events. As a result, the International Electrotechnical Commission (IEC), is revising the guidelines for wind turbine design standards (IEC 61400-1), for cases involving loads associated with ice.

TechnoCentre éolien participated in the first market study dedicated to wind energy in cold climates. The study, conducted by VTT Technical Research Centre of Finland, assessed the feasibility of installing wind turbines in areas where cold climate and icy conditions place special demands on the turbine technology. The VTT study was incorporated into the BTM World Market Update 2012 Report by Navigant Research, and was released in April 2013. The report dedicated a special section to cold climate turbines, highlighting the challenges presented by cold climates on turbine operation, the technological requirements for turbines in cold climates, as well as the opportunities for growth in cold climate markets. According to the report, 11.5 GW of the world's wind energy capacity is installed in areas where moderate to heavy icing conditions occur—66% of which are in North America, 14% of which are in Quebec. The study also predicted that Canada will have more than half of the world's cold climate wind energy capacity by 2017. Moreover, according to the report, "one of the most prominent test sites with state-of-the-art wind and icing instrumentation and two mainstream size wind turbines is in Gaspé, Canada and is owned by the TechnoCentre éolien."

The Wind Energy Institute of Canada (WEICan), located at North Cape, Prince Edward Island is a non-profit, independent research and testing institute (Figure 3). WEICan is recognized as a preferred non-accredited test site for small wind turbines by the Small Wind Certification Council for the North American market; and a non-accredited test site by TUV-NEL (www.tuv-nel.com), for Microgeneration Certification Scheme certification for the United Kingdom market.

WEICan is collaborating with researchers from Canada's Wind Energy Strategic Network (WESNet) to test a small wind turbine designed and manufactured by the WESNet team. The prototype turbine has

Figure 3. Wind Energy Institute of Canada (WEICan)

been installed at the Institute's North Cape site. Testing and data acquisition for power performance to IEC standard 61400-12-1 has begun, with an expected test period of approximately one year.

WEICan's Wind R&D Park was commissioned in April 2013. In excess of 11 GWh of energy, from commissioning to 1 September, was generated for the Prince Edward Island grid. The Wind Park features five DeWind D9.2 wind turbines with a combined total generating capacity of 10 MW, and incorporates a battery energy storage system from S&C Electric Canada and General Electric. As a demonstration project, the objective is to demonstrate the benefit of energy storage under various scenarios. Demonstration of operation in time-shift mode, power smoothing and voltage control, and other applications for energy storage systems should increase the acceptance and utilization of such systems. 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, as well as a 12.0 million CAD (8.2 million EUR; 11.3 million USD) loan from the government of Prince Edward Island. The loan will be repaid from the sale of power produced by the Wind R&D Park.

In March 2013, Eocycle Technologies was awarded an investment of over 6.3 million CAD (4.3 million EUR; 5.9 million USD) from the latest round of Sustainable Development Technology Canada's SD Tech Fund™. The funds will enable Eocycle to demonstrate the commercial and technical viability of its Transverse Flux Permanent Magnet (TFPM) generator technology for megawatt-capacity wind turbines. The high-torque, low-speed generator eliminates the need for conventional multi-stage gearbox and results in a smaller, lighter, and more cost-effective generator. Eocycle's generator technology has one of the highest electrical power per unit volume when compared to all competing technologies. The Eocycle 25 direct drive wind turbine, which incorporates the TFPM technology, recently completed a full year of uninterrupted operation at the WEICan's test site. The turbine successfully completed a series of tests, validating its power curve and sound power levels.

Temporal Power, an Ontario-based company, is working with Hydro One to provide up to ten 500-kW flywheels for frequency regulation on a feeder that is connected to two 10-MW wind farms in southwest Ontario. Temporal's 9,000-pound solid-steel flywheel provides about three to fifteen minutes of storage. Moreover, frequency regulation is the sweet spot for flywheel technology, which can quickly respond to the fluctuations on the grid to provide balancing services. The flywheel array for Hydro One will provide millisecond-level responses to balance wind ramping, starting in 2014. The project is partially funded by Sustainable Development Technology Canada. After the pilot phase, Hydro One will take over ownership and operation of the facility.

Furthermore, Temporal, in partnership with NRStor and Ontario Power Generation, won a contract with Ontario's Independent Electricity System Operator (IESO) to deliver 2 MW of regulation service. Together, Temporal and its partners will provide energy storage that would allow IESO to manage its system more efficiently, by integrating flywheel technology in the province's grid.

In Alberta, Suncor Energy, in conjunction with Teck, is planning to install a 3-MW/6.9-MWh battery at the existing Wintering Hills Wind Power Project. Alberta's Climate Change and Emissions Management (CCEMC) Corporation is providing 9.2 million CAD (6.3 million EUR; 8.7 million USD) to the battery storage pilot project, to test the feasibility of shifting power from off-peak periods to on-peak periods, and participating in ancillary energy service markets. The battery system could also provide quick power ramp-up and ramp-down service, as well as help balance the electrical grid. CCEMC is a non-governmental organization that receives money from the Climate Change and Emissions Management Fund and directs it towards innovative projects that have the potential to reduce greenhouse gas emissions in the province of Alberta.

Aercoustics, an engineering firm based in Ontario, Canada, recently became the first Canadian organization to receive accreditation for acoustic noise testing of wind turbines. The company has been classified by the Standards Council of Canada as an accredited laboratory that adheres to International Standards Organization (ISO) 17025:2005, General Requirements for the Competence of Testing and Calibration Laboratories. This means that Aercoustics is one of a handful of organizations worldwide that can perform IEC 61400-11, Wind Turbine Generator Systems–Acoustic Noise Measurement Techniques.

4.2 Collaborative research

Canada participates in IEA Wind Task 19 Wind Energy in Cold Climates, Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power, Task 31 Benchmarking Wind Turbine Flow Models, and Task 32 Wind Lidar for Wind Energy Deployment. Canada also participates in Technical Committee-88 of the IEC.

5.0 The Next Term

According to the Canadian Wind Energy Association, Canada's wind power industry is poised to add 4,500 MW of new generation over the next three years. Most of the new turbines will come on-line in the four provinces of Alberta, British Columbia, Ontario, and Quebec.

Opening photo credit: NRCan

Author: Melinda Tan, Natural Resources Canada, Canada.

18 CWEA

1.0 Overview

In 2013, the newly installed wind power capacity in China was 16,088.7 MW, and the accumulated installed capacity was 91,412.9 MW, which ranks at the top of the world. The newly grid-connected power reached 14,920 MW, with a total of 77,580 MW. The wind power generation reached 137.1 TWh in 2013, more than 36.7 TWh over generation in 2012. The wind power market grew steadily in 2013. However, compared with conventional energy, wind power only accounted for 2.6% of the total generation, meaning it has great potential. In the future, wind power could and should play a more important role in the clean and sustainable energy and electricity supply.

In 2013, the Chinese government made development plans and decisions strictly according to the target of the 12th FIVE-YEAR Plan for Renewable Energy Development and the 12th FIVE-YEAR Plan for Wind Power Industry Development. The government promulgated a number of policies to encourage development of the industry, to solve issues such as wind power curtailment, and to address the bottleneck of grid integration. According to statistics of the China Electricity Council, in 2013 the national average utilization hours of wind power equipment was 2,080 hours. This is the highest level since 2005, and 151 more hours than in 2012. The issues causing wind power curtailment have improved. Another positive event occurred in September 2013 when the government promulgated the Plan of Action for Prevention and Control of Atmospheric Pollution. This plan gives wind power a new mission for air pollution control. Adjusting energy structures and increasing the supply of clean energy will be the major tasks for the Chinese government at this stage.

The Decision on "Major Issues Concerning Comprehensively Deepening Reforms" was adopted at the close of the Third Plenary Session of the 18th CPC Central Committee in 2013. This decision put forward that the development of wind power is in accordance with the guiding ideologies of accelerating transformation of the economic development pattern and promoting a more efficient and sustainable economy. Wind power generation as a clean, non-polluting, sustainable use of energy utilization has great significance for adjustment of the energy structure, the economical utilization of resources, and the promotion of economically sustainable development. Thus, the wind power industry will certainly usher in new historical opportunity, a healthier market environment, and play a greater role in China's clean, sustainable energy and electricity supply.

2.0 National Objectives and Progress

2.1 National targets

In 2013, the government issued a number of notifications to require relevant organizations to pay attention to wind power consumption, improve the utilization rate of wind power, analyze the causes of wind power curtailment, and take measures to solve it. To improve the situation for managing wind farm grid connection, the government also deployed five guidelines for electricity grid-connection projects. Meanwhile, to increase wind power consumption in the north, a wind-rich area, and to reduce inefficient fossil energy combustion and pollution, parts of northern China will promote clean heating technology from wind power to improve air quality in winter.

Wind power will play an important role in the action plan for prevention and control of atmospheric pollution. The Plan of Action for Prevention and Control of

During 2013, China installed 9,356 new wind turbines for an added generating capacity of 16,088.7 MW.

Table 1. Key National Statistics 2013: China	
Total installed wind capacity	91,412.9 MW
New wind capacity installed	16,088.7 MW
Total electrical output from wind	137.1 TWh
Wind generation as % of national electric demand	2.6%
Average national capacity factor	23.7%
Target:	18,000 MW new capacity and 175 TWh/yr wind generated electricity in 2014 200 GW (30 GW offshore) total capacity and 390 TWh/yr electrical output by 2020.

Atmospheric Pollution proposed that by 2017, the portion of non-fossil energy consumption increase to 13%. The government also requires promotion of clean energy structure, acceleration of the development of wind power and other new energy industries, and is trying to solve the problem of renewable energy priority access, with priority given to renewable energy.

2.2 Progress

According to CWEA statistics, during 2013, China installed 9,356 new wind turbines in China with a generating capacity of 16,088.7 MW (excluding Taiwan). This accounted for 45.4% of the global new wind capacity installed. Compared to 2012, newly installed capacity increased by 24.1%, and the accumulated installed capacity increased by 21.4%, reaching 91,412.9 MW—the largest wind generation capacity in the world (Figure 1). In 2013, newly grid-connected wind capacity reached 14,920 MW, which increased 0.6% within the same period, to total 77,580 MW.

In 2013, under the guidance of various measures, the average full load operating hours of Chinese wind power equipment was 2,080 hours. This was an increase of 151 hours over 2012, indicating that there is less curtailment of wind farm production. Wind power's contribution to the national electricity grid was 137.1 TWh in 2013, an increase of 36% over the contribution in 2012 or more than 36.3 TWh of additional electricity. This demonstrates that grid connection issues of wind power were substantially improved during 2013.

All of the provinces, cities, and autonomous regions in China now have large wind farms. The Nagqu high-altitude wind test field was connected to the grid in Tibet in 2013, creating the highest altitude wind power project in the world. Also in 2013, the first Ultra-High-Voltage Direct Current (UHVDC) project, called the Southern Hami-Zhengzhou ±800 kV UHVDC transmission line was finally completed. This 800-kV, 800-MW UHVDC transmission standardization demonstration project created favorable conditions for wind power transmission.

China's wind power enterprises signed a number of contracts in 2013 with Canada, Cuba, Ethiopia, Romania, South Africa, and other countries. The total capacity of these projects was 59.7 MW, including

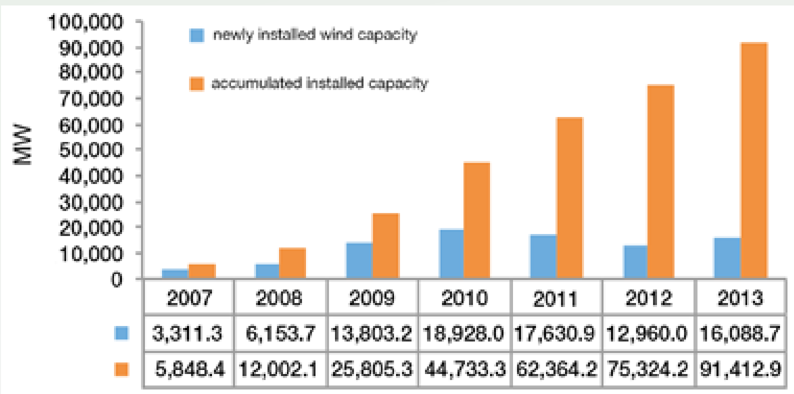

Figure 1. Newly and Accumulated Installed Capacity from 2007 to 2013

project development agreements, engineering procurement and construction projects, and equipment supply agreements. This "Go Global" strategy provided new business for the wind power enterprises.

2.3 National incentive programs

In 2013, in light of the new problems and trends of the wind power industry, the Chinese government formulated and adjusted a series of policies to promote scientific and stable strategies for wind power development. For example, in 2013, the government delegated the business investment approval authority of wind power projects (5+ MW total installed capacity) to the investment departments of local governments. This shows that the wind power industry is beginning to mature and is able to use market instruments to adjust. Simultaneously with the devolution of approval, the government issued The Notifications about Strengthening of Surveillance and Evaluation System Construction for Wind Power Industry. These rules require strengthening the monitoring and evaluation of important information in the wind power industry, gradually improving the monitoring and evaluation system, regulating the market, and promoting healthy and sustainable development of the wind power industry.

In addition, in order to support the development of the renewable energy industry, the national government not only clarified the requirements of the renewable energy tariff subsidy, but also pre-appropriated 9.31 billion Yuan (1.12 billion EUR; 1.54 billion USD) to wind electricity in accordance with the standards. To ensure the Chinese wind power feed-in tariff could be fully funded and provided on time, the government raised the renewable energy tariff from 0.008 Yuan/kWh to 0.015 Yuan/kWh (0.00096 EUR/kWh to 0.0018 EUR/kWh; 0.00132 USD/kWh to 0.002475 USD/kWh).

Baicheng City in Jilin Province has rich wind energy resources. In recent years, rapid growth of wind power capacity in the area has produced more electricity than the power system can handle. This has resulted in serious curtailment of wind energy production. To explore ways to promote wind power grid integration, enhance the ability of local power consumption, and inspire innovation to meet the needs of wind power and other renewable energy development, the central government made Baicheng City the first national demonstration area. The experiences of Baiching City to make the most use of local wind power and eliminate the need for curtailment will help other areas solve wind power curtailment.

2.4 Issues affecting growth

This year, China's wind power industry showed signs of bottoming out. During this period, problems such as grid integration, difficulties in consumption, wind power curtailment, and the slow development of offshore wind power have emerged and become the main bottlenecks to limit the development of Chinese wind power.

3.0 Implementation

3.1 Economic impact

In 2013, the Chinese government allocated a total of 14.81 billion Yuan (1.77 billion EUR; 2.44 billion USD) as additional renewable energy electricity subsidy funds, including 9.31 billion Yuan (1.12 billion EUR; 1.54 billion USD) for wind power subsidies. The wind power generation reached 137.1 TWh, which could satisfy the electrical needs of 62.75 million households in China.

3.2 Industry status

3.2.1 Developers

In 2013, the top five developers in China accounted for 46.5% of annual newly-developed wind farms (Table 2). Compared to 2012, the top ten developers of annual newly developed wind farm changed significantly.

Table 2. Top Ten Developers of Newly Installed Capacity in China in 2013

No.	Developer	Capacity/MW	Share
1	China Guodian Corporation	1,751.1	10.9%
2	China Power Investment Group	1,712.2	10.6%
3	CGN Wind	1,536.7	9.6%
4	Huaneng Group	1,325.5	8.2%
5	Huadian Group	1,164.0	7.2%
6	Longyuan Power Group	1,055.0	6.6%
7	Datang Group	820.5	5.1%
8	Guohua	753.0	4.7%
9	Guodian Group	696.0	4.3%
10	Huarun	554.3	3.5%
	Others	4,962.5	30.8%
	Total	16,330.8	100%

3.2.2 Manufacture industry

In 2013, the top five manufactures of newly installed capacity were Goldwind (3,750.2 MW), United Power (1,486.5 MW), Mingyang (1,286.0 MW), Envision (1,128.1 MW), and XEMC-wind (1,052.0 MW). There were 11 manufactures whose newly-installed capacity in 2013 was over 500 MW (Table 3). The top ten manufactures accounted for 77.8% of China's wind turbine generators.

The top five manufacturers represented 54.1% of the market, down 6% from the top-five share of 2012. The annual growth rate in terms of new installation

Table 3. Top Ten Manufactures of Newly Installed Capacity in China in 2013

NO.	Manufacture	Capacity/MW	Share
1	Goldwind	3,750.3	23.3%
2	United Power	1,487.5	9.2%
3	Mingyang	1,286.0	8.0%
4	Envision	1,128.1	7.0%
5	XEMC-wind	1,052.0	6.5%
6	Shanghai Electric	1,014.0	6.3%
7	Sinovel	896.0	5.6%
8	Vestas	786.7	4.9%
9	Dongfang Electric Corporation	573.5	3.6%
10	Zhejiang Windey	538.8	3.3%
	Others	3,575.9	22.2%
	Total	16,088.7	100%

by United Power decreased 26.7% compared to its 2012 performance. The other four companies' growth rates are as follows: Goldwind (48.7%), Ming Yang (13.5%), Envision (107.4%), and XEMC-Wind (17.8%).

3.3 Wind farm operation

In 2013, 1,600 wind farms were operating on the Chinese mainland and 9,356 new wind turbines were installed, bringing the total operating turbines to 63,120. The cumulative installed capaity reached 91,412.89 MW with the addition of 16,088.7 MW within 2013. The annual growth rate of new capacity was 24.1% and cumulative installed capacity was 21.4%, the highest of the global wind market.

At the provincial level, the new installed capacity of the top five provinces (Xinjiang (opening photo), Inner Mongolia (Figure 4), Shanxi, Shandong, and Ningxia) totaled 8,275.7 MW, accounting for 51.4% of the national total additions. In the top three provinces, Xinjiang added 3,146 MW, increasing 217%; Inner Mongolia added 1,646.5 MW, increasing 47%; and Shanxi added 1,308.95 MW increasing 27.6%. Inner Mongolia, Hebei, and Gansu Provinces are still the biggest three in terms of cumulative installed capacity, with cumulative capacity of 20,270.31 MW, 8,999.9 MW, and 7,095.95 MW, respectively.

3.4 Capital expenditures

With the expansion of the scale of renewable energy, compared to 2012, average wind farm capital expenditures dropped significantly in 2013. This was mainly caused by the decrease of the biggest part of capital expenditure, and wind turbine costs declined from 6,500 Yuan/kW (780 EUR/kW; 1,073 USD/kW) to 4,000 Yuan/kW (480 EUR/kW; 660 USD/kW). Unit investment in wind power projects decreased from 10,000 Yuan/kW (1,200 EUR/kW; 1,650 USD/kW) to around 8,000 Yuan/kW (960 EUR/kW; 1,320 USD/kW) in the "Three North" area. The cost of power generation has dropped at least 15%.

4.0 R, D&D Activities

4.1.1 Fundamental Research

In 2013, one project of the National Basic Research Program of China (973 Program), "The Research on the Key Mechanical Issues and Design of Large-scale Wind Turbines," was newly listed by the Ministry of Science and Technology (MOST) of the People's Republic of China.

The study subjects of this project are as follows:

(1) Unsteady Aerodynamic Mechanisms and High-Accuracy Numerical Simulation for Wind Turbines

(2) Aeroelastic Mechanisms and Structural Dynamics of a Nonlinear Large Deformation of Wind Turbine

(3) Offshore Floating Wind Turbine Dynamics under Wind, Ocean Wave, and Ocean Current Conditions

(4) Dynamics and Safety for Bottom-Fixed Offshore Wind Turbine Foundations

(5) Experimental Study of Wind Turbine Flow Structure and Aerodynamic Hydrodynamic Structure Coupling

(6) Comprehensive Mechanical Analysis and Integrated Optimization of High-Performance Wind Turbines

In 2013, among the newly-listed research subjects related to wind power by MOST, the 7-MW class wind turbine R&D and 10-MW class wind turbine concept designs are being smoothly carried out. The execution of the projects above will provide good technical support for Chinese wind power technology, especially for the development of offshore wind power.

4.1.2 Application Research

In recent years, as large-scale construction of wind farms in China developed, wind power grid problems have emerged. In 2013, China's average curtailment rate for wind power decreased by 11%. To further solve this constraint, the State Grid Corporation of China adopted ultra-high voltage (UHV) power transmission technology and made unified plans for the long-distance transmission of clean energy, such as transmission of hydroelectric power, wind power, photovoltaic power, etc. together with coal-fired power. In January 2014, the Southern Hami-Zhengzhou ±800kV UHVDC Transmission Project was put into operation allowing for the first time the packaged transmission of the wind power, photovoltaic power and coal-fired power, in China with a transmission capacity of 800 MW.

In addition, the second phase of the national demonstration project for wind, solar, storage, and transmission planned by the State Grid Corporation is under construction in the Zhangbei county of Hebei province. The demonstration project includes 400 MW of wind power, 20 MW of photovoltaic power, and 20 MW of energy storage, and it is expected to have an investment of nearly 4 billion Yuan (480 million EUR; 660 million USD). The first phase of this project was put into operation in December 2011, of which, wind power accounts for 100 MW, photovoltaic power for 40 MW, and energy storage for 20 MW. The results show that smooth and controllable power output can be achieved and the voltage fluctuation rate in ten minutes can be controlled within 5%.

Currently, power generation accounts for over 40% of the total CO_2 emission in the Chinese energy system. In order to push the power sector to reduce greenhouse gas (GHG) emissions, in 2013, Chinese Academy of Engineering organized and completed the project Research on Key Issues of Different Power Generation Energies GHG Emissions. The research analyzed and calculated GHG emissions during the life cycle of electricity generation from coal power, nuclear power, hydropower, wind power, and photovoltaic power. CWEA participated in the research of wind power. Results showed that the normalized amount of GHG emission during the life cycle of the wind power supply chain is 15.9 to 18.7 CO_2 eg/kWh. This includes 75% of the total during the wind turbine manufacturing stage and 25% during wind farm construction, and O&M. Wind energy, as a renewable energy, also needs to reduce the total energy consumption to cut down GHG emissions by measures such as constantly improving the efficiency of wind turbines, reducing the weight of wind turbines, prolonging wind turbine life, improving manufacturing processes, optimizing wind farm management, etc.

In October 2013, an icing wind tunnel (3 m x 2 m) in China's Aerodynamics Research & Development Center was put into operation and went through the NACA0012 airfoil iced model tests. This wind tunnel can provide the variable pressure icing cloud environment of low and high temperature for the icing tests. Besides its main use for research on aircraft icing and anti-icing, it can also be used for research on the icing and anti-icing issues of wind turbine blades in low temperature environments (Figure 2).

4.1.3 Offshore Wind Power Technology

Steadily developing offshore wind has always been a goal in the development of wind power in China. By 2013, the total installed capacity of offshore wind power had reached 428 MW. There are two main aspects of research on offshore wind technology; one is R&D of large-scale offshore wind turbines, and the other is R&D on construction equipment and construction processes developed for projects in water of the intertidal zone out to far offshore. In 2013, China designed and built a set of jack-up installation vessels for a Danish wind turbine company. The vessel integrates the functions of transport, crane lifting, and installation of wind turbine components and can be used for the installation for ten sets of wind turbines from 5 MW to 7 MW.

4.2 Collaborative Research

By 2013, CWEA had organized 27 domestic wind power companies, research institutes, and universities to attend the task work of IEA Wind. Chinese experts participate in 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 at Turbulent Sites, Task 29 Wind Turbine Aerodynamics, Task 30 Offshore Codes, Task 31 Benchmarking Wind Farm Flow Models (Figure 3), Task 32 Wind Lidar Systems for Wind Energy Deployment, and Task 33 Reliability Data. Task 19 Wind Energy in Cold Climates is being considered for 2014. This cooperative research will play an important role in developing the wind energy industry, advancing wind energy technology, and keeping wind energy sustainable for development.

Figure 2. Test section of icing wind tunnel


Figure 3. The vortex in the wake of a wind turbine


Figure 4. Wind farms in Inner Mongolia province (Credit: Bo Junming)

5.0 The Next Term

The wind power industry development in China showed a trend of recovery in 2013. Recently, the National Energy Administration has issued The Guidance for the Energy Work in 2014, which will guide the orderly development of wind power and help realize the goal 18 GW of a new capacity. Some related management measures, such as renewable portfolio standard and full protection of the renewable energy acquisition are under formulation.

Opening Photo: Wind farm in Da Ban Cheng, Xinjiang Province.

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

19 Denmark

1.0 Overview

In 2013, 24.7% of Denmark's energy consumption came from renewable sources, 36.9% from oil, 18.1% from natural gas, 17.7% from coal, and 2.2% from nonrenewable waste. The production from wind turbines alone corresponded to 33.2% of the domestic electricity supply in 2013, compared to 30.1% in 2012.

Wind power capacity in Denmark increased by 644 MW in 2013, bringing the total to 4,808 MW (Table 1). During the year, 692 MW of new turbines were installed, while 47.2 MW of old turbines were dismantled. Of the installed wind turbines, 350 MW were offshore, finishing the Kattegat project Anholt. The largest rated turbines to be installed in 2013 were the 6-MW Siemens; six of these turbines were added onshore at Oesterild for production testing next to the one erected in late 2012.

2.0 National Objectives and Progress

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

This agreement implies a 12% reduction of gross energy consumption in 2020 in comparison to 2006; a share of 35% renewable energy in 2020; and 50% wind energy in Danish electricity consumption in 2020. The agreement includes a series of energy policy initiatives for 2012–2020, and the parties involved will take stock of the developments regularly. Before the end of 2018, further initiatives reaching beyond 2020 are to be discussed by the Parliament.

More details of the agreement 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).

2.1 National targets

For wind power the agreement includes:

- 1,000 MW of large-scale offshore wind farms before 2020 (tendering process)
- Horns Rev III 400 MW (in operation in 2017–2020)
- Krieger Flak 600 MW (in operations before 2020)—EU support to grid connection is 1.1 billion DKK (1.5 million EUR; 2.0 million USD)
- 450 MW of near-coast offshore installations (tendering process)
- 50 MW of offshore turbines for R&D
- 500 MW added capacity on land before 2020
- 1,800 MW of new generation on land including 1,300 MW for repowering.

2.2 Progress

As shown in Table 1 and Figure 1, the contribution from wind alone to domestic electricity production was 32.7% in 2013 compared to 29.9% in 2012.

The added wind capacity in Denmark in 2013 was 644 MW, bringing the total to 4,808 MW. This year, 692 MW were installed (342 MW added on land) and 48 MW were dismantled. The largest rated turbine to be installed in 2013 was the 6-MW Siemens. Six of these turbines were erected onshore at the Oesterild Testsite adding to

The Danish production from wind turbines alone corresponded to 33.2% of the domestic electricity supply in 2013, compared to 30.1% in 2012.

Table 1. Key National Statistics 2013: Denmark	
Total installed wind capacity	4,808 MW
New wind capacity installed	644 MW
Total electrical output from wind*	11.1 TWh
Wind generation as % of national electricity demand	32.7%
Average capacity factor**	27.1%
Target:	50% of electricity demand from wind by 2020

* In 2013 the wind index was 93.4%
**Average capacity factor based on production from turbines installed before January 1, 2013

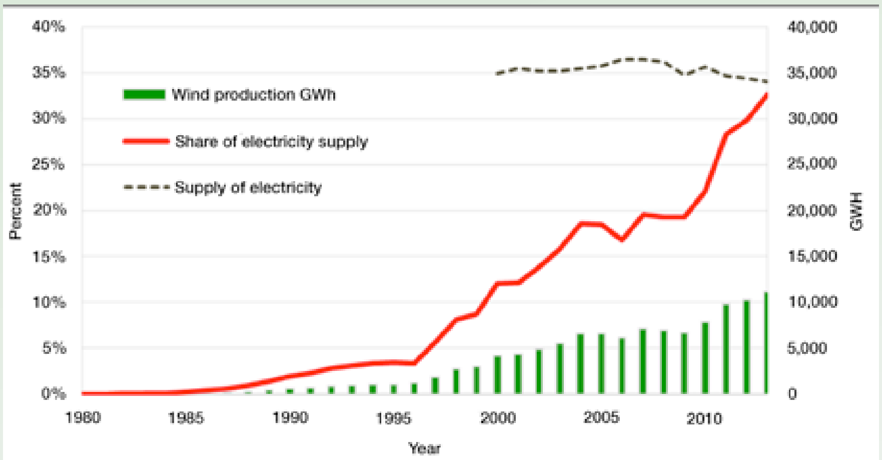

Figure 1. Danish wind power capacity and share of domestic electricity supply from 1980–2013

2.3 National incentive programs

The key legislation related to renewable energy are: the Act on promotion of renewable energy (consolidated act 1330/2013), the Act on Electricity Supply (consolidated act 1329/2013), and the Act on the Danish TSO (consolidated act 1097/2011). Unofficial English translations of previous versions of the legislation are available (4). Each of the acts has issued a number of ordinances. The two most important in this context are: executive order no. 1063/2010 on grid connection of wind turbines and executive order no. 891/2011 on system operation and use of transmission grid.

the one installed there in late 2012. A new Vestas 8-MW turbine was certified for test in December 2013 and was also erected at the Oesterild Testsite in January 2014 (Figure 2).

A detailed history of installed capacity and production in Denmark can be downloaded from the Danish Energy Agency (4).

The environmental benefits due to the 2013 wind energy production, assume coal is being displaced, saved coal: 3,749,412 tons (337 g/kWh) and the following emissions avoided: CO_2: 8,633,660 tons (776 g/kWh); SO_2: 776 tons (0.07 g/kWh); NOX 2,559 tons (0.23 g/kWh); particles 223 (0.02 g/kWh); and Cinder/Ash 589,670 tons (53 g/kWh) (5).

Figure 2. Vestas 8-MW turbine at the Oesterild Testsite (Source: Vestas Wind Systems A/S)

The Danish TSO that is responsible for operation of the electricity system has issued a number of regulations to be complied with for electricity generation equipment. They are all available online (6).

2.4 Issues affecting growth

The growth in offshore installation is a result of the installation of the Anholt Wind farm, where 350 MW (97 turbines) out of the planned 400 MW were installed in 2013. The growth on land (294 MW) resulted from government policies promoting more wind energy and from approval from local authorities of sites for large turbines on land. Most of the new large wind turbines on land were raised in Jutland, especially in the western and northern parts.

During the year, 48 smaller and older wind turbines were dismantled, removing a capacity of approximately 48 MW. Fewer turbines have been dismantled in 2013 than in 2008–2011; the earlier replacement scheme expired in 2011.

3.0 Implementation

The Danish wind turbine industry association (7) publishes an annual report on the industry status and economic impact. The information in the latest annual report "Branchestatistik 2013" is for 2012 (8).

3.1 Economic impact

Turnover in the wind industry in Denmark decreased from 11.0 billion EUR (15.2 billion USD) in 2012 to 10.8 billion EUR (15.0 billion USD) in 2013. Total exports also experienced a decline from 7.0 billion EUR (9.7 billion USD) in 2012 to 6.5 billion EUR (9.0 billion USD) in 2012. The export share of total sales in the same period was a little more than 60%. Hence, the Danish wind industry maintains activity levels with only a modest decline, indicating that the Danish wind industry remains competitive in the global and in particular the European wind market.

The employment level followed the decline in total exports and turnover. By the end of 2013, there were 27,490 employees in the Danish wind industry. This is a slight decrease compared to 2012 when there were 28,459 employees in the industry.

3.2 Industry status

Figure 3 shows the relative turnover, export, and employment in the Danish wind industry from 2006–2013.

The major Denmark-based manufacturers of large commercial wind turbines of one megawatt or larger are still Siemens Wind Power (formerly Bonus Energy A/S) and Vestas Wind Systems A/S.

3.3 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 the 2013 Anholt project (400 MW). Existing offshore wind farm locations in Denmark are described in the *IEA Wind 2012 Annual Report*.

The Anholt project was finished in 2013 with all 400 MW of capacity grid-connected and operating since June. More information can be found on DONG's Web Site for Anholt (9).

At the end of 2013, 5,194 turbines with a capacity of 4,808 MW were in operation and the total production in the year was 11.1 GWh. The average capacity factor was 27.1% (average wind index 93.4%) for the turbines that have been in operation the whole year. The 870 MW of offshore wind farms alone counted for more than one-third of the production with a capacity factor of 40.8% for turbines in operation the whole year. The total penetration rose to nearly 33.1% in 2013 compared to 29.9% in 2012.

The average capacity of turbines installed is now over 2.7 MW (Figure 4), continuing the trend to larger machines over the last three to four years.

3.4 Wind energy costs

The average turnkey prices for wind in 2013 is estimated by EA Energi Analyse to be a little higher than in 2012 but still lower than 2008 (Figure 6).

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 between Energinet.dk, the Energy Technology Development and Demonstration Programme, the Danish Council for Strategic Research, the European Commission representation in Denmark, and the Danish Advanced Technology Foundation. An updated list of Danish-funded energy technology research projects is also available online (13).

4.1 National R, D&D efforts

The main priorities for R, D&D in wind have since 2007 been defined in cooperation with the partnership Megawind. The most recent strategy is Megawind's report The Danish Wind Power Hub from May 2013 (10). Also in May 2013, Megawind released a roadmap for Megawind's strategy for offshore wind R, D&D "Denmark–Supplier of Competitive Offshore Wind Solutions," (11). All the Megawind Strategies can be downloaded (7).

The Danish Wind Power Hub strategy (10): Megawind's vision for Denmark is to continue to develop its position as the hub of globally leading companies and research institutions within the field of wind energy and that these companies will be the first to deliver competitive wind energy on market terms in the dominating wind energy markets. To support the vision it is recommended to develop attractive innovation frameworks with a strong focus on long- and short-term R, D&D in the entire supply chain.

The Megawind report gives an overview of the current situation and provides seven key recommendations, including:

- A commonly agreed and accepted method for calculating and tracking the cost of energy from wind power
- A comprehensive strategy for increasing the ability of Danish research and educational institutions to contribute to maintaining Denmark as a global

Figure 3. Industry status (index 100 in 2006)

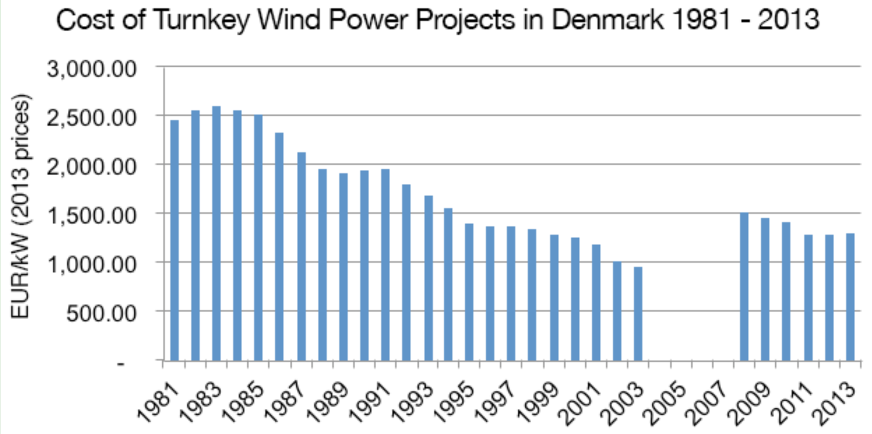

Figure 4. Development of cost of wind power projects 1981–2013 (2013 is estimated)

hub for the development of competitive wind power solutions

- A revised, comprehensive strategy for innovation, test, and demonstration facilities, including a benchmarking report containing a comparative analysis and mapping of available test and demonstration facilities globally
- A strategy for supply chain industrialization and modularization
- A report on potential technology-based solutions for reducing environmental and other local impacts of wind turbines
- A strategy for increasing the value of wind power in energy systems with high shares of wind energy
- A sustained, shared international approach from public authorities and private actors.

Roadmap for Offshore: The Megawind target for offshore wind energy is to drive down levelized cost of energy (LCOE) from offshore wind power plants and ensure that offshore wind energy becomes competitive with newly-built, coal-fired power by 2020. The LCOE in this roadmap should be understood as the societal cost of energy, i.e. the price society pays for one megawatt-hour coming from offshore wind power plants planned by developers in 2020.

Seven interrelated focus areas were selected in the report "Denmark–Supplier of Competitive Offshore Wind Solutions" (11), each of which holds potential for driving down the LCOE over the next seven years and bringing Danish competences to the forefront in offshore wind energy. The seven focus areas are as follows:

1. Planning, consenting, policy framework, and site selection
2. Wind power plants
3. Wind turbines
4. Foundations
5. Electrical infrastructure
6. Assembly and installation
7. Operation and maintenance

The focus area "planning, consenting, policy framework, and site selection" relates to all other areas, and determines the outer boundaries of what is possible to achieve in terms of cost of energy. The remaining focus areas are the same focus areas as the former Megawind offshore strategy and these areas are most important to ensure ambitious reductions of LCOE.

R, D&D in lowering construction and installation costs (CAPEX) includes four areas: wind turbines, foundations, electrical infrastructure, and assembly and installation. These areas are estimated to contribute significantly and equally to reducing life-time cost. Finally, with regard to the focus area of operation and maintenance, improvements in reliability and O&M strategies will reduce operational expenditure (OPEX) per megawatt-hour produced.

Statistics and information about supported Energy Research is published on the Web site (12). The latest annual report is "Energi13." In 2013, 14 projects (Table 2) received grants for a total of 131 million DKK (17.6 million EUR; 24.2 million USD). The total public research budget for the 14 projects is at nearly 198 million DKK. (26.5 million EUR; 36.6 million USD) (13), (14).

4.2 Test centers

The onshore and offshore test and demonstration facilities at Oesterild and the component test center LORC were described in more detail in earlier IEA Wind annual reports. Recent test center developments are described here.

DTU Wind Energy now has three wind turbine test sites in Denmark: Campus Risø, Roskilde; Høvsøre Test site for Large Wind Turbines, Lemvig; and Test Center Østerild, Thisted (15). At Høvsøre and Østerild, DTU Wind Energy has eight test stands. At the close of 2013, two test stands were available for rent at Test Centre Østerild. Vestas and Siemens also own four stands at Oesterild. There are five test stands at Høvsøre, where turbines up to 165-m blade tip height can be tested. Test Centre Østerild was established during 2012 and allows for wind turbines of up to 250-m tip height.

Several other test sites are in use. The old test site at Campus Risø is mainly used for specific research projects on components and for testing small wind turbines. DTU Wind also has a small component test center at Campus Risø. At the Lindoe Offshore Renewables Center, planning continues, and funding is now guarantied. There will be two test beds for nacelles of up to 10 MW (16).

4.3 Collaborative research

The Danish Energy Agency takes care of Danish energy policy interests through its international, multilateral, and bilateral cooperation on energy and environment policy and research.

The Danish Energy Agency seeks to promote Denmark's international position in the area of energy and to strengthen business and export opportunities for Danish energy technology and know-how. These activities take place in a number of different forums, including the EU, the European Energy Charter, the OECD, the IEA, the UN, the Nordic Council of Ministers, and IRENA, as well as with various bilateral cooperation partners including the Low Carbon Transition Unit's programs in México, South Africa, and Vietnam.

Under the IEA R&D Collaboration, Denmark participates in many areas including Wind. In 2013, Denmark participated in 11 out of 12 tasks under the IEA Wind agreement. Most Danish participants come from research institutions, but also the industry is playing an active role.

5.0 The Next Term

The next large offshore wind farms planned are Horns Rev III and Krieger's Flak, with a combined capacity of 1,000 MW (1). The planning of these projects was described in the *IEA Wind*

Table 2. Supported Wind Energy R&D Projects in 2013		
Title	Company	Million EUR (million USD)
Online WAsP for Small and Medium Size Wind Turbines	DTU Wind Energy Department Period: 1/2014–1/2016	Total budget: 1.40 (1.93) Grant: 0.70 (0.96)
Wind Load Simulator for Function and Durability Test of Wind Turbine Drivetrains	R&D Consulting Engineers Period: 12/2014–12/2016	Total budget: 1.50 (2.06) Grant: 1.04 (1.43)
IEA Wind Task 27 – Small Wind Turbines at Turbulent Sites	DTU Wind Energy Period: 4/2014–4/2016	Total budget: 0.13 (0.18) Grant: 0.10 (0.14)
ODIN-Wind-Decommission of Offshore Wind Turbines	NIRAS A/S Period: 9/2014–9/2016	Total budget: 1.56 (2.15) Grant: 0.90 (1.24)
Single Blade Installation in High Wind Speeds	LIFTRA ApS Period: 5/2013–5/2016	Total budget: 1.75 (2.41) Grant: 1.03 (1.42)
Stiffening of Wind Turbine Blades – Mitigating Leading Edge Damages	BLADENA ApS Period: 6/2013–6/2016	Total budget: 3.19 (4.40) Grant: 1.88 (2.59)
IEA Wind Task 33 – Reliability Data	DTU Wind Energy Period: 9/2013–9/2015	Total budget: 0.13 (0.18) Grant: 0.11 (0.15)
Integrated Solution for Maintenance and Repair of Wind Turbine Blades.	PP Techniq ApS Period: 10/2014–10/2014	Total budget: 0.80 (1.10) Grant: 0.36 (0.50)
Extreme Winds and Waves for Offshore Turbines	DTU Wind Energy Period: 2013	Total budget: 1.28 (1.76) Grant: 0.67 (0.92)
Management of Seabed and Wind Farm Interaction	DHI Period: 2013	Total budget: 2.01 (2.77) Grant: 0.74 (1.02)
ABYSS - Advancing BeYond Shallow waterS – Optimal Design of Offshore Wind Turbine Support Structures	DTU Wind Energy, Period: 2014–2017	Total budget: 3.69 (5.08) Grant: 2.9 (4.0)
Wind2050 – Multidisciplinary Study on Local Acceptance and Development of Wind Power Projects	DTU Management Engineering, Period: 2014–2017	Total budget: 3.16 (4.35) Grant: 2.67 (3.68)
UniTTe – Unified Testing Procedures for Wind Turbines Through Inflow Characterization Using Nacelle Lidars	DTU Wind Energy, Period: 2014–2017	Total budget: 2.60 (3.28) Grant: 1.85 (2.55)
HyDrive – Hydrostatic Drive Train Transmission for Renewable Energy Applications	Aaborg University Period: 2014–2019	Total budget: 3.32 (4.57) Grant: 2.57 (3.54)

2011 Annual Report. Pre-investigations and tendering procedure are on track for both wind farms. Locations are shown in Figure 6.

As mentioned above, the government's plans up to 2020 now include 500 MW (total) near-shore offshore wind farms (including 50 MW for test sites). In November 2012, the results of surveys and negotiations were announced. In addition to the offshore farms at Horns Rev III and Kriegers Flat, six areas close to the coast have been selected for wind farms each as shown in Figure 6. In each area, it is possible to install up to 200 MW. The six areas will be tendered in competition with each other. In contrast to the large-scale offshore wind farms, the constructor will pay for grid connection up to the coast. From the coast, costs will be paid by the electricity consumers, through their general charges.

Regarding large offshore wind farms, the Danish Energy Agency will conduct a negotiated tendering procedure with prequalification and technical dialogue. Because the near-shore wind farms will be visible from shore, local joint ownership of 20% of each project will be offered to local ownership. This is similar to the approach used on land in order to maintain local support. If 30% local ownership is achieved, there will be a further price

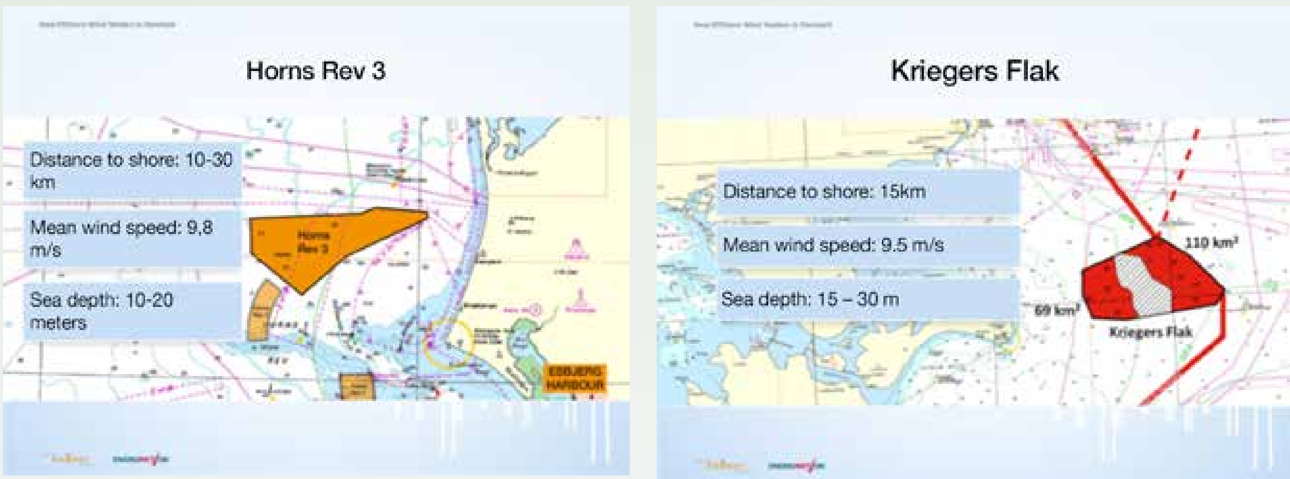

Figure 5. Selected areas for Horns Rev III and Krieger Flak

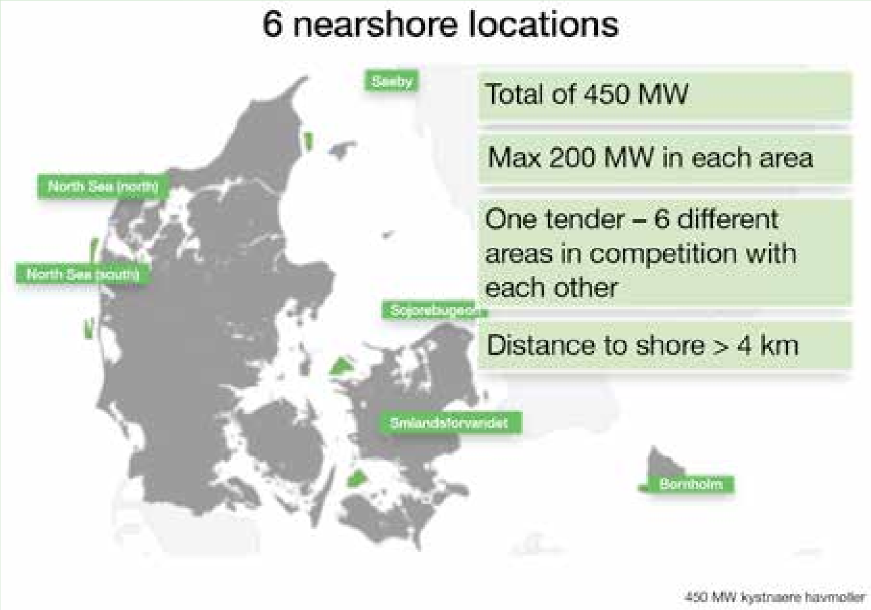

Figure 6. Area for new offshore farms up to 2020 (green: near-shore sites)

supplement of 0.13 EUR/kWh (0.18 USD/kWh) for the full subsidy period.

The government plan includes installation of new onshore wind turbines with a total capacity of 1,800 MW. It is expected that over the same period a capacity of 1,300 MW will be dismantled. Energinet.dk's website (6) provides information on current projects. Compiled at the end of 2013, and excluding test turbine projects, new onshore wind projects under way correspond to approximately 600 MW. It may take a long period of planning before these wind turbine projects can be started and the turbines connected to the grid. Some of these projects may not obtain final approval.

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Opening photo: Anholt Wind Farm. Credit: Wind Power Works/KeenPress

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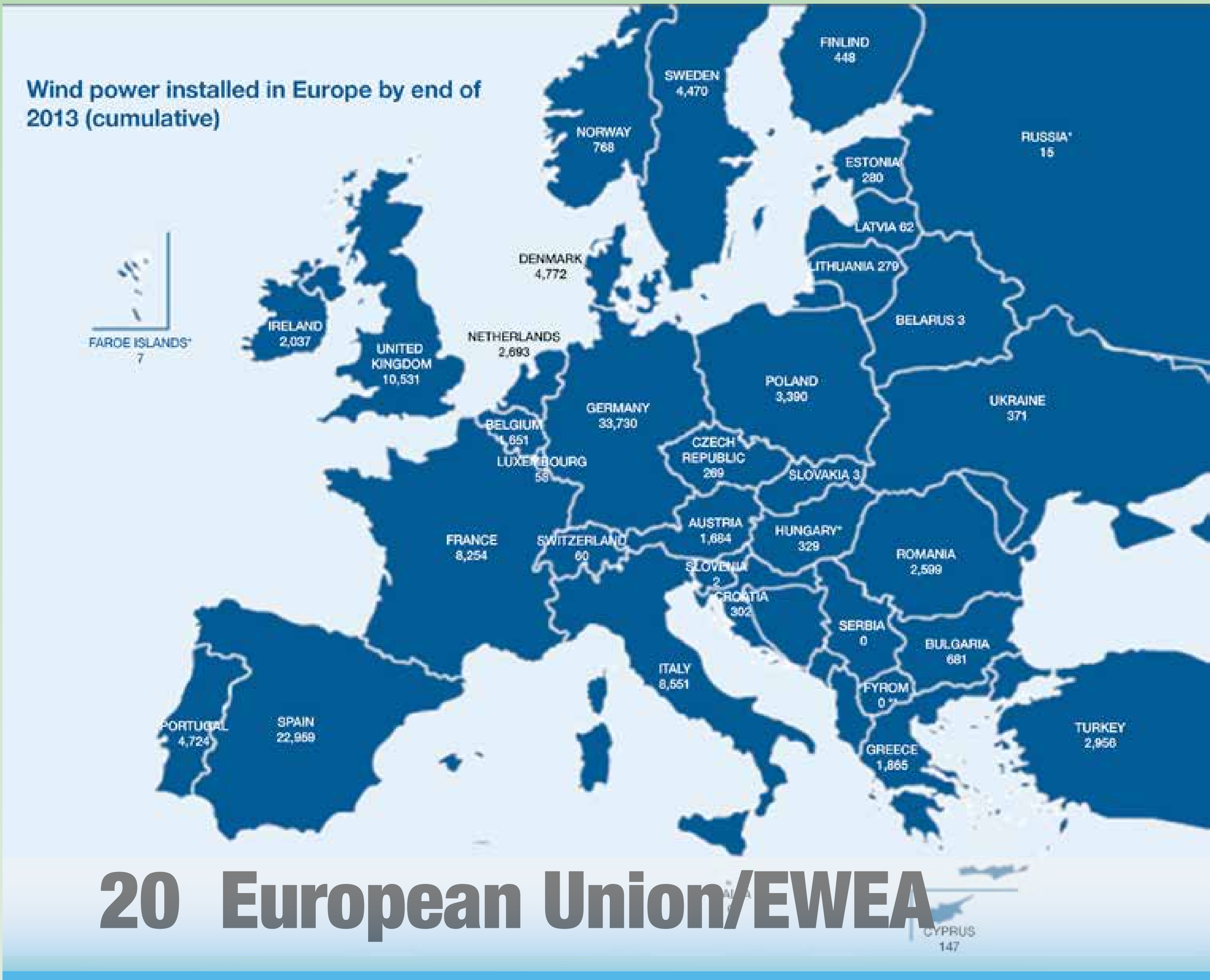

Figure 1. Wind power installations in Europe by end of 2013 (Source: EWEA)

1.0 Overview

In 2013, the European Union's (EU) total installed generation capacity increased by 35 GW, netting 385 GW of additional capacity since the year 2000. Wind power constituted 28.4% of the new capacity installed, 54.5% renewables, and 91.5% renewables and gas combined. The EU power sector therefore continues its move away from fuel oil, coal, and nuclear, with each technology continuing to decommission more than it installs. Wind power accounted for 32% of total 2013 power capacity installations helping renewable power installations to reach 72% of new installations during 2013: 25 GW of a total 35 GW of new power capacity, up 2% from 2012.

In 2013, 46% of all new wind installations were in just two countries: Germany and the United Kingdom (UK), a significant concentration compared to the trend of previous years, whereby installations were increasingly spread across healthy European markets. This level of concentration 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 healthy markets such as Spain, Italy, and France have seen their rate of wind energy installations decrease significantly in 2013, by 84%, 65%, and 24% respectively.

Nevertheless, 2013 was a record year for offshore wind energy installations, with 1,567 MW of new capacity grid-connected. Offshore wind power installations represented 14% of the annual EU wind energy market, up from 10% in 2012.

1.1 Overall capacity increases

During 2013, 12,030 MW of wind power was installed across Europe (Figure 1), of which 11,159 MW was in the EU-28. 9,592 MW onshore and 1,567 MW offshore, with a total estimated investment between 13 billion EUR to 18 billion EUR (18 billion

Table 1. Wind power installed in EU by end of 2012 and 2013 (cumulative, MW)				
EU Capacity (MW)				
	Installed 2012	End 2012	Installed 2013	End of 2013
Austria	296	1,377	308	1,684
Belgium	297	1,375	276	1,651
Bulgaria	158	674	7.1	681
Croatia	48	180	122	302
Cyprus	13	147	0	147
Czech Republic	44	260	9	269
Denmark	220	4,162	657	4,772
Estonia	86	269	11	280
Finland	89	288	162	448
France	814	7,623	631	8,254
Germany	2,297	30,989	3,238	33,730
Greece	117	1,749	116	1,865
Hungray	0	329	0	329
Ireland	121	1,749	288	2,037
Italy	1,273	8,118	444	8,551
Latvia	12	60	2	62
Lithuania	46	263	16	279
Luxembourg	14	58	0	58
Malta	0	0	0	0
Netherlands	119	2,391	303	2,693
Poland	880	2,496	894	3,390
Portugal	155	4,529	196	4,724
Romania	923	1,905	695	2,599
Slovakia	0	3	0	3
Slovenia	0	0	2	2
Spain	1,110	22,784	175	22,959
Sweden	846	3,582	724	4,470
United Kingdom	2,064	8,649	1,883	10,531
Total EU-28	**12,102**	**106,454**	**11,159**	**117,289**
Total EU-15	**9,879**	**99,868**	**9,402**	**108,946**
Total EU-13	**2,224**	**6,586**	**1,757**	**8,343**

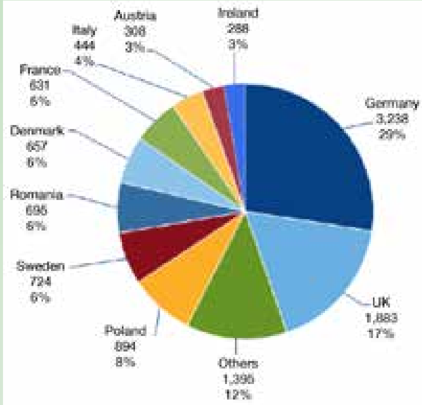

Figure 2. EU Member State market shares for new wind power capacity installed during 2013 (in MW; Total 11,159 MW) (Source: EWEA)

USD to 25 billion USD). In terms of annual installations, Germany was the largest market in 2013, installing 3,238 MW of new capacity, 240 MW of which (7%) was offshore. The UK came in second with 1,883 MW, 733 MW of which (39%) offshore, followed by Poland with 894 MW, Sweden (724 MW), Romania (695 MW), Denmark (657 MW), France (631 MW) and Italy (444 MW). The emerging markets of Central and Eastern Europe, including Croatia, installed 1,755 MW, which was 16% of total installations. In 2013, these countries represent a slightly smaller share of the total EU market than in 2012 (18%).

Wind power accounted for 32% (11.2 GW) of new EU electrical generation installations in 2013, followed by solar photovoltaic (PV) (31%, 11 GW), and gas (21%, 7.5 GW). No other technologies compare to wind, PV, and gas in terms of new installations. Coal installed 1.9 GW (5% of total installations), biomass 1.4 GW (4%), hydro 1.2 GW (4%), concentrating solar power (CSP) 419 MW (1%), fuel oil 220 MW, waste 180 MW, nuclear 120 MW, geothermal 10 MW, and ocean 1 MW (Figure 3.).

During 2013, 10.1 GW of gas capacity was decommissioned, as were 7.7 GW of coal and 2.7 GW of fuel oil (Figure 4.).

In 2000, new renewable power capacity installations totaled a mere 3.6 GW. Since 2010, annual renewable capacity additions have been between 24.7 GW and 35.2 GW—eight to ten times higher than in 2000.The share of renewables in total new power capacity additions has also grown. In 2000, the 3.6 GW represented 22.4% of new power capacity installations, increasing to 25 GW representing 72% in 2013. Since 2000, 385 GW of new power capacity has been

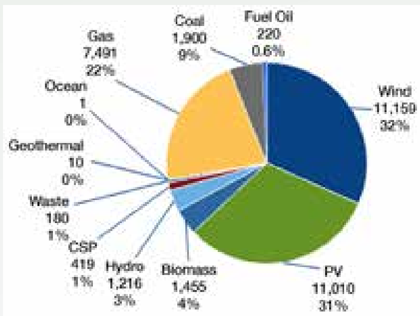

Figure 3. Share of new power capacity installations in the EU (Total 35,181 MW) (Source: Platts Powervision and EWEA)

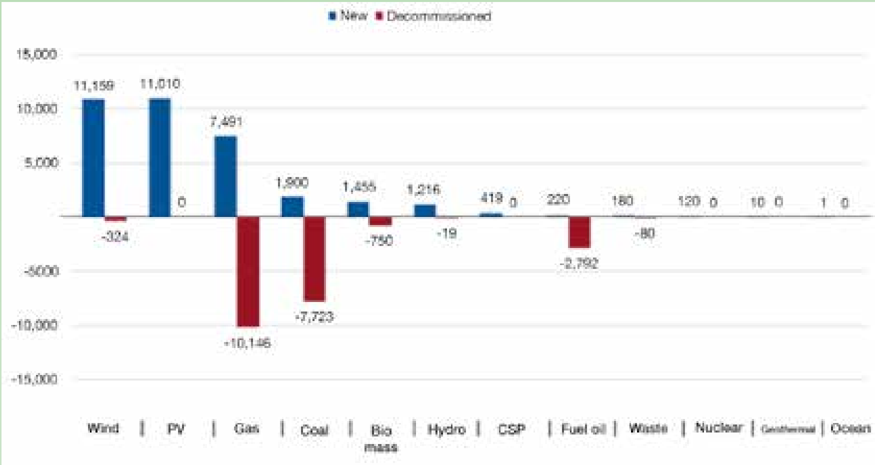

Figure 4. New installed power capacity and decommissioned power capacity in MW (Source: Platts Powervision and EWEA)

installed in the EU. Of this, over 28% has been wind power, 55% renewables, and 92% renewables and gas combined (Figure 5).

1.2 Offshore wind

Two thousand thirteen was a record year for offshore installations, with 1,567 MW of new capacity grid-connected. Offshore wind power installations represent 14% of the annual EU wind energy market, up from 10% in 2012. A total of 2,080 wind turbines are now installed and connected to the electricity grid in 69 offshore wind farms in 11 countries across Europe. Total installed capacity at the end of 2013 reached 6,562 MW, producing 24 TWh in a normal wind year, enough to cover 0.7% of the EU's total electricity consumption.

The UK has the largest amount of installed offshore wind capacity in Europe: 3,681 MW or 56% of all installations, followed by Denmark with 1,271 MW (19%), Belgium with 571 MW (7%) and Germany with 520 MW (8%). The Netherlands, Sweden, Finland and Ireland all together account for another 509 MW or almost 8%. (Figure 6).

Seven full-scale offshore wind farms were fully completed in 2013, together with three demonstration projects. Ten others plus one demonstration project were still under construction or only partially grid-connected. Once fully completed, the latter will connect to the grid a further 2,879 MW of capacity, taking total installed offshore wind capacity in Europe to 9,448 MW. With the completion of the wind farms that are currently under construction, approximately 3 GW of new capacity will come online in the coming years, which suggests that annual installations will remain stable in 2014 and 2015. Moreover, the European Wind Energy Association (EWEA) has identified 22 GW of consented offshore wind farms in Europe and future plans for offshore wind farms totaling more than 133 GW (Figure 7).

2.0 R, D&D Wind Energy Research in Europe

During 2013, the EU defined the main R,D&D funding tool for the period 2014–2020, Horizon 2020. Horizon 2020 is funded with nearly 80 billion EUR (110 billion USD) over seven years to help Europe produce world-class science, remove barriers to innovation, and make it easier for the public and private sectors to work together in delivering innovation. The main difference with the previous R, D&D funding

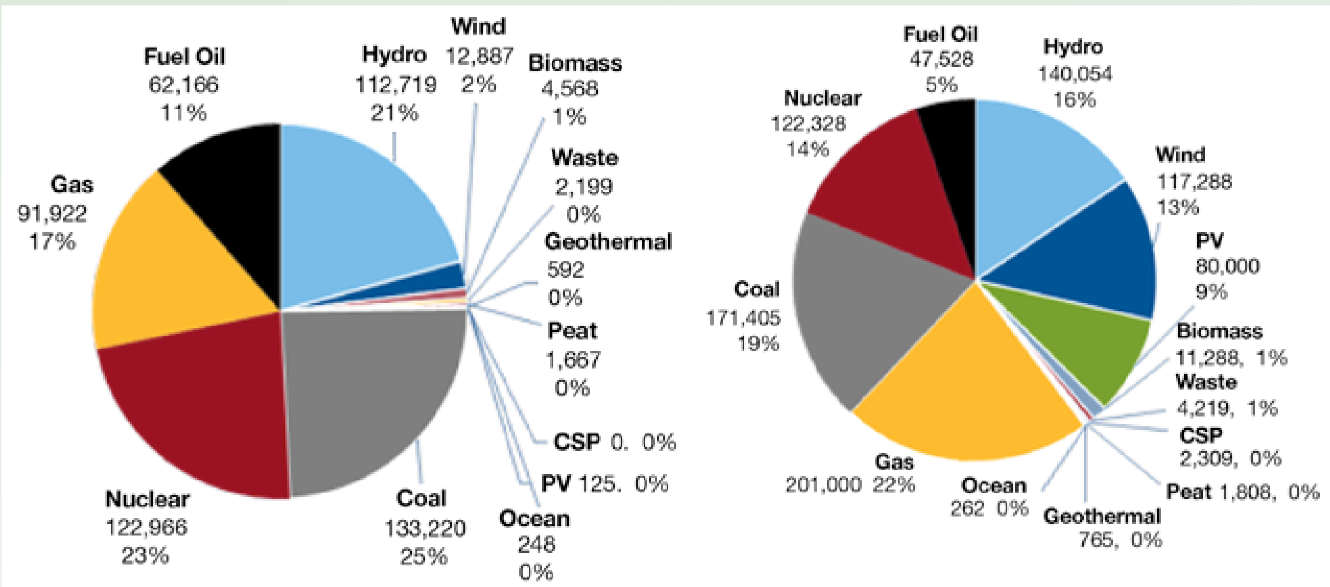

Figure 5. EU power mix in 2000 (on the left) and 2012 (on the right) (Source: Platts Powervision and EWEA)

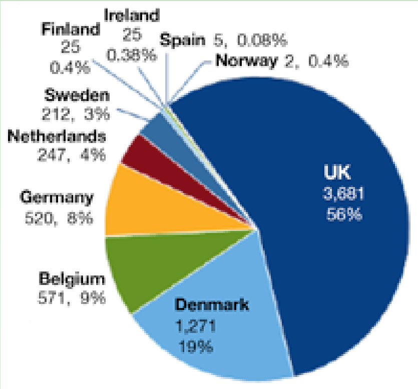

Figure 6. European countries' shares of cumulative offshore wind power capacity at end 2013 (Source: EWEA)

tool, the Framework Programme 7 (FP7) for Research and Innovation, is the addition of measures to complete and further develop the European Research Area. These measures will aim at breaking down barriers to create a genuine single market for knowledge, research and innovation.

In 2013, around 18 R&D projects were started with FP7 support acting on wind technologies or on materials and/or grid technologies directly related to wind energy. The following paragraphs summarize both the nature and objectives of the most important of these EU-supported projects started after January and managed by the European Commission (EC).

DeICE-UT aims at developing an innovative dual de-icing system combining both high-power ultrasonic guided waves and low-frequency vibrations to both prevent ice accumulation and remove already formed ice. This 1.38 million EUR (1.9 million USD) project, of which 1.08 million EUR (1.5 million USD) is the EC contribution, started on 1 August and will last for two years.

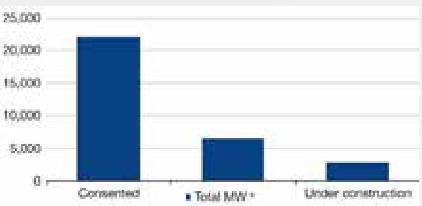

Figure 7. Offshore market: projects online, under construction and consented (MW) (Source: EWEA)

AVATAR aims at tackling the radical innovations needed for scaling up wind turbine designs towards 10–20 MW in the areas of aerodynamics. In particular, AVATAR will evaluate, validate, and improve aerodynamic and aero-elastic tools to ensure applicability for large wind turbines, thus demonstrating the capability of these models to produce valid load calculations at all modeling complexity levels. This 9.2 million EUR (12.7 million USD) project, of which 6.68 million EUR (9.21 million USD) is the EC contribution, started on 1 November and will last for four years.

HIPPOCAMP will develop a process to generate a light-weight, carbon-based nano-composite with both high static stiffness and high damping properties at a broad operating temperature and frequency range, applicable to blades. This materials-related 5.2 million EUR (7.2 million USD) project, of which 3.7 million EUR (5.1 million USD) is the EC contribution, started on 1 October and will last for three years.

IRPWIND is an integrated research program that combines strategic research projects and support activities, following the organizational structure and participation of the European Energy Research Alliance Joint Programme on Wind Energy. IRPWIND moves beyond the delivery of research projects and aims at integrating capacities and resources around the development of high-risk technologies, focusing on the medium- to long-term research. It includes two pilot funding schemes, one promoting the mobility of experienced researchers and another accommodating shared use of infrastructures to carry out experiments at multiple facilities all over Europe. This coordination is a 12.42 million EUR (17.11 million USD) project, of which 9.82 million EUR (13.53 million USD) is the EC contribution, started on 1 March 2014 and will last for four years.

LEANWIND attempts to apply lean principles, based on the ones originally developed by Toyota, to the critical project stages of offshore wind farm project development: logistical processes, shore-based transport links, port and staging facilities, vessels, lifting equipment, safety, and operation and maintenance (O&M) and decommissioning. LEANWIND assumes that properly applied, lean management will improve quality, reliability, and health and safety standards across the project supply chain and throughout the wind farm lifecycle. This FP7-Transport-funded, 14.90 million EUR (20.53 million USD) project of which 9.99 million EUR (13.76 million USD) is the EC contribution, started on 1 December 2013 and will last for four years.

SWIP aims at developing, implementing, and testing innovative solutions, components, and tools for tackling the current barriers to the integration of small wind turbines in urban and peripheral areas. In all, these technology improvements are expected to achieve: a nearly 40% reduction in maintenance costs, a 9% increase in small wind turbine performance, the mitigation and/or elimination of noise and vibrations, and a possible reduction in capital investment. This 6.54 million EUR (9.01 million USD) project, of which 4.90 million EUR (6.75 million USD) is the EC contribution, started on 1 October and will last for four years.

WINDTRUST has the objective to demonstrate the technical and economic feasibility of innovative and more reliable solutions for multi-MW wind turbines in order to improve the competitiveness of wind energy technologies. The selected components of the wind turbine are the rotor (specifically the blades), power electronics (specifically the converter), and control and communication system (specifically the controller system). The project will demonstrate the reliability of the proposed solution on an onshore 2-MW prototype turbine and will also extrapolate conclusions to larger wind turbines and off-shore locations. This 6.25 million EUR (8.61 million USD) project, of which 5.25 million EUR (7.23 million USD) is the EC contribution, started on 1 September and will last for three years.

OPTIMUS aims at making more cost-effective the turbine condition monitoring systems (CMS) by developing and demonstrating novel methods and tools for prognosis of the remaining lifetime of key components. The project is based in the idea that state-of-the-art CMS, such as vibration-based systems and temperature sensors, are able to monitor and evaluate the current condition of components of interest, but varying wind loads can result in the generation of false alarms or even misinterpretation of the data collected. The project also assumes that commercially available CMS offer no or very limited prognostics capability with regards to the remaining lifetime of a component before a serious fault occurs, and that for this reason the evolution to predictive maintenance strategies is currently impossible. This 5.65 million EUR (7.79 million USD) project, of which 3.34 million EUR (4.60 million USD) is the EC contribution, started on 1 August and will last for three years.

MEDOW explores a direct current (DC) grid based on multi-terminal voltage-source converter, particularly suitable for the connection of offshore wind farms or a future European offshore SuperGrid. MEDOW will study DC power flow, DC relaying protection, steady state operation, dynamic stability, fault-ride through capability, and impacts of DC grids on the operation of AC grids and power markets. This grid-related 3.93 million EUR (5.42 million USD) project, fully-funded by the EC, started on 1 April and will last for four years.

SANAD is a project that aims at developing new materials for the transportation sector that could be applied to improve wind turbine behavior towards turbulent drag and icing. It will focus on super-hydrophobic nanostructured top coatings, which do not only exhibit improved aerodynamic efficiency but at the same time they prevent icing on the surface applied. This transport-related 2.87 million EUR (3.95 million USD) project, fully-funded by the EC, started on 1 January and will last for four years.

From the end of 2013, no new projects will be funded by the Intelligent Energy Europe (IEE) Programme (2007–2013). Instead such "market uptake" activities will be funded under the new Horizon 2020 Programme's "Societal Challenge" on 'Secure, clean and efficient energy.'

Two new IEE projects, which address the future development of wind energy markets, were selected in 2013, namely Market4RES and Towards2030Dialogue. The Market4RES project focuses on electricity market design to support a more efficient integration of renewable electricity into the pan-European electricity system. The Towards2030Dialogue project aims to facilitate and guide the renewable energy source (RES) policy dialogue for the period towards 2030. The integration of wind energy into the grid is a key component in both of these projects.

A new IEE Concerted Action was also launched in 2013. This type of project facilitates a structured and confidential dialogue between government officials who are responsible for implementing the (2009) Renewable Energy Directive in the 28 EU member states. By sharing experiences on support schemes, cooperation mechanisms, and grid network management issues, the member state officials involved develop a broader understanding of wind energy policies and markets, which can help them to deliver the binding national targets that were set in the directive.

2.1 Plans and initiatives

The Strategic Energy Technology Plan (SET-Plan) and its tool the European Wind Initiative are increasingly shaping EU and Member State wind R&D programs. A new three-year implementation plan was launched in the spring covering the 2013-2015 period. The European Wind Initiative, which has a budget of 6 billion EUR (8.3 billion USD) (public and private resources) for the 2010–2020 period, integrates the following elements:

- Reinventing wind turbines through innovative design, integration of new materials, and development of advanced structures with particular emphasis on offshore wind applications that are far from shore and water depth independent
- Putting an automated wind manufacturing capacity in place
- Reducing the cost and enabling large wind energy integration into the grid by adapting the network and its operation to a progressive but fast up-take of wind power on land and offshore
- Accelerating market deployment through a deep knowledge of wind resources and a high predictability of wind forecasts.

3.0 The European Wind Energy Technology Platform

The European Wind Energy Technology Platform (TPWind) was officially launched in 2006, with the full support of the European Commission. TPWind is an industry-led initiative, composed of approximately 200 high-level experts representing the whole wind energy sector. The platform's objectives are to identify and prioritize areas for increased innovation, new and existing research, and development tasks. Moreover, TPWind formulates relevant funding recommendations to EU and national public authorities in order to support wind power R&D.

TPWind focuses not only on short to long-term technological R&D but also on market deployment. This is reflected in the TPWind structure, which is composed of four technical working groups and one focusing on policy and non-technological issues. TPWind also collaborates with an Advisory Board composed of external stakeholders that acts as a quick access point to the expertise and know-how developed by other sectors, essential to reduce fragmentation of R&D activities. The Platform is led by a Steering Committee of 25 Members, representing both the industry and the R&D community.

The Secretariat is hosted by EWEA, with the support of GL Garrad Hassan and DTU Wind (Technical University of Denmark).

3.1 Achievements

The main deliverables of the Platform so far are the following:

- The Strategic Research Agenda/ Market Deployment Strategy (SRA/ MDS), which outlines the main R&D challenges faced by the EU wind energy sector (published in March 2014);
- The European Wind Initiative (EWI), a long-term, large-scale program for improving and increasing funding to EU wind energy R&D. The EWI, which is rooted in the EU Strategic Energy Technology Plan (SET-Plan), was published by the European Commission in 2009 and is now being implemented by EU institutions, Member States, TPWind, and the European Energy Research Alliance (EERA, a network of major EU R&D Institutes);
- A Training Report, looking at the skills' gap in the EU wind energy sector and potential corrective actions. The report was launched in September 2013.

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21 Finland

1.0 Overview

Finland has a 14-GW winter peaking power system with 84 TWh of demand in 2013. There is already a considerable share of renewables in the electricity mix; 29% of electricity consumption was provided by renewables in 2013: 15% by hydro power, 13% by biomass, and 1% by wind power.

Wind power is the second largest source of new renewables in Finland, with a target of 6 TWh/yr in 2020. The new energy strategy has a target of 9 TWh/yr for 2025. A market based feed-in system with a guaranteed price of 83.50 EUR/MWh (115.06 USD/MWh) entered into force in 2011. There is an increased tariff of 105.30 EUR/MWh (145.10 USD/MWh) through the end of 2015. The difference between the guaranteed price and spot price of electricity will be paid to the producers as a premium.

Wind energy deployment has started after the new tariff system. In 2013, 192 MW were installed, reaching a total of 448 MW at the end of 2013. Wind produced about 0.8 TWh—almost 1% of gross demand in Finland. At the beginning of 2013, there were 8,000 MW of wind power projects in various phases of planning on land, and 3,000 MW of announced projects offshore.

Wind power technology in Finland employs more than 3,000 persons mainly in component and sub-system manufacturing (ABB, Hydroll, Moventas, and The Switch), sensors (Labkotec and Vaisala) and material production (Ahlstrom and Ruukki). Project development activities are increasing, and also innovative O&M methods have been developed (Bladefence).

2.0 National Objectives and Progress

2.1 National targets

The target for wind power in the climate and energy strategy set in 2008 is 6 TWh/yr (2,500 MW) for year 2020, corresponding to 6–7% of the total electricity consumption in Finland. The target for renewable energy sources (RES) in Finland is 38% of final energy consumption by RES (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.

Finland's generating capacity is diverse: 28% of gross demand was produced from combined heat and power (coal, gas, biomass, and peat), 27% by nuclear, 19% from imports, 15% by hydropower, and 10% from direct power production from mainly coal and gas. The new energy strategy published at the beginning of 2013 has an increased target for wind power of 9 TWh/yr in 2025.

2.2 Progress

An increasing building phase of wind power has started in Finland, despite delays in building permits for wind power plants. New capacity installed was 192 MW in 2013 compared to 57 MW installed in 2012. In 2014, close to 200 MW of new capacity are anticipated. The development in wind power capacity and production is presented in Figure 1. The wind energy index is calculated from Finnish Meteorological Institute (FMI) wind-speed measurements and converted to wind power production. The average wind production from 1997-2011 is 100%.

In 2013, there were 60 turbines (192 MW) installed in eight wind farms and two single turbine sites. The new wind farms are located either near coastline or on land, usually on forested areas at higher elevations. The new wind farms have 3–12 turbines each with total capacity ranging from 9–54 MW and turbines ranging from 2.3–4.5 MW:

- six 2.3-MW turbines in Merijärvi
- ten 3-MW turbines in Tervola
- nine 2.4-MW turbines in Honkajoki
- seven 3-MW turbines in Lappeenranta
- seven 3-MW turbines in Raahe
- four 4.5-MW turbines in Simo
- three 3-MW turbines in Ii
- twelve 4.5-MW turbines in Pori
- two single turbines were built: 2.6 MW in Teuva and 280 kW in Ilmajoki.

Two turbines were removed in 2013: one of the Oulunsalo turbines (1.3 MW installed in 1999) and one of the Kotka turbines (1 MW installed in 1999; the site will be re-powered in 2014). The net increase was 190 MW bringing the total capacity at the end of 2013 to 448 MW and 210 wind turbines (Figure 2). Almost all turbines (447 MW, 209 turbines) are in the VTT statistics. The average wind turbine size installed in 2013 was 3.2 MW and for the total installed capacity the average was 2.1 MW. About 17% of the capacity is from turbines originating from Finland, 45% from Denmark, 16% from Spain, 7% from Germany, 2% from South Korea, and 2% from the Netherlands (Figure

High towers and larger rotors provide higher capacity factors in forested landscape than before: up from 20-25% to above 30%.

Table 1. Key National Statistics 2013: Finland	
Total installed wind capacity	448 MW
New wind capacity installed*	192 MW
Total electrical output from wind	0.77 TWh
Wind generation as a % of national electric demand	0.9%
Average capacity factor	26%
Target:	6 TWh/yr (2,500 MW) in 2020, 9 TWh/yr in 2025
*Net increase was 190 MW because 2 MW were removed.	

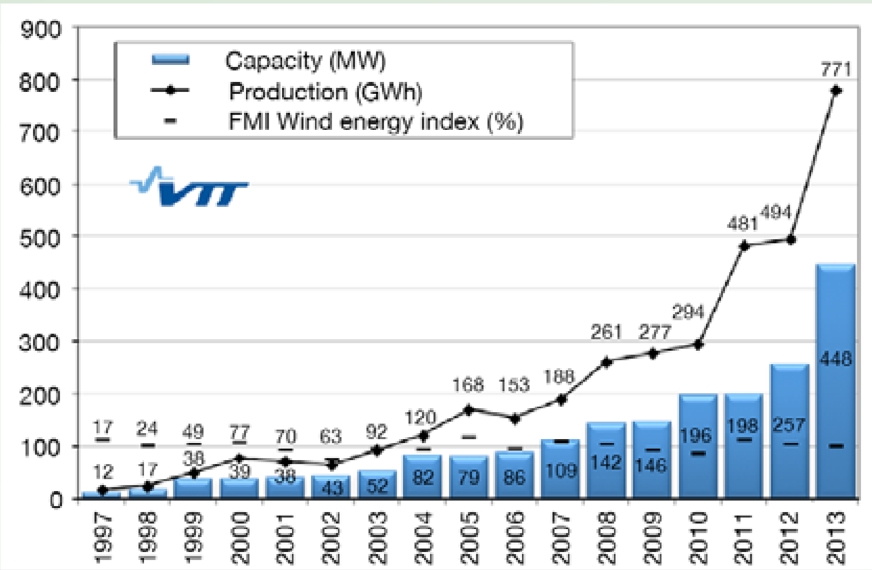

Figure 1. Wind power capacity and production: FMI Wind energy index is calculated from Finnish Meteorological Institute (FMI) wind-speed measurements and converted to wind power production; 100% is average production from 1997–2011.

3). The size of the installed capacity ranges from 75 kW to 4.5 MW.

Production from wind power increased by 56% to 771 GWh in 2013. This corresponds to 0.9% of the annual gross electricity consumption of Finland (Table 1). In December 2013, wind power's share was 1.7% of consumption. The environmental benefit of wind power production in Finland is about 0.5 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).

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 2013 with 22 MW of installed capacity. The region is not included in the price guarantee mechanism. Åland is planning to set up its own 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. Earlier, an investment subsidy scheme with a tax refund of 6.9 EUR/MWh (9.5 USD/MWh) was available. The small tax award subsidy (for older projects) was stopped in 2011.

A guaranteed price of 83.50 EUR/MWh (115.06 USD/MWh) 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 105.30 EUR/MWh (145.10 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. And if the price is 0, the producers will not get payments. This is to enable wind power plants to help the power system in cases of surplus power production. These situations have so far been only happening in Denmark with larger wind shares than those that are planned for Finland. Wind power producers will also be responsible for paying the imbalance fees from their forecast errors. This has been

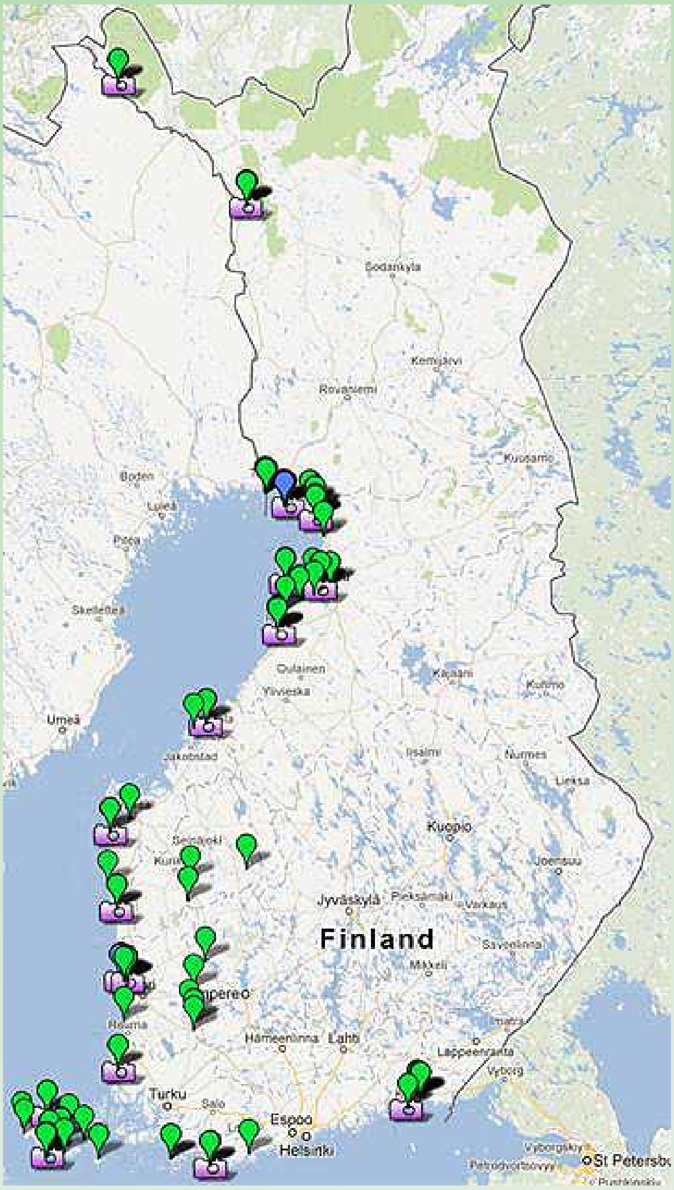

Figure 2. Wind power plant sites for turbines operating in Finland at the end of 2013

estimated to add 2–3 EUR/MWh (2.75–4.13 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 electricity taxes. The regulator Energy Authority is managing the system. In 2013, the total amount paid as subsidy was still moderate, less than 33.0 million EUR (45.5 million USD), because so far there are not many projects operating under the scheme.

There is no special subsidy for offshore wind power. A tender for an offshore demonstration wind power plant was made in autumn 2013 for a 20 million EUR (27.6 million USD) demonstration subsidy. Six companies with nine projects applied for the demonstration. The site and developer chosen will be published at the end of 2014.

2.4 Issues affecting growth

The target of 6 TWh/yr for 2020 (2,500 MW) and the guaranteed price system led to a rush for the best sites during the last couple of years. In September 2013, there were 236 wind power projects totaling 8,000 MW in various phases of planning on land, and 17 announced projects offshore totaling 3,000 MW. There is a huge offshore potential in Finland with shallow waters, but the guaranteed price is not sufficient to start offshore projects.

To overcome planning and permitting problems, a list of actions was proposed by Lauri Tarasti's report in 2012. After that report, the Ministry of Economy and Employment coordinated a committee of several ministries that produced their final report in December, 2013. The main barriers and actions taken are as follows.

Impact on radar systems

Radar influence became an issue in 2010 stopping all building permits for a while. A procedure and modelling tool was developed in 2011 to help the Ministry of Defence to estimate the impacts, and 89% of sites have received a positive decision.

A working group investigated necessary changes to radars for two regions. A compensation scheme for the Northern coast (Raahe region) includes investing in new radar technology: 15 million EUR (20 million USD) for a new radar system. With operating costs the total is 18.5 million EUR (25.5 million USD). The costs will be collected from the developers that are planning a total of about 250 turbines in the region. The estimated compensation cost is 50,000 EUR (68,900 USD) per turbine. Forty turbines in the region were not causing radar interference and were freed from the compensation scheme. A law approved in 2013 includes the first wind power development area near Raahe (two 425-km^2 areas in Hailuoto, Lumijoki, Pyhäjoki, Raahe, and Siikajoki). A similar solution for South-East Finland was not found feasible. For six separate areas in the Kotka/Hamina region where total of 69 turbines are planned, the investment cost for radars was 32.5 million EUR (44.8 million USD) and the costs to the wind power producers would have been closer to 500,000 EUR (689,000 USD) per turbine.

Noise

Noise is seen as one of the most critical issues in many sites, especially low-frequency noise that is more penetrating and disturbing than other noise emissions from wind turbines. Finland has a large number of summer cottages (about 500,000), and projects are often built in areas with low background noise.

Two sites have had noise issues. At one site, two gearboxes were changed at a wind power plant with Hyundai turbines in Hamina that had been operating only during the daytime due to excessive noise. A measurement campaign was made to see that the noise limits are not exceeded. At the other site in Raahe, extra measurements have been conducted from one wind power plant to investigate possible disturbance due to low frequency noise.

Recommendations by the Ministry of Environment published in 2012 used lower noise limits than the building law (by 5–10 dB). This low level is challenging at many sites, especially the night-time limit of 35 dB near summer cottages. A report on modeling and measurement guidelines was published in 2013. If there is the possibility for especially disturbing noise emission, a 5-dB increase to modeled values can be made. A governmental decree on noise limits is currently in preparation.

Limitations from roads/ railways and aviation

The Ministry of Traffic and Communication has acted to relieve limitations. Flight barrier limitations are now only 15 km lengthwise from the runway and 6 km breadthwise (previously the limitations were: 30 km lengthwise and 12 km breadthwise). In some areas the height of the turbines is limited. The required distance between wind turbines and roads has been reduced from 500–300 m. The Ministry of Traffic and Communication has relieved the rules for flight obstruction lights at nacelles of turbines enabling fewer disturbances to local inhabitants.

Planning and permitting process

The planning process with environmental impact assessment is considered lengthy by developers. There were 40 projects applying for a shorter process that is possible for smaller projects (less than 10 turbines or less than 30 MW).

The land use and building law was changed in 2013 to enable easier permitting to industrial sites.

There is an on-going practice by the authorities in all regional plan updates to add sites for wind power plants. This will help in permitting future wind power projects. However, in 2013 two decisions by local communities declined a building permit for sites marked for wind in regional plans. This shows that the planning even for these sites can be risky.

Public acceptance

A survey of attitudes toward wind power, both for local authorities and for ordinary people, was made in 2013. Of holiday residents, 57% were content with the wind power project in the commune and 16% did not like it. Of permanent residents, these shares were 73% and 10% respectively. Eighty three percent of both local authorities and ordinary people are positive or very positive towards wind power. Ninety percent of citizens and 87% of local authorities support increasing wind power.

The Finnish wind power association created recommendations to compensate land owners neighboring wind power plants. However, not all developers follow these recommendations.

In addition, TV signal interference has been reported from some sites. This has been solved by a new transmitter, invested in by project developers.

3.0 Implementation

3.1 Economic impact

Direct and indirect employment by development, operation, and maintenance is increasing. The technology sector is strong. More than 20 technology and manufacturing companies are involved in wind power in Finland, employing more than 3,000 people. 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.

In 2009, it was estimated that maintaining current market share in global wind power markets could increase employment in the wind power sector in Finland to 14,000 person-years in 2020. However, the financing crisis together with delayed ramp up of the domestic market has affected several Finnish companies. Attempts to initiate a national R&D program have also failed. The deployment of the targeted 2,500 MW of wind power is estimated to create employment of at least 12,000 person-years.

3.2 Industry status

3.2.1 Manufacturing

The Finnish turbine manufacturer WinWinD had been operating in the wind markets since 2001 with their 1- and 3-MW machines. Efforts to restructure their debt in 2013 failed and the company filed for bankruptcy. By the end of 2013, WinWinD had installed 314 MW of generating capacity in seven countries including Estonia, Finland, France, Portugal, and Sweden. Negotiations with potential buyers are on-going.

A new turbine manufacturer, Mervento, erected its first 3.6-MW direct-drive pilot turbine in 2012, especially designed for offshore applications. Mervento is currently seeking capital funding for an assembly line in Vaasa.

Several industrial enterprises have developed important businesses as world suppliers of major components for wind turbines (Figure 4). For example, Moventas Wind (acquired by David Brown gearbox business in 2013) is the largest

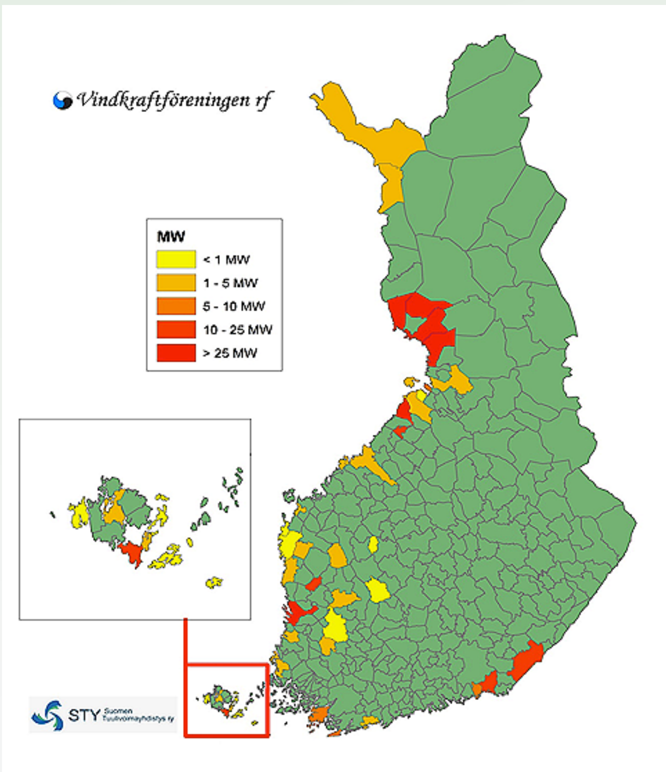

Figure 3. Wind power regional distribution by communes (Source: Finnish wind power associates STY/VKF)

independent manufacturer of gears and mechanical drives for wind turbines. ABB is a leading producer of generators and electrical drives for wind turbines. The Switch company 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 (Rautaruukki), and glassfiber products (Ahlstrom Glasfiber) are produced in Finland for the main wind turbine manufacturers. Sensors especially for icing conditions are manufactured by Labkotec and Vaisala. Bladefence offers inspection, repair, and maintenance of wind turbine blades also in harsh environments. STX Finland has developed foundation solutions for ice infested waters. Peikko has developed foundation technologies based on modular components.

3.2.2 Ownership and applications

Many newcomers have entered the 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.

New projects are seen in 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 26–35%. 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.

The first semi-offshore projects were built in 2007. Total capacity offshore is 24 MW. A mid-size demonstration is foreseen in 2015 with an extra investment subsidy of 20 million EUR (28 million USD). 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 assessment.

3.3 Operational details

The average capacity factor from wind turbines operating the whole year (149 turbines) was 26% (calculated as total generation 575 GWh divided by total capacity 255 MW and total hours 8,760 h). Average capacity factor of the 140 individual turbines that were producing was 22% in 2013, because there are still many small turbines included. There were 20 older turbines that generated at less than 10% capacity factor in 2013 (9 had 0% capacity factor). 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 31% for the 33 turbines with hub height 100 m or more, and there were total 38 turbines that reached a capacity factor of more than 30% (maximum capacity factor 48%). The total average capacity factor has ranged from 17% to 28% in previous years.

The wind resource in 2013 was good, and the wind power production index ranged from 91% to 110% in different coastal areas in Finland (turbine capacity weighted average 100%). The average technical availability of wind turbines operating in Finland has ranged from 84% to 96% in 2001 to 2012. Not all turbines report availability.

3.4 Wind energy costs

The feed-in tariff working group in 2009 estimated the cost of wind energy production for coastal sites in Finland to range between 60 to 80 EUR/MWh (82.7 to 110.2 USD/MWh) without subsidies. This calculation assumed yearly average production at 2,100 to 2,400 h/a full load hours; investment cost of 1,300 to 1,400 EUR/kW (1,791 to 1,929 USD/kW); project life of 20 years with 7% internal rate of return; and O&M cost of 26–28 EUR/kW/yr (36–38 USD/kW/yr). A balancing cost of 2 EUR/MWh (2.8 USD/MWh) was assumed—the balancing cost has been estimated to range between 2–3 EUR/MWh (2.75–4.13 USD/MWh) for a single site and 1.0–1.5 EUR/MWh (1.4–2.1 USD/MWh) for distributed sites in Finland, depending on balancing cost level from the electricity market. The estimated cost of offshore production could exceed 100 EUR/MWh (138 USD/MWh).

All wind energy installations in Finland 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 in 2013 was 41 EUR/MWh (56 USD/MWh); in 2012 it was 37 EUR/MWh (51 USD/MWh). Wind power still needs subsidies to compete even on the best available sites in Finland. The new guaranteed price, feed-in premium for wind energy fits the Nordic electricity markets, because the producers will sell their energy in the market or by bilateral contracts, and account for the balancing costs for their production.

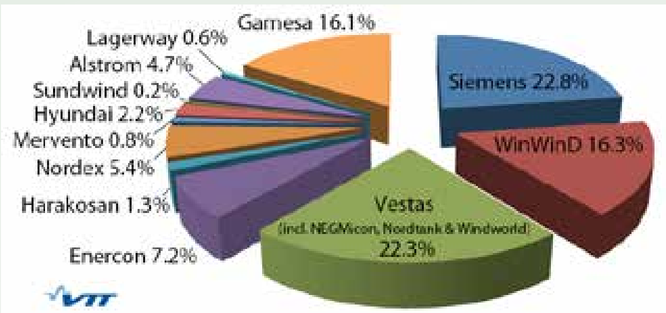

Figure 4. Market shares of turbine manufacturers in Finland as a percentage of total capacity at the end of 2013 (447 MW)

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 200 million EUR (276 million USD) in energy related R&D projects in 2013. Tekes funding for wind power in the last seven years is presented in Figure 5. Tekes granted 3.5 million EUR (4.8 million USD) in wind power R&D projects in 2013. Since 1999, Finland has 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 13 ongoing wind power connected R&D projects funded by Tekes in January 2014, most of them industrial development projects. The main developed

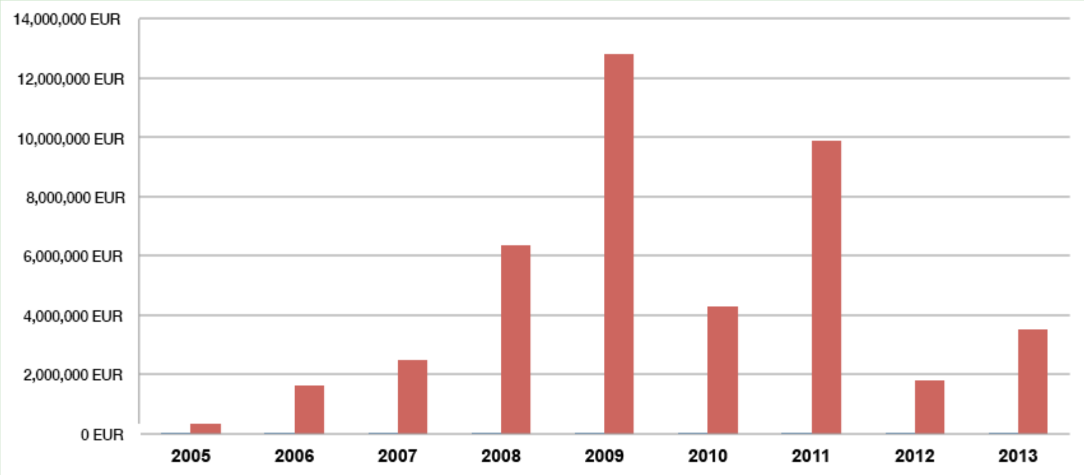

Figure 5. Tekes funding for wind power R&D projects in the last nine years

technologies were power electronics, generators, permanent-magnet technologies, gearboxes, wind turbines (large and small ones), sensors, blade manufacturing, foundry technologies, construction technologies, automation solutions, and 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 integration. VTT participates in two Nordic Energy Research projects: Offshore DC Grid and IceWind. VTT is a founding member of the European Energy Research Alliance (EERA) and participates actively in the joint programs in wind energy and smart grids.

In 2013, Finland took part in the following IEA Wind research tasks:

- Task 11 Base Technology Information Exchange (VTT)
- Task 19 Wind Energy in Cold Climates (Operating Agent, VTT)
- Task 25 Power Systems with Large Amounts of Wind Power (Operating Agent, VTT)
- Task 30 Offshore Code Comparison Collaboration Continuation OC4 (VTT)
- Task 33 Reliability data (VTT and ABB)

5.0 The Next Term

An increasing amount of installations are expected in 2014 for Finland, as developers try their best to take advantage of the higher guarantee price period that expires at the end of 2015. Approximately 200 MW of new capacity is anticipated for 2014 and more than 200 MW for 2015. An offshore demonstration site and developer will be chosen at the end of 2014. A huge number of projects are planned, under feasibility studies, or have just been proposed: 8,000 MW on land and 3,000 MW offshore.

In 2014, the wind power group of Technology Industries in Finland will update its roadmap to explore opportunities in the growing home market, global offshore market, and emerging cold climate market.

The blade heating system developed in Finland is now in commercialization, a spin-off from VTT (Wicetec) will start operations in 2014. Further research and development in this area of wind energy in cold climate will continue.

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Opening photo: Tuulimuukko wind power plant in Lappeenranta, East Finland (Credit: TuuliMuukko)

Further reading: The statistics of wind power in Finland (in English) can be found at www.vtt.fi/windenergystatistics

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22 Germany

1.0 Overview

Wind energy continues to be the most important renewable energy source in Germany, as it plays a key role within the German energy transition, the so called "Energiewende" (10). Within the German federal government, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) was in charge of renewable energy policy as well as of the funding of research for renewable energies in 2013. After the election for the German parliament (Bundestag), responsibility shifted to the Federal Ministry for Economic Affairs and Energy (BMWi) since March 2014.

The share of renewable energy sources in Germany's gross electricity consumption rose significantly in 2013 to reach 25.4%, with an amount of 152.6 billion kWh. This represents a continuing increase of two and a half percentage points compared to the previous year (with 22.9%). Wind energy provided a share of 35% of all renewable energy sources in 2013. Thus, as shown in Figure 1, the electricity generation from wind energy increased too, amounting to 53.4 TWh (compared to 50.7 TWh in 2012) (3).

The rather weak wind resource year was partially compensated for by installations of larger turbines and above-average rotor diameters for wind energy generators on land (Figure 2). Furthermore, an immense added installation regarding offshore wind farms took place. The combination of these aspects led to an estimated capacity factor that is just slightly below the long-term average.

As shown in Figure 3, construction of new turbines added 2,998.4 MW on land and 520.3 MW offshore, a clear increase over the previous year (2012: 2,440 MW on land and 280 MW offshore) (3) (8). In this context, it is important to know that only grid-connected offshore turbines are counted for the capacity statistics. At the end of 2013, 394.6 MW of offshore wind capacity was not yet connected to the grid (3).

Consequently, at the end of the year total installed wind capacity in Germany was nearly 34,660 MW on land and 903 MW offshore, with 23,864 wind turbines built in total (1), (2), and (3). Repowering measures accounted for an estimated 766 MW, while installations with a capacity of an estimated 258 MW were decommissioned, giving a net added capacity in 2013 of 3.356 MW on land and offshore (3).

With a share of 8.9% of total electric generation in Germany (2012: 7.7%), wind energy maintained a strong position as the main source of renewable electricity. The use of wind energy avoided 41.7 million tons equivalent of carbon dioxide emissions in 2013 (3).

Concerning R&D activities within the ongoing German 6th Energy Research Program from 2011, the BMUB provided 37.3 million EUR (51.4 million USD) of funds for new research projects in 2013 (Figure 8).

2.0 National Objectives and Progress

2.1 National targets

In September 2010, the German federal government decided on a new energy concept or plan. The scenarios upon which this energy concept was based showed that in 2050 wind energy will play a key role in electricity generation. Thus, the energy concept emphasized the expansion of land-based and offshore wind energy and explicitly formulated the target of 25 GW of offshore wind power installed by 2030. More general policy objectives are to increase the share of renewables in gross electricity consumption to 50% by 2030, 65% by 2040, and up to 80% by 2050 (11).

The use of wind energy in Germany has avoided 41.7 million tons of carbon dioxide equivalents for greenhouse gas emissions in 2013.

Table 1. Key National Statistics 2013: Germany (3) (4) (8)	
Total installed wind capacity	34,660 MW
New wind capacity installed*	3,356 MW
Total electrical output from wind	53.4 TWh
Wind generation as % of national electric demand	8.9%
Average national capacity factor	18.5%
Target:	35% share of electricity generation from renewables by 2020 and 80% by 2050 estimated 6.5 GW of offshore wind energy by 2020 and 15 GW by 2030
* Net increase	

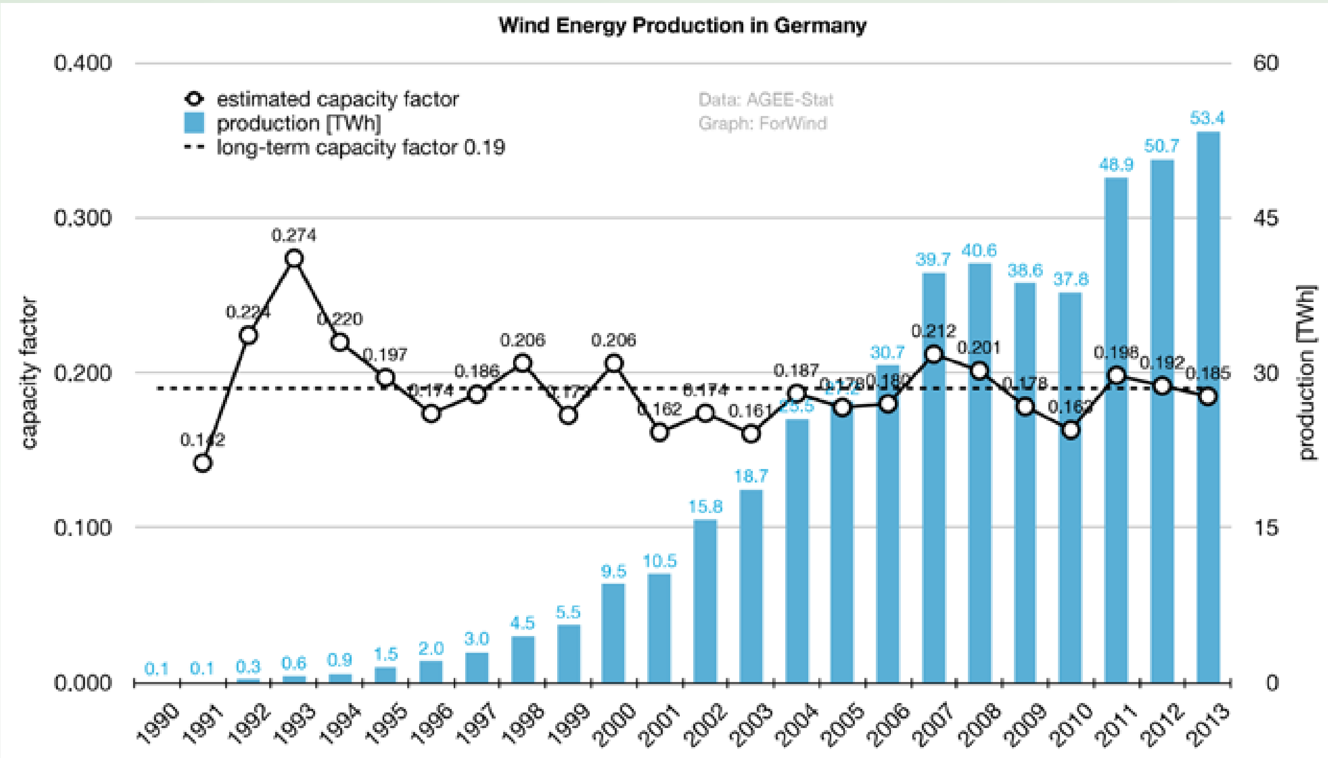

Figure 1. Wind energy production and capacity factor in Germany

However, due to the newly established German federal government in late 2013, a revision of the national targets within the Renewable Energy Sources Act (EEG) will probably take place in 2014. This could result in an adjustment of the national targets as well (12).

2.2 Progress

Wind power capacity development in Germany is shown in Figure 3. The main difference of 2013 from the previous year is the considerable growth in added capacity, especially offshore. The annual contribution to national electrical demand is shown in Figure 1, as well as the development of the capacity factor.

Regarding the environmentally compatible development of offshore wind energy, which plays an important role in Germany, the "StUKplus conference" by the Federal Maritime and Hydrographic Agency took

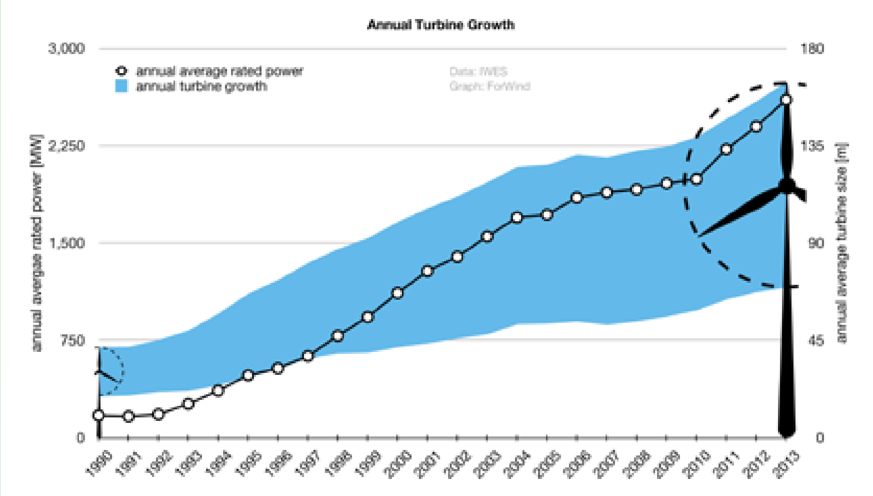

Figure 2. Annual turbine growth in Germany

place in 2013. The StUKplus conference dealt with lessons learned from five years of environmental monitoring and research on ecological effects at the offshore wind farm Alpha Ventus. The lessons of dealing with effects of offshore wind energy development to fish, benthos, birds, and marine mammals were also discussed. In that context, the standard for the "Investigation of the Impacts of Offshore Wind Turbines on the Marine Environment (StUK4)" was presented as an update and published (18) (19).

2.3 National incentive programs

For Germany's wind energy market, the Renewable Energy Sources Act (EEG) is the major incentive. Based on the EEG field report in 2011, the German Parliament voted for an amendment of the EEG, which became active January 1, 2012 (9). In 2013 there have not been any changes within the feed-in-tariffs (FIT) for land-based and offshore wind energy (13) (14). However, due to the newly established German federal government in late 2013, a revision of the EEG will probably take place in 2014 (12).

2.4 Issues affecting growth

The elections for the German parliament (Bundestag) in September 2013 affected the growth of wind energy. In order to limit further increases of the EEG apportionment, the Federal Environment Minister announced ideas of severe changes to the FIT in January 2013. This led to uncertainty concerning financing offshore projects and put several projects on hold. On the other hand, the planned revision of the EEG in 2014 stimulated several land-based projects to be grid connected in 2013 and by that contributed to the increase of annual added capacity (Figure 3).

3.0 Implementation

In 2013, wind energy reached all-time highs of installed capacity on land and offshore, of investments, of electricity produced, and consequently of avoided carbon dioxide emissions.

3.1 Economic impact

The total investment in renewable energy technologies in Germany in 2013 was 16.3 billion EUR (22.49 billion USD). Wind energy investments accounted for 43.4% of those investments, equal to 7.1 billion EUR (9.78 billion USD) (3). Compared to 2012, this is an increase of 89% (8). The operational costs remained at a more or less constant 1.4 billion EUR (1.93 billion USD).

According to leading wind energy developers, more than 60% of the German wind sector is devoted to exports, which leads to a roughly estimated total turnover of 12.8 billion EUR (17.64 billion USD) for domestic and export activities. With that, the number of people employed in the wind sector is nearly 137,800 (27). However, due to delays in the realization of offshore projects and missing follow-up orders, some offshore wind turbine manufacturers and sub-component suppliers announced that they have to decrease staff and put others to work shorter days.

3.2 Industry status

The offshore installations in 2013 changed the manufacturers' market shares significantly.

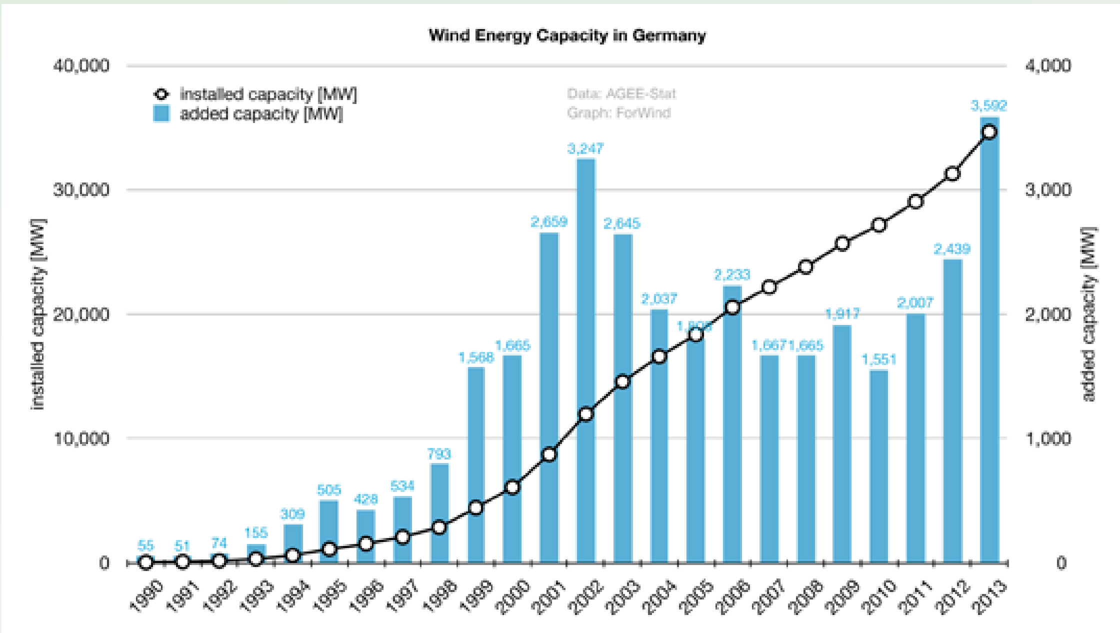

Figure 3. Wind energy capacity in Germany

While market leader Enercon held approximately 50% of the market on land, its overall market share dropped to 41.5% when offshore wind energy installations are also taken into account (Figure 4). Vestas (16.7%, minus 6.4 percentage points compared to 2012) and REpower (13.5%, plus 3.1 percentage points compared to 2012) are still holding position two and three. Siemens, which in 2012 had a market share of less than 1%, is now number four, with a market share of 9.7%, which is mainly due to offshore installations (25).

The turbine manufacturer REpower announced a new name for the company in 2013. As from 2014 the company will be officially named Senvion.

The majority of wind energy installations are privately owned. Utilities are holding just a minor share except for offshore wind energy, where public participation is limited. Two wind turbine manufacturers left the market. Fuhrländer AG filed for insolvency already in 2012 and eventually had to liquidate the incorporated company in the middle of 2013. Offshore wind turbine pioneer Bard's subsidiary Cuxhaven Steel Construction GmbH stopped its production of offshore support structures in spring 2013. Bard itself completed the 400-MW offshore wind park Bard Offshore I and announced that it will now be an operation and maintenance company only.

The development of new turbines for land-based and offshore wind energy progressed further in 2013. Prototypes of new wind turbines using larger rotors have been announced and erected by Enercon (E-115/3), Nordex (N131/3000), and Senvion (6.2M152). Near its headquarters in Aurich, Enercon started the operation of its newly opened innovation center. The center will accommodate approximately 700 engineers and will include test equipment and labs for rotor blade technology, acoustics, power electronics, generator technology, and overall turbine engineering.

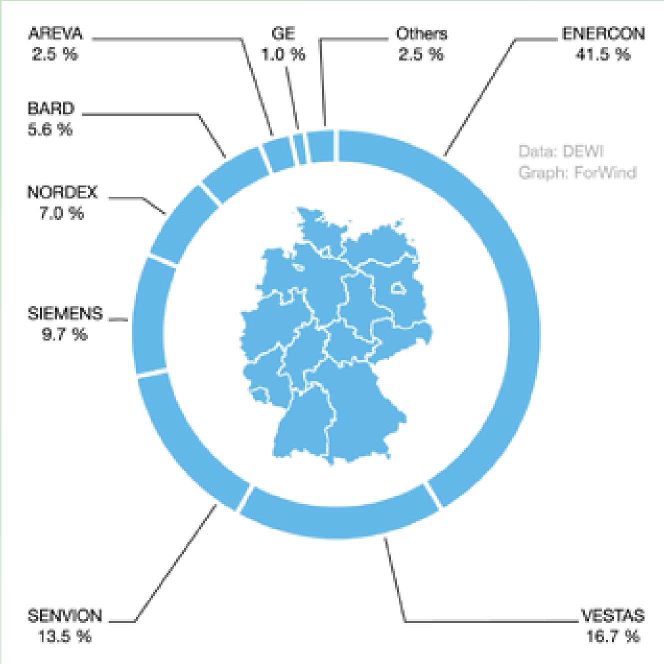

Figure 4. Market share by manufacturer of newly installed wind capacity in Germany (2013)

3.3 Operational details

As shown in Figure 1, the energy provided by wind energy increased to an all-time high of 53.4 TWh, which is approximately 5% above the previous year (3). However, if compared to an increase in installed capacity of approximately 10%, it is clear that 2013 has been a rather weak wind year. This has been slightly compensated by a strong contribution from the month of December (15.9% of the annual production) and the installation of taller and larger wind turbines (24). As illustrated in Figure 5, average hub height (85–136 m), rotor diameter (85–117 m), and rated power (2.0–2.97 MW) vary significantly between the different German states (1). Tall turbines with very large rotor diameters and relatively small generators have mostly been installed in southern states, in order to cope with the rather low regional wind speed conditions.

With Alpha Ventus, Baltic I, Bard Offshore I, and Riffgat, four offshore wind farm projects have been completed, while another seven are under construction (20) (Figure 6). The 2013 yield of Alpha Ventus amounted to 224.6 GWh, corresponding to 3,743 full load hours (25). Relatively low wind speeds in February, April, May, and July, as well as technical downtimes of individual wind turbines caused a decrease in the capacity factor, compared to previous years. The estimated national capacity factor was 18.5% (Figure 1), which is close to the long-term average of 19.0%.

3.4 Wind energy costs

The costs vary from project to project. Based on (1) and (6) the average costs for land-based wind energy installation and operation has been calculated for 2013 (Figure 7).

4.0 R, D&D Activities

4.1 National R, D&D efforts

Concerning wind energy R&D activities within the ongoing German 6th Energy Research Program from 2011, the BMUB provided 37.3 million EUR (51.4 million USD) of funds for new research projects in 2013 (Figure 8). In 2011 and 2012, many more funds for R&D were available in Germany than in 2013. Due to that shortfall, the annual R&D funds for 2013 are much less than in 2012 (93.2 million EUR; 128.4 million USD). Nevertheless, the funds for new R&D projects in 2013 were much higher than the average for newly funded projects in former years, which amounted from 2004 to 2010 to 29.6 million EUR (40.8 million USD) (9) (26).

After the election for the German parliament (Bundestag) in September 2013, the responsibility for national R&D activities within the renewable energy field changed and is since March 2014 under the BMWi.

For land-based wind energy, the progress of research funded by the BMUB in 2013 includes the examination of technical impacts in the long term regarding larger rotor diameters and hub heights as well as the combination of small-scale turbines on land with these increasing conditions. The development of optimized erection logistics and adjusted operation strategies is still necessary. To enlarge the maintenance intervals of turbines, component improvement and better condition monitoring systems are being investigated. With the help of more economical LIDAR devices, which investigate wind fields, and with faster operating control systems, potential loads of components—due to strong wind—can be reduced by pitching rotor blades in time.

The development of ecologically benign and cheap foundations for offshore wind

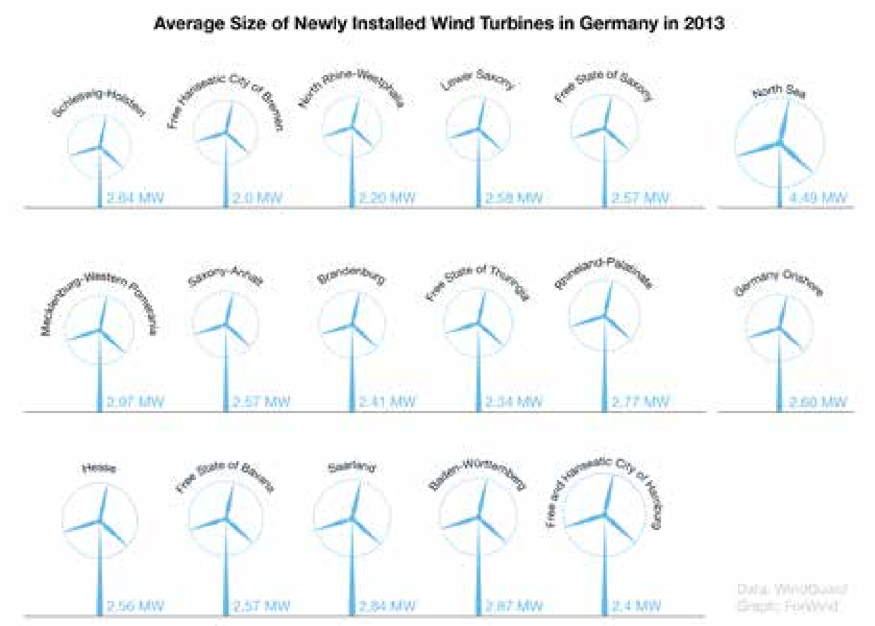

Figure 5. Average size of newly installed wind turbines in Germany in 2013 per state (wind turbines are illustrated in proportion to their actual size)

energy, including optimized installation logistics and maintenance procedures, are emphasized. Since there are no long-term experiences with offshore multi-MW turbines in deep water, further research topics will be determined during the scientific offshore monitoring program "OWMEP" led by Fraunhofer Institute for Wind Energy & Energy System Technology (IWES). OWMEP is a part of the research initiative "Research at Alpha Ventus" (RAVE) (9) (21).

Research funded by the BMUB in 2013 and the former years included special focus on offshore wind energy. Many results from offshore projects can be used for land-based wind energy projects as well, mainly regarding optimized reliability of multi-MW turbines. Test rigs for longer rotor blades and reduction of their manufacturing cost are also key aspects of ongoing research activities. New system and nacelle assembly test rigs have been developed to better understand damage mechanisms. In Aachen, the Centre for Wind Power Drives at RWTH Aachen has 4-MW drive capacity. In Bremerhaven, the Dynamic Nacelle Testing Laboratory (DyNaLab) at Fraunhofer IWES has 10-MW drive capacity.

Regarding ecological aspects of wind energy research, the impact on migratory birds and sea birds in the offshore area goes on. The results of the project "StUKplus" were published after a conference by the Federal Maritime and Hydrographic Agency in October 2013. Then the updated standard for the "Investigation of the Impacts of Offshore Wind Turbines on the Marine Environment (StUK4)" was published (18) (19).

Figure 6. Location of German offshore wind farms, operating or under construction in 2013

For land-based wind projects, examination of bats and wind turbines continues by considering the effects of larger rotor diameters as well as the yearly and small-scale regional variability of bats near wind turbines (9).

4.2 Collaborative research

German scientists and experts from industry participate actively in 12 of the 13 ongoing IEA Wind research tasks. Four tasks are still chaired or co-chaired by German researchers. In 2013, the new IEA Wind task, Full-Size Ground Testing for Wind Turbines and Their Components (Task 35) began its work, led by the Technical University Aachen as operating agent. The aim of this task is to develop recommendations and good practices for drive train and rotor blade testing (22).

5.0 The Next Term

In 2014 a new record is expected concerning the initial operation of newly built offshore foundations, including installed and grid-connected offshore wind turbines. Because the EEG will be revised in 2014, the development of land-based wind energy might not be as steady as it was in former years. However, if the revised EEG passes in 2015, pull-forward effects might take place in 2014, which could push the German wind market to a capacity increase of several gigawatts (9) (11).

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Opening photo: Wind turbines in Germany. Copyright: fos4X GmbH

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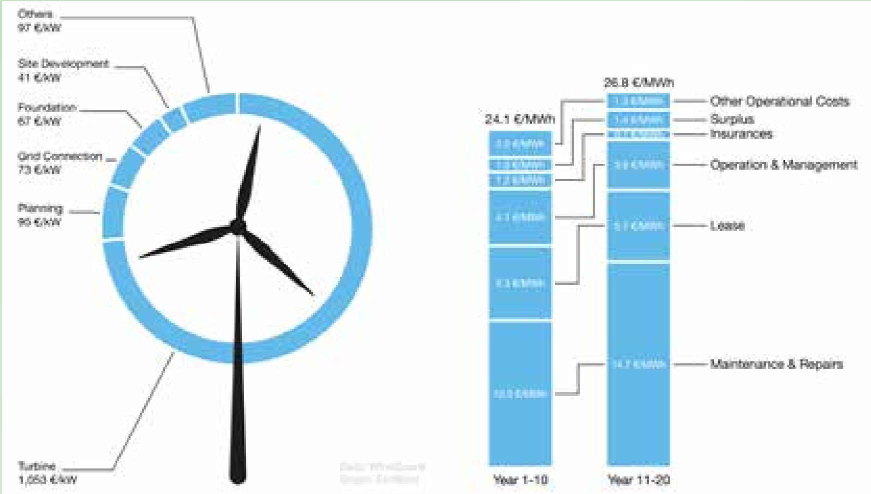

Figure 7. Average costs of land-based wind energy in Germany

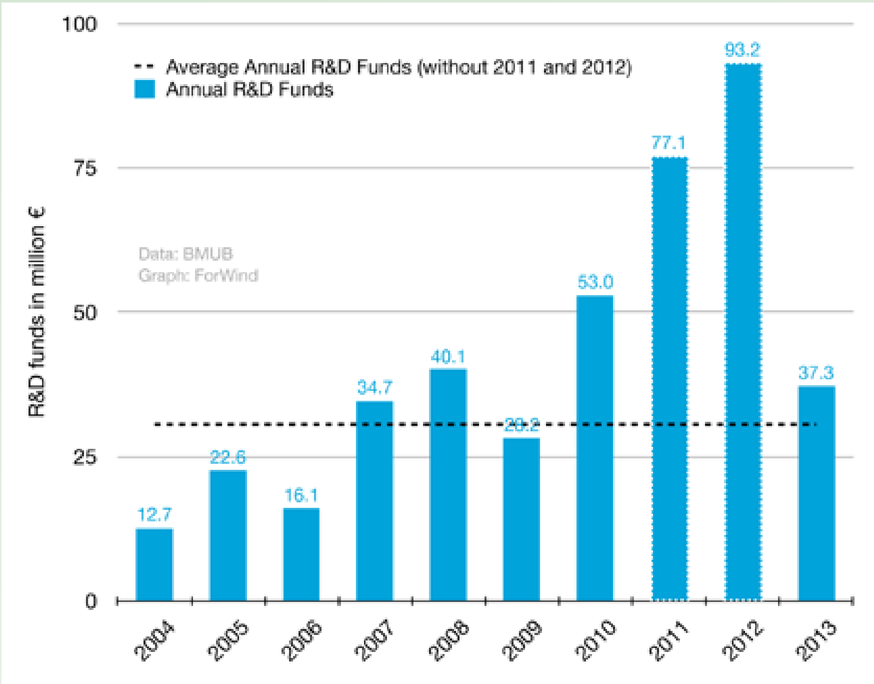

Figure 8. Federal wind energy R&D funding in Germany

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Authors: Franciska Klein, Forschungszentrum Juelich GmbH-Project Management Juelich, and Stephan Barth, ForWind Center for Wind Energy Research, Germany.

23 Greece

1.0 Overview

In 2013, 116 MW of new wind capacity were installed in Greece (Table 1). The total installed wind capacity is 1,865 MW, a 7% increase from 2012. Of the 116 MW, 52.9 MW were manufactured by Vestas; 32.9 MW by Enercon; 18 MW by Nordex; and 6.8 MW by Gamesa (3).

Greece has 121 wind farms.

Almost 150 million EUR (197 million USD) was spent in the Greek wind energy industry in 2012 (1). The pace of installation must increase to reach the 2020 target of 7,500 MW of wind capacity as included in the national renewable energy action plan. The government has many issues to consider in reaching this target. As part of a package of austerity measures approved in November 2012, wind and other renewable producers will be charged a 10% extraordinary tax on revenues for 12 months, dated back to 1 July 2012.

Greek wind farms currently receive a FIT of 89 EUR/MWh (122 USD) on the

Almost 150 million EUR (197 million USD) was spent in the Greek wind energy industry in 2012

Table 1. Key National Statistics 2013: Greece	
Total installed wind capacity*	1,865 MW
New wind capacity installed*	116 MW
Total electrical output from wind*	3.3 TWh
Wind generation as % of national electric demand	5.8%
Average capacity factor	27.5%
Target:	7,500 MW by 2020
*Global Wind Energy Council Global Wind Statistics 2013	

mainland. On the islands, wind farms receive a FIT of 99 EUR/MW (136 USD/MW), minus a 10% levy. However, there is a bill being drafted by the Greek government that would push back the FIT until the wind farms are actually grid-connected, which could create serious decreases in wind energy installations due to difficulties obtaining financing under these new rules (2).

In November 2013, the Greek Regulatory Energy Authority announced it had a new 144-MW wind farm to be built in on the Island of Evia by Enel and the Kopelouzos Group using Enercon turbines, a project set to start in 2014 (2).

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Opening photo: Skopies wind farm. Courtesy: Iberdrola
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24 Ireland

1.0 Overview

While 2013 was a noteworthy year for several aspects of wind energy deployment and a number of significant wind projects were connected to the grid, annual deployment remained below the average level required to achieve national 2020 renewable electricity targets. There was however, an increased uptake of grid connection offers to meet the offer acceptance deadlines for the Group Processing Scheme Gate 3. The year was also notable for the emergence of a concerted anti-wind energy movement in response to several proposed GW-scale, land-based wind energy developments.

Good wind conditions resulted in wind energy output increasing to 4.5TWh or 16.3% of demand in 2013, an increase of 12.5% over 2012 levels.

The UK and Irish governments signed a Memorandum of Understanding and continued negotiations to put in place arrangements for electricity exports direct to the UK from wind energy projects in Ireland as defined in the cooperation mechanisms in EU Directive 2009/28/EC.

2.0 National Objectives and Progress

Ireland remains committed to meeting an EU target of 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.

According to an Eirgrid report (2), between 3,200–3,700 MW of wind capacity will need to be installed on land in Ireland to meet 40% renewable electricity, as set out in the National Renewable Energy Action Plan. This will involve 1,300–1,800 MW of additional wind power capacity being added in the next seven years.

2.1 National targets

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.

According to an Eirgrid report (2), between 3,200–3,700 MW of wind capacity will need to be installed on land in Ireland to meet 40% renewable electricity, as set out in the National Renewable Energy Action Plan. This will involve 1,300–1,800 MW of

Wind energy output increased to 4.5 TWh or 16.3% of demand in 2013, an increase of 12.5% over 2012.

Table 1. Key National Statistics 2013: Ireland	
Total installed wind capacity (1)	1,896 MW
New wind capacity installed (1)	133 MW
Total electrical output from wind	***4.5 TWh***
Wind generation as % of national electric demand	***16.3%***
Average national capacity factor	***30.5%***
Target: (2)	***3,450 MW***
Bold italic indicates estimates	

additional wind power capacity being added in the next seven years.

2.2 Progress

The installed and energized wind capacity at the end of 2013 was 1,896 MW (1)—an increase of 133 MW since 2012. This continues a trend of capacity additions below the projected average of over 200 MW/yr required to achieve Ireland's 2020 renewable energy targets (Figure 1).

2.3 National incentive programs

The primary support scheme for renewable electricity in Ireland is the Renewable Energy Feed-in Tariff (REFIT) (3). This scheme has been in place since 2006, and the REFIT 1 tariff arrangements were applied to wind farm projects applying to the scheme up until 2010 (3). Projects qualifying for the scheme may be executed up to the end of 2015. The replacement REFIT 2 scheme was opened for applications in March 2012 and has a deadline of the end of 2017 for the energization of qualifying projects (3). 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 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 (55 million USD) (4). This cost does not consider the depression of electricity prices by wind power. An Economic and Social Research Institute study found that in the years from 2008–2012 wind depressed hourly market prices by amounts varying from 0.2–1.3% based upon monthly averages (5). This result is in line with prior findings of a 2011 Sustainable Energy Authority of Ireland (SEAI)/Eirgrid study (6). The average wholesale market price during 2013 was 107 EUR/MWh (147 USD/MWh), as compared to an inflation adjusted REFIT tariff of 69.235 EUR/MWh (95.406 USD/MWh) for wind farms larger than 5 MW and 71.664 EUR/MWh (98.753 USD/MWh) for wind farms smaller than 5 MW (3) (7).

2.4 Issues affecting growth

The pace of wind energy deployment has primarily been determined by the availability of grid connections and the allocation of these under the "Group Processing Approach." There was ultimately a high uptake of wind farm grid connection offers issued under the most recent "Gate 3" of the Group Processing Approach. By December 2013, the total amount of wind capacity contracted for connection under Gate 3 was 1,230 MW with 534 MW of remaining live offers to wind projects (8). This brought the total wind capacity contracted for future connection at the beginning of 2014 to 3,293 MW—almost double the additional capacity required to deliver the 2020 target. This contrasts somewhat with the trajectory delivery of capacity to date shown in Figure 2.

Local authorities in Ireland publish wind energy strategies in response to a statutory requirement to identify areas suitable for wind farm development, and some

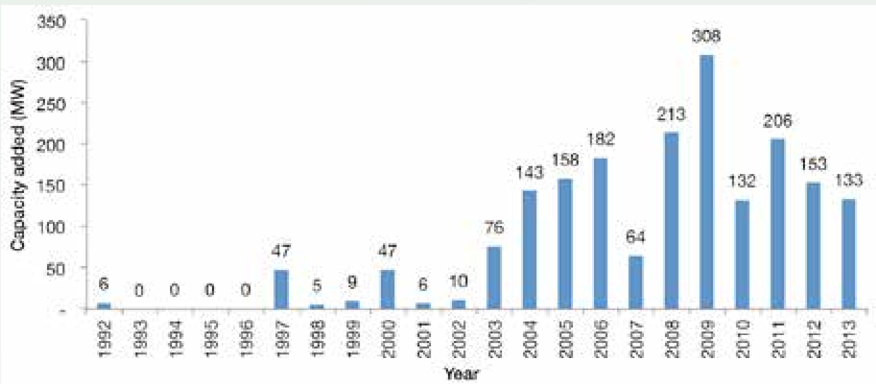

Figure 1. Annual wind farm capacity additions 1992–2013

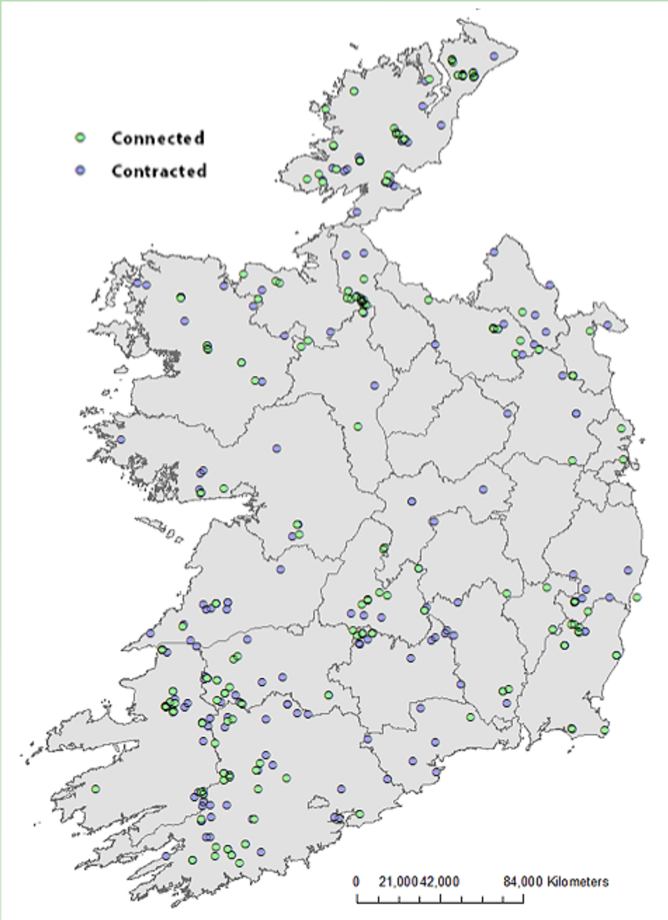

Figure 2. Connected and contracted wind farms in Ireland

authorities engage in developing holistic renewable energy strategies encompassing all available renewable energy resources. In order to provide support for a robust adoption of such renewable energy strategies by planning authorities, SEAI convened a steering group to oversee the preparation of a methodology and template to act as a guide for preparing renewable energy strategies. The SEAI "Methodology for Local Authority Renewable Energy Strategies" was published in 2013 and has since been adopted by several local authorities in preparing their renewable energy strategies (9). The methodological approach to identifying areas suitable for wind energy development should facilitate consistent outcomes in local and regional spatial plans for wind energy.

A review of the wind farm planning guidance in relation to noise and shadow flicker was initiated in 2013 by the Department of the Environment (10). SEAI commissioned a study on the impact of wind turbine noise to inform this review (11). Draft revised guidelines were published for public consultation in December 2013 proposing:

- A more stringent absolute noise limit of 40 dB (day and night) for future wind energy developments.
- A mandatory setback of 500 m between a wind turbine and the nearest dwelling for amenity considerations.
- A condition attached to all future planning permissions for wind farms to ensure that there will be no shadow flicker at any dwelling within 10 rotor diameters of a wind turbine. If shadow flicker does occur, the wind energy developer or operator will be required to take necessary measures, such as turbine shut down for the period necessary to eliminate the shadow flicker.

In excess of 3,500 submissions were received in response to the consultation and the Department of the Environment is considering these before issuing the final guidance and appendices.

Significant public disquiet regarding wind energy arose due to a number of proposed multi-GW scale wind farm developments in the Irish midlands. It was proposed that these wind farms would not be connected to the Irish electricity system but be connected directly to the UK system via underground and subsea cables. The early stage project development activities of the leading project promoters in an area that had, hitherto, seen very little wind energy development, resulted in public protests in the affected areas and significant negative media and political attention. There were, in particular, concerns that the projects' categorization as strategic infrastructure for planning purposes might lead to their being permitted without the opportunity for adjacent communities to engage in the planning process.

In October 2013, the Department of Communications, Energy and Natural Resources announced its intention to develop a "Renewable Energy Export Policy and Development Framework (with a spatial dimension) for renewable export opportunities from Ireland, in the first instance to the United Kingdom as stated, with particular focus on large-scale projects for renewable energy generation." It also announced that

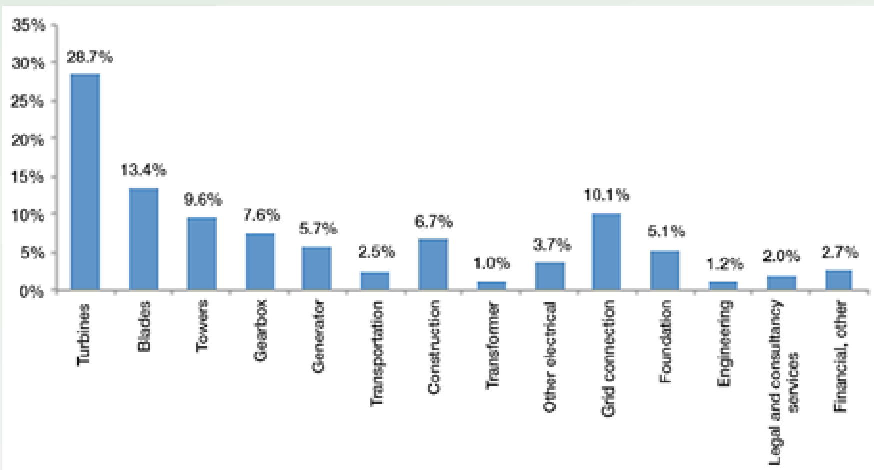

Figure 3. Allocation of land-based wind capital investment

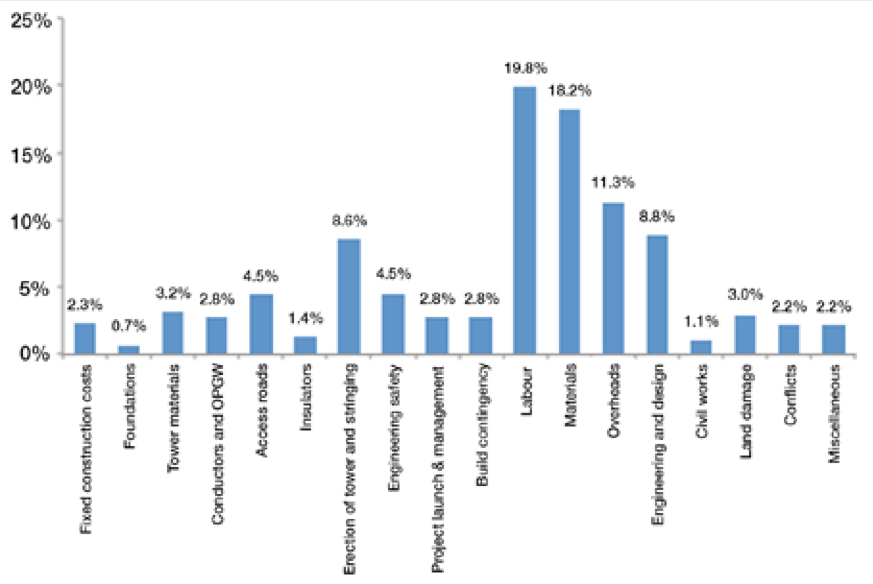

Figure 4. Allocation of transmission grid capital investment

this framework is to be informed by the carrying out of a Strategic Environmental Assessment and that this will be accompanied by a Habitats Directive Assessment (or Appropriate Assessment) under the Habitats Directive 92/43/EEC, and widespread consultation with the public and stakeholders. The first stage public consultation document was published with this announcement and substantial numbers of submissions were received in response to it (12).

In April 2014, Minister for Energy Pat Rabbitte said "that given the economic, policy and regulatory complexities involved, and the key decisions yet to be taken by the UK, delivery by 2020 of a Midlands Wind Export Project is not now a realistic proposition."

3.0 Implementation

3.1 Economic impact

SEAI has analyzed the employment and economic impacts of a land-based wind scenario that meets 32% of Ireland's electricity requirements by 2020, reaching a total capacity of 3,566 MW. This is in line with the Ireland's National Renewable Energy Action Plan and commitments to the larger EU 2020 energy strategy.

To reach a total installed capacity 3,566 MW of wind energy requires capital investment in new wind power plants, labor, materials, and operation costs. At an investment cost of 1.3 million EUR/MW (1.8 million USD/MW), based on REFIT estimates, to add 1,181 MW of wind capacity would require a total 1.53 billion EUR (2.11 billion USD) capital investment in wind farm development in the years leading up to 2020, with an additional 1.6 billion EUR (2.2 billion USD) investment in expanding the transmission grid up to 2025 to accommodate additional wind on the system. The breakdown of where capital investment in wind energy and the transmission grid filters through the supply chain is illustrated in Figures 3 and 4.

The impact of investment in wind energy in Ireland is measured using a macro-econometric model, Regional Economic Models, Inc. This model of the Irish economy has been developed specifically for SEAI to assess the economic impacts of investment in renewable energy and energy efficiency. Investment is modelled by comparing a baseline scenario (existing planned investment to reach baseline capacity above) with a scenario where 32% of electricity is supplied by wind energy, in line with National Renewable Energy Action Plan targets for 2020.

Developing an additional 1,181 MW of land-based wind from 2010 to 2020 would have a significant impact on the Irish economy. By 2020, gross domestic product (GDP) would increase by 314 million EUR (433 million USD) (2012 prices) with 2,969 net new jobs that year. The majority of employment is in the construction sector (2,243), created for the duration of the construction of the plant with 529 new long-term jobs created to support the operations and maintenance of new wind energy facilities and in the wider electricity supply sector. Most of the manufacture of turbines, towers, blades and their subcomponents is assumed to be imported (import intensity of 66% derived from Irish I-O tables) so fewer manufacturing jobs are generated domestically (13). Including the necessary investment in the transmission grid, wind farm development generates over double the number of new jobs, reaching net figures of 4,497 in 2020. Of these jobs, 3,426 are in the construction sector. In the electricity, gas, and steam industry, 679 net jobs are generated with the majority of remaining added employment as a result of increased spending generally in the economy from higher incomes in the renewable energy sector.

A 2013 study "The Value of Wind Energy to Ireland" by the Irish Wind Energy Association found a total current employment of 2,200 in the wind sector and projected employment of 10,700 by 2020 (14). The latter figure assumes 2020 target capacity is exceeded through the execution of large projects connected directly to the UK. This study into the economic impact of the wind energy sector in Ireland found that using wind energy to meet Ireland's 2020

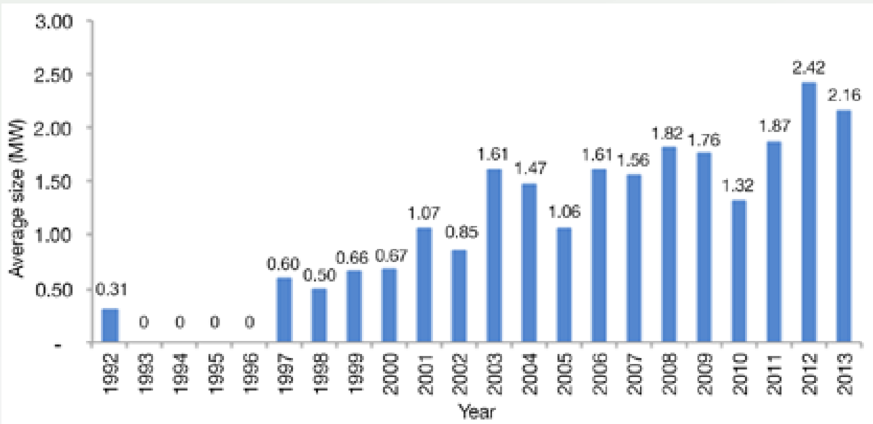

Figure 5. Average wind turbine power in MW 1992–2013

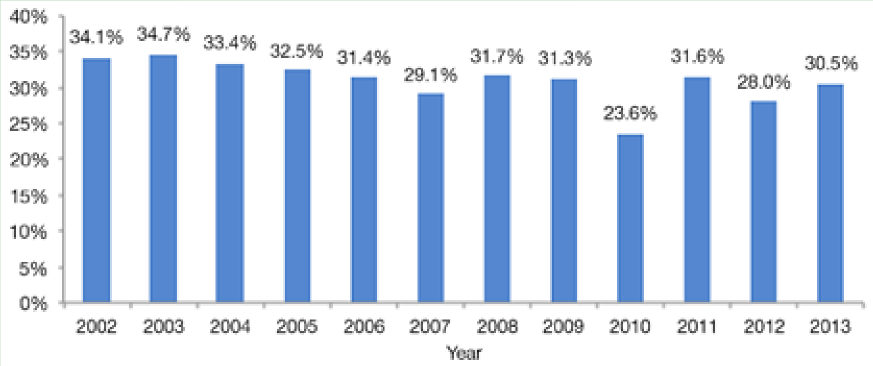

Figure 6. Annual capacity factors

targets and adding further capacity up to 2030, will dramatically reduce Ireland's costly dependency on foreign energy, lower wholesale electricity prices and deliver 1.8 billion EUR (2.5 billion USD) in new tax revenue to the Irish state, all without leading to any cost to Irish consumers.

"The Value of Wind Energy to Ireland" report developed jointly by the consultants Pöyry and Cambridge Econometrics, funded by SEAI, Coillte, SSE and the Irish Wind Energy Association (IWEA), represents a comprehensive study on the economic impact of wind energy development in Ireland and highlighted the economic benefits of further developing wind energy. The report shows that by installing the 3.8 GW of wind capacity required to meet the Republic of Ireland's 2020 targets and developing a further 1.6 GW between 2020 and 2030, to meet domestic energy demand, the wind energy sector would:

- Deliver 8.3 billion EUR (11.4 billion USD) of investment into the Irish economy
- Significantly contribute to economic growth
- Provide at least 1.8 billion EUR (2.5 billion USD) additional cumulative tax revenue to the Irish state
- Lower wholesale electricity prices
- Lead to no additional cost to Irish consumers
- Save Ireland 700 million EUR/yr (965 million USD/yr) in fossil fuel imports and reduce the country's dependency on energy imports
- Support 22,510 jobs (job-years)
- Protect the environment by significantly reducing CO_2 emissions

3.2 Industry status

A notable development in 2013 was the completion of the first community-owned wind farm, Templederry Wind Farm, comprised of two 2.3-MW wind turbines. The community-owned model of development had previously not met with success in Ireland. As reported in 2013, there is a roughly 50/50 split of wind farms that are owned by energy utilities and smaller wind farm operators. Another notable development in December 2013 was the initiation of work to install three 3-MW wind turbines by adjacent pharmaceutical companies to supply their operations in the Lower Harbour area of Cork City. The average size of a wind farm construction project in Ireland in 2013, at 13 MW, remains small by international standards.

Manufacturing:

To date no manufacturing of utility scale wind turbines, or any of their main components, has taken place in Ireland. C&F Wind Energy continues to produce and develop their range of small wind turbines. Their largest model is a 100-kW wind turbine launched in 2013.

Several successful Irish companies are providing international project development and consultancy services or servicing specialist niches within the wind energy sector. Sepam International in Clonmel, Ireland, was one of the main engineering contractors on the Greater Gabbard offshore wind farm. Airconmech in Enniscorthy, Ireland, supply cooling systems for wind turbines, ServusNet in Cork provide ICT and data services supporting wind farm O&M to international wind farm operators.

3.3 Operational details

The average size of land-based wind turbine for wind projects initiated in 2013 was 2.16 MW, a significant increase over the 2.0-MW average in 2011 and a continuation of a long term trend of increasing sized for land-based wind turbines, as shown in Figure 5.

Average national capacity factor:

The average capacity factor of wind farms in Ireland in 2013 was 30.5% (a preliminary figure from TSO, Eirgrid, data based upon the actual capacity in operation throughout the year). This number is around the long-term average capacity factor of 29–30%. Due to the favorable wind conditions and a modest capacity addition the total wind energy output in 2013, at 4.5 TWh, was 12.5% higher than in 2012 (Figure 6).

3.4 Wind energy costs

Wind turbine prices in 2013 averaged in the range of 800–1,000 EUR/kW (1,102–1,378 USD/kW) for medium-to-large projects involving multiple turbines. The downward trend in the price per installed kW 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. Because these turbines yield a higher energy capture per installed kW, they will allow continued reduction in the cost of wind energy. Total wind farm development costs averaged 1,550 EUR/kW (2,136 USD/kW) for a typical project in 2013 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

Priorities:

Strategic research priorities were identified for Ireland in 2012 in a mapping exercise led by Science Foundation Ireland with input from relevant sectoral stakeholders. While wind energy per se was not among the shortlisted energy sector priorities, R&D on smart grid technologies including research on the integration of wind power has been prioritized.

Budget:

Wind energy has benefited from a relatively small share of energy research funding in Ireland. This may in part be due to the absence of a large-scale wind turbine manufacturing sector in Ireland diminishing the demand for government support for industrial and academic R&D supporting wind turbine technology development. Despite wind energy being the primary technology contributing to achieving 2020 renewable energy targets, the total public funding for R,D&D directly related to wind energy in 2012 remained below 1.0 million EUR (1.4 million USD).

SEAI is the primary source of public funding for wind energy R&D, while Enterprise Ireland is the primary provider of public funding for industrial wind energy R, D&D.

Results:

Along with providing funding for participants in IEA Wind Tasks, SEAI sponsored a suite of wind energy related research projects under its Renewable Energy Research, Development and Demonstration Programme, the most salient of which were: SEAI—examination of the significance of noise in relation to land-based wind farms (Marshall Day Acoustics); and IWEA—study on the value of wind energy to Ireland (Poyry/Cambridge Econometrics).

4.2 Collaborative research

Participation in IEA Wind collaborative research Tasks is an important element of Ireland's research effort and Ireland currently has membership in IEA Wind Task 11 Base Technology Information Exchange, Task 25 Design and Operation of Power Systems with Large Amounts of Wind Energy, Task 26 Cost of Wind Energy, Task 27 Small Wind Turbines in Turbulent Environments, Task 28 Social Acceptance of Wind Energy Projects, and Task 33 Standardizing Reliability Data. SEAI coordinates Ireland's participation in IEA Wind, funds membership fees, and, when required, provides funding to cover costs incurred by national participants.

4.3 Electricity system research

While limited research is carried out on wind energy technology in Ireland, the Electricity Research Centre in University College, Dublin, has significant research competence in the field of grid integration of wind power. Details of current wind-related research projects may be found on the ERC website (14). The Irish transmission system operator, Eirgrid, is continuing to implement an advanced program of work entitled "Delivering a Secure Sustainable Electricity System (DS3)." DS3 is supported by a program of research, with the ultimate objective of managing the integration of very high levels (75%) of instantaneous renewable penetration on the island (15). Successful implementation of this program will be critical to maintaining wind energy curtailment at acceptable levels. There have been delays to implementing several key regulatory changes critical to delivering the program, most saliently a proposed change to Rate of Change of Frequency protection settings for all generators. However, Eirgrid is making good progress on the deliverables from the program.

5.0 The Next Term

The Irish government will publish a new energy policy green paper in 2014. This will outline the high level energy policy options for the period from 2020 to 2030 and invite public submissions to contribute to the shaping of energy policy for this period.

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(1) The installed capacity in 2012 is reported based upon the sum of the nameplate power rating of all commissioned and energized wind turbines. In previous years the TSO, Eirgrid, reported newly installed wind energy capacity on the basis of the full ultimate capacity of the wind farm project being available at the date of first energisation of the wind farm connection. In cases where groups of wind turbines within a wind farm are energised in discrete tranches over a protracted period this may have resulted in over reporting of capacity additions within a single year. For 2013 capacity additions, Eirgrid modified their reporting of capacity additions to the actual installed and energized wind turbines. This may lead to a discontinuity in the reported statistic for Ireland in 2013.

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Author: John Mc Cann, with contribution from Sarah Stanley, the Sustainable Energy Authority of Ireland (SEAI), Ireland.

25 Italy

1.0 Overview

In Italy, installed wind capacity reached 8,554 MW in 2013, with the addition of 434 MW net capacity during the year (a decrease of 66% in new installations with respect to 2012). This dramatic decrease in the wind energy development trend (e.g., 1,266 MW of new capacity installed in 2012) is mainly due to the enforcement of the new renewable energy systems (RES) supporting scheme, in which the incentive access is constrained by established annual quotas, which involve a severe limitation for new installations compared with previous years.

This new supporting scheme for RES, which came into force at the end of 2012, considers three different incentive access mechanisms: direct access, registration access, and auction access. Registration and auction access is constrained by annual quotas. The access mechanism depends on the plant size and characteristics (i.e., integrally rebuilt, repowered, or refurbished plant). Incentive tariffs depend on plant size and characteristics as well (i.e., land-based or offshore plant). An issue critical to investors is the annual quotas established for auction in the next three years. These quotas are thought to be too low with respect to the annual new added capacity usually installed so far. What is more, the auction access threshold of 5 MW as wind park capacity is also considered to be too low. These fears were confirmed by the dramatic decrease in new installations during 2013.

In 2013, 221 new turbines were deployed, reaching a total of 6,391 installed wind turbines. Wind electricity generation increased from 13.1 TWh in 2012 to 14.9 TWh (12%) in 2013, corresponding to about 4.7% of total electricity demand on the Italian system.

Issues affecting wind energy growth include the new support scheme mentioned above and permitting procedures, which still represent a bottleneck for new wind energy projects. Acknowledgement by the regions of the national permitting guidelines issued in 2010 is expected to overcome this obstacle.

Another critical issue has been wind production curtailments ordered by the transmission system operator (TSO). The noteworthy efforts made by the TSO TERNA to upgrade the grid in order to match RES-production dispatching needs have resulted in a significant decrease in wind production curtailments, from 5.5% in 2010 to about 1% in 2012 and less than 1% in 2013. Moreover, the regulatory authority AEEG has provided for curtailed production to be estimated and wind park owners indemnified.

Erg Renew became the first operator owning more than 1 GW of the installed capacity. Leitwind is the only Italian manufacturer of large turbines. As a consequence, most of the large turbines installed in 2013 were supplied by foreign manufacturers. The market for small wind turbines is growing, reaching about 20 MW of overall installed capacity (estimated value).

Because of the lack of a coordinated national research program, wind energy R, D&D activities have been carried out by different entities, mainly CNR (National Research Council) and ENEA (the first and second national research institutions respectively), RSE (Research on the Electric System), some universities and other companies.

Production from wind power plants was 14.9 TWh, an increase of 11.6% compared to 2012, and represents about 4.7% of total electricity demand.

Table 1. Key National Statistics 2013: Italy	
Total installed wind capacity	8,554 MW
New wind capacity installed	434 MW
Total electrical output from wind	***14.9 TWh***
Wind generation as % of national electric demand	***4.7 %***
Average capacity factor	***21%***
Wind generation goals from Italy's National Action Plan (PAN) for RES issued by the Italian Government on 30 June 2010	12,680 MW and 20 TWh/yr by 2020
Italy's overall RES target from Directive 2009/28/EC	17% of total energy consumption from RES by 2020
Bold italic indicates estimates	

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 on land and 680 MW offshore) was set as the installed capacity target and 20 TWh/yr (18 TWh/yr on land and 2 TWh/yr offshore) as the energy production target.

2.2 Progress

A dramatic decrease in new added capacity was experienced in 2013 with only 445 MW installed—the lowest annual amount since 2004 (Figure 1). This led to a total grid-connected wind capacity of 8,554 MW at the end of 2013, a net increase of 434 MW over 2013 (including 10.9 MW reduction due to decommissioning old installations). The corresponding growth rate was 5.3%, considerably lower than in 2012 (18.4%). According to the Italian wind resource availability, most of the new installations took place in the South of Italy (Apulia, Calabria, Campania, Sardinia, and Sicily). The wind cumulative and newly-added installed capacities for the Italian regions are shown in Figure 2.

Overall 2013 energy production from renewable sources was about 108 TWh (estimated by TERNA provisional data). A significant decrease (-3.4%) in the total electricity demand (317.1 TWh) was recorded in 2013 with respect to 2012. An 87% quota of this demand was satisfied by domestic production and 13% by imports. The production from wind parks, 14.9 TWh (+11.6% compared to 2012) represents about 4.7% of total electricity demand on the Italian system (total consumption plus grid losses). Italian wind-energy production development is shown in Figure 3.

2.3 National incentive programs

As a consequence of the Italian government Legislative Decree No. 28 on 3 March 2011, new incentive mechanisms have been introduced and implemented. This Decree recognizes the EU Directive 2009/28/EC on RES promotion and outlines a new incentive scheme concerning RES plants. This new scheme came into force on 1 January 2013. The old incentive scheme, mainly based on Tradable Green Certificates was guaranteed for plants authorized before 11 July 2012 and became operative before 30 April 2013. This previous scheme of quotas and Tradable Green Certificates is to expire by 2015. Transition measures are provided for entitled plants.

The main issues of the new mechanisms are special energy purchase prices fixed for RES-E plants below a capacity threshold

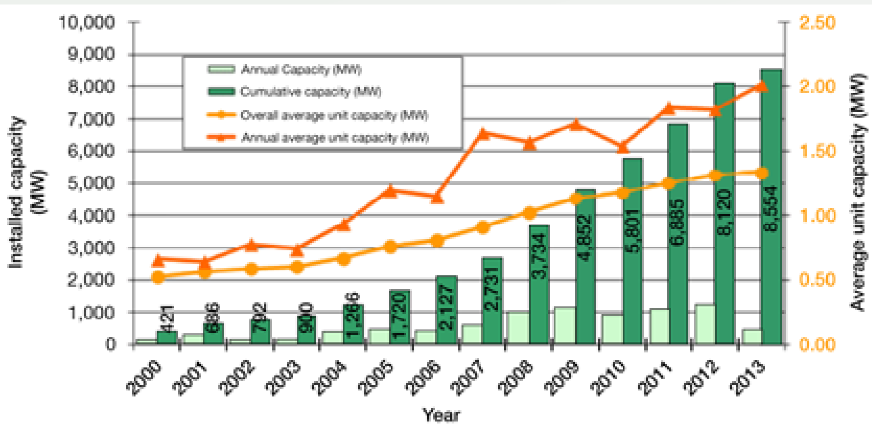

Figure 1. Trend of Italian annual and cumulative wind turbine installed capacity and new added and overall average unit capacity

Region	end 2013 (MW)	2013 (MW)	
Friuli V. Giulia	0	0	North
Lombardia	0	0	North
Marche	0	0	North
Umbria	0	2	North
Trentino A.A	0	3	North
Val d'Aosta	0	3	North
Veneto	8	10	North
Emilia Romagna	0	16	North
Piemonte	6	19	North
Lazio	0	51	Center
Liguria	11	58	Center
Toscana	30	115	Center
Abruzzo	0	236	Center
Molise	0	374	Center
Basilicata	66	425	Center
Calabria	28	988	South + Islands
Sardegna	10	1,024	South + Islands
Campania	16	1,223	South + Islands
Sicilia	0	1,746	South + Islands
Puglia	271	2,262	South + Islands
TOTAL (onshore)	445	8,554	
TOTAL (offshore)	0	0	

Figure 2. Wind capacities in the Regions of Italy at the end of 2013

Table 2. Annual quotas for incentive access

	2013 MW	2014 MW	2015 MW
onshore	710	710	710
offshore		650	

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: <60 kW, direct access; for new, integrally rebuilt and repowered plants, access by registration in the range 60 kW–5 MW; access by auction through calls for tenders for plant size >5 MW. For refurbished plants greater than 60 kW, no auction procedures are considered and the access is by registration irrespective of the plant size. Both registration and auction accesses are limited by established annual quotas.

In 2013–2015, 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) was established for onshore wind capacity and a quota of 650 MW of offshore wind capacity was established for the whole period (Table 2). Table 3 shows the basic-incentive tariff set for 2013 and conventional plant life vs type and plant size. It should be noted that these tariffs, in compliance with the 6 July 2012 Decree, are going to be reduced by 2% in the next two years (2014 and 2015).

According to Table 3 values, new incentives are significantly lower than those assessed in the old scheme. For example, for a wind plant exceeding 5 MW the reduction is around 20%. It has to be noted that small (P<200 kW) and offshore plants still benefit from greater incentives than land-based ones (P>200kW). Due to these more favorable incentives, small plants are growing quite fast in Italy. According to a preliminary National Wind Energy Association (ANEV) estimate of small wind plant deployment, about 20 MW of capacity is already installed.

2.4 Issues affecting growth

The drastic reduction of new installed capacity (-66% from 2012) is due to the above mentioned introduction of an annual quota of wind capacity that can benefit from the incentives equal to 500 MW for the years 2013–2015 for plants with size greater than 5 MW. It has to be noted that in 2013 new capacity (445 MW) was even lower than this quota and for 2014 the established quota (465 MW) is almost the same. Moreover, the above mentioned incentive tariffs for onshore plants greater than 200 kW are significantly lower than those assessed in the old scheme.

In order to facilitate the achievement of the 2020 national target for renewable energy production, regional RES targets were set by Decree 78 of 02/04/2012 on 15 March 2012 entitled "Defining and Characterizing Regional Targets on Renewable Sources, and Definition of Managing Procedures for Cases of Failed Achievement of the Goals by the Regions and Autonomous Provinces" (called burden sharing decree). In spite of this decree, and the consequent expected significant growth in the Basilicata and Sardinia regions, new capacity is almost all concentrated in the Apulia region, which strengthens its supremacy by totaling more than 2 GW of installed capacity.

For small and offshore turbines the incentive mechanisms are still favorable. As already mentioned, small turbines total around 20 MW (from unofficial census). This confirms the interest of many national small and medium-sized enterprises in this sector. Regarding offshore plants, it should be pointed out that the authorization in Italy is given by the central government (for onshore parks

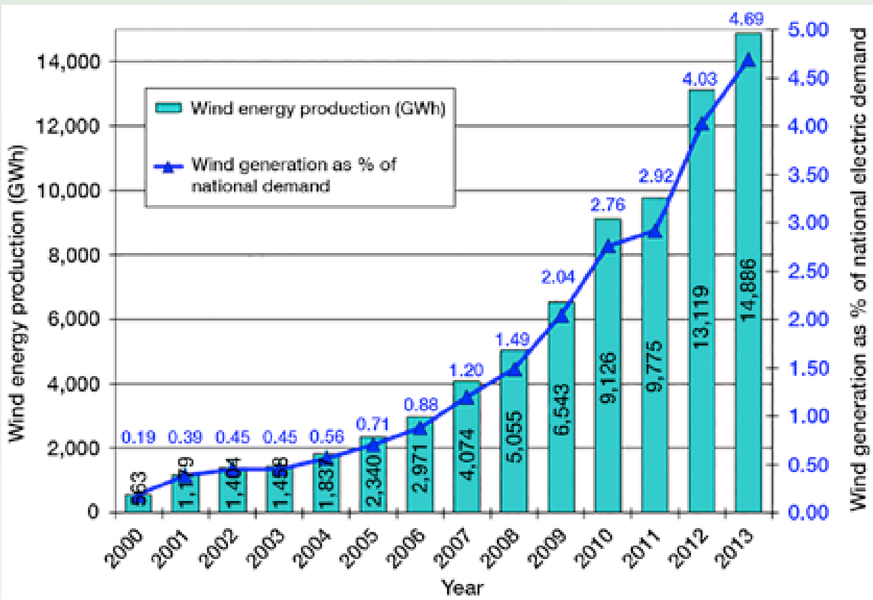

Figure 3. Italian wind energy production and percent of national electric demand

Table 3. Conventional plant life and basic incentive tariff vs plant type and size			
	Power kW	Conventional Plant Life Years	Basis Incentive Tariffs year 2013 EUR (USD)
Onshore	1 < P ≤ 20	20	291 (401)
	20 < P ≤ 200	20	268 (369)
	200 < P ≤ 1,000	20	149 (205)
	1,000< P ≤ 5,000	20	135 (186)
	P > 5,000	20	127 (175)
Offshore	1 < P ≤ 5,000	25	176 (243)
	P > 5,000	25	165 (227)

the authorization is given by regional government) after very long and complex procedures. The only offshore wind farm fully authorized at the end of 2013 is a near-shore 30-MW plant in Taranto harbor. Strong opposition to these initiatives has still to be registered both from regional and local administrations and from some environmental associations.

Another issue affecting growth is the connection of wind parks to the grid even though at present this is less important than in the past. Technical and economic conditions have been set by the Italian Regulatory Authority for Electricity and Gas (AEEG) in Deliberations ARG/elt 125/10 and 99/08. Both provisions grant RES plants some better terms, with a view to speeding up connection and alleviating costs. Despite that, delays in grid connection, especially in the permitting of new electrical lines by local authorities, are still reported. Moreover, Italy's 2010 PAN for Renewable Energy has bound TERNA to plan the upgrading of the grid needed to guarantee full access of RES electricity. In particular, for the period 2013–2022, TERNA planned for grid reinforcements an investment of 7.9 billion EUR (10.9 billion USD). TERNA was sometimes compelled to ask wind parks to stop or reduce output, because of overloads or planned work in grid zones (especially in the South and Sardinia) that were not yet fully adequate. From preliminary estimation, in 2013 curtailments were almost negligible. The Italian body that provides financial support for utilization of renewable energy sources (GSE) calculated the "missed production" and indemnified the owner for that.

3.0 Implementation

3.1 Economic impact

The Italian estimated turnover related to the wind conversion system sector in 2013 was around 1.0 billion EUR (1.4 billion USD). This amount includes both preliminary (design, development) and executive (construction, equipping, grid-connection) activities involved in the new wind park installations. This represents a dramatic decrease of the turnover with respect to 2013 (-52%), due to the severe reduction in new installed capacity. Although most of the new installed wind turbines were made abroad, nevertheless wind sector initiatives have a significant impact on employment. It should be noted that many Italian firms supply components to wind turbine manufacturers based in Italy and abroad.

According to ANEV, the previous positive trend of employment reversed in the last two years, as a consequence of the dramatic investment reduction due to the new incentive system. Overall reduction of jobs in the wind energy sector in the last two years was estimated in about 10,000 units, compared with more than 40,000 people employed before (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, showing the overall market shares of wind turbine manufacturers in Italy at the end of 2013. The shares of the wind turbines erected in 2013 alone are: 231 MW by Vestas (Denmark), 64 MW by Enercon (Germany), 60 MW by Sinovel (China), 40 MW by Gamesa (Spain), 32 MW by REpower (Germany), 16 MW by Leitwind (Italy), and 2.5 MW by GE Wind (U.S.).

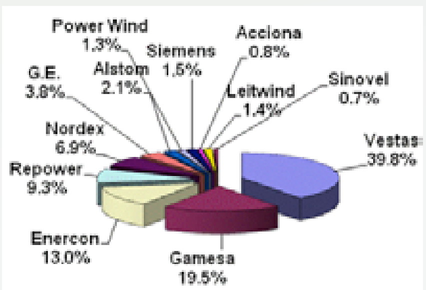

Figure 4. Market shares of wind turbine manufacturers in Italy at the end of 2012 (as percentage of total online capacity)

Leitwind is the only Italian manufacturer of large wind turbines. This company produces turbines in the range 1.5–3 MW in its factories located in Telfs (Austria) and Chennai (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 and offices in Rome. All the other large wind-turbine manufacturers operate in Italy by their commercial offices. The Italian firms have a significant share of the component market for large wind turbines, 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.

The Italian wind energy production market is quite fragmented; the first ten producers hold about 54% of overall installed capacity. The leaders are ERG Renew, ENEL Green Power, and Edison Energie Speciali companies. Other substantial capacity are held by FRI-EL, E.ON, SER, Falck Renewables, Veronagest, Tozzi, IVPC, and Alerion Clean Power.

ANEV is the main association of energy producers and manufacturers in the wind sector in Italy.

In contrast to the large wind turbine sector, Italian firms have a significant presence in the small-sized wind plant market, i.e. market of plants having a capacity up to 200 kW. According to a recent study of the Energy & Strategy Group of the Polytechnic of Milan, there are about 100 companies involved in wind turbines and components manufacturing, half of which are Italian companies. About 50 companies (96% Italian) are in the design, installation and supplying business of small wind energy conversion systems (WECS). Finally, 200 companies, all Italian, produce and sell energy by small WECS.

3.3 Operational details

The 221 new wind turbines installed in 2013 have 2,010 kW of average unit capacity, corresponding to 445 MW of new added capacity. As a consequence, the number of online wind turbines rose to 6,391 having an overall average capacity of 1,320 kW/unit. This corresponds to an overall capacity of 8,554 MW for the national wind system. There are no offshore wind parks in Italy, so all the plants are on land. Hill or mountain sites are typical for Italian wind parks.

The registration and auction procedure for 2014 was completed by GSE in compliance with the 6 July 2012 Implementing Decrees. For the registration procedure, applications totalized 201 MW, exceeding the annual available quota of 60 MW established for 2014. For the auction procedure, onshore applications of 1,086 MW exceeded the quota of 465 MW established for 2014.

Moreover, the first auction procedure according to the new support scheme had a very poor response for offshore applications (only 30 MW was allotted out of an available quota of 650 MW). In the second call for tender (March 2013) there were no offshore applications for the allowable 620 MW, so all this quota will be available in the next auction for 2015.

The average capacity of the new wind parks connected to the grid in 2013 is about 11 MW, and the average number of turbines in a wind parks is six. Among the largest parks built in 2013 are those of Gravina Poggiorsini (72 MW), Deliceto (42 MW), and Matisse (39 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 2013 an average capital cost of 1,750 EUR/kW (2,411 USD/kW) has been estimated. This cost shows a large variability in the Italian context and is about 20% higher than averaged European installation cost. This is because of Italian site characteristics and the extra costs induced by the permitting procedures length and complexity. Two types of wind parks exist in Italy: the first type are installed in plains of southern regions and the second type are built at rather remote hill or mountain sites. The hill sites in general have higher wind regimes, but increased costs for transportation, installation, grid connection, and operation. RSE recently estimated the levelized cost of energy for typical onshore wind parks installed in Italy in the last two years. The levelized cost of energy ranges from 106–159 EUR/MWh (146–219 USD/MWh). The reference value of 127 EUR/MWh (175 USD/MWh) corresponds to 1,750 average annual equivalent hours, close to the capacity factor recorded in 2013.

4.0 R, D&D Activities

4.1 National R, D&D efforts

R, D&D activities are carried out mainly by CNR, ENEA, RSE S.p.A., and universities.

CNR activity in wind energy now involves eight institutes and is in the frame of National and EU FP7 projects. The main topics are the following:

- 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 onshore 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).

ENEA has been working, with its wind tunnel facility on aerodynamic studies of vertical axis wind turbines. Moreover ENEA has been involved in the study and the development of materials for blades and other components of small wind turbines. It has carried out research on joint laminated assemblies, artificially aged, by means of both ultrasonic and mechanical testing in order to evaluate the reliability of the adhesive bonding. Furthermore, it has optimized a process of blade manufacturing that uses commingled thermoplastic structures.

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 million EUR (2.8 million USD) for 2012–2014. Main issues concern resource assessment, wind forecasting, simulation of the dynamical behavior of an offshore floating wind turbine, and social acceptance (Italian Wind Atlas http://atlanteeolico.rse-web.it/viewer.htm).

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 LES modeling and simulation of turbulent flows and wind turbine wakes, off-shore floating wind turbines and their aeroelastic 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 European Energy Research Alliance (EERA) Joint Program on Wind Energy as an associate member.

The Department of Energy of the Polytechnic of Turin has been working on a model of wind energy conversion and on the comparison between statistical data of wind resource and weather forecasts for the prediction of power injection into the grid. The Department of Mechanical Engineering has been working on a floating small wind turbine (3-kW horizontal axis—spar buoy type), that will be installed in Lake Maggiore in June 2014, with the design of the ballasted floating system in all its mechanical components, its instrumentation with dedicated sensors and control drives, the realization of a collective blade pitch control, and the design of the mooring system for a water depth of about 50 m. Behavior of the structure will be monitored for one year to compare and validate the developed mathematical tools.

The Inter-University Research Center on Building Aerodynamics and Wind Engineering (CRIACIV) has focused on the development of accurate simulation tools for large fixed-bottom offshore wind turbines, with particular emphasis to investigate the effects of nonlinear random waves on the dynamic structural response; additional ongoing researches are aimed to the development of a coupled nonlinear dynamic numerical solver for floating offshore wind platforms. CRIACIV established a strong collaboration with CNR-INSEAN and other national and international research institutions. CRIACIV is partner of FP7 EU project MARINET and led two national research projects on wind energy structures.

The ADAG group of Department of Industrial Engineering, University of Naples, has been continually involved in design, development, installation, and field testing of small wind turbines also according to IEC 61400-2 standards. Both vertical and horizontal axis turbines with rated power ranging from 1–60 kW have been designed and tested both at reduced scale in wind tunnel and at full scale in the field. Current research topics include airfoil and blade design, system identification, and performance estimation from field data as well as optimization of 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 the national research project on aerodynamic characterization on vertical axis wind turbines and is part of a FP7 EU project on vertical offshore floating turbines (Deepwind). Dedicated research on wind energy exploitation 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 cooperates 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 in 2013 and they were devoted to definition of guidelines for the design of off-shore wind parks; assessment of the more promising solutions for floating platform design; and design of an 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.

Within the European Energy Research Alliance (EERA), Joint Program on Wind Energy, CNR is a member as full participant and ENEA and Polytechnic of Milan are associated partners. 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

On March 2013 the Ministry of the Economic Development and the Ministry of the Environment and for Territory and Sea Preservation issued the Decree that enforces the National Energy Strategy as the official document that defines the national energy strategy up to 2020. The key elements for RES development and deployment are:

- Overtake of the European 20-20-20 target.
- Increase the role of thermal RES and the economic sustainability of the RES incentive mechanisms, by conforming them to the European standards and progressively driving them to grid parity.
- Preference to RES having the stronger effects on the national economic system.
- Progressive electric market and grid integration as far as electric RES are concerned. In this strategy RES research is addressed on innovative RES (e.g., concentrated solar power and second generation biofuels) in which there is a stronger national position.

Moreover, a recent Government's Decree (13 December 2013) allows renewable energy producers with operating plants to opt for a reduction of incentive tariff against a seven-year extension of the incentive period. This was issued in order to reduce the burden of incentives on the cost of electricity for the final user (an annual cut of about 700 million EUR (965 million USD) was estimated).

Growth in wind capacity is expected to be fully controlled by quotas, resulting in a contraction of the sector in the coming years compared to recent ones. In spite of that, the target of 12 GW of installed capacity on land by 2020 seems to be still achievable.

Opening Photo: Fossa del Lupo wind plant (Source: ERG Renew)

Authors: Giacomo Arsuffi, and Alberto Arena, ENEA C.R. Casaccia; Laura Serri, RSA S.p.A., Italy.

26 Japan

1.0 Overview

In 2013, the total installed wind capacity in Japan reached 2,670 MW with 1,925 turbines, including 49.7 MW from 27 offshore wind turbines (Figure 1). The annual net increase was only 56 MW. Total energy produced from wind turbines during 2013 was about 4 TWh, and this corresponds to 0.5% of national electric demand (846 TWh).

In the aftermath of the earthquake and tsunami of March 2011 and the Fukushima nuclear power plant accident, all 48 of the nuclear reactors were shut down for safety checks against earthquakes. Since then, Japan has seen its energy imports rise and is spending an extra three trillion JPY (20.7 billion EUR; 28.5 billion USD) per year for additional fossil fuel imports. This is neither sustainable for the environment nor for the economy. It has become obvious that a rapid mass introduction of renewable energy is the right solution.

2.0 National Objectives and Progress

2.1 National Targets

Since the Fukushima nuclear power plant accident in 2011, a review of the Basic Energy Plan has been conducted and the Ministry of Economy, Trade and Industry (METI) published the draft Basic Energy Plan in December 2013. In this draft, promotion of renewable energy is reconfirmed as a goal and the cabinet decision on the new Basic Energy Plan will be made early in fiscal year 2014 through a public comment procedure.

The Japan Wind Power Association (JWPA, industry association) is currently working on a new long-term roadmap, revising the present target of 50 GW of wind by 2050. Some of the other key issues the roadmap will be looking to address are: effective use of the feed-in tariff (FIT); finding a solution for grid access; the need for extensive deregulation of the energy-market; and expansion of offshore wind. The roadmap is expected to be finalized by May 2014.

2.2 Progress

Cumulative wind power capacity reached 2,670 MW (1,925 turbines), with 56 MW of annual net increase in 2013. The reason for this year's low annual net increase may be attributed to the enforcement of a strict Environmental Impact Assessment (EIA) law to wind farm projects started in October 2012. This law requires developers of wind power plants that have total capacity of more than 10 MW to implement an EIA of the project. The assessment and approval process takes two to three years, and it causes some delays in wind farm projects in Japan.

Only two wind farms started operations in 2013. Almost half of the new installations (24.4 MW) were offshore wind power. One site of new installations is the Kamisu offshore wind power plant (Figure 2). It survived the devastating earthquake and associated tsunami that struck the wide northeastern region of Japan in 2011. At the Kamisu site, an additional eight Hitachi 2-MW downwind type wind turbines were installed in 2013 near the offshore power plant that already had seven 2-MW wind turbines. The new wind turbines were also installed about 40 m offshore from the shoreline. Another wind farm that started operation last year was installed in the southern area of Japan. Five Enercon 2-MW wind turbines were installed on complex mountainous terrain.

2.3 National incentive programs

In Japan, the incentive program was changed from investment subsidies and Renewable Portfolio Standards to the FIT system starting in July 2012. The first FIT system

Projects with capacity of 174 MW completed the required environmental impact assessment and assessments for projects with 4,700 MW were in progress.

Table 1. Key National Statistics 2013: Japan	
Total installed wind capacity	2,670 MW
New wind capacity installed	56 MW
Total electrical output from wind	***4 TWh***
Wind generation as % of national electric demand	0.5%
Average capacity factor	***17%***
Target:	Not specified
	17% of total energy consumption from RES by 2020
Bold italic indicates estimates	

began in November 2009 and was only for photovoltaics. The new FIT system 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 procurement prices (FIT price) are 22 JPY/kWh (0.152 EUR/kWh; 0.209 USD/kWh) for wind power greater than or equal to 20 kW of capacity and 55 JPY/kWh (0.380 EUR/kWh; 0.523 USD/kWh) for small wind with less than 20 kW of capacity. The above FIT prices do not include the 5% consumption tax. The FIT period is 20 years for wind, including small wind.

2.4 Issues affecting growth

The FIT prices have been revised every fiscal year in consideration of technological innovations and decline in power generation costs. In the next fiscal year, 2014, it is expected that the FIT price for wind will be kept the same as the initial FIT price, because of the small increase of installed capacity since the introduction of FIT system. And the premium FIT price for offshore wind will be set in the next fiscal year 2014 based on the cost estimates of offshore wind in Japan.

Good wind resources are expected in the northern part of Japan such as Hokkaido and Tohoku; however, most of these regions are rural areas with sparse populations. Therefore, electricity demand in these regions is relatively low and the electric grid capacity is limited. In order to promote the introduction of wind power generation, METI has started financial support for the reinforcement of the electric grid in northern Japan. This support program grants a 50% subsidy to develop the grid system in parts of the Hokkaido and Tohoku regions that are suitable for wind power generation but have limited grid capacity. This grid reinforcement will stimulate wind power development in Japan.

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 Machine Industry, 68 companies with 3,300 people were manufacturing wind turbines and their components during fiscal year 2012. Annual sales were estimated at close to 188 billion JPY (1.297 billion EUR; 1.786 billion USD).

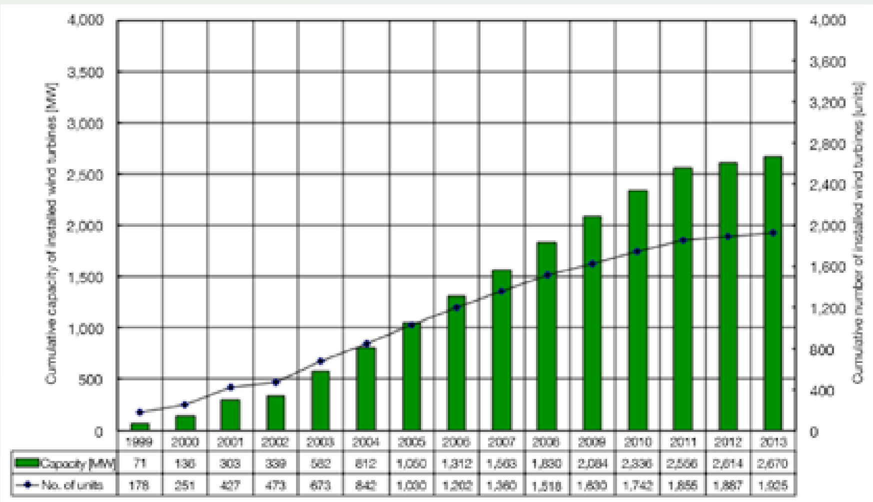

Figure 1. Total installed wind capacity and number of turbine units in Japan

3.2 Industry status

Three Japanese wind turbine manufacturers produce turbines larger than 2 MW: Mitsubishi Heavy Industries (MHI), Japan Steel Works (JSW), and Hitachi. They have kept more than 60% domestic market share for several years. They are developing new wind turbines as shown in Table 2. JSW developed a new 2.7-MW gearless, permanent-magnet, synchronous generator wind turbine, the J100-2.7 (Figure 3). This machine has almost same concept as JSW's existing 2-MW models, JSW70-2.0 and JSW80-2.0. The first machine of the J100-2.7 model began operation in September 2013 in Kitakyusyu. Hitachi developed a new 2-MW, downwind wind turbine, the HTW2.0-86. It is a low-wind-speed version of HTW2.0-80 with

Figure 2. Wind Power Kamisu No. 2 offshore wind power plant in Ibaraki prefecture (Source: Komatsuzaki Urban Development Corporation)

longer rotor blades. The first machine has been installed in Niigata prefecture and will begin operation in early 2014. MHI developed 7-MW offshore wind turbine with hydraulic drive train, and the prototype will start operation in 2014.

Because of the shrinking domestic market, Japanese companies intend to expand their business worldwide by merging or collaborating with foreign companies. Yasukawa Electric Company has signed a cooperation agreement with the Finnish wind-power technology specialist, The Switch Engineering Corporation. The combination of Yasukawa's high voltage technology and The Switch's wind power experience will enable them to produce compact generators for larger wind turbines. And, many Japanese trade companies have started investing in European offshore wind power businesses.

3.3 Operational details

The average capacity of new wind turbines was 1.47 MW in 2013, compared to 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 17% in 2013.

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; 2,850 USD/kW)
- Cost of energy: 11.0 JPY/kWh (0.076 EUR/kWh; 0.105 USD/MWh)
- Operation and maintenance costs: 6,000 JPY/kW/unit/yr (41.4 EUR/kW/unit/yr; 57.0 USD/kW/unit/yr)
- Wind electricity purchase price: 22 JPY/kWh (0.152 EUR/kWh, 0.209 USD/kWh) for wind power greater than or equal to 20 kW of capacity, and 55 JPY/kWh (0.380 EUR/kWh, 0.523 USD/kWh) for small wind less than 20 kW of capacity (see Section 2.3 for details).

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 the Ministry of Environment (MOE) are as follows.

A. NEDO Research and Development of Offshore Wind Power Generation Technology (FY 2008 to FY 2013). In this project, an offshore wind turbine and an offshore measurement platform were planned to be 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. In 2013, a JSW 2-MW gearless offshore wind turbine with the hybrid substructure between gravity and jacket was installed in the Kitakyusyu offshore site. It started operation for demonstration research in June 2013 (Figure 4).

B. MOE Floating Offshore Wind Turbine Demonstration Project (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 1 km offshore in Nagasaki Prefecture, it began operation for demonstration research in October 2013 (Figure 5). At this offshore site, the water depth is about 100 m, and the extreme significant wave height is 7.7 m.

C. METI Floating Offshore Wind Farm Demonstration Project (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. They began operation in November 2013 (opening photo). In Phase 2

Table 2. New wind turbines developed by Japanese manufacturers

Company	Model	Rated output	Prospective start of operation	Type
MHI	MWT167/7.0	7.0 MW	2014	Digital hydraulic drive
Hitachi	HTW5.0-126 HTW2.0-86	5.0 MW 2.0 MW	2014 2014	Downwind Downwind
JSW	J100-2.7	2.7 MW	2013	Gearless PMSG

Figure 3. The new JSW 2.7-MW wind turbine "J100-2.7"

Figure 4. JSW 2-MW wind turbine and offshore measurement platform on the jacket and gravity hybrid foundation in Hibikinada offshore wind power demonstration project (Source: NEDO)

(FY 2014 to 2015) of this project, 7-MW wind turbines with three-column, semi-submersible floaters and advanced spar type floaters will be installed. 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.

D. MOE Environmental Assessment Model Project for Wind Power (FY 2011 to FY 2016)

E. NEDO Advanced Practical Research and Development of Wind Power Generation. In this new national project, R&D on advanced components and maintenance technologies applicable to next-generation large wind turbines began in fiscal year 2013 with the aim of the further reduction of cost of wind energy. They include: E1. Advanced Practical Development of Wind Turbine Component (FY 2013 to FY 2015); E2. R&D of Smart Maintenance Technologies (FY 2013 to FY 2015); and E3. Research on Over 10-MW Class Wind Turbines, (FY 2013 to FY 2014).

4.2 Collaborative research

The Japanese wind power industry and academia started cooperating to solve grid problems.

The Japan Wind Energy Association (JWEA, academic society) has introduced European grid operation experience including "aggregation" to Japan by translating many reports regarding IEA Wind Task 25 into Japanese.

5.0 The Next Term

The strict EIA requirement for large wind projects has slowed the development of wind farms, but this should be temporary. Looking to the near future, five wind farm projects with total capacity of 174 MW have finished the EIA procedure, and the EIA of more than 80 projects with about 4,700 MW are now in progress. This amount is more than 1.5 times larger than the current wind power capacity operating in Japan. It is expected that the Japanese wind power market has bottomed out in 2013, and the annual installation will rise to more than 200 MW in 2014. And, it will grow rapidly after 2016, when projects that are now under assessment clear EIA procedures. Furthermore, MOE and METI have decided to cut the EIA process time in half and have approved new support covering 50% of the pre-EIA assessment with a fund of 2 billion JPY (138 million EUR; 190 million USD).

Opening photo: A Hitachi 2-MW downwind wind turbine with a 4-column semi-submersible floater and a 66-kV floating offshore electrical substation with a measurement platform (Source: METI)

Author: Tetsuya Kogaki, National Institute of Advanced Industrial Science and Technology (AIST), Japan.

Figure 5. Hitachi 2-MW wind turbine with spar type floater in the MOE floating offshore wind turbine demonstration project (Source: MOE)

27 Republic of Korea

1.0 Overview

The cumulative installed wind power in The Republic of Korea was 487 MW in 2012 and 561 MW in 2013, an increase of 15%. Most wind turbine systems installed in 2013 were supplied by local turbine system manufacturers. The renewable portfolio standard (RPS) proposal for new and renewable energy was enacted in 2012 and the required rate of RPS in 2013 was 2.5%; it will increase to 10% by 2022. In 2013, the second year of the RPS, more than 65% of the target rate was achieved.

A nine-year construction plan for a 2.5-GW offshore wind park on the west coast was announced in 2010. The first stage of the project, construction of a 100-MW wind park, is in progress. The RPS as well as construction of a 2.5-GW offshore wind park are expected to accelerate the growth of wind energy in Korea. Since 2009, the government has concentrated on developing local supply of components to secure the supply chain. More of the government's R&D budget is allocated to develop local component supply and 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 that could possibly replace fossil fuels and nuclear power. It is also seen 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. Most major shipbuilding and heavy industry companies have become involved in the renewable energy business, especially wind energy. In 2013, total installed wind power was 561 MW, a 15% growth over 2012.

2.1 National targets

The national target is to promote renewable energy and replace 11% of total energy consumption with renewable energy. Currently, renewable energy production depends mostly on biomass and the Korean government will try to reduce the dependency by focusing on the wind energy and solar PV. Table 3 shows the detailed target of each resource among the whole renewable energy resources.

2.2 Progress

In 2013, 74 MW of wind power were newly installed, increasing total wind power by 15%. The amount of wind capacity installed in 2013 is slightly lower than 2012, but all of the turbine systems were supplied by the domestic manufacturers such as Doosan, Hyundai, and STX. Domestic manufacturers have developed their systems and established a track record of operations. Net sales of the wind energy business in 2013 increased 13% over the previous year to an estimated 1.36 million USD (0.98 million EUR). The net sales were mostly represented by tower and casting components, however production of the casting components is decreasing because the market is competitive.

The first stage of a 2.5-GW offshore wind project is in progress with the construction of a 100-MW offshore wind park.

Table 1. Key National Statistics 2013: Korea	
Total installed wind capacity	561 MW
New wind capacity installed	74 MW
Total electrical output from wind	0.913 TWh
Wind generation as % of national electric demand	0.17%
Target:	2% wind energy by 2035

Table 2. Total Installed Wind Capacity in Korea

Year	~'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	Total
Capacity (MW)	18	50	31	79	18	108	44	33	27	81	74	561
Electrical Output (GWh)	25	47	130	239	376	436	685	817	863	913	-	-

Sales of the turbine systems are steadily increasing. In 2013, the turbine sales increased 70% over the previous year to an estimated 515 million USD (374 million EUR). Table 4 shows the total sales of Korean wind turbine systems.

The number of manufacturers has increased steadily, with 38 companies involved in wind energy in 2012. The number of employees is estimated to be 2,366 in 2013. Restructuring of the wind energy industry is in progress, and many of the casting components companies have changed their business because of the severe competition from Chinese companies. Therefore the employees working on casting components have steadily decreased from 1,163 in 2009 to 347 in 2013. On the other hand, turbine system employment has increased from 236 employees in 2007 to 1,112 in 2013 (Table 5). Most manufacturers are concentrating on developing products and technologies, and the majority of employees are dedicated to R&D rather than production.

2.3 National incentive programs

The government subsidizes the installation of new and renewable energy facilities to enhance deployment and to relieve the end user's burden. The government has specifically focused on 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 the residential area, the government expanded the 100,000 solar-roof program to one million green houses thus diversifying and optimizing home renewable energy use. The target is to construct one million homes equipped with green energy resources by 2020. By the end of 2013, 126,817 homes were equipped with green energy.

• Green 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

Table 3. National Targets of Renewable Energy Resources

Energy Resources (Year)	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 USD; million EUR)	0.19; 0.14	2.4; 1.7	82; 60	212; 154	164; 119	303; 220	515; 374
Growth Rate (%)	-	1,200	3,273	157	-23	85	70

Table 5. Number of Employees in the 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	2,366

10% of total energy with the renewable energy.

• Feed-in Tariff (FIT): The standard price is adjusted annually to reflect changes in the new and renewable energy market and economic feasibility of new and renewable energy. Concerning wind energy, the FIT was 0.10 USD/kWh (0.07 EUR/kWh) as a flat rate for 15 years in 2013. The FIT is being applied to wind parks installed by 2011, while new parks constructed from 2012 on are supported with the RPS.

• RPS: RPS was approved by Congress and 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 parks are 1.0, for offshore parks less than 5 km from shore are 1.5, and for offshore parks more than 5 km from shore are 2.0. About 67% of the yearly target was achieved in 2013, the second year of the RPS.

In addition, Loan & Tax Deduction, Local Government NRE Deployment Program, and others are available as the national incentive programs.

2.4 Issues affecting growth

There are two major issues escalating the growth of wind energy. The first issue is the construction of the 2.5-GW offshore wind park in the west sea. According to the roadmap announced by the government, a 2.5-GW park will be constructed in three stages over nine years, beginning in 2011. For the first four years, 100 MW of wind power will be installed to establish a track record of performance and develop the technology of site design. Then, 400 MW more will be installed to gain operational experience and commercial purposes for the next two years. At the final stage, a 2-GW wind park will be constructed with 5-MW wind turbines for commercial purposes. The total budget is estimated to be 7.5 billion USD (5.5 billion EUR).

The other issue affecting growth is the RPS program that started in 2012. Major electric power suppliers are required to provide some amount of their electric power with renewable energy including wind power and the rate will increase to 10% in 2022. This regulation was expected to encourage power suppliers to invest in wind energy deployment. However, new wind park construction is being hindered by the environment protection law and activities.

3.0 Implementation

3.1 Economic impact

As reported in the *IEA Wind 2012 Annual Report,* major shipbuilding and heavy industry companies have developed their own wind turbines and some companies have established good track records. The net sales of 2013 were less than in 2010 and recorded only 916 million USD (665 million EUR). The export of turbines began in 2009, but the oversea sales have not been large. Even employment in the wind sector has decreased slightly with 2,356 employees recorded in 2013. The overall size of the wind energy industry is very small compared to the entire Korean industry and the impact is still very weak.

3.2 Industry Status

Some manufacturers have expanded their business into other renewable resources such as solar energy, tidal energy, etc. to provide stable renewable energy. However the global economic crisis has clouded the vision of renewable energy and new investment plans are being reviewed seriously. The industry is steadily growing but the rate is very low.

3.3 Operational details

In 2013, 74 MW of wind power were newly installed and most turbines were supplied

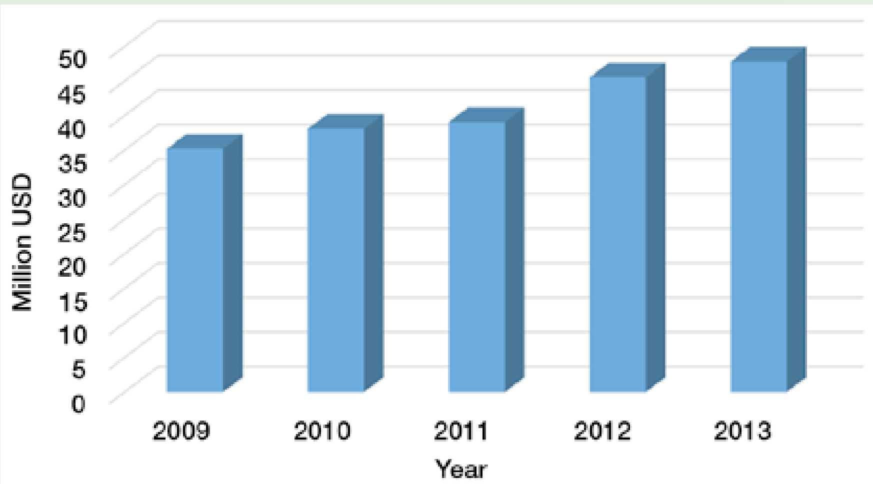

Figure 1. The budget trend of government sponsored R, D&D (million USD)

Table 6. The 2.5-GW Offshore Wind Park Construction Plan			
	Demonstration	Standardization	Deployment
Objective	Test record set up; Establish track record; Site design	Operation experience; Validate commercial operation	Cost effectiveness; GW site development; Commercial operation
Wind Power	100 MW	400 MW	2,000 MW
Schedule	2011–2014 (four years)	2015–2016 (two years)	2017–2019 (three years)

Table 7. Government R&D Budget Allocation 2009–2013 (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%

by domestic manufacturers. Eight units of 2-MW and three units of 3-MW turbines were supplied by Doosan. Hyundai supplied seven units of 2-MW and one unit of 1.65-MW turbines. STX also installed one 2-MW turbine.

3.4 Wind energy costs

Newly installed wind turbines, especially supplied by the domestic manufacturers, are not operated for commercial purposes but for system checks and accumulating performance data. There is not enough electric output recorded and it is still difficult to estimate the real cost of wind energy in Korea.

4.0 R, D&D Activities

4.1 National R, D&D efforts

The government has continuously increased its R&D budget and ensured the progress of the wind energy industry. The government has allocated R&D budget for local development of wind turbines and the government also realized the importance of a stable supply chain. Therefore, the budget to develop the technologies for components has increased, and several government-sponsored R&D projects are under way. More component development projects, as confirmed in Table 7, are launched every year. Table 7 presents the budget and the portion of the turbine system, core component, wind park development, grid connection, etc. among the government R&D budget. The budget for turbine system development has decreased, while wind park development and grid connection research have increased.

5.0 The Next Term

The first stage of the 2.5-GW offshore wind park was initiated in 2011 and the RPS was enacted in 2012. These major issues are expected to encourage electric power suppliers and turbine system manufacturers to plan for profitable wind park construction. Because many wind parks are planned by private companies and provincial governments, it is quite difficult to predict future activities about wind energy in detail.

Opening photo: Gyeongin Arabaetgil wind park, Korea (Source: Korea Energy Information Center)

Authors: Cheolwan Kim, Korea Aerospace Research Institute; Sang-geun Yu, Korea Energy Management Corporation; and Chang-Sun Kim, Korea Institute of Energy Technology Evaluation and Planning, Korea.

28 México

1.0 Overview

During 2013, 426 MW of new wind turbines were commissioned in México, bringing the total wind generation capacity to 1,551 MW. The Law for Renewable Energy Use and Financing of Energy Transition (enacted in November 2008) is successfully achieving its main objectives. Wind energy is now a competitive option within the Mexican electricity market, and the Secretariat of Energy (SENER) issued a Special Program for the Use of Renewable Energy. A 2,000-MW, 400-kV, 300-km electrical transmission line for wind energy projects in the Isthmus of Tehuantepec was commissioned. Presently, the construction of 316 MW of new wind power capacity has been secured. This will bring the total generation capacity to at least 1,867 MW by the end of 2014. It is expected that, public and private companies will be capable of managing appropriately pending social requirements.

The Energy Regulatory Commission has granted permits for a total of 4,999 MW of wind power capacity. Currently, it is estimated that around 12,000 MW of economically-feasible projects could be implemented within the next ten years (by 2024). 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%. The Mexican states of Baja California, Chiapas, Jalisco, Nuevo León, and Tamaulipa are emerging as the next wind energy deployment regions in México.

2.0 National Objectives and Progress

2.1. National targets

It is expected that by the end of 2024 wind energy capacity in México would be around 12,000 MW. Assuming an average capacity factor around 30%, contribution of wind generation to national electric demand would be around 5%.

2.2 Progress

Remarks to Table 2:

- La Venta I, Guerrero Negro, and La Venta II (Figure 2) were first in the implementation of wind energy in México and are owned and operated by the Comisión Federal de Electricidad (CFE).
- Parques Ecológicos was the first privately owned wind energy plant in México (the main investor is Iberdrola Renovables) and is supplying electricity for a number of private companies.
- EURUS is the largest wind power plant in México and is aimed at supplying around 25% of the CEMEX Company's electricity demand.
- La Rumorosa 1 is the first wind energy project for public municipal lighting.
- Certe-IIE is the first Mexican wind turbine test center and was supported by the Global Environment Facility (GEF) by means of the United Nations Development Program (UNDP). It is the first small wind energy power producer in México.

2.2.1 Contribution to electrical demand

During 2013, total electrical output from wind was around 3.9 TWh, which is equivalent to around 1.5% of national electric demand.

2.2.2 Environmental benefits

Reduction of CO_2 emissions due to wind generation for the year 2013 was 2.2 million tons, considering a mitigation rate of 0.58 tons CO_2 per each wind-generated MWh.

2.3 National incentive programs

The Law for the Use of Renewable Energy and Financing of Energy Transition is a sound signal from the government of México regarding both political will and commitment for implementing energy diversification toward sustainable development. The main elements of the strategy in the law include: presenting strategic goals; creating a special program for renewable energy;

A 2,000-MW, 400-kV, 300-km electrical transmission line was commissioned for wind energy projects in the Isthmus of Tehuantepec, where annual capacity factors could reach around 40%.

Table 1. Key National Statistics 2013: México	
Total installed wind capacity	1,551 MW
New wind generation installed	426 MW
Total electrical output from wind	***3.9 TWh***
Wind generation as % of national electric demand	***1.5%***
Average capacity factor	***30%***
Target:	***12,000 MW by 2024***
Bold italic indicates an estimate.	

creating a green fund; providing access to the grid; recognizing external costs; recognizing capacity credit; encouraging technical standards for interconnection and infrastructure for electricity transmission; providing support for industrial development; and providing support for R&D. Some of the regulatory instruments for this law have already been issued while others are still under development. The existing incentives are:

• Model agreement for the interconnection of renewable energy power plants to the national electrical grid (2001), allows administrative interchange of electricity among billing periods
• Accelerated depreciation (up to 100% in one year) (2004)
• Recognition of certain capacity credit for self-supply projects
• Reduced tariffs for electricity transmission

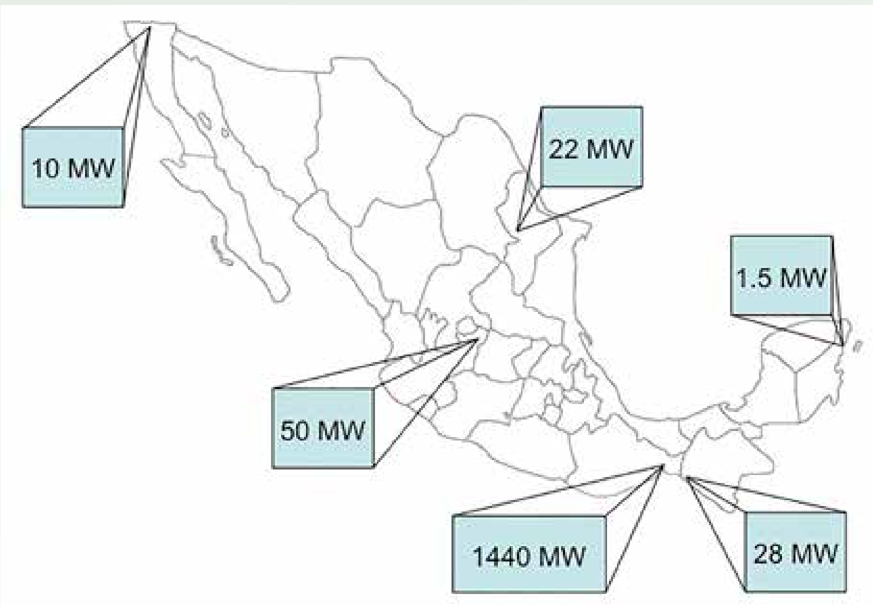

Figure 1. Wind generating capacity installed in México as of December 2013

2.4 Issues affecting growth

There is a critical need to include fitting and fair social benefits to wind landowners (especially to peasants and fishermen) in the negotiation of wind power projects. Planning studies for deploying wind power at the national level have not yet been carried out.

3.0 Implementation

3.1 Economic impact

By the end of 2013, it was estimated that the total investment in the construction of wind power plants was around 2.18 billion EUR (3.0 billion USD). Assuming that around 80% of this amount corresponds to the cost of the wind turbines, the rest, around 435 million EUR (600 million USD) could be considered as the economic distribution to México. Nevertheless, a substantial portion of the work is carried out by foreign employees.

3.2 Industry status

At present there are more than 1,050 wind turbines installed in México. The Spanish wind turbine manufactures Acciona Windpower and Gamesa Eólica are leading the Mexican wind turbine market, but nowadays other companies like Vestas and

Table 2. Progress on wind generation capacity in México (wind power plants in operation)							
Wind power station	Number of Wind Turbines	Wind Turbine Size (kW)	Turbine Manufacturer	Station capacity (MW)	Owner type (1)	Year in service (2)	State
La Venta I	6	225	Vestas	0.9	FGOB	1994	OAX
Guerrero Negro	1	600	Gamesa	0.6	FGOB	1998	BCS
La Venta II	98	850	Gamesa	83.3	FGOB	2007	OAX
Parques Ecológicos	93	850	Gamesa	101.9	POSS	2009	OAX
EURUS	167	1,500	Acciona	250	POSS	2009	OAX
Bii Nee Stipa	31	850	Gamesa	26.3	POSS	2010	OAX
Certe-IIE (F1)	1	300	Komai	0.3	I+D	2010	OAX
E. Valle de México	27	2,500	Clipper	67.5	POSS	2010	OAX
Mexicali	5	2,000	Gamesa	10.0	SGOB	2010	BC
Fuerza Eólica	20	2,500	Clipper	80.0	POSS	2011	OAX
La Venta III	121	850	Gamesa	102.9	IPP	2012	OAX
Oaxaca I	51	2,000	Vestas	102.0	IPP	2012	OAX
Oaxaca II	68	1,500	Acciona	102.0	IPP	2012	OAX
Oaxaca III	68	1,500	Acciona	102.0	IPP	2012	OAX
Oaxaca IV	68	1,599	Acciona	102.0	IPP	2012	OAX
Stipa Nayaa	37	850 & 2,000	Gamesa	74.0	POSS	2012	OAX
Eólica de Arriaga	14	2,000	Vestas	28.0	POSS	2012	OAX
DEMSA (F1)	45	2,000	Gamesa	90.0	POSS	2013	OAX
Eoliatec Istmo	82	2,000	Gamesa	164.0	POSS	2013	OAX
Eólica Zopiloapan	35	2,000	Gamesa	70.0	POSS	2013	OAX
Eólica Santa Catarina	8	1,500	GE	22.0	POSS	2013	NL
Eólica Los Altos	25	2,000	Gamesa	50.0	POSS	2013	JAL
Accumulated	1071	-	-	1,551			
(1) FGOB=Federal Government, SGOB= State Government, POSS= Private owned self-supply, IPP= Independent Power Producer, I+D= Research and Development							
(2) Commissioning year							

Alstom have been awarded important contracts. GE has started activity by installing eight wind turbines.

Several types of developers have emerged. CEMEX, a global leader in the building materials industry, is playing the main role regarding investment in wind energy projects for self-supply purposes. Iberdrola is playing the main role in implementing wind energy projects for sharing electricity with both big- and medium-sized electricity consumers under the creation of self-supply consortiums. With the support of the federal government, the government of the state of Baja California implemented a 10-MW wind energy project for public municipal lighting. This project was commissioned during 2010.

More than 200 Mexican companies have the capacity to manufacture some parts required for wind turbines and wind power plants. Trinity Industries de México, S. de R.L. de C.V. is manufacturing towers for a number of wind turbine companies. The Mexican firm Potencia Industrial S.A. de C.V. was manufacturing permanent-magnet electric generators for Clipper Windpower. The country also has excellent technical expertise in civil, mechanical, and electrical engineering that could be tapped for plant design and construction. The law for renewable energy instructs the SENER and the Secretary of Economy to promote manufacturing of wind turbines in México.

3.3 Operational details

Operational details for each of the wind power stations are not available to the public. In general terms, one can say that wind turbine manufactures are learning to deal with the outstanding wind regime and particular conditions of the Isthmus of Tehuantepec. Some of them have had serious problems. As is happening in many parts of the world, some investors are worried because there is

Figure 2. La Venta II 83.3-MW wind farm in the Isthmus of Tehuantepec, México

too much uncertainty how much post-warranty maintenance is going to cost.

3.4 Wind energy costs

Investment cost for installed wind energy projects in the Isthmus of Tehuantepec are around 1,450 EUR/kW (2,000 USD/kW). In that region, the buy-back price for independent power producer (IPP) generators is around 0.049 EUR/kWh (0.065 USD/kWh), depending of the project.

4.0 R, D&D Activities

4.1 National R, D&D efforts

The Sustainable Energy Fund created by the 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 will start operations in June 2014, developing 13 projects that will be carried out during the next four years. More institutions and private companies are willing to play a part in the CEMIE-Eólico, therefore it is expected that in the short term synergy and collaboration is achieved both at the national and the international level.

The Wind Turbine Test Center (CERTE) sponsored by GEF by means of the UNDP will be part of the CEMIE-Eólico. The CERTE started operations in 2010, some of the products of the R&D projects that will be carried out within the CEMIE-Eólico will be tested in the CERTE. The GEF is also co-financing one of the projects of the CEMIE-Eólico by means of the Inter-American Development Bank (IDB).

4.2 Collaborative research

The IIE participates in IEA Wind Task 11 Base Technology Information Exchange. It is expected that during 2014 México will become a member of IEA Wind Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power.

5.0 The Next Term

Presently, the construction of 316 MW of new wind power capacity has been secured. This will bring the total generation capacity to at least 1,867 MW by the end of 2014. It is expected that public and private companies will be capable of appropriately managing pending social requirements. If social requirements are addressed, more wind power capacity could be installed during 2014 exceeding 2,000 MW.

Opening photo: Eurus wind farm

Author: Marco A. Borja, Instituto de Investigaciones Eléctricas (IIE), México.

Figure 3. The Wind Turbine Test Center operated by the Instituto de Investigaciones Eléctricas

29 the Netherlands

1.0 Overview

The Netherlands had a net installation of 281 MW of wind power in 2013. There is a clear tendency toward replacing smaller wind turbines (around 1 MW) with larger ones (around 3 MW). The biggest change in energy policy in 2013 came from the Social and Economic Council of the Netherlands (SER), which redefined energy targets (somewhat lower) in 2020 (and 2023) but provided a clear roadmap on how to reach those targets, including agreements on necessary incentive subsidies. The total investment in wind energy installations built up to 2013 is estimated at approximately 4.5 billion EUR (6.2 billion USD) (price level: 2013). After some years of low activity, Dutch turbine manufactures are gradually coming back into the market. The capacity factor on-land in 2013 was 22%, near the last 10-year average of 21.4%. This indicates that, despite the windex of 91%, average turbines on land are currently performing better than before. Offshore, the capacity factor in 2013 was 38.6%. In the seven years of offshore experience, the average capacity factor was 37.8%.

2.0 National Objectives and Progress

2.1 National targets

In the Netherlands, 2013 was the first full year under the administration of the left-right cabinet Rutte II. The biggest change in energy policy in 2013 came from an initiative from the Social and Economic Council of the Netherlands (SER)—an advisory and consultative body of employers' representatives, union representatives, and independent experts—that led to a nation-wide energy agreement in September 2013. The “SER Agreement” redefines energy targets in 2020 (and 2023) but, more importantly, it gives a clear roadmap on how to reach those targets, including agreements on necessary incentive subsidies. The parties to the SER Agreement will strive to achieve the following objectives:

• An annual average savings in final energy consumption of 1.5%, which 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 jobs, a large proportion of which will be created in the next few years.

In short, for renewable energy it means target reduction to 14% renewable energy in 2020 (the 2020 objectives in the last decade were: 14%, 16%, and 20%) and 16% renewable energy in 2023. But the main gain is the clear, and nation-wide agreed setting of the interim targets and an action plan including moments of feedback and correction.

The 228 MW of offshore capacity already installed and the planned installation of approximately 745 MW (total: ~1,000 MW) will add up to a total installed offshore wind capacity of ± 4,450 MW by 2023. For offshore wind energy the targets are now defined as in Table 2.

In addition to the SER Agreement, earlier in 2013 an agreement between the

Despite the windex of 91%, average turbines on land are currently performing better than in prior years.

Table 1. Key National Statistics 2013: the Netherlands

Total installed wind capacity	2,709 MW
New wind capacity installed	303 MW
Total electrical output from wind	5.6 TWh
Wind generation as % of national electric demand	4.7%
Average national capacity factor	24%
Target:	14% renewable energy in 2020

national government and the provinces was reached to have 6,000 MW of land-based wind power installed by 2020. This target has been endorsed in the SER Agreement, but the SER Agreement does not give intermediate targets for land-based wind energy. 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. Project developers will be obliged by law to maximize acceptance. Having the possibility for citizens to participate financially in projects is one of the tools. Furthermore multifunctional spatial use has to be forced, for example adding wind energy along dikes and dams and near sluices.

2.2 Progress

The Netherlands has a net installation of 281 MW. This value consists of a gross installation of 111 wind turbines (303 MW), while 20 wind turbines (22 MW) have been dismantled. This shows there is a clear tendency toward smaller wind turbines (around 1 MW) being replaced by larger ones (around 3 MW). All changes happened on land, while offshore remained unchanged at 228 MW. Currently, the main projects are project "Princess Alexia" (Zuidlob) consisting of 36 Repower turbines of 3.4 MW (122 MW total) and project "Kreekraksluis" consisting of 31 Nordex turbines of 2.5 MW (77.5 MW total).

Table 2. Additional Offshore Wind Energy Targets Defined in the SER Agreement

Call for tender	Offshore additional wind power	Operational by
2015	450 MW	2019
2016	600 MW	2020
2017	700 MW	2021
2018	800 MW	2022
2019	900 MW	2023
Total	**3,450 MW**	

2.3 National incentive programs

In 2011, the system of SDE+ subsidy was introduced, and in 2013 this whole system has 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 basis price is the final price which the applicant 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 the SDE+ is that every technique has its own maximum allowed basis tariff. SDE+ can be applied more or less throughout the year (April–December) and the earlier in the year applications are done, the lower the basis tariffs for the projects will be, meaning a lower SDE+ subsidy. The purpose of this system is that the cheapest option will be granted first.

A simplified example is presented here for clarification. Photovoltaics (PV) can be submitted for a basic tariff of 150 EUR/MWh (207 USD/MWh) in November or later, but earlier for a lower tariff. Wind onshore can be submitted for 96 EUR/MWh (132 USD/MWh) in September or later, but earlier for a lower tariff. Hydropower (renovation) can be submitted for 70 EUR/MWh (96 USD/MWh) in April, the opening of the SDE, or later. This will lead to the situation that in principle the cheapest option (hydro power) will take first from the total SDE+ budget, but it also gives opportunities for wind or PV developers to apply to the April-subcall, as long as they submit for 70 EUR/MWh (96 USD/MWh): a much lower tariff than their maximum.

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. Further fine-tuning was done by splitting up in six sub-calls (70, 80, 90, 110, 130, and 150 EUR/MWh or equivalent in gigajoules (GJ) or equivalent in nm^3 natural gas (96, 110, 124, 152, 179, and 207 USD/MWh or GJ, nm^3 equivalent), each closing one or two months after the previous one has closed. Also, new renewable energy categories have been defined. Onshore wind for example has been split up in two categories: <6 MW and ≥ 6 MW turbine size. They are limited to maximum full-load hours of 2,200 and 3,000 hours per year respectively. In total, an SDE+ budget was available of 3.0 billion EUR (4.1 billion USD).

2.4 Issues affecting growth

The SDE+ incentive program explained above made it difficult for wind energy to receive subsidies in the first years of the SDE+ because there were many renewable energy projects applying for a lower basic tariff than the basic tariffs of the cheapest wind energy projects. Even in 2012, only 2.0 million EUR (2.8 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 2013 onshore wind energy received approximately one-fifth of the SDE+ budget.

Although from a financial point of view there are good reasons 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 going on to correlate this limit to the size of the swept area rather than to the size of the generator.

With a characteristic price of around 150 EUR/MWh (207 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. In the future, special tenders for offshore wind SDE+ are being considered.

The availability of good wind locations also affects growth. General policy for wind on land is to shift from stand-alone turbines to wind farms. Many provinces simply forbid the installation of stand-alone turbines and even forbid upgrading existing ones. Due to the high population density, space for wind farms is limited. For offshore wind, lack of appropriate space is an important issue as well.

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 becoming 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.

Finally, the lack of harmonization of national and regional policies affects growth. This can result, for example, in difficulties in obtaining SDE+ benefits. SDE+ applications can only be submitted after regional permissions, like environmental permission and construction permits, are obtained.

Obtaining these permits costs around 0.5% of the whole project, which is a high barrier for project developers to spend when the SDE+ allowance to make a project profitable is far from certain.

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 the permissions. This regulation coordinates and shortens procedures and is meant to speed up employment.

3.0 Implementation

3.1 Economic impact

The total investment in wind energy installations in the Netherlands for 2013 can be estimated at 409 million EUR (564 million USD), assuming an average investment cost for land-based wind of 1,350 EUR/kW (1,860 USD/kW) for the 303 MW gross installed. The total investment in wind energy installations built up to 2013 is estimated at approximately 4.5 billion EUR (6.2 billion USD) (price level: 2013). In 2011, a report about the economic impact of the offshore wind sector was published. This was the result of extensive research at 112 companies. Based on the research, the employment of the sector was estimated at 1,800 full-time employees, but likely could be as high as 2,200 full-time employees. Regarding employment, 74% are in construction, 12% in O&M, 11% in R&D, and 3% in project development. In construction, seven companies in the construction sector generate two-thirds of the employment in the wind at sea sector. The turnover of the offshore wind sector is estimated at a minimum of 997 million EUR (1.3 billion USD), but it is very likely that the real turnover is much more than 1 billion EUR (1.4 billion USD). The report is currently being updated.

3.2 Industry status

After some years of near absence, Dutch turbine manufactures are gradually coming back. The Lagerweij 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 and 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.

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 United Kingdom 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 sold its first ten XD115/5-MW offshore turbines in 2013. Most of the turbines will be installed in the German part of the North Sea (Albatros I). Darwind will be the main implementation company providing customer service, installation, and repair. The XD115 is currently the world's first direct-drive, permanent-magnet, megawatt-scale offshore wind turbine.

Besides these turbine manufactures, many supply companies or companies delivering transport, installation services, or knowledge services (controlling, aerodynamics, strength calculations, etc.) are present in the Netherlands. The large companies include Ballast Nedam, Smulders, and VanOord. 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 it is difficult to compare from year to year and has long-term varition, the 2013 windex was 91%. Only four months had a windex >100% (113, 116, 121, 161%), and four months had a windex <80% (35, 47, 64, 77%). Given these facts, the capacity factor on-land in 2013 was 22%. This is more or less around the last 10-year average capacity factor of 21.4%. This indicates that, despite the windex of 91%, average turbines on land are currently performing better than before. Key factors to this are the increased average hub height and the increased swept area/power ratio. Offshore, the capacity factor in 2013 was 38.6%. Since the first offshore wind farm became operational in 2007, only seven years of offshore statistics are available. In these seven years, the average capacity factor was 37.8%.

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, a new wind category has been defined in 2012 in the SDE+ systematics: wind in lakes (the IJsselmeer was a sea until 1932 and covers 1,100 km^2 with a maximum depth of 9 m). Besides that, the onshore wind category is split up in the categories <6 MW and ≥ 6 MW. Onshore wind cannot receive more subsidy than 93 EUR/MWh (128 USD/MWh) for ≥ 6MW or 95 EUR/MWh (131 USD/MWh) for <6 MW. Offshore wind cannot receive more subsidy than 150 EUR/MWh (207 USD/MWh). Wind in lakes is in between and cannot receive more subsidy than 122 EUR/MWh (168 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 Topconsortia for Knowledge and Innovation (TKI) Wind Offshore. TKI 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 politics and governmental organizations. Furthermore, the intention is to have a 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 to 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. Besides this, TKI can receive a bonus subsidy depending on the extent the industrial sector and the R&D institutes are cooperating.

In 2013, the total R&D budget (subsidies) was around 10.8 million EUR (14.8 million USD). On average, the projects were subsidized at a rate of 73%, because most of the awarded projects have a fundamental research or industrial research profile. The government is trying to reduce this percentage to approximately 50%.

The R&D vision describes the need for support in the field of six themes: supporting structures, wind turbines and wind power plants, internal grid and connection to the high-voltage grid, transport installation and logistics, operation and maintenance, and wind farm development. Under the R&D tender, in 2013, five projects were granted:

- High Yield, Low Loads, Enlarged Rotor (HYLLER): a project in which a new rotor blade concept will be designed and validated: the blade consists of a root and a chosen, mounted extension. For different wind regimes different extensions can be mounted, introducing a simple solution for the need to have variable blade lengths for given wind turbine platforms (Figure 1).
- HiLo Pile Driving: a project to measure the pile stresses and accelerations at the pile top during hammering, together with a very accurate measurement of the pile penetration and hammer performance. Furthermore, a model is developed to determine the consumed life-time during piling based on global piling parameters. This will give insight into a more gentle way of hammering, introducing less fatigue and deformation in the foundation of large offshore wind farms and reducing emitted noise.
- Efficient Support Structure Design through Improved Dynamic Soil Structure Interaction Modelling: a project to increase the knowledge of the dynamics of the soil and the interaction with the support structure. This will be done by measuring dynamic soil behavior, modelling soil behavior, and calculating the impact on (the design of) support structures. Since this all leads to reduction of uncertainties in the interaction between soil and support structure, it results in less need for over dimensioning and through that reduced cost of energy (Figure 2).
- Micromechanics based modeling and condition monitoring of rotor blade: a project aiming at improving the knowledge and understanding of the behavior of composites through mechanical modelling of the composites' microstructure. Also the project aims to develop techniques to measure the condition of rotor blade laminates based on the actual state of the microstructure, making it possible to provide early warning of degradation.
- Design for Reliable Power Performance: a project consisting of subprojects including: improving the availability modular electrical generator systems that are fault tolerant, re-configurable, and self-healing; reducing uncertainty in aerodynamic performance and the reliance on failure-prone features; development of probabilistic structural design techniques; development of self-adaptive control algorithms dealing with variable environmental conditions; and planning maintenance by bridging the gap between existing condition monitoring and fault tolerant control schemes.

More than a dozen strategic projects have started. Subjects of research include projects like standards for offshore wind, cost modeling, options of financing offshore wind, supply chain gap analysis, bottlenecks in permitting, and also some more coordinating projects.

Projects awarded in 2012 under the TKI flag and already underway are:

- Investigation of connecting an offshore wind farm directly to an interconnector through the North sea

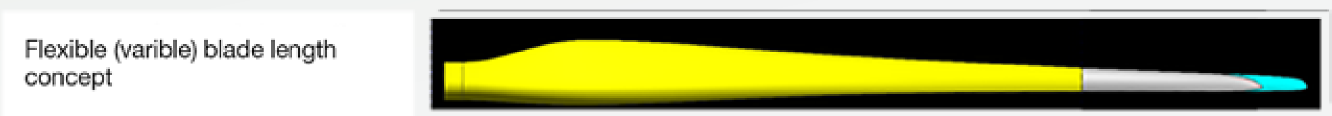

Figure 1. A new rotor blade concept developed by LM, consisting of a root and an extension of choice for variable blade length

Figure 2. Equipment used for soil research to determine the interaction between soil and support structure and foundation

• Development of the technique of driving monopiles (BLUE Piling) using explosives at the bottom of a pile filled with water
• Development of a motion-compensated crane for transferring people and goods up to 5 metric tons
• Modeling the dynamics of extreme wave events
• Efficiency improvements of lidar
• Fatigue modelling for metal, leading to mass reduction and extended inspections intervals.

Besides this new budget for TKI, old budgets from previous R&D programs are being used. The main subjects are:
• projects on wind turbine development (XEMC Darwind (5-MW offshore), 2B Energy (6-MW offshore)
• research projects on porous turbine blades and/or blades with air inlets leading to better aerodynamic performances (ActiFlow) and on vortex generators (CortEnergy)
• projects on controller development (e.g. fault tolerant control, extreme event control, non-linear predictive control, etc.).

Finally, the extended Far and Large Offshore Wind energy (FLOW) program with an expected 47 million EUR (65 million USD) in project costs is fully operational. In FLOW, 13 parties are involved (industry and utilities) working on approximately 55 projects. The main themes here are: wind farm design (projects on cost calculation, wind farm wake modelling, and wind farm controls), support structures (projects on monopiles for depth of 50 m, development of design tools for support structures, scour protection study, designing of slip joints, study of concrete gravity bases substructures), peripheral infrastructure (designing optimal infrastructure for XEMC and 2BE, regulatory aspects of integration of large offshore wind farms and interconnectors), turbine concepts (developing controlling concepts, control design tool for 2-bladed turbines, smart turbine, upgrade of 2B energy concept to 140-m rotor and IPC), and societal aspects (such as cost assessment).

Especially interesting projects awarded in 2013 are projects on optimizing wind turbine (blade) installation (Figure 3), optimizing cable installation, design of a full-scale concrete monopile, the application of free hanging cables inside a monopile, development of a met ocean buoy with lidar (Figure 4).

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 may include new Tasks under formulation (Task 30, 31, and 34). Participation in the IEA Wind tasks has proven to be a cost-effective way to conduct research. On average, 1 EUR (1.38 USD) spent in the Netherlands on research gives access to a value of 5 EUR (6.89 USD) of research spent in the other participating countries.

Figure 3. Art impression of the boom based blade manipulator, being designed and developed under the FLOW program

Figure 4. The Met Ocean Buoy with lidar being developed under the FLOW program

5.0 The Next Term

5.1 Innovation Contract/TKI

In 2014, continuation of the work under the guidance of TKI 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 the cost of energy and the economic impact on society.

5.2 SDE+ in 2014

The SDE+ 2014 will not be very much different from the 2013 system, but the budget will increase to 3.5 billion EUR (4.8 billion USD). Since there is an extra category of 0.08 EUR/kWh (0.11 USD/kWh) and applications on geothermal (which claimed a big part of the budget in the past) are limited, projects now can apply for basic tariffs up to 123 EUR/MWh (170 USD/MWh). Since the "low hanging fruit already has been picked," it is expected that there will be more budget left for higher-tariff categories than in previous years. This should make successful application of onshore wind projects again more likely than in previous years.

5.3 Projects

The construction of project Noordoostpolder (458 MW) will continue in 2014. This project will consist of 38 land-based, 7.5-MW turbines and 48 offshore, 3.6-MW turbines in Lake IJsselmeer. The pile driving for the third Dutch offshore project Luchterduinen (old name: Q10) is expected to happen in 2014. This park will consist of 43 turbines, with a total capacity of 129 MW.

References:

Opening photo: An image taken during rush hour along the track Utrecht-Den Haag, showing that wind turbines are becoming a phenomenon of daily life. (Credit: André T. de Boer)

(1) www.rvo.nl/onderwerpen/duurzaam-ondernemen/duurzame-energie-opwekken (Dutch)

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Author: André T. de Boer, Rijksdienst Voor Ondernemend Nederland, (Netherlands Enterprise Agency (previously: NL Agency), The Netherlands.

30 Norway

1.0 Overview

In 2013, 97.5 MW of new wind power capacity was installed in Norway. Total installed capacity was 811 MW at the end of the year and production of wind power in 2013 was 1,898 GWh, compared to 1,569 GWh in 2012. The calculated wind index for Norwegian wind parks in 2013 was 100%, corresponding to a production index of 101%. The average capacity factor for Norwegian wind parks in normal operation was 29.2%. Wind generation amounted to 1.4% of the total electric production in the country.

Electric energy in Norway is generated using a very high share of renewable energy. The primary source of electricity is hydropower, which in 2013 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 2013 are shown in Table 1 and Figure 1.

2.0 National Objectives and Progress

2.1 National targets

Renewable sources of electricity amounted to 97.5% of the national electricity production in Norway in 2013. Wind power supplied 1.4% of the electricity production. Two thousand thirteen was a near-average year for both wind- and hydropower production in Norway and the total electricity production for the year was 134.2 TWh. With electricity consumption in the country totaling 129.2 TWh for the year, this meant a net electricity export of 5 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, 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. The objective of this policy is rather to allow the market to dictate what type 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

In Norway, the average wind plant capacity factor was 29.2%, and the average technical availability was 96.3%.

Table 1. Key Statistics 2013: Norway	
Total installed wind capacity	811 MW
New wind capacity installed	97.5 MW
Total electrical output from wind	1.9 TWh
Average capacity factor	29.2%
Wind generation as % of national electric demand	1.4%
Target:	EU target of 67.5% energy from RES

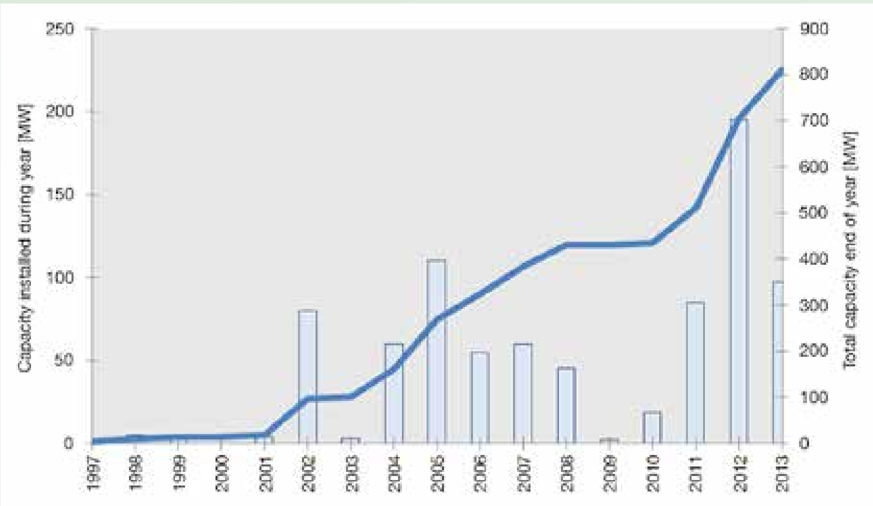

Figure 1. Installed wind capacity in Norway 1997–2013

Norwegian wind park participating in the scheme is phase II of Midtfjellet Wind Farm.

2.3 National incentive programs

From 2001–2010 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 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

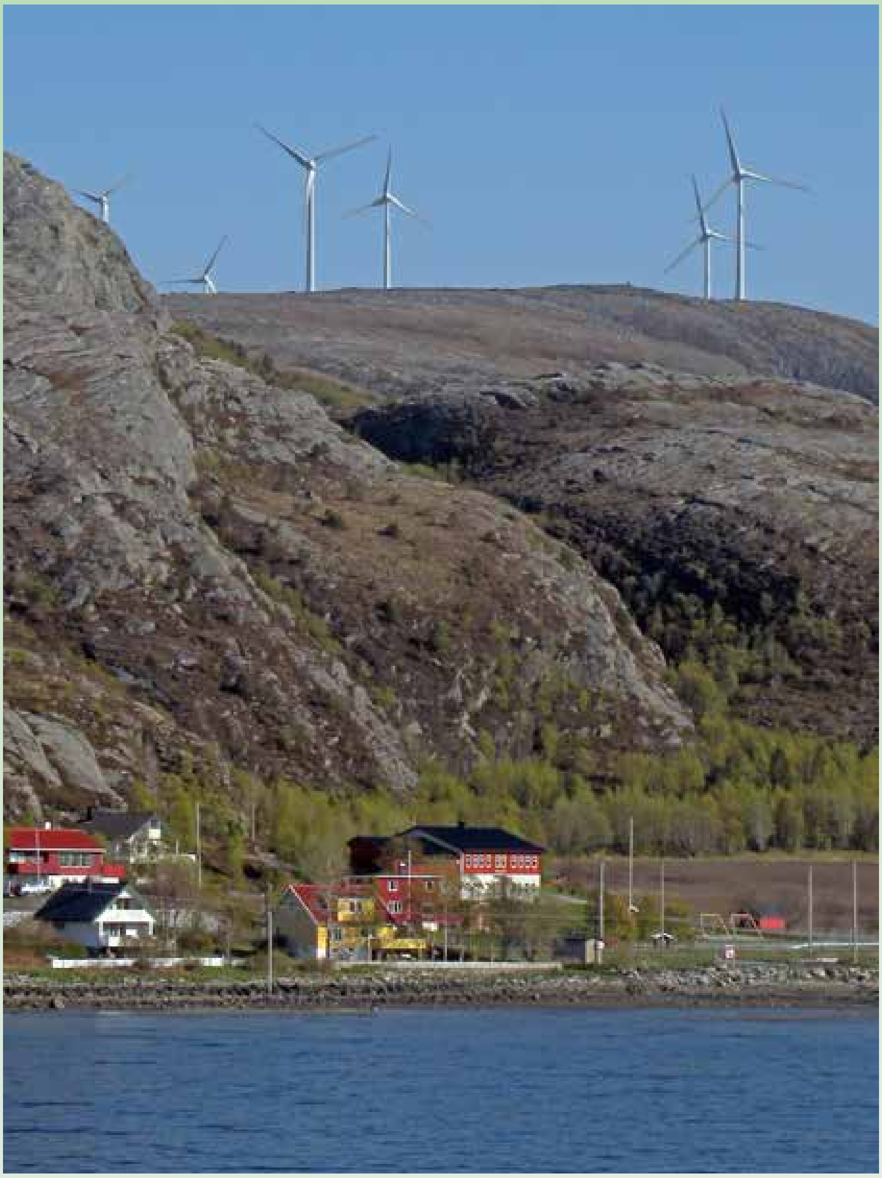

Figure 2. Norwegian Wind Farm on the coast of the North Sea (Photo Credit: PWT Communications)

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 parks 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 2013, the capacity factor of wind parks in normal operation varied between 17–41%. The average capacity factor was 29.2%, and the average technical availability was 96.3%. The technical availability of new wind turbines in Norway is usually in the range of 95–99%. Annual energy per swept area ranged from 622–1,873 kWh/m^2, with a national average of 1,158 kWh/m^2.

3.4 Wind energy costs

The total wind park installation costs reported between 2012 and 2013 vary between 10.5–13.5 million NOK/MW (1.3–1.6 million EUR/MW; 1.7–2.2 million USD/MW). Annual maintenance is reported to be between 0.12–0.16 NOK/kWh (0.014–0.019 EUR/kWh; 0.020–0.026 USD/kWh), with an average cost of 0.15 NOK/kWh (0.018 EUR/kWh; 0.025 USD/kWh). Estimates of production costs from sites with good wind conditions (33% capacity factor) suggest a production cost of about 500 NOK/MWh (60 EUR/MWh; 83 USD/MWh), including capital costs (discount rate 6.5%, 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 system, and sustainable transport (hydrogen, fuel cells, biofuels and batteries). Industry, research institutes, and universities may receive funding for their research based upon proposals in response to regular calls. The budget for 2013 was 385 million NOK (46 million EUR; 63 million USD). In total the Research Council granted 110 million NOK (13 million EUR; 18 million USD) to wind energy research in 2013. In December 2013, the following wind energy R&D projects were approved for funding:

- Crane-free foundation for offshore wind, SEATOWER AS
- Kongsberg on-line Wake model, KONGSBERG MARITIME AS
- Sensors for monitoring of wind turbine blades, KONGSBERG MARITIME AS

In total, 14 R&D projects are funded by ENERGIX, and 32 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 environmentally friendly technology. Wind energy is included in this definition. Projects are supported with up to 45% of eligible costs.

4.2 Collaborative research

In 2013, Norway participated in the following 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 26 The 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 Continuation (OC4); Task 31 WAKEBENCH: Benchmarking Wind Farm Flow Models, Task 32 Wind 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 parks in Norway by large international companies. As of late 2013, one wind park was under construction.

References:

Opening photo: Midtfjellet Wind Farm (Source: Stein Erik Gilje)

Authors: Harald Rikheim, Norwegian Research Council and David E. Weir, Norwegian Water Resources and Energy Directorate, Norway.

31 Portugal

1.0 Overview

Within a sustainable development framework, wind energy in Portugal during 2013 continued the trend of the previous years and increased its influence in the Portuguese electricity system. This influence was felt in several ways. Portugal added 192 MW of installed wind power capacity and reached 4,709 MW of wind generation. This represents 23% of renewable energy capacity in the country. With this amount of wind capacity, 11.9 TWh was supplied to the electricity system during the year (1), (2). These increases resulted in a wind power penetration rate of 24% in electricity consumption, rising 4% compared to 2012. The high value of wind penetration was influenced by the especially favorable wind conditions observed in mountain areas where the majority of the installed wind capacity is concentrated. It is important to notice that this amount of penetration is only exceeded worldwide by Denmark.

The generation of electricity from renewable energy sources was 57% of the national consumption (which is a new record in Portugal). The individual renewable contribution in Portugal was different from last year. After an atypical year in hydro power production in 2012 (due to the fifth driest year of the last 80 years), the contribution of this renewable energy source grew 17% during 2013 reaching 27 % of electrical demand. Due to this increase, wind energy decreased 12% in its share within the renewable energy production (3). The high contribution from the endogenous resources enabled Portugal to reduce to 6% dependency on foreign energy in meeting consumption after reaching as high as 16% in 2012 (1).

Total electricity consumption in 2013 was 50.6 TWh, which corresponds to a slight increase of 3% compared to 2012 (1), (2). Despite the economic recession that continues in the country and the energy efficiency measures that were implemented in the last years, this small increase reverses the downward trend observed in the last few years.

In 2013, the Portuguese government approved a new National Renewable Energy Action Plan (NREAP). Compared to the previous NREAP 2010, the 2013 NREAP reduced the wind power capacity targets to 5,300 MW compared to the previous 6,875 MW (4).

2.0 National Objectives and Progress

2.1 National targets

During April 2013, the capacity targets for supporting renewable energy systems were modified by the former government through the NREAP 2013–2020 (4). The new targets were amended by taking into consideration the current excess supply of electricity production due to a reduction in demand, and the economic context. Regarding wind power, this action plan sets the need to reach an installed minimum capacity of 5,300 MW by 2020 instead of the previous 6,875 MW. This new value is divided into 5,273 MW installed onshore (with 400 MW corresponded to expanding the capacity of current wind parks—"overcapacity") and 27 MW offshore.

2.2 Progress

During 2013, a net capacity of 192 MW was added, which represents an installed capacity growth rate of 4% above the previous year. From this value, 10.3 MW is

One day in 2013, wind energy reached 90% instantaneous penetration and supplied 69% of the day's electrical consumption...During these events, the TSO reported no technical problems.

Table 1. Key National Statistics 2013: Portugal	
Total installed wind capacity	4,709 MW
New wind capacity installed	192 MW
Total electrical output from wind	11.9 TWh
Wind generation as % of national electric demand	24%
Average national capacity factor	29%
Target:	Onshore: 5,273 MW Offshore: 27 MW by 2020

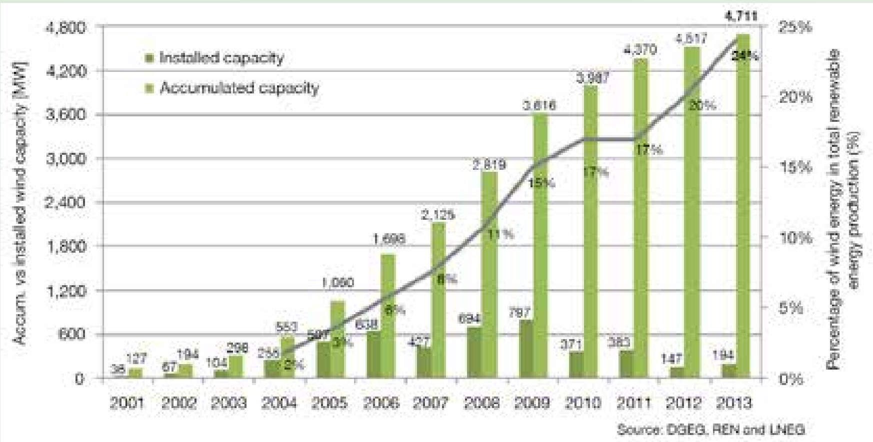

Figure 1. Installed versus accumulated wind capacity (bar graph) and percentage of wind energy production (line graph)

related to the Azores archipelago, and in Madeira Island 0.9 MW was decommissioned (2), (3).

As shown in Figure 1, the added capacity is in line with the year of 2012 demonstrating an onshore wind capacity saturation tendency. Compared with the previous ten years, this value was the second lowest since 2004, when the strongest wind deployment began. The cumulative installed capacity up to 2013 is distributed over 247 wind farms with 2,739 wind turbines operating across the country (mainland and islands), one of them being a floating offshore wind turbine (2), (3).

The Portuguese wind capacity generated in 2013 was 11.9 GWh and corresponded to 24% of the electricity demand. Wind's share of total renewable production was 39%, a decrease of 12% compared to 2012. This reduction was the result of a 17% increase in hydro production over 2012. For the same reason, the remaining mix of renewable sources also reduced their share with the biomass sector representing 10.4% and PV representing 1.5% (2).

In 2013, the average production at full capacity was 2,529 hours at the continental wind parks, which corresponds to a 9% increase with respect to the same period of 2012 (2,313 equivalent hours per MW), as shown in Figure 2. This result is mainly explained by the increased rate of wind energy index. The wind energy production by classes of number of hours at full capacity (NEPs) was concentrated in the wind farms with NEPs between 2,500–2,750 hours and above 3,000 hours. These represent a strong increase of 34% over the previous year and 62% of the total wind energy production. On the other hand, wind farms with NEPs between 2,000–2,500 hours diminished their contribution to the total from 58% to 36%, during 2013. Given the high wind energy index, the wind farms with NEPs below 2,000 reduced their share in 2013 from 14% to 1% (2).

2.3 National incentive programs

In 2013, a new NREAP for 2013–2020 was established as part of the new strategic vision for the energy sector for 2020. It revoked the previous NREAP established in 2010. This new plan to support the promotion of

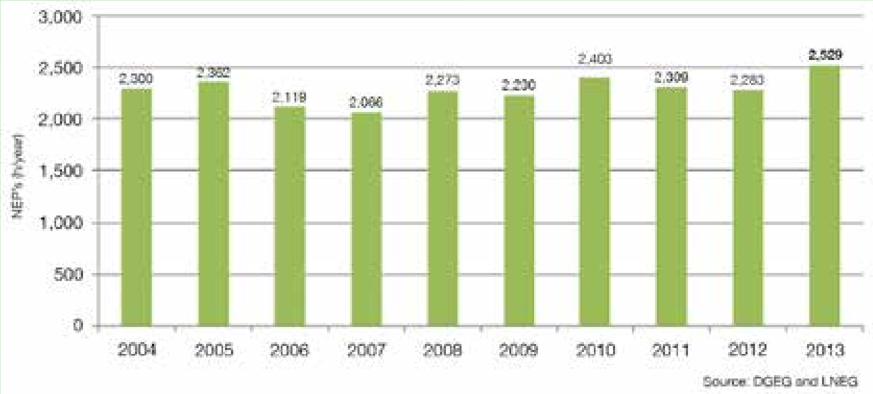

Figure 2. Average number of hours at full capacity per year

renewable energies is based on the indicators from 2010 where the contributions from renewables were of 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. Compared to the NREAP 2010, the new NREAP reduces the 2020 targets for the installed capacity of renewable energy source based technologies by 18%. Despite this reduction, a higher renewable energy share (60% versus the previous 55%) is expected in 2020 by increasing energy efficiency (reducing demand) (4).

In order to ensure the economic sustainability of the National Electric System, a further remuneration regime was created in Decree-Law 35/2013 (5) for the renewable energy producer (except non-hydro). This law determines that wind power producers may remain in a guaranteed tariff regime for an additional period (five or seven years) after the end of the initial 15-year term (6). The option for this new remuneration scheme implies the payment of annual compensation by the producers to National Electric System of: a) 5,000 EUR/MWh (6,890 USD/MWh) of installed power during a period of eight years with a guaranteed tariff for an additional five years; or b) 5,800 EUR/MWh (7,992 USD/MWh) of installed power during a period of eight years with a guaranteed tariff for an additional period of seven years.

Renewable energy installations for micro-generation (up to 11 kW) and mini-generation (up to 250 kW) units were still the object of incentive programs through a feed-in tariff (FIT) in Portugal during 2013. 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. The tariffs for 2013 were set by the energy sector regulator—Direcção Geral de Energia e Geologia—to a value of 272 EUR/MWh (375 USD/MWh) for the first eight years of operation and 150 EUR/MWh (207 USD/MWh) for the second period of seven years with a limit of 11.0 MW for annual grid-connected power approved by ordinance number 431/2012 (8). For PV based technology the FIT values are lower and are justified by the reduction in the materials costs.

The mini-generation program was published in Decree-law 34/2011 (9). This program enables small companies to install renewable-based production centers of up to 250 kW. During 2013, Direcção Geral de Energia e Geologia reduced the reference tariff by 14%, reducing the values from a maximum of 215 EUR/MWh (296 USD/MWh) to 185 EUR/MWh (255 USD/MWh) with an annual maximum of power injection of 30 MW.

2.4 Issues affecting growth

In 2012, the Portuguese government suspended the capacity attribution for grid connection to reevaluate the legal framework for electricity generation (10). Therefore, the deployment of onshore wind projects during 2013 (and in the next years) corresponds to the installation of the remaining power previously attributed.

Through 2013, Portugal reached wind penetration of 24% of the annual energy consumed—a very high value and the second highest in the world, only surpassed by Denmark.

A design parameter limit of electric systems like the Portuguese is the extreme penetration of renewable, non-dispatchable sources (e.g., wind power or river run-off hydropower). A new record for instantaneous wind contribution was reached on 10 December 2013 at 23:15; wind generation was 3,878 MW with 58% of power connection. On 25 December 2013 at 8:30 AM, an instantaneous penetration of 90% from wind generation was recorded. Wind contributed 3,330 MW and on the same day a record

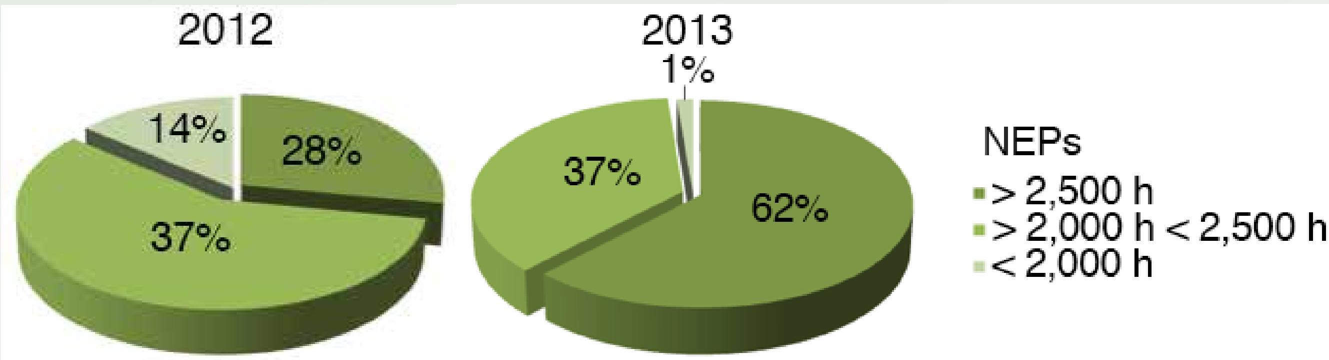

Fig. 3. Wind energy production by classes of number of hours at full capacity (NEPs) for 2012 and 2013.

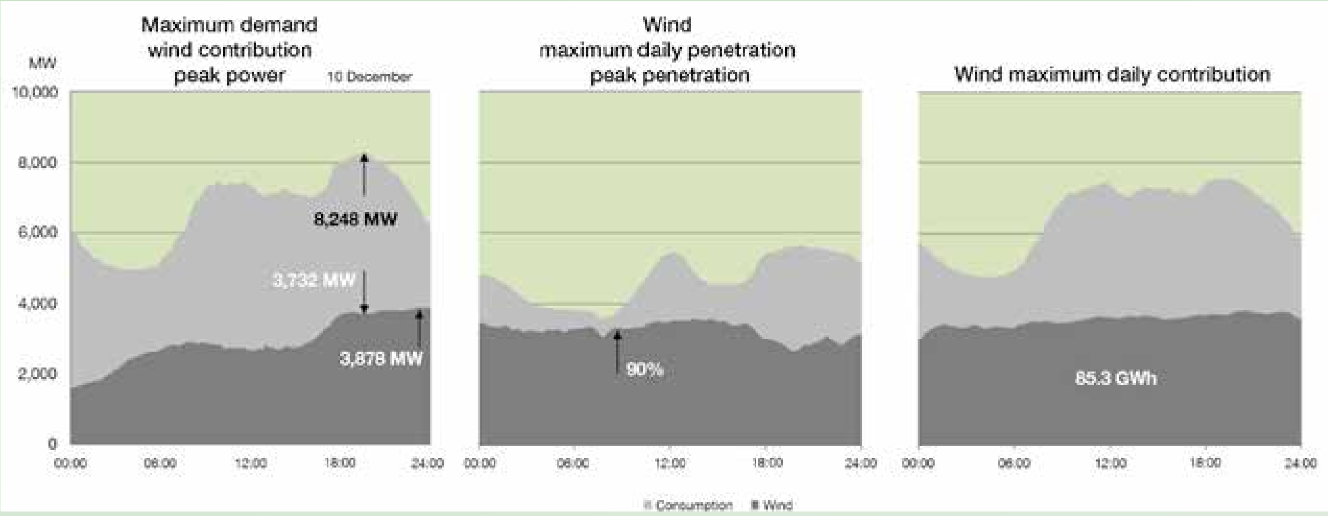

Figure 4. Record wind power penetration and energy generation during 2013 (1)

69% of the consumption was supplied by wind energy. The highest daily wind energy production occurred on 18 January 2013 with 85.3 GWh, which accounted for 55% of the daily demand (1). 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.

Figure 4 depicts the wind generation profiles on: (i) the maximum demand day; (ii) maximum daily and peak penetration from wind; and (iii) maximum wind daily contribution.

3.0 Implementation

3.1 Economic impact

The wind industry in Portugal, together with the wind deployment activity (192 MW) supported an estimated 3,200 jobs. In 2013, wind generated electricity produced an estimated income of 1,170 million EUR (1,612 million USD) and allowed the estimated saving of 4.3 million tons of CO_2 emissions.

3.2 Industry status

During 2013, Enercon reinforced its leading position in Portugal as the most important supplier of turbines. In fact, from the 108 wind turbines installed in 2013, 100 corresponded to Enercon wind turbine models (Enercon E82 and E92 models). The remaining new wind turbines were installed by Vestas. As a consequence, Enercon increased its share of the overall Portuguese market to 55.3% of the installed capacity. In second place is Vestas with a 14.0% share, followed by Gamesa (9.3%), Nordex (8.7%), Senvion (former Repower) (3.9%), GEWE (2.3%), Alstom (2.3%), Suzlon (2.2%), Bonus (1.6%), Furlander (0.2%), and other manufacturers (0.4%) (Figure 5)(2).

After the initial commission procedures, the offshore floating wind turbine installed in northern Portugal is still in the demonstration stage. So far, it has proved to be a technically viable solution for future floating offshore wind parks despite the adverse storm conditions observed in the open sea environment. By November 2013, the WindFloat turbine had produced about 7.9 GWh (11). This project is being developed by WindPlus as a joint venture from Energias de Portugal (EDP), Principle Power, A. Silva Matos (ASM), Vestas Wind Systems A/S, InovCapital, and Fundo de Apoio à Inovação (FAI). The performance achieved with this floating system has allowed this consortium to transfer knowledge, technology, and innovation to begin designing the first wind park with floating technology in Portugal and in the U.S. coastal waters.

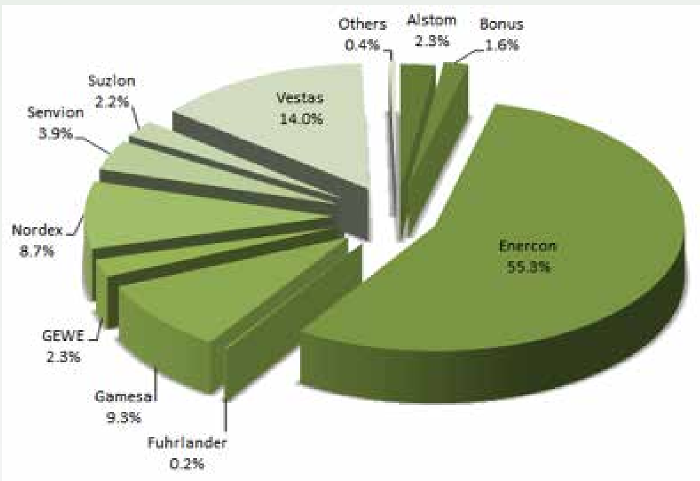

Figure. 5. Distribution of installed wind capacity by manufacturer

3.3 Operational details

In mainland Portugal five new wind parks were connected to the grid in 2013. In Açores Island, two new wind parks were connected with capacities of 4.25 MW and 3.60 MW. The overall installed capacity of the 247 wind parks in Portugal by the end of 2013 can be grouped into three categories where 52% have a small installed capacity (<10MW), 40% have a medium capacity (10–50 MW) and the remaining 8% are above 50 MW (3).

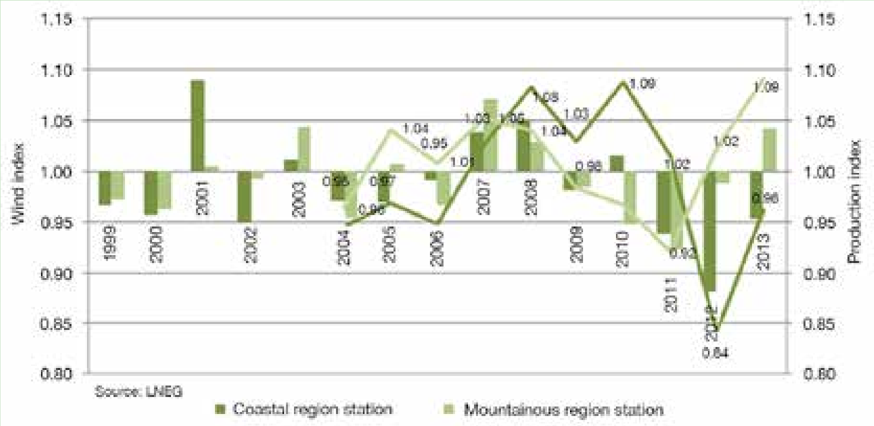

Figure 6. Wind (bar graph) and production indexes (line graph) on coastal and mountainous regions of Portugal.

Figure 6 shows the wind and production indexes for the last fourteen years. These values were achieved for two typical regions where wind turbines are operating in Portugal: coastal and mountainous. In both regions, Laboratório Nacional de Energia e Geologia (LNEG) indexes for wind and production show a pronounced increase from the previous year. In 2013, the production availability for mountainous regions was the best year since 1999. The wind availability was 4% above the average while the production index stood at 9% above the average. These results justify the high level of wind penetration in Portugal since most of the operating capacity is installed in mountainous regions. 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 (1) is in the line with the results presented from LNEG, indicating an annual wind generation index of 1.18, when considering the period between 2001 and 2013.

3.4 Wind energy costs

During 2013, wind turbine and installation costs remained unchanged from 2012. The average cost per MW installed was 1.35 million EUR (1.86 million USD). 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 (1.48 million USD) per MW.

The mean tariff paid to the wind power plants in 2013 was 93.90 EUR/MWh (129.40 USD/MWh), according to the Portuguese energy regulator (ERSE). This tariff decreased 4.40 EUR/MWh (6.06 USD/MWh) when compared to the previous year (12).

4.0 R, D&D Activities

4.1 National R, D&D efforts

The national R&D efforts during 2013 were mainly focused on offshore wind energy, development of tools and methodologies to maximize the penetration of renewable energy, and promoting energy sustainability. Also a national funded program to constitute an R&D Infrastructures Roadmap in Portugal took place at the end of 2013. This program is aimed at the constitution of R&D infrastructures and valued the connections between national and international R&D Infrastructures Networks. These activities are taking place at the main institutes and universities of the country being financed through national or European programs. The following paragraphs describe the main projects underway in Portugal.

- Project FCT Roadmap: a Portugal-based project funded by the Portuguese Science and Technology Foundation (FCT). Its purpose is to identify the constraints and barriers to the development of marine energies in Portugal. This project ended in the second half of 2013.
- Project FCT Fluctuating Wind: a Portugal-based project funded by FCT with the coordination of LNEG. One of the main goals is to create a tool that will serve as a warning to the power system operators for possible severe wind power ramps.
- 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 Portuguese participation of INESC-Porto.
- 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 WindFloat 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 intends to establish in several European countries a 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 from 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.

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, and IEA Wind Task 27 Small Wind Turbines in Turbulent Sites. During 2012, Portugal joined the IEA Wind Task 30 Offshore Code Comparison Collaboration Continuation (OC4) through Wavec and Centec. This participation is 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), an initiative funded by leading European research institutes. EERA aims to strengthen, expand, and optimize EU energy research capabilities.

5.0 The Next Term

For the onshore wind energy market, 2014 is expected to be a stagnant year due to the few pending licensing procedures. Regarding offshore wind energy, a better scenario is foreseen with some expectation due to the success achieved with the WindFloat project. With the NER300 program support, the first offshore floating wind park on the Portuguese coast will be installed, with an estimated capacity of 25 MW.

National incentives, especially for micro-generation and mini-generation, are under evaluation and might be merged into a single category and changed to a market regime (4). At end of 2013, a new reference FIT value was established for 2014 by the energy sector regulator with a reduction in the incentives.

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Opening photo: Windfarm in Portugal (Credit:Vitor Andrade)

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32 Spain

1.0 Overview

According to the Spanish Wind Energy Association's (AEE) Wind Observatory, the installed wind capacity in Spain reached 22,959 MW in 2013 with the addition of only 175 MW, the lowest amount since 1996. Compared to 2012 when 1,112 MW were installed, the market dropped by 84% in 2013.

According to the national transmission systems operator Red Eléctrica de España, (REE), electrical energy demand decreased 2.3% from 2012 to 246.16 TWh. Wind energy produced approximately 54.3 TWh of electricity, equaling 20.9% of the yearly energy electricity demand. For the first time in Spain's history wind power was the main source of electricity generation over a whole year. Other big contributors to the system were nuclear power plants (20.9%), coal (14.3%), hydro (12.9%) and gas combined-cycle power plants (9.3%) (Figure 1).

In January 2012, the Spanish government approved a decree (RDL 1-2012) halting the existing feed-in-tariff (FIT) support scheme that allowed tariffs up to 0.082 or 0.087 EUR/kWh (0.113 or 0.120 USD/kWh) or for a period of 20 years. At that time all the renewable energy generation plants pre-registered in the FIT system still had the possibility to go ahead 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.

But the RDL 1-2012 was not the only hardship for wind power promoters. The government has been facing huge problems to deal with the so-called "tariff deficit." In 2013, according to official data, Spain had accumulated a 26 billion EUR (36 billion USD) electricity tariff deficit—the 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 measures, 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).

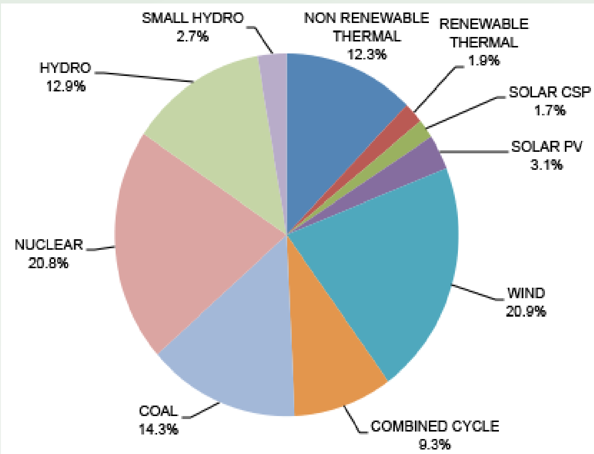

Figure 1. Percentages of the 2013 power supply mix in Spain (Source: REE, AEE)

Also, in February 2013, the Spanish government decided to withdraw renewable energies from the spot market and established a mandatory regulated FIT, which would no longer be updated by CPI (RDL 2/2013).

In July 2013, the Spanish government decided to change the current renewable energy FIT payment system (RDL 9/2013). Instead of paying the established tariff for 20 years, the remuneration to be paid will be based on the so-called "reasonable profitability" for each project, depending on a wide variety of factors including age, cost, and amount of subsidies the project has already received. This scheme still has to be approved but will likely further reduce the income of current renewable energy plants.

The Law 24/2013 on the electricity sector and the draft of Royal Decree on renewable energies (in the pipeline), added to the economic impact of other provisions not related to wind, and will also cause economic loss (such as the Order on interruptiblity and the draft royal decree on capacity payments). The new state regulation on renewables—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

In 2013, wind energy was the main source of electricity generation for the year producing approximately 54.3 TWh of electricity, equivalent to 20.9% of electricity demand.

Table 1. Key National Statistics 2013: Spain	
Total installed wind capacity	22,959 MW
New wind capacity installed	175 MW
Total electrical output from wind	54.3 TWh
Wind generation as % of national electric demand	20.9 %
Average capacity factor	26.9 %
Target 1. Official Network Planning	29,000 MW by 2016
Target 2. New National Renewable Energies Action Plan (NREAP)	29,000 MW by 2016 35,000 MW by 2020

of the compensation parameters may be reviewed as well, including the alleged reasonable profitability. As a result, investors have no guarantee about income for the entire regulatory life of the projects, which is 20 years.

But regulation is not the only insecurity in the Spanish power system—electricity demand has dropped approximately 8% since 2008. With more than 100 GW of installed total electrical generation capacity, and a historical demand maximum of 45 GW, there is currently an overcapacity of generation and some of the existing combined gas cycle 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 the regulatory uncertainty and economic recession has created an uncertain situation, not very favorable for new installations. For this reason more than 5,000 MW projected promotions have been stopped.

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 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 from 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) onshore and 750 MW (1,845 GWh/yr) offshore.

All of these targets are strongly dependent on the regulation already in force in Spain and this regulation is currently discouraging potential promotions of new wind farms.

2.2 Progress

The electrical generation capacity in the Spanish mainland system increased more than 556 MW during 2013 for a total of 102,281 MW, according to REE (3). The technologies that contributed most to this growth were PV solar power (140 MW) and renewable thermal (300 MW). REE does

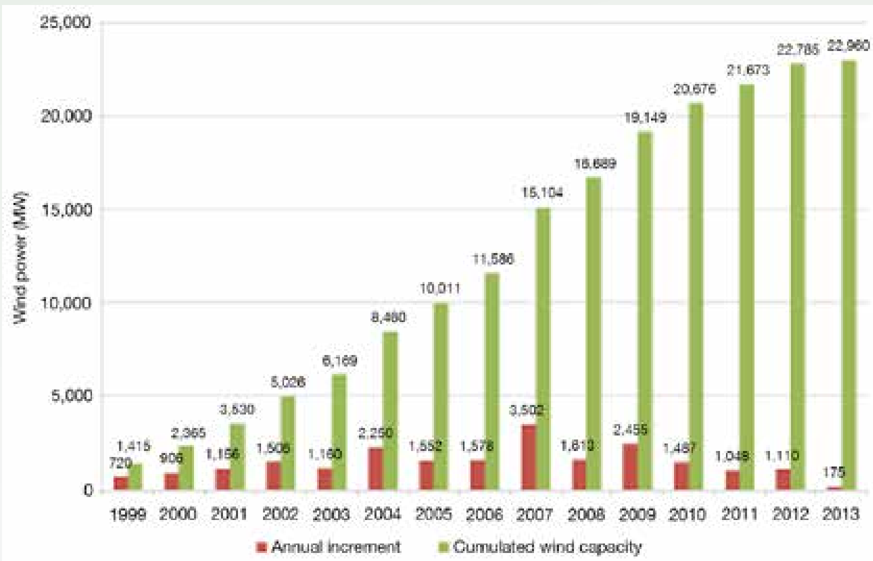

Figure 2. Annual and cumulative installed wind capacity in Spain

not include in this register the installation of new wind power plants (175 MW, according to AEE). As shown in Figure 2, Spain has nearly 23,000 MW of wind power installed. There are approximately 20,252 turbines operating in Spain, grouped among 1,072 wind farms. The average size of an installed wind farm in 2013 was 10 MW, whereas the overall wind farm size is 21 MW.

Wind energy is present in 15 of the 17 autonomous communities (Figure 3). However, only six of them increased their wind capacity during 2013. Andalucia had the biggest growth with 74.5 MW added in 2013, to a total of 3,337 MW that led it to the third position, only behind Castilla y León which is the overall leader, with 49.40 MW (second highest increase) installed in 2013 and a total of 5,560 MW. Castilla–La Mancha remains in second place with 3,806 MW but with no increase during this year. Navarra installed 24 MW, the third biggest growth, reaching 1,004 MW wind capacity. Another five regions increased their installed wind capacity, but with an increase lower than 10 MW each: Cataluña (9 MW, with a total of 1,267 MW), Asturias (6 MW, with 518 MW total), Canarias (5 MW, 165 MW total), Aragón (4.50 MW, with a total 1,893 MW) and Galicia (2.65MW, with 3,314 MW is the fourth region in the ranking). As mentioned before, six of the traditional regions did not install any new wind power: Baleares, Cantabria, Comunidad Valenciana, La Rioja, Murcia, and País Vasco. Only two autonomous regions, Extremadura and Madrid, have not yet installed any wind power capacity.

The use of wind power has lowered carbon emissions by about 27.5 million tons during 2013. Overall CO_2 emissions of the mainland electric sector in 2013 experienced a 23.1% decrease in relation to 2012, due mainly to the increase in generation from wind and hydro. Furthermore, wind generation has saved up to 10.4 million tons of conventional fuels and has supplied the electrical consumption of more than 17.4 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 tool within this policy at a national level has been the new NREAP (2011–2020), which included midterm objectives for each technology that could not be achieved due to new regulations.

Payment for electricity generated by wind farms in Spain has been based on a FIT scheme. As stated in the Overview, 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.

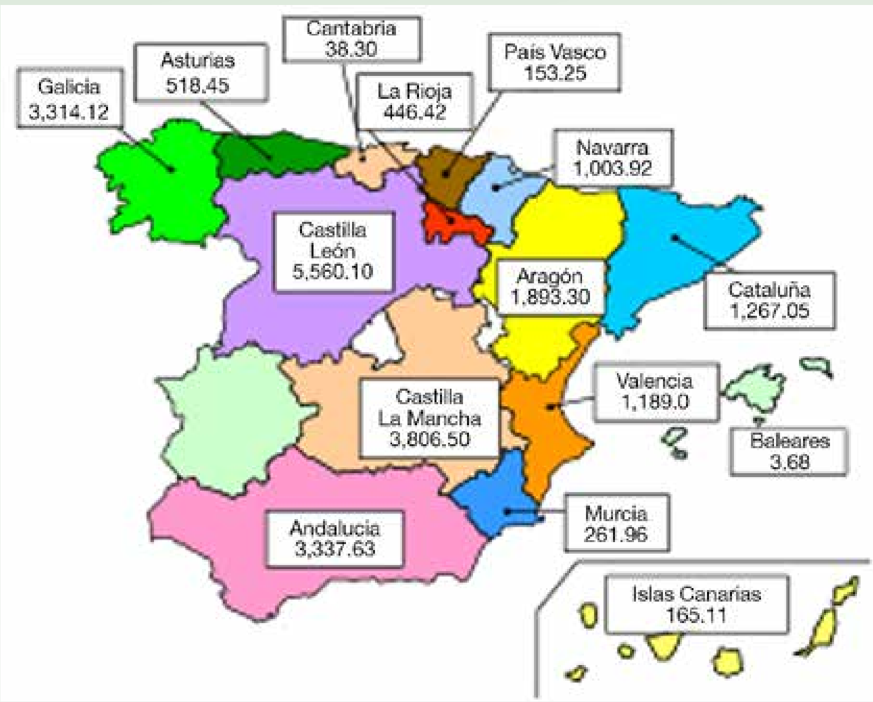

Figure 3. Wind energy capacity distributions by autonomous communities (MW)

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 has not been published yet.

2.4 Issues affecting growth

The economic slowdown continued to affect the wind industry in 2013. In addition, the application of the Pre-allocation Register has limited wind energy development. As a result, wind turbine production in Spain is declining and more than 3,600 jobs have been lost during 2013 (though there are still more than 20,000 people working in the wind sector).

3.0 Implementation

3.1 Economic impact

Given the regulatory situation in Spain, installed wind capacity during 2013 has been limited to 175 MW, reaching a total capacity of 22,959 MW. Installing and operating wind plants to cover 20.9% of the Spanish electrical demand implies a huge accomplishment by the developers and manufacturers, being the first country in the world where wind power is the largest contributor to the energy production mix.

3.2 Industry status

Most of the main manufacturers in the world are present in the Spanish market, but only a few got to install any power during 2013. The largest manufacturers were Gamesa (85.5 MW new capacity), Acciona Wind Power (70.50 MW new capacity), MTOI (9.90 MW new capacity), EOZEN (4.5 MW new capacity), Alstom Wind (2.55 MW new capacity), and Vestas Wind Power (2 MW new capacity) as shown in Figure 4.

Gamesa is still the top manufacturer in Spain with 12,008 MW total wind capacity installed (52.3% of the total wind capacity installed). In the second position is Vestas Wind Power with 4,076.99 MW total wind capacity installed (17.8% of the total wind capacity installed), and Alstom Wind in third place with 1,739 MW (7.6% of the total wind capacity installed). The Spanish manufacturer Acciona Wind Power is in the fourth position with 1,728 MW (7.5% of the total wind capacity installed).

Regarding new technology, Gamesa has installed the first prototype of the G128-5, 5-MW offshore wind turbine in the Canary Islands. This wind turbine is based on technology that has already been proven and validated over the last few years at onshore sites.

Several manufacturers are developing small wind turbines from 3–100 kW for grid-connected applications (Norvento Enerxia Distribuida nED connected one 100-kW wind turbine to the grid in 2013).

Iberdrola Renovables, the largest Spanish utility, has the largest accumulated wind power capacity (5,513 MW, 24.0% of the whole wind market) even though it had no new additions in 2013. Acciona Energy, in second place, has accumulated capacity of 4,268 MW with 39 MW installed in 2013. The Portuguese company EDPR, with 2,099 MW total, installed 13.23 MW during 2013. But it is the Italian utility Enel Green Power Spain, in the fourth overall position with a total capacity installed of 1,403 MW, that experienced the highest growth with 88.27 MW installed in 2013.

Under this discouraging situation almost all the Spanish companies that have not stopped their activity in this area have opted to emigrate to better markets. Some of the world's largest developers like Iberdrola or Acciona Energy are working quite well abroad.

In 2013, Iberdrola finished the extension of the Whitelec project, which with 539 MW of capacity is the largest onshore wind farm in the UK. Iberdrola has already developed 1,200 MW in the UK and 14,000 MW worldwide, with more than 8,000 MW in the pipeline.

Acciona Energy also had a good cumulative installed capacity in 2013: a total of 8,631 MW of wind power in 295 wind farms located in 16 countries. Of this total, 2,562 MW were systems installed outside Spain. In January 2013, Acciona announced the signature of a 93 MW supply agreement in Brazil.

Similarly, the main Spanish manufacturer Gamesa seems to be getting off the ground. After some layoffs and an employment regulation process from 2010–2013 that involved some 600 employees, Gamesa was the company with the highest growth on the Spanish stock market with an appreciation of 336% in 2013. By September 2013, the firm had acquired 1,400 MW of new orders, of which 50% were bound for Latin America and 29% for Europe. Its gross operative profit increased 32% year on year in the same period.

Finally Alston Wind is to manufacture 29 ECO 74 wind turbines in Navarre (Spain) for a wind farm located near the city of Hamada in the West coast of Japan. The project which will be fully operative in 2016 has been promoted by Green Power Investments Corp.

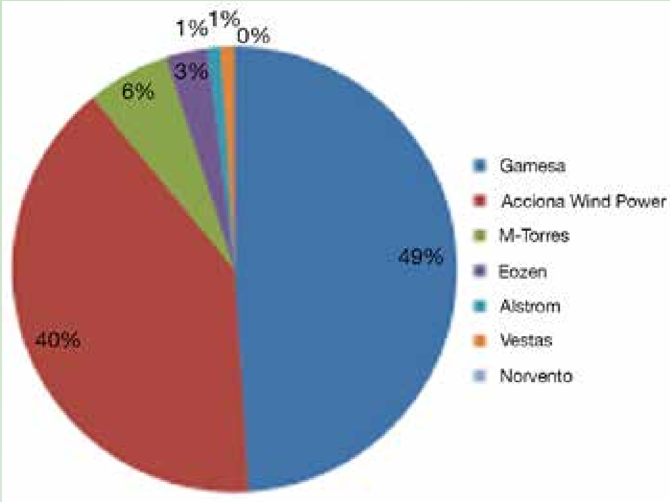

Figure 4. Installed wind capacity in 2013 by manufacturer (in percentages) (Source: AEE)

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 53,930 GWh. During 2013, equivalent hours at rated power were approximately 2,350 hours for all of the wind farms. This shows that 2013 was an excellent wind resource year overall. On several occasions in 2013, wind power exceeded previous historical instantaneous power peaks and maximum hourly and daily energy production. On 6 February 2013 (15:49) instant wind power generation reached 17,056 MW (2.5% higher than the previous record). On that day another record was reached for hourly production (16,918 MWh). Overall, in January, February, March, and November wind generation made the highest contribution to the energy mix among all the existing technologies.

3.4 Wind energy costs

There are no new inputs for this figure for 2013, so the official cost at the factory during 2012 in Spain of 800 EUR/kW (1,102 USD/kW) is considered to be valid also for 2013.

4.0 R, D&D Activities

4.1 National R&D efforts

In 2013, the Spanish government launched 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 new Plan tries to align as much as possible the research and innovation lines with the lines defined in the new European research and innovation frame call Horizon 2020. The structure of action plan for 2013 is based on four state programs:

- Promoting talent and employability in Research, Development, and Innovation (R&D&I)
- Promoting scientific and technical excellence
- Inspiring corporate leadership in R&D&I
- Conducting R&D&I focused on the challenges of the society.

One of the challenges identified is titled safe, efficient, and clean energy for the state R&D&I program established to face the challenges of the society. During 2013, the new Plan was just starting so only one call for proposals has been made for non-oriented or fundamental research projects.

Another important initiative regarding research activities on wind energy is the Alliance for energetic research and innovation (ALINNE). ALINNE is a non-profit initiative created by the Ministry of Science and Innovation through Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT). CIEMAT will help bring together and coordinate efforts among all actors in the value chain of R&D in energy. This will allow the actors to respond to the major challenges that the policy of I + D + i have in the field of energy sector and help define working guidelines at the national and European level.

Finally, an important activity has been developed by Spanish research centers in the European Energy Research Alliance (EERA). The Spanish wind team is coordinated by Centro Nacional de Energías Renovables (CENER) with the participation of CIEMAT, CIRCE, CTC, IC3, IREC, and TECNALIA, which are participating in most of the initiatives (IRPWIND Project, NEWA ERA NET+, etc.)

Some of the most important projects funded by the Spanish government have concluded in 2013 including:

AZIMUT Project

The Azimut project completed applied research activities in 2013 on the development of world's largest capacity wind turbine by 2020. Eleven Spanish companies and 22 research centers, coordinated by Gamesa have worked for four years on the Azimut project.

The main results involve new materials including a new resin with improved properties for the manufacture of blades. The project identified technologies for the precise detection of the advancing front of the resin flow in infusion molds. A passive coating for wind turbine blades has been obtained with anti-icing properties and extremely high resistant to erosion, called Bladeshield™.

In addition, the participants developed some design and calculation tools. An analytical design tool provides preliminary electromagnetic, thermal, and mechanical design of permanent magnet generators. It was validated using finite element method tools and during laboratory measurements in a small-scale permanent magnet generator. Also an evolutionary algorithm design tool has been developed to optimize the blade design (both the aerodynamic and the structural properties). The objective is to maximize the annual energy production subject to some constraints such as blade mass and blade maximum. Finally, a fatigue estimator for the drive train was developed that gives as a result the remaining load capability of a gearbox and other rotating parts.

Ocean LIdar Project

Iberdrola Ingeniería, leader of a consortium consisting of 20 companies and 25 research centers, presented the results of the Ocean LIdar R&D project. This project, with a budget of almost 30 million EUR (41 million USD), has been carried out by the consortium over the last four years. It has become the largest R&D&I project involving ocean renewable energies and is contributing to unprecedented advances in the sector.

This R&D project involved setting up a smart system that is capable of placing offshore installations in the most suitable locations. The following three tools for analysis and assessing marine resources were used: the Wave Rider buoy to measure wave motion; the LIdar Flotante measurement tower for waves, and the Awac for currents. New marine technologies were also designed, such as a system of floating wind turbines for deep water and a new turbine for generating energy from currents. Other developments include a next-generation system for the transmission and distribution of the electricity generated by these installations, including a new type of semi-submersible floating substation with specially adapted connectors and dynamic power lines. The project also created a ship that enables this infrastructure to be installed speedily and cost-effectively, as well as an operating system managed from a control center designed especially for this type of energy infrastructure.

SEDAR Project

Iberdrola and the Barcelona Supercomputing Center—Centro Nacional de Supercomputación (BSC-CNS)—are jointly developing a major R&D&I initiative known as the Sedar Project (High Resolution Wind Simulation). Sedar is an innovative project aimed at developing a new computer model to improve estimates of electrical energy production in wind farms before their construction. Current models have a significant limitation in their calculation times. This project has overcome this shortcoming by using supercomputing techniques. Furthermore, the project will develop improvements for the resolution of physical models which, so far, have been constrained by computing times.

In relation to the participation of Spanish entities in projects funded by the European Union under the FP 7 Program, the following projects could be highlighted.

INNWIND Project

The proposed project investigates and evaluates innovative approaches to the design of the most critical subsystems of multimegawatt wind turbines (10–20 MW) concepts; that is, rotor, electromechanical conversion, and support structures. The main objective is to reduce the cost of energy produced. Different concepts are investigated in isolated ways but also at a wind turbine integrated with the other components of approximation. The benefits of these new designs are quantified through performance indicators. The project includes trials to small and large scale and has duration of five years. The main tasks of CENER within the project consist of aerodynamic and structural studies of offshore wind turbines.

SYSERWIND Project

Under the auspices of the FP7 European project titled Twenties, this R&D&I initiative created new power-frequency and voltage control equipment and systems to optimize the connection between wind farms and electricity transmission grids. To be more specific, the project was carried out at 15 of Iberdrola's wind power facilities located in Andalucia, which are equipped with Gamesa wind turbines and have a combined installed capacity of over 480 MW. These wind farms are connected to three nodes in the 400-kV transmission grid operated by REE Red Electrica de España (Spanish TSO). They were equipped with the systems developed in the Syserwind project, allowing coordinated work on controlling the power generated by the facilities and altering the voltage in the grid. This demonstration project, which was analyzed by the IIT an Institute for Research in Technology at the Comillas Pontificial University, confirmed the technical feasibility of wind power when taking part in the power-frequency and voltage control services in the electricity system. Syserwind, an initiative headed by Iberdrola, was one of six full-scale demonstration projects carried out under the European program Twenties.

Finally, the following projects have been funded by Regional R&D&I Programs.

NAUTILUS Project

The Nautilus project is focused on the design and validation of a floating platform for offshore wind, for installation in water more than 60 m deep. 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 based on development aspects such as manufacturing costs and its logistical requirements and installation. The project is developed by a consortium of local entities of the Basque Country including 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 a world leader in the supply of chains and mooring systems for the offshore industry.

This new technological and industrial development will undergo a pilot test in a testing channel in 2014. It is expected to commence production of commercial units by 2016, and is expected to have a positive impact on Basque industrial activity.

MARIN-EL Project

In 2013, Iberdrola Engineering launched, in collaboration with a group of Basque businesses, the R&D project called Marin-el, which aims to design a new model of marine offshore wind farm substation to facilitate installation and achieve lower costs.

The initiative has a budget of 10 million EUR (14 million USD) and the support of the Basque government. It aims to provide an alternative to existing substations that are too bulky and heavy for offshore. This would eliminate one of the main difficulties founded in the development of all power marine technologies. These types of marine facility must meet increasingly stringent requirements, derived not only from the increased rated power of wind farms offshore, but the need to manage reliable electricity and, in this line, try to minimize losses due to the remoteness of the coastal areas. The project is based on creating a self-installing substation, which would have many advantages in the construction phase (it would be constructed 100% on land), in the transport, and during assembly.

In this sense, companies that drive the project proposed a facility that incorporates supports that allow attachment to the seabed without requiring the help of special crane vessels, which complicate the process and have many technical limitations. In late 2015, the Marin-el project will begin its effort toward a significant technological leap in the field of marine energy. The consortium is led by Iberdrola and other companies involved are Ingeteam for power electronics development, Ormazabal for transformers, and Arteche for electrical devices.

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 Small Wind Turbines at Turbulent Sites, and, most recently, Task 31 Wakebench: Benchmarking Wind Farm Flow Models, a new task lead by Spanish experts in wind flow modeling in complex terrain.

5.0 The Next Term

Despite the bleak situation expected for 2014, in the mid-term the tables may be turned. The country has renewable energy targets agreed with the EU of 22.7% of final energy consumption. That means some more new renewable energy capacity has to be installed. Without any subsidy it appears to be a complicated task. Some expectation has been created with the future Energy Law, which may include a bidding scheme that adds to the high energy prices in the pool market. This should be enough to awake the activity for wind generation.

Also, in the short term, some markets such as the Canary Islands may support local demand. The new Energy Act contemplates the approval of 460 MW in the archipelago during the next few years with an approximate tariff of 85 EUR/MWh (117 USD/MWh). Wind energy may be competitive with the local generation price that reaches approximately 230 EUR/MWh (317 USD/MWh) due to the high dependence on fossil fuels.

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Opening photo: Wind farm in Spain (Credit: Ana Maria Rodriguez)

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33 Sweden

1.0 Overview

Sweden's new wind energy installations in 2013 had a capacity of 862 MW, compared to 755 MW installed in 2012. At the end of 2013, the total installed wind generation in Sweden was 4,459 MW from 2,681 wind turbines. The goal is to increase renewable generation by 25 TWh compared to the level in 2002 by 2020. 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 resources 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

In 2008, the Swedish government expressed a planning framework of 30 TWh wind power by 2020, comprised of 20 TWh onshore and 10 TWh offshore. Within the electricity certificate system, the goal is to increase renewable electricity generation by 25 TWh by 2020 compared to the level in 2002. Electricity generation from wind power has increased from 7.1 TWh in 2012 to 9.9 TWh in 2013 (Figure 1).

The Swedish electricity end use in 2013 was 139.0 TWh, a decrease of about 2% compared to 2012. The wind power electricity generation share for 2013 was 7%.

2.1 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."

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, improving the economics of electricity production from renewable energy sources and encouraging the construction of new plants for the purpose. 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 shared a common electricity certificate market. This means that the electricity certificate can take place across borders. The goal of the joint certificate market is to increase renewable electricity by 26.4 TWh between 2012 and 2020. This represents approximately 10% of electricity production in the two countries.

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

Electricity generation from wind power in Sweden increased from 7.1 TWh in 2012 to 9.9 TWh in 2013.

Table 1. Key National Statistics 2013: Sweden	
Total installed wind capacity	4,469 MW
New wind capacity installed	862 MW
Total electrical output from wind	9.912 TWh
Wind generation as % of national electric demand	7%
Average capacity factor*	***28.3%***
Target:	Planning framework of 30 TWh wind power by 2020

Bold italic indicates an estimate
* Estimate based on the average installed capacity during the year.

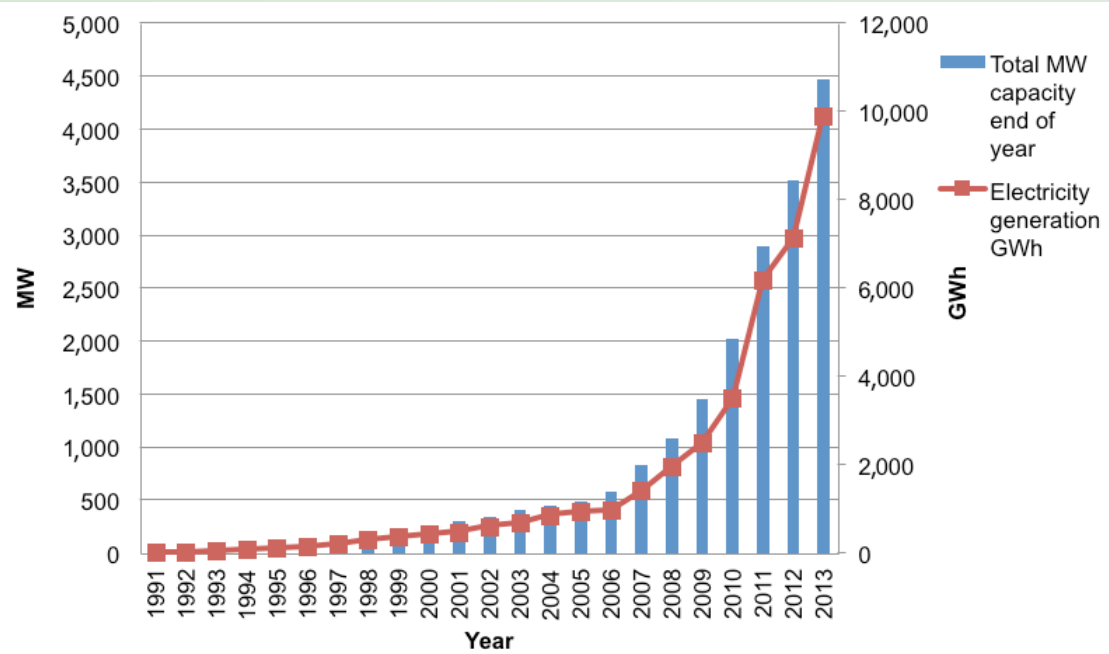

Figure 1. Installed wind power capacity in Sweden 1991 to 2013

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 (79.1 million EUR; 109.0 million USD). The market introduction program has been prolonged with an additional 10 million SEK per year (1.1 million EUR; 1.6 million USD).

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.

Network for wind utilization (1)

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. Therefore, the Swedish Energy Agency has started a national network for wind utilization. A national network 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 other authorities in their work on wind power.

Vindlov.se (2)

One of the key obstacles prolonging the permission process for wind power is the huge number of stakeholders in the process. Therefore, the 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. In this process some stakeholders might also 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, and all wind power in place and in planning. This includes detailed site and technical information for every single turbine and park, 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 map application functions as a geographic based e-service tool between developer and authority. The developer forms his application in the web map application including all necessary information. He then 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.

3.0 Implementation

3.1 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, 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), ABB (electrical components and cable), Dynavind (tower production), EWP Windtower Production, and Vestas Castings (formerly Guldsmedshytte Bruk AB). Other companies worth mentioning are ESAB (welding equipment), Nexans (cables), and Oiltech (hydraulic systems and coolers). 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.

3.2 Operational details

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/anti icing. To support the deployment in cold areas the Swedish Energy Agency is supporting a number of projects financially.

In the Swedish Energy Agency support program for large demonstration projects, two pilot projects were completed during 2013. The project “Havsnäs” with a normal annual production of 256 GWh has contributed to the development in areas such as health and safety, project financing, foundation development, and production conditions in cold climates. The project “Large-scale wind power in southern Sweden's forests” has a normal production of 140 GWh. This

Figure 2. Wind turbines in Sweden

project has contributed to the accumulated valuable experience from establishments in forest environments and complex terrain and production potential in geographically separate areas in southern Sweden. Both projects have contributed with knowledge in the areas of wind energy in cold climates, de-icing, construction in forested terrain, geographical differences in the conditions for wind power, large-scale projects, communication with neighbors, environmental studies, resource-building, and foundation development. Altogether, the pilot projects have facilitated the introduction and contributed to an increased interest for wind power in Sweden.

4.0 R, D&D Activities

The publicly-funded wind energy research in 2013 was mainly carried out within the research programs Vindforsk (3), Vindval (4), SWPTC (5) and wind power in cold climate (6).

The present period of Vindforsk (called Vindforsk IV) runs from 2013–2016, with a total budget of 60 million SEK (6.8 million EUR; 9.3 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 2008, the program was extended through 2012 with a new budget of 35 million SEK (4.0 million EUR; 5.4 million USD). The Vindval program has two research projects supported by the Swedish Energy Agency in 2013; the two projects relate to wind power impact on birds.

The SWPTC runs from 2010 to 2014. The program is financed by the Swedish Energy Agency, by industry, and by Chalmers University and has a total budget of 100 million SEK (11.3 million EUR; 15.6 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 climates.

The program wind power in cold climate runs from 2013–2016. The program is financed by the Swedish Energy Agency and has a total budget of 32 million SEK (3.6 million EUR; 5.0 million USD). The program focuses on removing barriers that arise for wind power in cold climates.

During 2013, the program management for Vindforsk, Vindval, SWPTC, and wind power in cold climate organized the annual conference "Wind Power Research in Focus" where the researchers and organizations participated and presented research projects in the different programs. Vindval also organized the international conference "Conference on Wind Power and Environmental impacts" (CWE 2013). The Swedish wind energy association organized the international conference "Winterwind" (6) that is a conference about wind power in cold climate and icing conditions.

5.0 The Next Term

The research programs wind energy in cold climate, Vindval, Vindforsk, and SWPTC will continue during 2014. 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 high 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.

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Opening photo: Wind turbines in Sweden

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34 Switzerland

1.0 Overview

By the end of 2013, 34 wind turbines of considerable size were operating in Switzerland with a total rated power of 60 MW. These turbines produced 108 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 additional 3,283 GWh under the FIT scheme. Due to continuous obstacles in the planning procedures and acceptance issues, only two new turbines plus four new turbines for repowering with an accumulated new rated power of 10.7 MW were installed in 2013.

In Switzerland, an ancillary industry for wind turbine manufacturers and planners has developed, which acts mainly on an international level. A recent study estimates that the total turnover in 2010 was about 38.9 million EUR (53.6 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 2013, the energy yield from operating wind turbines was 108 GWh; advanced projects may generate in the near future an additional 300 GWh.

Since the introduction of the FIT in 2009, projects with an estimated energy yield of 1,730 GWh have been registered; additional projects with a potential energy yield of 1,553 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 (Figure 1).

2.2 Progress

Today, approximately 58% of Switzerland's overall electricity production comes from

New projects with modern wind turbines are showing substantially higher performance, also thanks to lessons learned within research activities.

Table 1. Key National Statistics 2013: Switzerland	
Total installed wind capacity	60 MW
New wind capacity installed	10.7 MW
Total electrical output from wind	***0.1 TWh***
Wind generation as % of national electric demand	***0.2%***
Average national capacity factor*	20%
Target:	4 TWh/yr in 2050
Bold Italic indicates estimate	

renewable sources, with hydropower by far the biggest contributor (95%). In 2013, six wind turbines were put in operation with an average rated power of 2.2 MW (including turbines for repowering). In total, 34 wind turbines of a considerable size have been installed with a rated capacity of 60 MW. These turbines produced 108 GWh (Figure 2).

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 2013, this levy is set to a maximum of 0.083 EUR/kWh (0.114 USD/kWh), based on the current electricity consumption in Switzerland. This leads to more than 500 million CHF (407.5 million EUR; 561.5 million USD) annually of available funds. By 1 January 2014, this levy can be raised up to 0.124 EUR/kWh (0.171 USD/kWh), in order to be able to reduce the waiting list of the signed in projects.

The current feed-in tariff for wind energy is in a range of 0.18 to 0.12 EUR/kWh (0.25 to 0.17 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 recent study estimates that the total turnover in wind energy in Switzerland in 2010 was about 38.9 million EUR (53.6 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 (11.9 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 has increased to around 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,

Figure 1. Wind turbine in Gütsch (Source: Suisse Eole)

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 (1,998 USD/kW). Including installation, the figure rises to 2,070 EUR/kW (2,853 USD/kW). The regulation for the compensatory FIT scheme provides 0.12–0.18 EUR/kWh (0.17–0.25 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 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 2013, the budget for wind energy related R&D projects was 410,000 EUR (564,980 USD). Within the national "SwissEnergy" program, 620,000 CHF (505,300 EUR; 645,773 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 research projects were underway in 2013.

After considering social psychological acceptance of wind power projects at potential sites (9), the Universität Halle-Wittenberg conducted a large research project about social acceptance of the main operating wind energy site in Switzerland (10). This research focuses on local acceptance of wind energy projects in five Swiss municipalities. In this study, 467 persons were interviewed. They all live less than 5 km from an existing wind turbine site. This study shows that neighbors have usually a positive attitude toward wind turbines.

Wind turbines are supported by 78% of the respondents, whereas only 6% are opposed. Among those opposed, 36% are actively involved in an opponent association. Only 6% of the supporters of wind energy have an active role. The perception of the planning phase is one of the main factors of the opinion of the local population. If the results of the new study are compared with (9), it seems that acceptance is better in the operating phase than in the planning phase.

The planning process has to address this issue of acceptance. For 2014, a public exchange platform will be created in one of the Swiss cantons to support a more participative process, and a guide will be published to describe the good practices in terms of social acceptance.

Other important R&D projects are supported in the area of de-icing, monitoring of environmental impact of wind energy and evaluation of solution to reduce the interference between wind energy and radars.

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 Wind Farm Flow Models. Switzerland is participating in the launch of 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. The energy research concept 2013 to 2016 elaborated by the Swiss Federal Office of Energy (SFOE) includes the following key issues:

- 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: A V44 600-KW wind turbine being replaced by a V90 2-MW at Mont Crosin, Switzerland (Source: Stephan Boegli)

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35 United Kingdom

1.0 Overview

With its extensive natural resource the United Kingdom (UK) is a world leader in offshore wind development, large-scale land-based sites have by now mostly been completed. Wind makes up on average around 5–6% of total electricity demand.

The UK has approximately 40% of Europe's entire wind resource and has significant potential for both land-based and offshore wind. The UK government has, in recent years, put in place a range of measures to enable the deployment of that potential resource and is committed to ensuring the further growth of wind generation in the UK. In 2009, the UK signed up to an EU target of 20% of primary energy (electricity, heat, and transport) to be generated from renewable sources by 2020. The UK contribution to that target is 15% by 2020, with wind energy playing an important role to achieving this target.

The offshore wind industry has enjoyed a record deployment year in 2013. Offshore wind capacity grew 79% in 12 months and the combined amount of land-based and offshore wind increased by over 40%. New offshore projects are getting bigger, while land-based projects are becoming smaller. For the first time, more wind capacity was installed offshore than on land in a 12-month period.

2.0 National Objectives and Progress

2.1 National targets

In 2009, the UK signed up to the target of obtaining 15% of its primary energy from renewable sources as part of the EU renewables target of 20% of primary energy, electricity, heat, and transport. By 2020 in order to meet this target, the UK predicts that it will need to supply 30% of its electricity and 12% of its heat from renewable sources. Up to two-thirds of the electricity component of the UK's 2020 renewable energy target is likely to be provided by wind energy, both on land and offshore.

2.2 Progress

UK electricity is generated from a range of sources. Of electricity generated in 2013, provisional data highlights that fossil fuel generation was broadly unchanged; gas accounted for 27.2% and coal accounted for 33.3%. Nuclear energy's contribution increased to 23.9% of the total, while renewable energy's share of generation increased from 11.7% to 13.2% (3).

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 Renewables Obligation (RO) is currently the government's chief financial incentive mechanism for eligible renewable electricity generation and has been in operation since 2002, but will be replaced by the Contracts for Difference (CfD). It is also an important part of the government's program for securing reductions in carbon dioxide emissions, working in support of other policy measures such as the EU Emissions Trading System.

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. According to the latest figures approximately 50% of the total ROCs go to onshore and offshore wind developments.

Plans are for offshore wind support levels to be bought down to 1.9 ROC/MWh for generating stations accrediting during 2015–2016, and to 1.8 ROC/MWh for generating stations accrediting during 2016–2017. After a review of onshore wind costs in 2013, support levels were retained at 0.9 ROC/MWh. These levels are consistent throughout the United Kingdom, although when the contract for difference is introduced there will be a higher rate for onshore Scottish Island projects, due to their economics.

The Feed-In Tariff (FIT) scheme was introduced on 1 April 2010, under powers in the Energy Act 2008. Through the use of FITs, the government hoped 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 0.345 GBP/kWh (0.41 EUR/kWh; 0.56 USD/kWh) for installations smaller than 1.5 kW, dropping to 0.045 GBP/kWh (0.053 EUR/kWh; 0.073 USD/kWh) kWh for installations of 1.5–5.0 MW. This stimulated the installation of more than 17,000 small and medium wind systems across the UK. The rates were cut in July 2012 and degression triggers were introduced.

The Electricity Market Reform to be implemented by the Energy Act is a new support system for all forms of low carbon power beyond 2017 was passed in December

Offshore wind capacity grew 79% in 2013 and for the first time, more new wind capacity was installed offshore than on land.

Table 1. Key National Statistics 2013: United Kingdom	
Total installed wind capacity	10,861 MW
New wind capacity installed	2,422 MW
Total electrical output from wind	26.1 TWh
Wind generation as % of national electric demand	6.0%
Target	15% renewables by 2020

2013. The Act changes the support for renewables from a fixed certificate price to a guaranteed strike price for their power, with a levy on energy bills funding the difference payments from a day-ahead reference price. The contracts are also only 15 years compared to the RO's 20-year run.

The Electricity Market Reform programme will provide incentives to support investment in secure, low-carbon electricity generation, while improving affordability for consumers. The electricity sector is a critical part of the UK economy, is an important driver of growth, and is key to meeting the UK's commitment to reduce its emissions of carbon dioxide. The key elements of this market reform will be delivered through two new mechanisms: CfDs and the Capacity Market.

CfDs will support new investment in all forms of low-carbon generation: renewables, nuclear power and carbon capture and storage and have been designed to provide efficient and cost-effective revenue stabilization for new generation, by reducing exposure to the volatile wholesale electricity price. CfDs require generators to sell energy into the market as usual but, to reduce this exposure to electricity prices, CfDs provide a variable top-up from the market price to a pre-agreed "strike price." 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 CfD will be implemented through a bilateral contract between the generator and the CfD Counterparty Company Ltd.

Additional investments of around 40 billion GBP (48 billion EUR; 66 billion USD) are expected in renewable electricity generation projects before 2020 in the UK, after the government updated the terms of contracts and strike prices. The strike price arrangements are far more enticing for offshore wind compared with onshore, as the government seeks to encourage developers to construct new windfarms around the coastline of Britain, where they face less public objection. The strike price for offshore wind will be 155 GBP/MWh (187 EUR/MWh; 257 USD/MWh) in 2014–2015, while onshore wind will receive 95 GBP/MWh (114 EUR/MWh; 157 USD/MWh).

Transitional measures will allow renewable investors to choose between the new system and the existing RO which will remain stable up to 2017. The current ROCs scheme will close in 2017 and be overtaken by CfDs—this is intended to stabilize revenues for investors in low-carbon electricity generation projects helping developers secure the large upfront capital costs for low carbon infrastructure while protecting consumers from rising energy bills.

The government is taking steps to introduce a capacity market, allowing for capacity auctions from 2014 for delivery of capacity in the winter of 2018–2019, if needed, to help ensure the lights stay on 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.

Table 2. Current level of ROCs/MWh	
Onshore Wind	0.9
Offshore Wind	2.0

2.4 Issues affecting growth

Wind energy, on land in particular, continues to be a subject for debate. In addition there has been much policy disruption this year, given the Energy Act and also a review of financial support for land-based wind in the shorter term. Whilst delays in planning have reduced, time for decisions is still too long, and issues around aviation are still not yet fully resolved. In addition, the grid needs to be strengthened to accommodate renewable energy and the economic situation ensures that costs need to be reduced, particularly for offshore, which has faced challenges in attracting sufficient levels of financing.

The ongoing financial and economic difficulties across Europe have made it hard for some projects to proceed. This has been coupled with the process of Electricity Market Reform, which was legislated for via an Energy Act in the UK, completed in December. As a result, the entire financial support system will change in the UK, with the RO being phased out to new entrants by 2017 and the CfD being introduced from 2014. Sadly, two planned offshore projects were withdrawn this year—Argyll Array and Atlantic Array.

2.4.1 Offshore strategy

In August 2013, the UK government published the Offshore Wind Industrial Strategy which was developed in partnership with industry. The document aims to ensure that the maximum economic benefit can be derived for the UK supply chain from the development of offshore wind and announced a number of support programs.

Its vision was that, "industry and government work together to build a competitive and innovative UK supply chain that delivers and sustains jobs, exports and economic benefits for the UK, supporting offshore wind as a core and cost effective part of the UK's long-term electricity mix." The vision is to deliver: economic growth creating tens of thousands of long term UK jobs; a clear and sustainable project pipeline; major manufacturing facilities in the UK; a competitive UK-based supply chain: a technology cost-competitive with other low carbon technologies.

2.4.2 EC targets

The European Commission decided not to set mandatory renewable energy targets for member states, beyond 2020. Although an EU-wide binding target for renewable energy of at least 27% by 2030 has been proposed, there is no legislation to enforce member states to adopt these as national targets. To date these national targets have been helped the UK maintain the momentum of recent years and ensure continued investment in projects and technology developments.

The European Parliament voted in favour of more binding renewable energy targets to be implemented through national thresholds. However, this decision is still pending.

The UK has opposed binding, country-level renewable energy targets, because they want to use nuclear, carbon capture and storage, and new gas-fired power stations as part of their energy mix in future decades.

3.0 Implementation

3.1 Economic impact

The UK wind industry already employs over 16,500 people in direct full-time jobs and in a survey conducted by trade association, RenewableUK, 54% of member companies expect to take on more staff over the next 18 months.

3.2 Industry status

Until recently the UK did not have an established wind turbine manufacturer. In 2013, Siemens announced plans to invest 160 million GBP (193 million EUR; 265 million USD) in wind turbine production and installation facilities in the UK. Having a leading wind turbine manufacturer invest in the UK market will help strengthen and develop a home-grown supply chain, enabling the industry to reduce costs and achieve its offshore wind goals.

Manufacturing capacity was added in the small and medium wind sector in 2013 by Hutchinson Engineering (towers for medium-size turbines) and Endurance Wind Power (small wind turbines). In addition TAG Energy on Teesside secured its first offshore wind order to supply monopiles for the E.On Humber Gateway Project. In February 2013, a 50 million GBP (60 million EUR; 83 million USD) logistics facility was completed in Belfast Harbour for DONG Energy and ScottishPower Renewables, supporting up to 300 long-term jobs.

The top four market players for 2012–2013 (last figures available) were: Siemens (25%), Vestas (22%), Senvion (13%), and Alstom (13%).

3.3 Operational details

In 2013, the UK saw further achievements in wind power development and further large developments took place on land in Scotland.

Offshore installed capacity stood at 3,321 MW at the end of June 2013, up from 1,858 MW one year earlier—an increase of 79%. Four large-scale offshore projects went operational during the year—Greater Gabbard, Gunfleet Sands III, Sheringham Shoal, and London Array. London Array is the world's biggest offshore wind park (630 MW), exemplifying the trend towards larger offshore schemes.

The 1,463 MW installed offshore marks the first year in which offshore deployment has outstripped land-based wind. On land, 1,258 MW of new capacity came into operation, bringing the total installed on land to 6,389 MW—an increase of 25%.

On land and offshore, a total of 2,721 MW were installed between July 2012 and June 2013, taking the UK's total wind capacity up from 6,856 MW to 9,710 MW—a 40% increase—enough to power more than five and a half million UK homes. The new capacity brought 2.0 billion GBP (2.4 billion EUR; 3.3 billion USD) of activity to the UK economy.

On land, project sizes are declining overall, due partly to the growth of the vibrant 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 number of land-based projects approved at local authority level (i.e. less than 50 MW) fell slightly to 68% (from 72% in 2011–2012), and 56% of projects were approved on appeal.

There is also a substantial pipeline of projects under construction, approved but not yet built, and in planning. New guidance has also been issued clarifying that landscape and visual effects need to be considered.

4.0 R, D&D Activities

To continue and accelerate the development of wind energy, the UK government provides funding for R&D projects in partnership with industry. Innovation support is needed from early stage development through to demonstration and pre-commercial deployment.

The National Renewable Energy Centre (Narec), based in northeast England, is a focus for UK offshore renewable research, testing, and demonstration. It opened a 15-MW drive train test facility for offshore wind turbines in 2013 and once final commissioning is complete will test Samsung Heavy Industries' 7-MW nacelle assembly. Narec provides the most comprehensive open-access test and research facilities anywhere in the world for the scale-up of offshore renewable energy technologies. Facilities include: a 50-m and a 100-m blade test bed, a 3-MW tidal turbine drive train test stand, three dry dock facilities, as well as a UK Accreditation Service accredited electrical and materials laboratory. They help get new technologies ready for deployment sooner by providing accelerated life testing and proof-of-concept trials. This helps improve device reliability, reduce product costs, and accelerate the development and deployment of offshore renewable energy technologies in the UK.

In 2013, Narec was granted dual planning consents for the construction of a 99-MW offshore wind site and onshore substation. As a result an offshore wind demonstration site can be built in deep water, just off the coast of Blyth, Northumberland.

The 11-turbine offshore demonstration site at the European Offshore Wind Deployment Centre near Aberdeen, Scotland is being led by Vattenfall, together with the Aberdeen Renewable Energy Group (AREG). It was granted consent from Scottish ministers last year. U.S. tycoon Donald Trump tried to get the approval overturned, but this legal challenge was rejected by the Court of Session.

Samsung Heavy Industries has finished erecting its 7-MW demonstrator turbine, off the Methil coast as part of the Methil Offshore Wind Demonstration Farm located in Fife, Scotland.

Wave Hub, the offshore renewable energy test facility in Cornwall, has applied for consent to install and operate a floating wind platform demonstrator. If successful, it could host the project as early as 2015.

4.1 National R, D&D efforts

4.1.1 Research Councils UK Energy Programme

Each year the Research Councils invest around 3.0 billion GBP (3.6 billion EUR; 4.9 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. 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 maximize 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 (751 million EUR; 1.0 billion USD) in research and skills to pioneer a low carbon future. This builds on an investment of 839 million GBP (1.0 billion EUR; 1.4 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.

Table 3. Offshore wind projects by the end of 2013

Wind farm name	Total capacity (MW)
Barrow	90.0
Beatrice	10.0
Blyth Offshore	3.8
Burbo Bank	90.0
Greater Gabbard	504.0
Gunfleet Sands I + II	172.8
Gwynt y Mor*	576.0
Inner Dowsing	108.0
Kentish Flats	90.0
Lincs*	270.0
London Array 1	630.0
Lynn	97.0
North Hoyle	60.0
Ormonde	150.0
Rhyl Flats	90.0
Robin Rigg	180.0
Scroby Sands	60.0
Sheringham Shoal	317.0
Teesside*	62.0
Thanet	300.0
Walney 1	184.0
Walney 2	184.0
West of Duddon Sands*	389.0

* under construction

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 expertise in wind turbine technology, aerodynamics, hydrodynamics, materials, electrical machinery and control, and reliability and condition monitoring.

The Technology Strategy Board (TSB) is an executive, Non-Departmental Public Body, established by the government in 2007 and sponsored by the Department for Business, Innovation and Skills (BIS). The TSB activities are jointly supported and funded by BIS and other government departments, the devolved administrations, and research councils. The TSB 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.

The TSB is one of the public sector members of the Energy Technologies Institute and, in addition, is working closely with other funding agencies such as the Department of Energy and Climate Change (DECC), the Research Councils, and Carbon Trust to develop a coordinated Energy R&D program for the UK. The TSB will continue to oversee the development and execution of the Catapult Centres—a network of world-leading centers designed to transform the UK's capability for innovation in seven specific areas and help drive future economic growth. One of the centers is dedicated to offshore renewable energy.

4.1.2 The Offshore Renewable Energy (ORE) Catapult

The ORE Catapult is a technology innovation and knowledge center established by the TSB for the identification, development and rapid commercialization of innovative technology to deliver affordable, offshore renewable energy. The ORE Catapult works in collaboration with policy makers, industry large and small, utilities, owners, and the UK's research organizations.

Established in 2012 as a not-for-distributed profit organization, the ORE Catapult has grown rapidly and now has more than 35 members of staff, with a view to being approximately 120 strong in four years. Having moved into its new headquarters in Glasgow in January 2014, the ORE Catapult is now establishing a center of deep technical expertise to lead innovation and research development and provide support services to others, such as small- and medium-sized enterprises (SMEs). The ORE Catapult has completed a number of pilot projects focusing on industry standardization, offshore cables, and performance and reliability. These pilot projects have led to a full program of projects, including:

System performance, Availability and Reliability Trend Analysis (SPARTA): Collaborating with The Crown Estate and offshore wind farm owner/operators to create a database of offshore wind farm performance data that will improve wind turbine operational performance by increasing safety, reliability and availability, thereby cutting the cost of electricity generated from offshore wind. A pilot is being run from April 2014 to March 2015, with full roll-out of the database scheduled for March 2015.

Marine Farms Accelerator: In collaboration with the Carbon Trust, the ORE Catapult is identifying and agreeing areas where innovation in marine technology is needed, and then funding the development and deployment of projects to physically test and demonstrate the technologies, and strategically guide them into delivery.

The Tidal Array Model Real-World Evaluation Project: A joint project with Nova Innovation Ltd aimed at improving existing tidal modelling techniques to give a greater understanding of our tidal resource, and therefore maximize energy generation from tidal devices.

In the future the ORE Catapult will be focusing on key areas where it can have an impact on cost reduction. We will work in the areas of blade materials and manufacturing processes, drawing in new expertise from the High Value Manufacturing Catapult and its partners. The ORE Catapult will also play a key role in unlocking the opportunity through supporting design, testing and demonstration of new foundations concepts, and by supporting standardization and development of new manufacturing techniques. The ORE Catapult is already working in this area to support the standardization of cable designs and facilitate R&D in polymeric cables rated above 400 kV that can be used for both offshore wind and interconnector high voltage direct current (HVDC) projects. It also supports the development of fault detection and condition monitoring equipment specifically for the offshore wind sector.

Power transmission is a significant area of cost reduction which is often overlooked.

The ORE Catapult's role will be to support the standardization of electrical systems and substation design and promote innovation in HVDC networks. Finally, the ORE Catapult can contribute by supporting work to increase the range of working conditions offshore, improve the efficiency of crew access for maintenance and standardize strategies for component replacement and turbine access. It will facilitate the move to condition-based (rather than time-based) maintenance of turbines though the introduction of new sensor technologies, many of which will be developed by UK SMEs. ORE Catapult will also facilitate collaborative research programs such as the SPARTA platform.

4.1.3 Energy Technologies Institute (ETI)

The 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. Public sector representation is through the BIS, with funding channeled through the TSB and the EPSRC. DECC are observers on their Board.

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. The ETI has the following projects in offshore wind energy technology.

Offshore Wind Test Facility—In 2011 ETI commissioned GE Energy Power Conversion and MTS to design, develop and commission an indoor test rig capable of testing a complete wind turbine drive train and nacelle. Samsung Heavy Industries delivered a 450-ton nacelle, one of the largest of its kind in the world, which will eventually undergo a rigorous on-shore testing program within the world's largest test rig facilities at Narec, once installation and final commissioning is complete.

Very Long Blades Project—Blade Dynamics announced in December 2013 that the design phase of their 'Very Long Blade Project' had successfully concluded and that the prototyping phase would now begin. Blade Dynamics will now assemble an approximately 80-m long blade prototype, and will begin static and fatigue tests before the end of 2014.

Offshore wind floating platform—This activity is aimed at demonstrating floating foundation technology for 60–100 m water depth. The global market for floating turbines is potentially greater than for fixed foundations. The ETI is now evaluating the outcome of the front end engineering design study for the Glosten tension leg demonstrator floating platform. Floating turbine technology may be of strategic importance to both UK energy supply and industrial strategy. Glosten is currently using the insights generated by the study to work up an investment case for a full-scale demonstrator; most likely at the Wave Hub site in Cornwall.

Condition Monitoring—This project developed an intelligent, integrated, predictive package, which has shown improvements in the capability to holistically monitor wind turbines. The condition monitoring project showed that it is feasible to increase turbine availability. Asset managers can use it to maintain turbines in a smarter way and thus reduce downtime. Through increased revenue and reduced O&M costs, potential savings of up to (0.008 GBP/kWh 0.0096 EUR/kWh; 0.0132 USD/kWh) for offshore wind turbines could be achieved. Launched in September 2009 with 5.4 million GBP (6.5 million EUR; 8.9 million USD) of ETI funding, the system was tested on turbines belonging to EDF in France and E.ON in North Yorkshire. The project was completed in 2013.

4.1.4 GROW: Offshore Wind

GROW: Offshore Wind is a 20 million GBP (24 million EUR; 33 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 SMEs 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 utilize 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 (601,500 EUR; 828,500 USD) toward the costs of tangible and intangible assets associated with businesses' investment plans, and toward the costs of jobs directly related to this investment. This support is available to SMEs and to large enterprises that fall within an EC-designated assist area.

Finally, the GROW programme offers Process Technology Innovation support up to 500,000 GBP (601,500 EUR; 828,500 USD) to allow beneficiaries to work with technology partners on R&D programs focussed on developing products to take to market. Support can cover costs of personnel, instruments and equipment, materials and supplies, land and buildings, and other eligible overheads. This support is available to SMEs and large enterprises.

The program was launched at the RenewableUK conference in June 2013 with the turning on of the GROW website (www.growoffshorewind.com), where companies can register an interest in receiving support or register to become a consultant in the program. RenewableUK spent 2013 completing a detailed supply chain mapping exercise. This should give program participants insight into the components they can sell in the offshore wind supply chain and the necessary prerequisites to enter these markets.

The GROW advisors are also helping to identify projects that can benefit from larger grant awards under the Flexible Enabling Fund and Process Technology funds. A number of beneficiaries have been awarded grants of between 10,000–20,000 GBP (12,030–24,060 EUR; 16,570–33,140 USD) for the acquisition of various fixed assets (plant, machinery, equipment, software) to help them deliver their investment plans.

For 2014, larger projects are being developed, and larger developers are referencing GROW within their procurement strategies linked to the wider roll out of the national Round 3 Offshore Wind programme.

4.1.5 Other efforts

The Offshore Wind Programme Board (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 levelized cost of energy (LCOE) of 100 GBP/MWh

(120 EUR/MWh; 166 USD/MWh) for projects reaching the final investment decision in 2020. In 2014, the work of the OWPB moves from planning and establishment of structures to real delivery.

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 and is funded by ETI and the EPSRC RCUK Energy programme.

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. The Centre will train up to 50 students in the research and skills needed to accelerate the development of renewable energy technologies. They 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 gain an internationally-leading engineering doctorate.

The Carbon Trust—Offshore Wind Accelerator 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 Offshore Wind Accelerator research, development, and demonstration program focuses on five areas:

- Access systems—Developing improved access systems to transfer technicians and equipment onto turbines for operations and maintenance in heavier seas
- Cable installation—Improving cable installation methods
- Electrical systems—Developing new electrical systems to reduce transmission losses and increase reliability
- Foundations—Developing new turbine foundation designs for 30–60 m water depths that are cheaper to fabricate and install
- Wake effects—Improving the layout of large wind farms to reduce wake effects and optimize yields

The Low Carbon Innovation Co-ordination Group brings together the major public-sector backed funders of low carbon innovation in the UK. Its core members include DECC, BIS, Carbon Trust, ETI, TSB, the EPSRC, the Scottish government, the Scottish Enterprise, and several other organizations. 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 the UK's capabilities, knowledge and skills.

4.2 Collaborative Research

The Regional Growth Fund Wind Innovation Project provides technical support and administration of 11 million GBP (13 million EUR; 18 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. The program is expected to create or safeguard in the region of 750 jobs with further employment opportunities expected to follow.

The Demonstration of Methods and Tools for the Optimisation of Operational Reliability of Large-Scale Industrial Wind Turbines (OPTIMUS) is a collaborative FP7 project to develop and demonstrate novel strategies to enable the prognosis of the remaining lifetime of key wind turbine components.

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.

4.2.1 Offshore renewable energy R&D facilities

Narec, on behalf of The ORE Catapult, is mapping all the open access R&D testing facilities within the UK to enable prospective customers identify facilities which can be used to deliver commercial as well as funded R&D programs. The online directory will also be a useful resource helping to identify any potential capability gaps in UK.

5.0 The Next Term

Whilst the renewable energy industry as a whole has experienced highs and lows over the past 12 months, the offshore wind sector has enjoyed a record breaking year in terms of new deployment, with offshore wind capacity growing by a record 79% in 12 months. Over one thousand offshore wind turbines have already been installed and the UK is the most attractive destination for investment in the world. DECC and industry have set out a plan to continue to be the largest global market for offshore wind, with the scenarios recently published enabling deployment of 8–15 GW by 2020, and up to 41 GW by 2030.

It is inevitable there will be some degree of attrition in the industry with the scale of the projects planned—the strike price announced late last year is far more enticing for offshore wind developments and there remains a large number of projects awaiting consent and under development.

With the Energy Act now passed, and also final decisions due to be made on which projects qualify for final investment decision, the economic climate may also be easier for investors. However, the UK has a general election in May 2015 so we can expect debate around wind energy to heat up in the second half of the year, following local and European elections.

In summary, Energy Minister Michael Fallon recently commented that, "the UK is the world leader in offshore wind—with more deployed than any other country, and a framework in place to retain our global lead. The benefits that offshore wind can bring are clear: as costs fall it can enhance our long-term energy security, reduce our dependence on imports, and help reduce our carbon emissions. And, crucially, offshore wind can play a vital role in driving growth—adding billions of pounds of value to the UK economy and supporting thousands of jobs."

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Opening photo: London Array Limited

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36 United States

1.0 Overview

The United States installed 1,087 MW of new wind power capacity in 2013. Wind energy accounted for nearly 4.1% of national electricity generation, was deployed in 40 states and territories (1), and represented 9.95% of new U.S. electricity generation capacity at the end of 2013, down from 43% in 2012 (2). The reduction of installed capacity between 2012 and 2013 is largely attributed to the late extension of the production tax credit (PTC).

The distributed wind sector in the United States also continued to advance at a much slower pace in 2013, installing 26.6 MW of new capacity. Although domestic installations decreased, U.S.-based small wind manufacturers were able to take advantage of the global market and increase exports in 2013 (3).

Offshore wind development progressed in 2013 with 14 projects representing 4.9 GW of potential capacity in advanced stages of development and the successful completion of the country's first offshore wind lease auctions conducted by the Bureau of Ocean Energy Management (BOEM) (4).

The U.S. Department of Energy (DOE) opened three new research and testing facilities in 2013. In addition, the Wind Program launched a new research effort—Atmosphere to Electrons (A2e)—to gain a better understanding of the underlying physical processes and causal effects driving wind plant underperformance. DOE also announced 70 grants totaling 10.50 million USD (7.62 million EUR) to small businesses to develop innovative wind energy technologies with a strong potential for commercialization and a 1.70-million-USD (1.23-million-EUR) funding opportunity to assist small wind turbine manufacturers in lowering the cost of energy by improving components and manufacturing processes. In offshore wind research, the University of Maine deployed the world's first concrete-composite floating platform and Wind Program researchers continued their development of computer-aided engineering design tools for floating offshore wind turbine platforms. Other areas of research included studies on the integration of large penetrations of wind, new technologies to mitigate the impacts of wind on radar, and measures to mitigate the impacts of wind energy on local bird and bat populations. DOE also launched a Collegiate Wind Competition that challenges undergraduate students to design, build, and test a small portable wind turbine and develop a business plan to market it.

2.0 National Objectives and Progress

In an effort to address climate change, the Obama administration released *The President's Climate Action Plan* in June 2013 (5). The United States doubled renewable energy generation (largely driven by wind) between 2008–2012. It is expected that wind energy will contribute significantly to achieving the President's 2020 goal.

In December 2013, the White House released a memorandum that directed federal agencies toward a new goal of 20% renewable energy consumption by 2020. The new objective reflects the progress federal agencies have made toward the previous sustainability goals that were established in Executive Order 13514 of 5 October 2009.

In addition, DOE launched an effort in 2013 to renew the vision of its *20% Wind Energy by 2030* report published in 2008 (6) that will characterize the progress made toward achieving that vision and develop a roadmap to address the challenges

The U.S. wind fleet generated almost 168 GWh of electricity in 2013, which avoided nearly 96 million tons of carbon dioxide (CO_2) emissions from power generation.

Table 1. Key National Statistics 2013: United States	
Total installed wind capacity (1)	61,110 MW
New installed wind capacity (1)	1,087 MW
Total electrical output from wind (1)	168 TWh
Wind generation as a percentage of national electric demand (1)	4.1%
Average national capacity factor (Wiser and Bolinger, 2013)	32.1%
Target	80% of electricity from clean sources by 2035. Double renewable electricity generation by 2020 (relative to 2012 levels)

to achieving higher levels of wind in the nation's energy mix.

2.1 National targets

Although the U.S. government has no official targets for wind energy, in his 2011 State of the Union Address, President Obama proposed achieving 80% of U.S. electricity from clean energy sources (including renewable energy technologies, nuclear, clean coal, and natural gas) by 2035.

2.2 Progress

Total U.S. wind capacity at the close of 2013 was more than 61 GW compared to just 2.5 GW in 1999. Wind generation represented nearly 4.1% of total U.S. electrical consumption in 2013. In 17 states, wind generation meets more than 5% of demand. The U.S. wind fleet generated almost 168 GWh of electricity in 2013, which avoided nearly 96 million tons of CO_2 emissions from power generation. This avoided CO_2 is equivalent to reducing national power system emissions by 4.4% or to eliminating the emissions of almost 17 million cars (1). In addition, 61 GW of wind plants operating for a full year avoids the consumption of more than 36.5 billion gallons of water.

U.S. wind turbines in distributed applications reached a cumulative installed capacity of 842 MW at the end of 2013, reflecting nearly 72,000 units installed. In 2013, 30.4 MW of new distributed wind capacity was added, a decline of 83% from 2012 (3).

Although domestic installations were down in 2013, exports from U.S.-based small wind turbine manufacturers increased 70% from 8 MW in 2012 to an estimated total of 13.6 MW in 2013. Small wind turbines (those up to 100 kW in size) were exported to more than 50 countries in 2013, with top export markets reported to be in countries in Africa as well as China, Germany, Greece, Italy, Japan, México, South Korea, and the United Kingdom (3).

By the end of 2013, 14 offshore wind projects were in various stages of development. These projects representing 4.9 GW of anticipated capacity and are primarily located in the Northeast, Mid-Atlantic, Great Lakes, and Gulf of México regions (1).

2.3 National incentive programs

Federal tax and grant incentives and state renewable portfolio standards (RPS) help stimulate the growth of wind capacity. The PTC, a performance-based tax credit for electricity produced by a wind facility after it is built, was enacted as part of the Energy Policy Act of 1992 and has been the primary driver of wind development over the past 20 plus years. PTCs, loan programs, and various levels of bonus depreciation were effective through 2012, but the late one-year extension of the PTC had minimal effect during the first two quarters of 2013 (1.6 MW installed). The industry began rebounding in the third and fourth quarters, installing 68.3 MW and 1,012.4 MW, respectively. The language associated with the extension of the PTC should allow for industry growth in 2014, 2015, and possibly 2016. The Internal Revenue Service released clarification that allows projects to qualify for the PTC if they began construction, or incurred 5% of total costs, by the end of 2013 and remain under continuous construction (7).

State-based RPS that require utilities to purchase a percentage of their overall generating capacity from renewable resources are major drivers of wind deployment and represent local support for the increased use of clean energy technologies. Twenty-nine states, the District of Columbia, and Puerto Rico have RPS. Another eight states have goals for renewables (8). Utility resource planning requirements, voluntary customer demand for "green" power, state clean energy funds, and state and regional carbon-reduction policies also play roles in supporting wind energy development.

The Maryland Offshore Wind Energy Act of 2013 established offshore wind renewable energy credits for up to 200 MW, requiring peak load price suppression and limiting rate impacts to be considered. Also in 2013, the state of Illinois passed the Lake Michigan Wind Energy Act, which requires the Illinois Department of Natural Resources to develop a detailed offshore wind energy siting matrix for Lake Michigan (4).

The business energy investment tax credit (ITC) is another incentive that has historically been used to develop both small and residential wind energy in the United States. Extended through the American Recovery and Reinvestment Act of 2009, the ITC is available through 2016 for small wind systems with a capacity range of 100 kW or less (9).

In 2013, a second phase of the 48C Advanced Energy Manufacturing Tax Credit Program was launched to take advantage of 150 million USD (109 million EUR) in tax credits that were not used by awardees during the first round of funding. The 48C program was initiated under the Recovery Act to support investments in projects that establish, expand, or reequip clean energy manufacturing facilities. LM Wind Power was the only wind-related manufacturer selected. The company received a 700,000 USD (508,200 EUR) tax credit to assist in reequipping its North Dakota blade facility. The project is expected to result in 170 new jobs at the facility.

2.4 Issues affecting growth

The wind industry and DOE's Wind Program are addressing barriers to increased deployment of wind energy through research, development, and demonstration (R, D&D) projects.

2.4.1 Consistent federal policy incentives

As the primary incentive for wind energy development, consistency in terms of the PTC has been one of the major issues affecting the growth of the industry in the United States. The boom-bust cycle associated with the PTC has historically seen wind energy development drop once the tax credit has been allowed to expire. This is illustrated by the 92% reduction of installed capacity between 2012 (13,131 MW) and 2013 (1,084 MW) (1).

2.4.2 Cost of energy

Low natural gas prices have suppressed wholesale power prices across the nation, making it harder for wind and other renewable power technologies to compete on cost alone despite their recent cost and performance improvements (10). Research conducted by DOE indicates that future wind deployment will be relatively low unless additional incentives are provided that result in wind being cost competitive with existing gas-fired generation (11).

2.4.3 Transmission and integration

Transmission access has historically been one of the barriers to development of wind energy projects, driving project developers to choose sites with less wind potential but with access to transmission. Developing sites with less wind potential increases the resulting cost of energy. According to the Edison Electric Institute (EEI), 12,200 miles of transmission are currently being added or upgraded to support renewable energy (wind, solar, biomass, hydroelectric, geothermal, and biofuels).

Another barrier to increasing deployment of wind energy has been concern from utilities about wind-induced cycling of fossil-fueled generation. The Wind Program continues to work with industry and other stakeholders, conducting various analyses to better understand the cycling impacts and help reduce these barriers.

2.4.4 Siting issues

Siting issues—including wildlife impacts, radar interference, and human impacts (acoustic and visual)—can push wind development into lower-quality wind regimes and increase the cost of energy. For this reason, DOE continues to fund work to identify, measure, and mitigate the negative impacts that can limit development in quality wind resource areas.

2.4.5 Issues affecting distributed wind growth

Several factors contributing to slower distributed wind market growth in 2013 include competitive photovoltaic and natural gas prices and suspended or reduced state and federal incentives. Utility confidence about the integration of distributed wind systems is another issue hampering market growth.

3.0 Implementation

By the end of 2013, the state of Texas had the most total wind capacity at 12,354 MW, followed by California at 5,829 MW, Iowa at 5,177 MW, and Illinois at 3,568 MW (1). According to the American Wind Energy Association (AWEA), new construction activity has been focused in the nation's interior, particularly from North Dakota through Texas. The completion of the Competitive Renewable Energy Zone (CREZ) transmission project in Texas is expected to further increase wind energy development in the state by providing the capability to transmit approximately 18.5 GW of wind power to various load centers (12).

Although no offshore projects were in the water at the end of 2013, 14 offshore wind projects were identified as being more advanced in the development process (4). In addition, BOEM successfully conducted two offshore wind lease auctions (in Rhode Island/Massachusetts and Virginia). In December 2013, BOEM announced a third offshore wind lease auction for Maryland that is expected to be completed in 2014.

3.1 Economic impact

The wind industry has supply chain or utility-scale wind facilities in all 50 states. According to AWEA, the 61.1 GW of wind capacity operating at the close of 2013 represented close to 120 billion USD (87.1 billion EUR) in U.S. investment, and the new installations in 2013 alone represented approximately 2.0 billion USD (1.45 billion EUR) in private investment. AWEA estimates that the entire U.S. wind energy sector directly employed 50,500 full-time workers. Of these jobs, 17,400 were in manufacturing. There are currently 35 manufacturing facilities in the United States that produce the major wind turbine components and 560 wind-related manufacturing facilities spread across 43 states (1).

3.2 Industry status

Approximately 60 power purchase agreements (PPAs) were signed for wind energy across the country in 2013–three times the number signed in 2012. These PPAs total almost 8,000 MW with 5,200 of the 8,000 MW having yet to begin construction. More than 905 wind facilities were operating in 39 states and Puerto Rico. Major wind manufacturers across the country currently have more than 5,600 MW in turbine orders. The number of wind turbine suppliers fell from 28 in 2012 to only seven in 2013–General Electric Energy (GE Energy), Siemens, Sany, Vestas, EWT Americas, PowerWind, and Vergnet. GE Energy continued to hold the largest market share providing 90.5% of the capacity installed in 2013 (1).

Although direct utility ownership of wind projects is increasing, reaching 14% in 2013, the majority of wind projects are still owned by independent power producers with approximately 64% of the wind energy procured through long-term PPAs. Corporate purchasers such as Google and Microsoft continued to invest in wind power along with companies such as Facebook, Walmart, BD, and Starbucks (1).

3.3 Operational details

Excluding projects with one or two turbines, the average project size in 2013 was 82 MW. Projects completed in 2013 used wind turbines ranging in size from 225 kW to 2.85 MW (1). The U.S. wind fleet comprises approximately 46,100 wind turbines with 582 installed in 2013. The average capacity rating of the wind turbines installed in 2013 is 1.87 MW, average hub height is 80.3 m, and average rotor diameter is 97 m (1). Of the 582 turbines installed in 2013, 437 had a 100-m or larger rotor diameter.

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 cost per kilowatt in the 900–1,300 USD/kW (653–944 EUR/kW) range.

4.0 R, D&D 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 program's new A2e effort aims to develop high-fidelity modeling tools for wind plants, and to assess opportunities to maximize performance, minimize costs, and mitigate risk from an integrated wind plant systems perspective. A2e is designed to ultimately furnish industry with validated tools and demonstrated concepts for developing next-generation technologies.

4.1 U.S. R, D&D efforts

DOE also conducted R, D&D in 2013 in the areas of offshore wind deployment; new research and testing facilities; emerging technology applications; supply chain capabilities; distributed wind applications; grid system integration, planning, and operations; workforce and education efforts; and siting, radar, and environmental studies.

4.1.1 Offshore wind

The University of Maine-led DeepCwind Consortium deployed the world's first concrete-composite floating platform wind turbine off the coast of Maine. Funded in part by DOE, the 1:8th-scale system employs a 20-kW turbine that is 19.8 m tall and has a 9.6-m diameter rotor (Figure 1). The primary objectives of the project are to validate coupled aero-elastic/hydrodynamic computer models for floating offshore wind turbines and to better understand the dynamic response behavior of floating offshore wind systems.

To facilitate the safe deployment of offshore wind projects, DOE published a report that summarizes the regulations, standards, and guidelines for the design and operation of offshore wind projects in the United States (13). The report introduces the pertinent international and domestic offshore design standards, discusses their relative applicability and shortcomings, and provides a snapshot of industry and government efforts that are under way (or planned).

DOE is also funding research to determine the design basis for offshore systems related to "slam loads" from breaking waves (Figure 2). A computational fluid dynamics model simulates breaking wave loads on a monopile to analyze time variation of horizontal and vertical forces and associated moments in water depths where breakers are anticipated. Improved design methods will reduce uncertainty of the design basis for offshore wind power generation systems and result in more robust designs while reducing the cost of construction and, ultimately, the cost of energy.

Figure 1. The University of Maine's 1:8th-scale offshore wind demonstration project (Photo by University of Maine)

4.1.2 New wind research and test facilities

DOE opened three new research and testing facilities in 2013. Clemson University's Drivetrain Test Facility, located on a former navy base in South Carolina, is equipped with two dynamometers (a 7.5-MW and a 15-MW) capable of testing wind turbine drivetrains with capacity ratings up to 15 MW. The facility will also be 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 new 5-MW dynamometer test facility at 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. The 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

In 2013, DOE announced 70 grants totaling 10.5 million USD (7.6 million EUR) to small businesses to develop innovative technologies with a strong potential for commercialization. The awards included three projects that will explore concepts for improving the performance and reducing the costs of land-based and offshore wind technologies: a compact, low-power wind sensor to monitor offshore winds and optimize wind power; a lightweight 5–6 MW superconducting wind turbine generator that is easily transportable; and field-assembled, component-based rotor blades that will avoid the expense and logistical challenges of transporting very large blades.

DOE is also funding the development of an innovative, medium-speed, medium-voltage wind turbine drivetrain design. The design consists of a single planetary stage gearbox that uses a fraction of the rare-earth magnets typically used in direct-drive permanent-magnet generators of similar power,

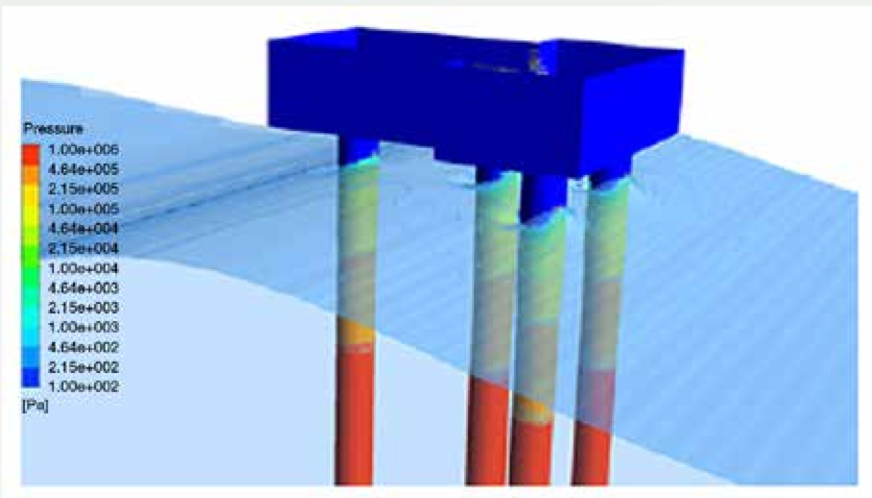

Figure 2. Simulation of breaking wave loads on a monopile (Courtesy of MMI Engineering)

improves the load distribution, and increases the drivetrain's overall reliability.

4.1.4 Supply chain capabilities

To ensure long-term industry growth, DOE conducted several studies on the nation's infrastructure and supply chain capabilities. The *U.S. Offshore Wind Manufacturing and Supply Chain Development* report (14) assesses the domestic supply chain and manufacturing infrastructure required to support a growing U.S. offshore wind energy market. The report includes baseline information on current industry status and a strategy for meeting future supply chain needs under several long-term industry growth scenarios. The *Assessment of U.S. Manufacturing Capability for Next-Generation Wind Turbine Drivetrains* report (15) evaluates the current state of manufacturing and supply chain capabilities for advanced wind turbine drivetrain technologies in the United States. The *Analysis of Transportation and Logistics Challenges Affecting the Deployment of Larger Wind Turbines* study (16) examines the influence of transportation and logistics on the deployment of larger land-based turbines in the United States.

4.1.5 Distributed wind applications

For distributed wind technologies, DOE announced a 1.70-million USD (1.23-million EUR) funding opportunity to assist small wind turbine manufacturers in lowering the cost of energy by improving components and manufacturing processes and increasing system performance and reliability through testing. DOE also continued to support the testing of wind turbines at four small wind regional test centers and the establishment of the Small Wind Certification Council to provide third-party verification of test results in accordance with international standards.

4.1.6 Grid system integration, planning, and operations

DOE published a study on how the contribution of wind power providing active power controls could benefit the total power system economics, increase revenue streams, and improve reliability while having negligible impacts on the turbine and its components (17).

DOE also published several studies that examined the impacts of integrating large penetrations of wind energy into the nation's electrical grid. The *Western Wind and Solar Integration Study Phase 2* (18) examined the wear-and-tear costs and emission impacts of wind and solar power on the cycling of the fossil-fueled fleet in the U.S. Western Interconnection. Results from this study showed that from a system perspective, the avoided fuel costs from larger deployments of wind energy are greater than the increased cycling costs for fossil-fueled plants. The results from the *Eastern Renewable Generation Integration Study* (19) comprehensively characterized the variability and uncertainty inherent in wind and solar power, to which the balance of the generation portfolio will need to respond. The analysis can help determine the effectiveness of operational strategies and could be used to help electric utility owners and operators better plan and operate the eastern interconnections while minimizing the cost of integrating high penetrations of wind and solar power.

4.1.7 Workforce and education efforts

Ten college and university teams were chosen to compete in the inaugural Collegiate Wind Competition. The competition challenges undergraduate students from multiple disciplines to design, build, and test a wind turbine to perform according to a customized, market-data-derived business plan, as well as to demonstrate their knowledge of key market drivers and deployment acceleration opportunities.

Through the establishment of new Regional Resource Centers, DOE supports a regional approach to stakeholder engagement and outreach, in recognition that deployment opportunities and concerns as well as information needs vary across the country, and that partnerships among regional organizations have a unique and critical role to play in meeting these needs.

4.1.8 Siting, radar, and environmental studies

DOE and its federal agency partners recently completed the final operational field test in a two-year initiative to accelerate the deployment of the most promising new technologies for mitigating radar interference caused by the physical and electromagnetic effects of wind turbines. These new mitigation technologies are expected to give wind developers access to new areas where projects have been deferred, delayed, or cancelled because of wind turbine interference with radar systems.

To mitigate potential barriers to increased wind deployment in more highly populated areas, DOE's Berkeley Lab conducted two studies on the impacts of wind development on residential property values: The *Relationship Between Wind Turbines and Residential Property Values in Massachusetts* (20) and *A Spatial Hedonic Analysis of the Effects of Wind Energy Facilities on Surrounding Property Values in the United States* (21). These reports examined 122,000 Massachusetts real estate transactions between 1998 and 2012, and 50,000 U.S. transactions between 1996 and 2011, respectively. The studies found no evidence of impacts of wind turbines on home property values.

DOE is also funding studies on the potential impacts of offshore and land-based wind energy development on bird and bat populations. These studies include the monitoring acoustic bat activity at 36 sites distributed across the three regions around the Great Lakes and Atlantic coastal areas, sage-grouse studies in the Great Plains states, and golden eagle studies in the Appalachian Mountains.

4.2 International collaborations

International collaborations supported by DOE's Wind Program in 2013 included work with:

- Bats and Wind Energy Cooperative
- International Electrotechnical Commission
- Institute of Electrical and Electronics Engineers; Underwriters Laboratory
- International Measuring Network of Wind Energy Institutes
- Technical University of Delft (Netherlands)
- Det Norske Veritas-Germanischer Lloyd (DNV-GL)
- Offshore Renewable Energy Conversion platforms–Coordination Action
- Norwegian Research Centre for Offshore Wind Technology
- National Renewable Energy Centre (United Kingdom)
- National Renewable Energy Centre (CENER) of Spain
- International Energy Agency (IEA) Wind Implementing Agreement.

U.S. representatives also participated in research conducted for most of the IEA Wind tasks in 2013 and served as operating agents for Task 26, Cost of Wind Energy; Task 30, Offshore Code Comparison Collaboration Continuation (OC4); Task 31, WAKEBENCH: Benchmarking Wind Farm Flow Models; and Task 34, Environmental Assessment and Monitoring, a new task that held its kickoff meeting in December 2013.

5.0 The Next Term

DOE's Wind Program announced a new Wind Vision initiative in May 2013 that will revisit the findings of the 2008 DOE *20%*

Wind Energy by 2030 report (6) to develop a renewed vision for U.S. wind power R, D&D based on the current status of the industry. The objectives of the initiative are to:

- Provide leadership for developing a cohesive long-term vision for the benefit of the broad U.S. wind power community
- Analyze a range of aggressive but attainable industry growth scenarios
- Disseminate best available information to address stakeholder concerns
- Deliver objective and relevant information for use by policy and decision makers.

To achieve these objectives, the Wind Program is working closely with more than 150 key wind energy companies and organizations that are contributing to various task forces formed to examine key industry issues and considerations. Task force topic areas include the following:

- Wind plant technology
- Manufacturing and logistics
- Operations and maintenance, project performance, and reliability
- Transmission and integration
- Wind power project development—siting and permitting
- Scenario modeling
- Market data and analysis
- Offshore wind
- Roadmap

The IEA Wind Technology Roadmap, IEA Wind Strategy 2014–2018, and Long-Term R&D Needs documents provided input for the new Wind Vision roadmap. Initial results and a draft of the Wind Vision are expected to be released in 2014.

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Opening photo: Forward Wind Energy Center in Fond du Lac and Dodge Counties, Wisconsin. (Credit: Ruth Baranowski)

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Appendix A

ExCo 71 Meeting in Vienna, Austria (Credit: Rick Hinrichs)

Appendix B

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Appendix C

Currency Conversion Rates IEA Wind Annual Report 2013			
Country	Currency	1 EUR	1 USD
Australia	AUD	0.648	0.893
Austria	EUR	1.000	1.378
Canada	CAD	0.683	0.941
China	Yuan	0.120	0.165
Denmark	DKK	0.134	0.185
Finland	EUR	1.000	1.378
Germany	EUR	1.000	1.378
Greece	EUR	1.000	1.378
Ireland	EUR	1.000	1.378
Italy	EUR	1.000	1.378
Japan	JPY	0.0069	0.0095
Korea	KRW	0.0007	0.00094
México	MXP	0.055	0.076
Netherlands	EUR	1.000	1.378
Norway	NOK	0.120	0.165
Portugal	EUR	1.000	1.378
Spain	EUR	1.000	1.378
Sweden	SEK	0.113	0.155
Switzerland	CHF	0.815	1.123
United Kingdom	GBP	1.203	1.657
United States	USD	0.726	1.000
Source: Federal Reserve Bank of New York (www.x-rates.com) 31 December 2013			

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-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

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.

WT: wind turbine

Yr: year

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