IEA WIND
2012 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

July 2013

ISBN 0-9786383-7-9

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Message from the Chair

Welcome to the IEA Wind 2012 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 countries representing 85% of the world's wind generating capacity.

In 2012 record capacity additions (MW) were seen in nine member countries, and cooperative research produced five final technical reports as well as many journal articles and conference papers. The technical reports include:

- *IEA Wind Task 19 State-of-the Art Report of Wind Energy in Cold Climates*
- *Design and operation of power systems with large amounts of wind power: Final summary report, IEA Wind Task 25, Phase two 2009–2011*
- *The Past and Future Cost of Wind Energy, IEA Wind Task 26 Work Package 2 Report,*
- *Final Report IEA Wind Task 28 on Social Acceptance of Wind Energy Projects 2008–2011*
- *Final report of IEA Wind Task 29, Mexnext (Phase 1): Analysis of MEXICO wind tunnel measurements.*

In 2012, we approved another IEA Wind Recommended Practice, *RP 13 Wind Energy Projects in Cold Climates*, which contributed to reducing the risks of projects in cold climates, where the wind resource is so abundant. We held Topical Experts Meetings on advances in wind turbine and component testing, social acceptance of wind energy projects, and wind farm control methods. Moving forward, we approved a new research task to share results on environmental assessment and monitoring techniques for wind developments on land and offshore.

In 2013, we expect to approve Recommended Practices on social acceptance of wind energy projects, on remote wind speed sensing using SODAR and LIDAR, and on conducting wind integration studies. The 12 active research tasks of IEA wind will offer members many options to multiply their national research programs, and a new task on ground-based testing of wind turbines and components is being discussed for approval in 2013.

With market challenges and ever-changing research issues to address, the IEA Wind co-operation works to make wind energy an ever better green option for the world's energy supply. Considering these accomplishments and the plans for the coming years, it is with great satisfaction and confidence that I hand the Chair position to Jim Ahlgrimm of the United States.

Hannele Holttinen
Chair of the Executive Committee, 2011 to 2012

Jim Ahlgrimm
Chair-Elect of the Executive Committee

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1 Executive Summary

Source: PWT Communications

1.0 Introduction

Wind generation now meets a significant percentage of electrical demand worldwide. In 2012, the world added a record 44.8 gigawatts (GW) of wind generation, bringing the total to more than 282.5 GW (GWEC 2013). This capacity, now operating in 100 countries, can provide more than 3% of the world's electricity demand (WWEA 2013).

Nearly 85% of the world's wind-generating capacity resides in the 21 countries participating in the IEA Wind Implementing Agreement, an international co-operation that shares information and research activities that advance wind energy deployment. These IEA Wind member countries added nearly 37 GW of capacity in 2012, which is more than 82% of the worldwide market for the year. With approximately 240 GW of wind generating capacity, electrical production from wind met 3.3% of the total electrical demand in the IEA Wind member countries (Tables 1–3).

This *IEA Wind 2012 Annual Report* contains chapters from each member country, the Chinese Wind Energy Association (reporting on the People's Republic of China), and the European Wind Energy Association and European Commission (reporting on all of the European Union countries). The countries report on 2012 activities: how much wind energy they have deployed, how they benefit from wind energy, and how their policies and research programs will increase wind's contribution to the world energy supply. This 2012 annual report also presents the latest research results and plans of the 13 active co-operative research activities (Tasks) of IEA Wind.

Record increases in MW capacity were reported in Australia, Austria, Finland, Italy, México, Norway, Sweden, United Kingdom, and the United States.

Table 1. Key Statistics of IEA Wind Member Countries through December 31, 2012	
Total installed capacity	239.59 GW
Total offshore wind capacity*	4.58 GW
Total new wind capacity installed in 2012	On land 35.71 GW Offshore 1.25 GW Total 36.96 GW
Total annual output from wind	449.39 TWh
Wind generation as a percent of IEA Wind members' national electric demand in 2012	3.3%

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

Table 2. National Statistics of the IEA Wind Member Countries 2012

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	2,584	0	358	1,397	2,000	7.7	226.0*	3.4%
Austria	1,378	0	296	763	2,740	2.5	60.5	5.0%
Canada	***6,201***	0	***936***	***3,580***	***1,975***	***16.3***	***590.0***	***2.8%***
China	75,324	389.6	12,960	53,764	1,646	100.4	4,940.0	2.0%
Denmark	4,162	920.0	210	5,016	2,731	10.3	34.9	29.9%
Finland	288	26.0	90	162	2,800	0.5	85.2	0.6%
Germany	31,315	280.0	2,244	22,962	2,377	46.0	594.5	7.7%
Greece**	1,749	0	117	1,357	1,145	3.3	57.0	5.8%
Ireland	1,827	25.0	153	1,266	2,420	***4.0***	***27.8***	***14.5%***
Italy	8,144	0	1,266	6,166	1,760	***13.1***	325.3	***4.0%***
Japan	2,614	25.3	78	1,887	2,438	4.5	860.8	0.52%
Korea	487	2.0	81	301	1,209	0.86	451.1	***0.2%***
México	1,212	0	645	800	1,500	***3.4***	272.0	***1.2%***
Netherlands	***2,431***	228.0	***161***	2,062	2,370	4.9	120.3	4.1%
Norway	704	2.0	195	325	2,166	1.6	130.0	1.1%
Portugal	***4,517***	***2 .0***	***147***	***2,408***	***1,800***	***10.0***	***49.1***	***20.0%***
Spain	22,785	0	1,112	20,185	1,920	48.2	252.19	17.8%
Sweden	3,524	0	755	2,391	2,127	7.1	142.0	5.0%
Switzerland	49	0	3.9	***32***	***1,531***	***0.1***	***59.8***	***0.1%***
UK	8,292	2,679.0	1,822	4,414	2,200	***21.8***	365.3	***6.0%***
United States	60,007	0	13,131	45,125	1,945	140.1	4,054.5	***3.5%***
Totals	239,594	4,576.9	36,957.0	175,671	2,038	449.4	13,705.49	3.3

Bold italic indicates estimates
* Percent of national electricity demand from wind = (wind generated electricity / national electricity demand) × 100
** Global Wind Energy Council (GWEC 2013) numbers in 2012

Table 3. Worldwide Installed Wind Capacity for 2012

IEA Wind Members*		Rest of World**	
Country	MW	Country	MW
China	75,324	India	18,421
United States	60,007	France	7,564
Germany	31,315	Other Countries***	4,650
Spain	22,785	Brazil	2,508
UK	8,292	Poland	2,497
Italy	8,144	Turkey	2,312
Canada	***6,201***	Romania	1,905
Portugal	***4,517***	New Zealand	623
Denmark	4,162	Taiwan	564
Sweden	3,524	Egypt	550
Japan	2,614	Morocco	291
Australia	2,584	Caribbean	271
Netherlands	***2,431***	Argentina	167
Ireland	1,827	Costa Rica	147
Greece**	1,749	Tunisia	104
Austria	1,378	Nicaragua	102
México	1,212	Iran	91
Norway	704	Pakistan	56
Korea	487	Ethiopia	52
Finland	288	Uruguay	52
Switzerland	49	Venezuela	30
Totals	239,594	Cape Verde	24
		Pacific Islands	12
		Total Rest of World	42,993
		Grand Total	282,587

* Numbers reported by IEA Wind member countries
** Numbers reported by GWEC (2013)
*** Countries not in this list or in IEA Wind
Bold italic indicates estimates

This Executive Summary presents highlights from the report's country and task chapters as well as compiled statistics for all countries. Data from the past 16 years as reported in previous IEA Wind documents (IEA Wind 1995–2011) are included as background for discussions of 2012 events.

2.0 Objectives and Progress

In 2012, the International Energy Agency (IEA) published its Energy Technology Perspectives 2012 that demonstrates how technologies can make a difference in limiting global temperature rise to 2 degrees C. (IEA 2012). Wind energy, especially offshore wind energy, are seen as having great potential. In 2013, IEA will update its Technology Roadmap for Wind Energy (IEA 2010). The upcoming roadmap targets 15% to 18% of global electricity from wind power by 2050. The previous target of 12% has been seen as too conservative.

In 2012, wind energy supplied 3% of global electricity. Significant investments will be required to reach that goal. Governments and industry in IEA Wind member countries have set national targets for renewable energy and wind energy (Table 4), designed incentive programs (Table 9), and conduct focused research and demonstration programs to help reach these targets (Table 14). Their reasons for supporting wind energy include increasing domestic energy supply, reducing greenhouse gas emissions, building domestic industry, and replacing coal-fired and nuclear generation.

In 2012, the fruits of these efforts came to bear as nine IEA Wind countries saw record increases in wind capacity: Australia, Austria, Finland, Italy, México, Norway, Sweden, United Kingdom, and the United States.

2.1 National targets

The IEA Wind member countries have targets embedded in legislation, appearing in roadmap documents, or announced by elected officials for increasing the amount of renewable energy or low-carbon energy in the electrical generation mix (Table 4).

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. Some EU countries have chosen goals that exceed the targets of their NREAPs (including Austria, Denmark, and Germany).

Outside of Europe, planning is under way to increase wind power development. Australia's Renewable Energy Target scheme is designed to deliver 20% of Australia's electricity from renewable sources by 2020. Canada set the goal to reduce greenhouse gas emissions by 17% below 2005 levels by 2020. The Chinese government issued its 12th Five-Year Plan, which included goals for grid-integrated wind capacity of 100 GW by 2015.

After the Fukushima nuclear power plant accident in 2011, a fundamental review of Japan's Basic Energy Plan was conducted. All but one of the 190 wind turbines shaken by the earthquake or struck by the tsunami resumed operation immediately after and contributed to Japan's power supply during the continuing crisis. Therefore, wind energy is viewed as a viable contributor in the future. The review developed new options or scenarios for energy through 2030. In the three new scenarios, the share of renewable energy would be from 25% to 35%. It is estimated that a reasonable growth rate of 18% in wind capacity would meet the most aggressive (0% nuclear) scenario for Japan by 2030.

The Republic of Korea's Third National Energy Plan 2030 sets the goal to replace 11% of electrical consumption with wind energy and to develop the domestic wind industry. México is on track to have 12 GW of wind generation by 2020, supplying approximately 5% of electric consumption.

2.2 Progress

2.2.1 Capacity increases

In 2012, wind generation capacity increased in every IEA Wind member country; the countries added a total of nearly 37 GW, a 15% increase over 2011 capacity. Capacity has

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

Country	Renewable Energy Sources (RES) Target	Wind Target
Australia	45 TWh by 2020	---
Austria	---	3 GW by 2020
Canada	---	---
China	---	100 GW (5 GW offshore) by 2015; 200 GW (30 GW offshore) by 2020
Denmark	100% by 2050 More than 35% renewable by 2020	50% of electricity 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	10 GW offshore by 2025
Greece	40% of electricity by 2020	---
Ireland	40% by 2020	3.5 GW by 2020
Italy	17% by 2020	12.68 GW and 20 TWh/yr by 2020
Japan	Prospect: 25% to 35% by 2030	Prospect: 5 GW by 2020
Korea, Republic of	12% of consumption by 2030	7.3 GW by 2030; 11% of consumption
México	---	12 GW by 2020
Netherlands	16% by 2020; 20% reduction CO_2 in 2020 as compared to 1990 level	---
Norway	67.5% of total energy consumption in 2020	---
Portugal	31% of gross energy consumption by 2020	6.8 GW onshore, 0.075 GW offshore by 2020
Spain	20% of overall energy consumption by 2020	35 GW onshore, 0.75 GW offshore by 2020
Sweden	Increase generation by 22.6 TWh/yr over 2002 level by 2050	30 TWh by 2020: 20 TWh onshore, 10 TWh offshore
Switzerland	Increase generation by 22 TWh by 2050	4.0 TWh/yr by 2050 (0.6 TWh by 2020, 1.5 TWh by 2035)
United Kingdom	15% by 2020	---
United States	80% of electricity from clean sources by 2035	54 GW offshore by 2030

--- = No target available

increased in the IEA Wind member countries as a whole from less than 5 GW in 1995 to more than 239 GW in 2012 (Figure 1).

- Record increases in capacity were reported in Australia, Austria, Finland, Italy, México, Norway, Sweden, United Kingdom, and the United States.
- More wind capacity was added in 2012 than in 2011 in 13 countries: Australia, Austria, Denmark, Finland, Germany, Italy, Korea, México, the Netherlands, Norway, Spain, Switzerland, and the United States.
- More than 1 GW was added in six countries: United States (13.13 GW), China (12.96 GW), Germany (2.44 GW), the United Kingdom (1.82 GW), Italy (1.27 GW), and Spain (1.11 GW) (Table 2). Canada, Sweden, and México also added more than 600 MW each. In all, 17 countries added more than 100 MW of new capacity.
- México had the highest growth: a 113% increase. Nine countries saw growth of 20% or more in 2012, compared to five countries in 2011 (Table 5).

A notable shift toward renewable energy sources was reported in 2012. In the EU, renewable power installations accounted for 70% of new capacity, and wind power alone accounted for 26.5% of total 2012 power capacity installations. In the United States, wind capacity represented 43% of new generation installed in 2012.

2.2.2 Offshore wind progress and plans

Among the IEA Wind member countries, offshore wind systems totaling more than 4.5 GW were operating at the close of 2012 (Table 6), with the addition of more than 1.25 GW in China, Denmark, Germany, and the United Kingdom. The UK brought 841 MW online in 2012 and will connect the 630-MW London Array in 2013 as the world's largest offshore wind power plant.

During 2012 in the EU, offshore wind power installations represented 10% of the annual EU wind energy market, up from 9% in 2011. With the completion of the wind farms that were not fully grid-connected during 2012, approximately 1.4 GW of new offshore capacity is due to come online in 2013. The European Wind Energy Association (EWEA) has identified 18.4 GW of consented offshore wind farms in Europe and plans for offshore wind farms totaling more than 140 GW.

Outside of Europe, many countries are planning to expand capacity with offshore wind. In China, nine coastal provinces have released offshore wind power development plans. Japan installed a demonstration floating offshore wind project and is planning for wind turbines in its deep waters offshore. Korea began construction of the first phase of a 2.5-GW offshore wind farm in 2011—the first 100 MW will demonstrate the technology and the quality of the site.

In the United States, 10 offshore wind projects totaling 2.84 GW were identified by the end of 2012 as advancing in the development process. The National Offshore Wind Strategy published in 2011 calls for reducing the cost of offshore wind energy and deployment of 54 GW by 2030. In 2012, the Department of Energy made Phase 1 awards in a 168 million USD (127 million EUR) offshore wind initiative. Seven technology partnerships will plan and design offshore wind demonstration projects. In Phase 2, three of these partnerships will be selected to build full-scale offshore wind generation facilities. Offshore wind facility developments were further

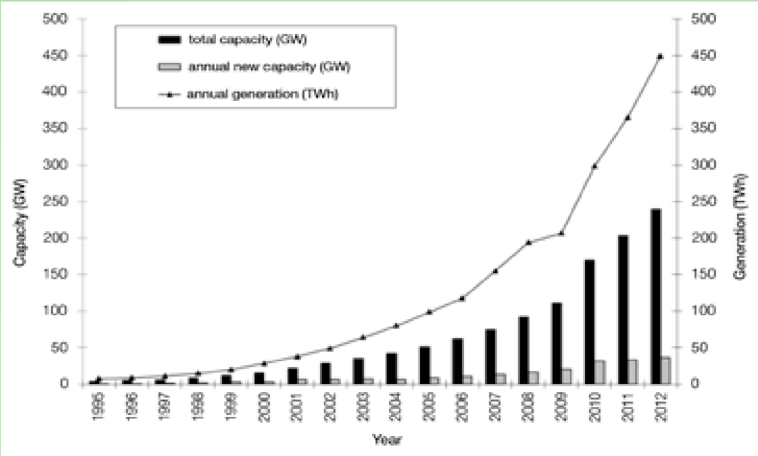

Figure 1. Annual installed capacity, cumulative installed capacity, and annual generation as reported by IEA Wind member countries, 1995–2012 (Note: China is first represented in 2010.)

Table 5. Wind Energy Capacity Increases in IEA Wind Member Countries

Country	Cumulative capacity (MW) (2011)	2012 added capacity (MW)	Increase (%)
México	570	645	113
Finland	199	90	45
Norway	511	195	38
United Kingdom	6,470	1,822	28
United States	46,916	13,131	28
Austria	1,084	296	27
Sweden	2,899	755	26
China	62,364	12,960	21
Korea	406	81	20
Canada	***5,265***	***936***	***18***
Italy	6,878	1,266	18
Australia	2,224	358	16
Ireland	1,633	153	9
Germany	29,075	2,440	8
Switzerland	46	3.9	8
Greece	1,640	117	7
Netherlands	2,368	***161***	7
Denmark	3,952	210	5
Spain	21,673	1,112	5
Japan	2,536	78	3
Portugal	4,302	***147***	3

% increase = (added capacity 2012 / capacity in 2011) x 100
Bold italic indicates estimates

facilitated with the adoption of the American Wind Energy Association (AWEA) *Offshore Compliance Recommended Practices* that address the unique conditions for wind energy development in U.S. waters.

2.2.3 Electrical production

Total wind energy electrical production from all IEA Wind member countries increased by more than 73 TWh in 2012. Meanwhile, total national electrical demand for 2012 *increased* in six IEA Wind member countries (Canada, China, Finland, Japan, México, and the United States) and *decreased* in nine countries (Australia, Austria, Germany, Ireland, Italy, the Netherlands, Norway, Portugal, and Spain). National electrical output from wind energy increased in all countries except Germany, Ireland, and the Netherlands, where lower-than-average winds dominated the year.

Electrical production is influenced by the quality of the wind resource for the year and the operating availability of the wind plants. 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 five-year or ten-year average wind resource. Table 7 classifies the wind resource in 2012 compared to average as reported by some member countries.

Some countries set records in 2012 for wind penetration (contribution to electric demand) (Table 8). Denmark has the new world record by meeting nearly 30% of national electric demand from wind energy in 2012. Wind energy met 20% of Portuguese electricity demand in 2012 and at one moment in October, instantaneous wind contribution to demand reached 86%. In Spain, wind power exceeded previous instantaneous power peaks and maximum hourly and daily energy production. In November 2012, wind generation contributed 21.3% of the energy mix, the highest of all the existing technologies in Spain.

2.3 National incentive programs

All IEA Wind member countries have government structures designed to encourage renewable energy development. Most of these incentives also apply to wind energy (Table 9). In 2012, feed-in tariffs (FITs) were used by 16 of the 21 IEA Wind member

Table 6. Offshore Wind Energy Capacity in IEA Wind Member Countries 2011–2012

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

Table 7. Reported Wind Resource for 2012 Compared to Average

High wind Country (index%)	Average wind Country (index%)	Low wind Country (index%)
Austria (110%) Canada Italy Norway (103%) Switzerland (110%) United Kingdom	Australia China Japan Korea Spain Sweden United States*	Denmark (95.2%) Finland (88%) Germany Ireland the Netherlands (89%) Portugal (97%)

* Regional resources vary across the continent in any year

countries to encourage wind development and are reported as 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 (RPS).

In some countries, existing incentive programs were at risk of expiring or being rescinded (e.g., Portugal, Spain) due to changes in the political climate or, in some cases, resulting from the financial crisis. In others, new incentives are being discussed, such as carbon taxes. In Australia, a fixed carbon price per ton of carbon dioxide equivalent emissions began in July 2012. This cost is added to the retail product (mostly electricity) resulting from combustion. Half of the income raised will be used to accelerate the deployment of clean energy sources. The other half will assist households to pay for the higher cost of electricity.

In China, the trading of green certificates by electricity-generating enterprises was being considered. In Japan, incentives will be considered as part of the new energy scenarios to reduce dependence on nuclear and fossil energy. In Korea, the RPS that took effect in 2012 is having a positive effect. In México, the new law for renewable energy instructs the Secretariat of Energy and the Secretary of Economy to promote manufacturing of wind turbines in México. In the United States, a key incentive, the production tax credit, was extended for another year.

2.4 Issues affecting growth

At the end of 2012, fewer countries were able to report on projects planned or under construction due to uncertainty in many markets (Table 10). For the EU, EWEA has identified 1.4 GW due to come on line in 2013 and another 1.9 GW in 2014. EWEA also reports 18.4 GW of consented offshore wind farms in Europe and plans for wind farms totaling more than 140 GW.

The following issues, which are reported as limiting renewable energy growth, are being addressed through national research projects, incentive programs, and co-operative research projects of IEA Wind and other groups:

Economic Climate: Surprisingly, the global economic climate did not have the expected slowing effect in 2012, but a slow economy is expected to reduce renewable energy installations in 2013.

Table 8. Percent Contribution of Wind to National Electricity Demand 2010–2012

Country	2010	2011	2012
Denmark	21.9	28.0	29.9
Portugal	17.0	18.0	***20.0***
Spain	16.4	16.3	17.8
Ireland	10.5	15.6	***14.5***
Germany	6.0	7.6	7.7
United Kingdom	2.6	4.2	***6.0***
Greece	4.0	5.8	***5.8***
Sweden	2.6	4.4	5.0
Austria	3.0	3.6	5.0
Netherlands	4.0	4.2	4.1
Italy	***2.6***	***3.0***	***4.0***
United States	***2.3***	***2.9***	***3.5***
Australia	2.0	2.4	3.4
Canada	***1.8***	***2.3***	***2.8***
China	1.2	1.6	2.0
México	***0.6***	***0.6***	***1.2***
Norway	0.7	1.0	1.1
Finland	0.3	0.6	0.6
Japan	0.4	0.5	0.52
Korea	0.2	0.2	***0.2***
Switzerland	0.05	0.1	***0.1***
IEA Wind Average	**2.3**	**2.8**	**3.3**

Bold italic = estimate

Policy Uncertainty: Government programs to increase access to financing, provide larger subsidies, and issue targeted grants are mentioned as ways to reduce the effects of policy uncertainty. In several countries, government cost-cutting measures have targeted funds allocated for incentive programs.

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

Grid Integration and Capacity Issues: In many countries, the electrical grids are adapted to the needs of centralized, large-scale power plants, and their capacity is limited to absorb large amounts of wind power. Curtailment results when the grid operators shut down wind farms to alleviate transmission bottlenecks. Improved forecasting and grid upgrades are addressing this problem. Several countries made progress in upgrading or adding transmission lines to carry wind capacity.

Permitting Delays: Delays due to permitting requirements have limited wind developments in several countries. In Finland, the effect of wind turbines on radar became a permitting issue, so an impartial and transparent procedure and scientific tool were developed to help the Ministry of Defence estimate the radar impacts. In Japan, adding the requirement for an environmental impact assessment could delay projects for 3–5 years.

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

Social Acceptance: Social acceptance is becoming an issue in nearly every country with wind development. IEA Wind Task 28 Social Acceptance of Wind Energy Projects is addressing the process of wind project development. In Australia, best practice documents include *Community Engagement Guidelines for the Australian Wind Industry* and *Wind Industry Best Practice Technical Guidelines* for the implementation of wind energy projects in Australia.

Skilled Labor Availability: Demand for skilled labor is increasing with annual increases in operating wind capacity. The United Kingdom commissioned its first Industrial Doctorate Centre in Renewable Energy. It will train up to 50 students in the research and skills needed to

Table 9. Incentive Programs in IEA Wind Member Countries for 2012 into 2013

Type of program	Description	Countries implementing
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.	Australia; Austria; Canada; China; Denmark (offshore and small wind turbines); Finland (special definition); Germany; Ireland; Italy; Japan (from July 2012); Korea; the Netherlands (special definition); Portugal; Switzerland; United Kingdom (15 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.	Australia; Canada; China; Italy; Japan (till June 2012); Korea; Norway; Portugal; Sweden; United Kingdom; United States (11 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.	Australia; Austria; Canada; Denmark; Finland; Netherlands; Sweden; Switzerland; United States (9 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)
Spatial planning activities	Areas of national interest that are officially considered for wind energy development.	China; Denmark; Korea; México; the Netherlands; Sweden; Switzerland (7 countries)
Special incentives for small wind	Ireland: Reduced connection costs, conditional planning consent exemptions. Value-added tax (VAT) rebate for small farmers. Accelerated capital allowances for corporations. Can include microFIT.	Australia; Canada; Denmark; Ireland; Italy; Japan (from July 2012); Portugal; United States (8 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)
Net metering	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.	Canada; Denmark; Italy; Korea; United States (5 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 (voluntary supplier tariff for domestic micro-wind); Sweden; Switzerland; United States (7 countries)
Investment funds for wind energy	Share offerings in private wind investment funds are provided, plus other schemes that focus on wealth creation and business success using wind energy as a vehicle to achieve these ends.	Australia; Canada; Switzerland; United Kingdom (4 countries)
Net billing	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.	Netherlands (small wind only); Portugal (micro-generation only); United States (3 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 UK (3 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; Ireland; Portugal (3 countries)
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.	Netherlands; Switzerland
Payroll tax credit	A rebate for payroll tax (4.95% of wages) incurred during project construction that developers of renewable energy projects with capacities greater than 30 MW may receive.	Australia
Carbon tax	A tax on carbon that encourages a move to renewables and provides investment dollars for renewable projects.	Australia
Relief from import tax	Large wind turbine technology and related components included on lists of imports are exempt from customs and import VAT charges.	China
Special licensing to reduce administrative burden	RES plants are exempt from the obligation to attain certain licenses; on islands, RES plants that are combined with water desalination plants get priority.	Greece

Table 10. Potential Increases to Capacity in IEA Wind Member Countries			
Country	Planning approval* (MW)	Under construction** (MW)	Total planned and/ or under construction (MW)
Australia	4,277	1,627	5,904
Austria	400	419	819
Canada (by 2016)	5,000	---	5,000
China	18,000	---	60,000
Denmark (Anholt)	---	400	400
Finland	104	21	125
Korea	---	420	420
México	2,082	413	2,495
Norway	1,943	66	2,009
Spain	245	115	360
Switzerland	15	3	18
United Kingdom	6,441	4,904	11,345
United States	---	---	***539***

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

accelerate the development of renewable energy technologies.

3.0 Implementation

3.1 Economic impact

A key impact of wind energy development is creating employment and economic activity. A study in Australia estimated that a 50-MW wind farm could contribute up to 2.6% to the gross regional product. A Canadian study estimated that 1 GW of new wind energy creates 10,500 person-years of employment. In 2012, Canada added 0.94 GW of new wind capacity. A study in the United States concluded that wind plant installations between 2000 and 2008 in 12 states resulted in local employment of 0.5 jobs/MW. Another key impact is domestic manufacture and export of wind turbines, components, and consulting expertise. Table 11 shows reported labor and economic turnover effects for 2012 in the IEA Wind member countries.

One of the positive effects of wind energy is displacing fossil fuel consumption and the related economic and environmental costs. Most countries perform a calculation of 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.

3.2 Industry status

The wind industry is growing, and several countries are making concerted efforts to attract wind turbine manufacturing to their domestic economies. Wind projects are owned by utilities, co-operatives, independent power producers (IPPs), private companies (i.e., industries for self-supply), income funds, and communities (including First Nations).

3.3 Operational details

Wind plants composed of many individual wind turbines are becoming more productive by several measures. One of these is capacity factor. The annual capacity factor is the amount of energy a generating plant produces over the year divided by the amount of energy that would have been produced if the plant had been running at full capacity during that same time interval. For wind turbines, capacity factor is dependent on the quality of the wind resource, the availability of the machine (i.e., reliability) to generate when there is enough wind, and the turbine design.

The capacity factor will be reduced if the utility curtails production due to load management. Most wind power plants operate at a capacity factor of 25% to 40%. For reference, the world average capacity factor for wind has been estimated at 21% (IEEE 2012); the highest capacity factor reported offshore is 52% at Horns Rev, Denmark (energynumbers 2013); and the highest capacity factor reported onshore is 57.9% at Burradale, Shetland Islands (REUK 2013). IEA Wind countries report their average annual capacity factors Table 12.

The average power rating of new wind turbines installed in 2012 was slightly more than 2 MW; however, turbines as large as 7.5 MW have been installed. In Austria one of these 7.5-MW turbines covers the energy requirements of approximately 4,000 households.

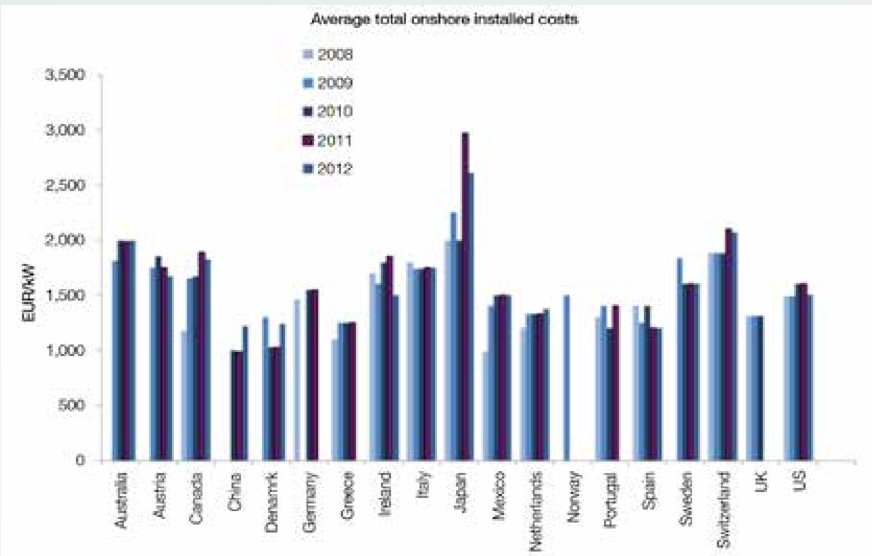

Figure 2. Average installed costs of wind turbines 2007–2012 as reported by IEA Wind member countries. Costs are not adjusted.

Table 11. Capacity in Relation to Estimated Jobs and Economic Impact 2012

Country	Capacity (MW)	Estimated number of jobs	Economic impact (million EUR; million USD)
China	75,324	250,000	---
United States	60,007	80,700	91,000; 120,000
Germany	31,315	117,900	---
Spain	22,785	16,970	2,894; 3,744
United Kingdom	8,292	---	---
Italy	8,144	30,000	2,100; 2,768
Canada	***6,201***	10,500	1,520; 2,003
Portugal	***4,517***	***3,200***	---
Denmark	4,162	***23,000***	***7,400; 9,575***
Sweden	3,524	---	---
Japan	2,614	2,500	1,582; 2,109
Australia	2,584	1,800	709; 935
Netherlands	***2,431***	2,100	740; 957
Ireland	1,827	2,200	---
Greece	1,749	1,800	---
Austria	1,378	3,300	500; 647
México	1,212	1,500	208; 269
Norway	704	---	---
Korea	487	1,103	1,092; 1,413
Finland	288	2,000	930; 1,230
Switzerland	49	---	38.9, 51.3
Total	239,594		

--- = No data available
Bold italic = estimate

3.4 Wind energy costs

The cost of electricity from wind generation, often referred to as the levelized cost of energy (LCOE) is declining. IEA Wind Task 26 is addressing this key metric 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.

Country chapters also address costs for turbine, development, and O&M costs in some detail. For example, a study in Australia found that the turbines represented 60% to 75% of project development costs. An Austrian study estimated O&M costs per kilowatt-hour (kWh) showing expected increases over time. Costs are higher for areas with mountainous terrain, long permitting processes, or long waits for grid connection.

Table 13 shows reported *turbine* costs in 2012 currency. Figure 2 shows trends of reported *installed* costs for wind projects by country. Please note that the historic cost numbers have not been corrected to 2012 currency.

4.0 R, D&D Activities

A significant benefit of participation in the IEA Wind agreement is the ability to participate in the research tasks that are only open to organizations within member countries. In 2012, 12 active research tasks were advancing wind energy technology and deployment. To guide these activities, the Executive Committee of IEA Wind will prepare in 2013 a new strategic plan for the period 2014 through 2019. This plan will be based on the document *Long-Term Research and Development Needs for Wind Energy for the Time Frame 2012 to 2030* developed through a Topical Expert Meeting, a working group, and a consensus process within the IEA Wind participants in 2012.

4.1 National R, D&D efforts

The major research areas discussed in the individual country chapters are listed in Table 14. 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). It is difficult to calculate the total research dollars supporting wind energy technology; however Table 15 lists government budgets reported by some countries. The investment of research partners must be considered as well.

The European Commission is a significant source of funding for wind energy research projects proposed by its member countries. In 2012, 28 wind R&D projects were running with the support of the Seventh (FP7) Framework Programme of the EU (the Framework Programmes are the main EU-wide tool to support strategic research areas). In addition, five offshore demonstration projects funded by the European Energy Programme for Recovery (EEPR) were under construction and three more were in the pipeline. Finally, six other innovative demonstration projects were awarded funding by the New Entrants Reserve funding program in late December. Fourteen EU Countries and the European Commission participate in IEA Wind research activities.

Outside of Europe, 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 to the chapter from the European Commission/European Wind Energy Association. A few highlights are presented here.

4.1.1 New test and research facilities

Several important new research centers were opened, under construction, or being planned in 2012.

Denmark opened the new onshore test center at Oesterild for wind turbines up to 250 m and plans an offshore test center for turbines up to 10 MW.

In Canada, construction of WEICan's new 10-MW Wind Energy R&D Park was completed in December 2011. In 2013, the park will be adding a utility-sized electricity storage system. The park will be able to study the economic and technical feasibility of wind-generated storage in Canada, in order to examine grid integration technologies to increase the economic viability of variable electricity generation.

In Germany, research at the alpha ventus test site continued with 45 organizations including universities, institutes, and companies. Three years of results were published in 2012. Among the extensive research activities on wind energy in Germany, test stands are under construction for 4-MW and 10-MW drive trains and for large support structure components.

In Spain, an experimental onshore wind farm located in complex terrain has six calibrated positions to install prototypes of large wind turbines up to 5 MW. A deep-sea offshore test station will test new technology and stimulate collaboration among major research centers, the industry, and universities. And, an open sea test facility can test full-scale prototypes as single devices or arrays to assess and monitor performance. A small wind test site can perform tests needed for certification.

In the United Kingdom, the National Renewable Energy Centre, (Narec) opened a new 100-m wind turbine blade test facility in 2012. A 15-MW drive train test facility for offshore wind turbines will be commissioned in summer 2013. Narec obtained a 100-MW grid connection and a lease from The Crown Estate for an offshore wind demonstration site in deep water, just off the Blyth coast. An Offshore Anemometry Hub was installed in November 2012 as part of the project.

In the United States, a new Scaled Wind Farm Technology test facility will open in 2013 with three research-scale wind turbines spaced and oriented to study turbine-to-turbine interactions. It will also help validate aerodynamic, aero-elastic, and aero-acoustic simulations used to develop new technologies. Blade test facilities and dynamometers for testing large drive trains are operating or near completion.

Table 12. Reported Average Capacity Factors (%)*

Country	2011 Average capacity factor (%)	2012 Average capacity factor (%)
Australia	---	35.0
Austria	---	30.0
Canada	31.0	31.0
China	---	18.4
Denmark	28.4	22.6
Finland	28.0	24.0
Germany	19.0	---
Greece	---	---
Ireland	31.6	28.4
Italy	18.0	---
Japan	19.0	19.9
Korea	---	---
México	30.0	30.0
Netherlands	---	On land 20.0 Offshore 39.5
Norway	31.3	31.2
Portugal	26.0	28.0
Spain	---	24.1
Sweden	---	26.0
Switzerland	20.0	<20.0
United Kingdom	On land 27.4 Offshore 36.7	On land 27.4 Offshore 36.7
United States	33.0	33.0

* 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.
--- = No data available

4.1.2 Highlights of completed research

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, the production penalties due to cold climates was assessed using actual production data from 24 wind farms located across the country. It is estimated that the cumulative weighted average loss for all wind farms currently operating in Canada is 6.6%. In eastern Canada, annual production loss percentage is much higher at 15.7%.

In Finland, the wind atlas was amended by adding an icing atlas in 2012. Challenging environments (e.g., offshore, in complex terrain, and exposed to extreme weather) are the focus of several national research projects and of IEA Wind Task 25 Wind Energy in Cold Climates.

Japan demonstrated a major commitment to offshore wind in 2012 by installing the following: a 2.4-MW wind turbine with a gravity foundation and offshore platform in the Pacific Ocean 3 km offshore; an offshore measurement platform 1.4 km offshore; and a 100-kW demonstration wind turbine on a spar-type floater 1 km offshore. In 2013, a large-scale floating offshore wind demonstration project will begin 20 km offshore of Fukushima prefecture. In Phase 1 of that demonstration, a 2-MW downwind wind turbine with a 4-column semi-submersible floater and a 66 kV floating offshore electrical substation will be installed.

In the Netherlands, the ecology/environmental study of the Monitoring and Evaluation Program (MEP) of the Offshore Wind farm Egmond aan Zee (OWEZ) was completed in 2012. The results show that the wind farm had few negative effects and several positive effects upon marine life. It also became clear that fruitful monitoring can only be done when good models exist to interpret the data. The new IEA Wind Task 34 Environmental Assessment and Monitoring will address the state of the art in techniques and models for evaluating environmental impacts of wind farms on land and offshore.

In Norway, a 1:6 scale model floating offshore turbine called SWAY is being tested in the sea outside Bergen under real conditions. Also, the world's first full-scale floating wind turbine (Hywind concept developed by Statoil) has operated for over two years and results for both production and technical availability have been positive. Hywind survived a powerful extra tropical cyclone, other storms with winds over 40 m/s, and maximum waves over 18 m. The next generation

Table 13. Estimated Average Turbine Cost and Total Project Cost for 2012

Country	Turbine cost (EUR/kW*)	Total installed project cost (EUR/kW*)
Australia	1,220	2,000
Austria	1,430	1,675
Canada	---	1,824
China	463.6	1,220
Denmark	---	on land 1,240
Greece	1,050	---
Ireland	900	1,500
Italy	1,200	1,750
Japan	1,740	2,610
México	1,200	1,500
Netherlands	---	on land: 1,376 offshore: 3,200
Spain	800	1,000–1,400
Sweden	1,400	1,600
Switzerland	1,450	2,070
United States	720-985	1,470

* Total Installed Project Cost includes: costs for turbines, roads, electrical equipment, installation, development, and grid connection.
** Applicable conversion rate EUR to USD: 1.318
--- = No data available

of Hywind will be deployed in the United States off the coast of Maine.

In Switzerland, an experimental design was used to determine the influence on local public acceptance of three wind project characteristics. Acceptance was higher if the project developer was a well-known Swiss company experienced with wind energy projects in contrast to an unknown developer acting on behalf of an investor. Local benefits associated with the project had the highest impact on local acceptance. Wind energy projects that included financial investment opportunities for local citizens were perceived more positively by local citizens than wind energy projects with the leasing of land as the only local benefit. IEA Wind Task 28 Social Acceptance of Wind Energy Projects is continuing its work with researchers of social acceptance issues.

A U.S. study used a global positioning system to track the movements of golden eagles and gain a deeper understanding of their movements and hence, the risks they face from wind energy development. A reliability database tracking the performance of the country's wind facilities published its second benchmark report in 2012, which covers three turbine manufacturers, six turbine models (at least 1-MW capacity), and more than 180,000 days of turbine operation. IEA Wind Task 33 Reliability: Standardizing Data Collection for Wind Turbine Reliability, Operation, and Maintenance Analyses will be accumulating the information from this kind of study worldwide.

Small wind turbines are attracting considerable interest in research programs. In Austria, several projects are underway addressing issues of small wind turbine deployment and operation. Ireland completed its field trials of small wind turbines and concluded that turbulent winds are a key design driver for small wind turbines. The United States published the Built-Environment Wind Turbine Roadmap in 2012 to guide development of safe, reliable small wind turbines. IEA Wind Task 27 Small Wind Turbines in Turbulent Sites began its second term by adding research on the turbulent wind regime of the urban or complex environment.

4.2 Collaborative research

The collaborative research conducted by organizations in the IEA Wind member countries made significant progress in 2012.

Task 11 Base Technology Information Exchange held Topical Expert Meetings on the following topics: Advances in Wind Turbine and Components Testing; Social Acceptance of Wind Energy; and Wind Farm Control Methods. Meetings planned for 2013 include Wind Energy in Complex Terrain; Operation and Maintenance Challenges; Noise Reduction Technologies; and Forecasting. In 2012, Task 11 also managed the approval process for three new Recommended Practices from IEA Wind research tasks (see below). 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 developed and IEA Wind approved a *Recommended Practice 13 Wind Energy Projects in Cold Climates* early in 2012. This work formed the basis for the fourth revision of the IEC standard 61400-1 Design Requirements, which included the effect of ice loads and low temperatures in design load cases. Having a dedicated design load case for wind turbines with ice accretion on blades gives manufacturers a tool to design turbines for these adverse conditions. This, in turn, leads to better technologies, reduction of O&M costs, and lower cost of energy from cold climate wind plants.

Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power published a paper, "Recommendations for Integration Studies," that will evolve into an IEA Wind Recommended Practice in 2013. A summary report of the 2009-2012 work was published at the beginning of 2013. Analysis of recent wind integration studies has addressed reserve requirements, balancing costs, impacts to the transmission grid, and capacity value of wind power. The task has involved the transmission system operators to ensure seamless application of the results. Publication through journal articles and conference presentations further improves understanding of wind integration issues.

Task 26 Cost of Wind Energy issued a report *The Past and Future Cost of Wind Energy Work Package 2* that reviews historical costs, evaluates near-term market trends, reviews the methods used to estimate long-term cost trajectories, and summarizes the range of costs projected for land-based wind energy across forward-looking studies and scenarios. It also highlights high-level market variables that have influenced wind energy costs in the past and are expected to do so in the future. Continuing work of this task will identify the primary cost drivers of offshore wind energy

Table 14. Reported Research Activities in IEA Wind Member Countries		
Type of program	Country activities reported	IEA Wind co-operative activities in 2012
Offshore wind	Technology development and testing for turbines, including turbines up to 10 MW and foundations (fixed and floating); design work; drive train advances; transmission issues; bigger blades; resource assessment; and reliability of operations and maintenance.	Task 30 Comparison of Dynamic Codes and Models for Offshore Wind Energy (structures)
Wind farm modeling	Data acquisition and model development at alpha ventus offshore test site.	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.	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.	
Technology improvements	Two-bladed rotors, upwind and downwind designs, blade materials and design work, control systems.	
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; work on forecasting techniques; implementation of predictions of wind energy generation.	Task 32 LIDAR: Wind lidar systems for wind energy deployment and work to develop IEA Wind Recommended Practices for using SODAR and LIDAR for Wind Measurements
Environmental issues	Developing assessment procedures and conducting assessments in sensitive areas. Includes wildlife impacts, sound propagation, and impacts 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 Recommended Practice for Consumer Labeling of Small Wind Turbines
Cold climate, severe conditions, and complex terrain	Assessing effects of cold on production; mitigating ice formation; design for lightning, turbulence, and high winds.	Task 19 Wind Energy in Cold Climates and work to update IEA Wind Recommended Practice on Calculation of Performance and Load Conditions for Wind Turbines in Cold Climates
Building domestic industry	Support to 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, wake effects, etc.	Task 29 Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models
Reducing and assessing costs	Wind turbine research and design to reduce manufacturing costs and operation and maintenance costs; improvement of modeling tools used for wind turbine design; development of condition monitoring systems for efficient operations.	Task 26 Cost of Wind Energy; work to draft IEA Wind Recommended Practice for Calculating Cost; Task 29 Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models; Task 30 OC4; 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 and develop strategies to minimize costs, including use of storage and demand management.	Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power
Innovative concepts	Vertical axis, hydraulic drive, kites, airships, etc.	

and explore the variation of these costs among participating countries.

Task 27 Development and Deployment of Small Wind Turbine Labels for Consumers was organized to increase the use of common methodologies for testing small wind turbines that can quickly provide feedback and know-how to develop international standards in the area of quality and performance. IEA Wind *Recommended Practice 12 Consumer Label for Small Wind Turbines* (2011) has been included as an appendix to the IEC TC 88 standard on wind system testing. In 2012, the IEC compliance group began work to implement the labelling of small wind turbines applying the IEA Wind RP 12. The Small Wind Turbine Association of Testers organized by Task 27 will work to increase the number of accredited test facilities of small wind turbines.

Task 27 Small Wind Turbines at Turbulent Sites will continue with the participants of the original task (and others) to conduct research to evaluate the wind resource in areas of high turbulence (forests, rooftops, complex terrain, etc.) and effects on small turbine performance. It is expected to 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 Practices 14 Social Acceptance of Wind Energy Projects* to guide good practices by developers and local authorities. The wide input collected during the development of this document has already increased the knowledge base and a database of studies is available on the Task 28 web pages at ieawind.org. The task issued a final report on the first phase of the work (2008–2011) in 2012. The second term will continue through 2015.

Task 29 MexNext II: Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models is working with existing wind tunnel data sets to improve aerodynamic models used to design wind turbines. Improving these models should result in more durable, productive wind turbines. A final report was issued in 2012 and analyses of the databases were published in journals and presented at conferences. Additional work approved for the next term will assemble an inventory of unexplored experiments and carry out analysis of these "lost" data sets to improve models.

Task 30 Offshore Code Comparison Collaboration Continuation (OC4) is coordinating the work of 12 countries and 47 organizations to improve the design of offshore wind turbines using verified and improved codes. Jacket structure results were published in 2012 and provide enhanced tools for designers of offshore wind turbines. Work on semi-submersible substructures contributed to work with DeepCwind model test data to advance the offshore floating wind turbine industry.

Task 31 Wakebench: Benchmarking Wind Farm Flow Models manages the work of 16 countries and 30 organizations to improve atmospheric boundary layer and wind turbine wake models. The Task provides a forum for industrial, governmental, and academic partners to develop and define quality-check procedures. In 2012, the first benchmarks from the identified test cases and model inter-comparisons were initiated. The work will produce a Model Evaluation Protocol for wind farm flow models in 2013.

Task 32 LIDAR: Wind Lidar Systems for Wind Energy Deployment was approved in late 2011. Remote sensing could increase the accuracy and reduce the cost of wind resource assessment and wind farm operation. This task 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*. This document is expected to promote use of this new, potentially powerful method for measuring the wind resource with remote sensing devices (Sodar and Lidar) by consolidating descriptions of current theory and industry practices. 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 was approved late in 2011. Collection, processing, and analysis of wind turbine reliability and failure statistics is crucial to developing operations and maintenance strategies that minimize costs. The work 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. The expected outcome is the formulation of guidelines for data collection, data structure, and data analyses for overall wind turbine failure statistics. As the foundation for developing Recommended Practices for Reliability Data, three State-of-the-Art Reports are planned. In 2012, work began on the first State-of-the-Art Report, "Initiatives Concerning Reliability," that will summarize activities in the wind energy sector as well as relevant experience from other sectors.

The new IEA Wind 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, to: (1) improve monitoring approaches; (2) make data easily accessible to all interested parties; (3) aggregate information on biological species affected; (4) aggregate information on effects of mitigation strategies; and (5) identify successful approaches to monitoring impacts, analysis techniques, and assessment methodologies. Participants will begin work in 2013.

5.0 The Next Term

Based on the upcoming IEA Technology Roadmap for wind energy and the targets and strategies of the IEA Wind member countries, wind energy deployment will continue to expand over the next decade. The stress being felt in many markets across Europe throughout the wind industry's value chain may translate to a reduced level of installations for some countries in 2013, possibly continuing into 2014. However, economic recovery and stable incentives in other countries may counteract this trend overall.

Expanded efforts to develop offshore wind will be seen in China, Denmark, Finland, Germany, Japan, the Netherlands, Norway, Portugal, the United Kingdom, and the United States.

The work of the IEA Wind research tasks will support efforts worldwide to increase the contribution of wind energy. New activities will be guided by the *Long-Term Research and Development Needs for Wind Energy for the Time Frame 2012 to 2030* and by the Strategic Plan for the term 2014–2019 to be published in 2013. Significant reports are expected on integration of large amounts of wind power,

Table 15. National R&D Budgets 2010–2012 for Reporting Countries

Country	2010 R&D Budget (million EUR; million USD)	2011 R&D Budget (million EUR; million USD)	2012 R&D Budget (million EUR; million USD)
Canada	---	6.00; 7.76	---
China			7.63; 10.00
Denmark	134.00;173.00	134.00; 173.00	7.80; 10.40
Finland	4.00; 5.20	10.00; 12.90	2.00; 2.64
Germany	53.00; 71.40	77.00; 101.60	93.20;122.80
Ireland	0.30; 0.40	0.30; 0.40	---
Italy	3.00; 3.96	3.00; 3.96	3.00; 3.96
Japan	22.51; 30.01	39.30; 52.40	50.61; 67.48
Netherlands	38.00; 51.07	7.08; 9.15	---
Norway	12.60; 16.72	14.87; 19.69	17.14; 22.68
Spain	150.00; 197.70	150.00; 197.70	120.00; 158.16
Sweden	10.80; 14.51	10.80; 14.51	---
Switzerland	0.41; 0.53	0.41; 0.53	0.41; 0.53
United States	59.52; 80.00	59.52; 80.00	70.90; 93.50

--- = no data available

cost of wind energy, small wind systems, social acceptance of wind energy projects, and aerodynamic models and wind tunnel data. It is expected that the International Energy Agency will approved the IEA Wind Implementing Agreement to continue its work for another 5-year term.

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Opening Photo: NEDO offshore wind turbine and wind and wave measurement platform in Choshi, Japan. 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 February 2012. 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 listed at www.ieawind.org IEA Wind Members about ways to benefit from the IEA Wind research tasks.

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.

This, the thirty-fifth *IEA Wind Annual Report*, lists accomplishments by the close of 2012. The Executive Summary (Chapter 1) compiles information from all countries and tasks to highlight important statistics and trends. Activities completed in 2012 and planned for 2013 are reported for the overall agreement (Chapter 2) and for the research tasks (Chapters 3 through 14). Member country chapters (Chapters 15 through 36) describe activities in the research, development, and deployment of wind energy in their countries during the year just ended. The *IEA Wind 2012 Annual Report* is published by PWT Communications, LLC in Boulder, Colorado, United States, on behalf of the IEA Wind Executive Committee (ExCo).

2.0 Collaborative Research

Participation in research tasks (Table 2) is open to any organization located in member countries of IEA Wind (Table 1). Member countries choose to participate in tasks that are most relevant to their current

* 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 28 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..

national research and development programs. A lead organization in each country must agree to the obligations of task participation (pay a common fee and agree to perform specified parts of the work plan). Research tasks are approved by the ExCo as numbered annexes to the Implementing Agreement text. Tasks are referred to by their annex number. The numbers of active tasks are not sequential because some tasks are extended and some have been completed and do not appear as active projects.

Additional tasks are planned when new areas for co-operative research are identified by members. In 2012, member countries continued work on eleven tasks and approved the start of one new research task: Task 34 Assessing Environmental Effects and Monitoring

Table 1. Participants in IEA Wind in 2012

Country/Organization	Contracting Party to Agreement
Australia	Clean Energy Research Institute
Austria	Republic of Austria
Canada	Natural Resources Canada
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 Ireland
Italy	RSE S.p.A. and 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

Table 2. 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	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	Consumer Labeling of Small Wind Turbines OA: CIEMAT, Spain (2012-2015)
Task 28	Social Acceptance of Wind Energy Projects OA: ENCO Energie-Consulting AG, Switzerland (2012-2014)
Task 29	Mexnex(T): 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

Efforts for Offshore and Land-Based Wind Energy Systems. Discussion began for a task to be proposed in 2013 on full-scale ground testing of blades and gearboxes.

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.

Research efforts of each country are returned many times over. The following statistics reported by the task OAs show the added value of co-operative research.

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

Contribution per participant for two years: 6,666 EUR (8,786 USD) plus in-kind effort. Total value of shared labor received: 11,199,600 EUR (14,761,072 USD)

- Task 26 Cost of Wind Energy

Contribution per participant for three years: 17,430 EUR (22,972 USD) plus in-kind effort. Total value of shared labor received: 5,799,600 EUR (7,643,873 USD).

- Task 29 Mexnext Aerodynamic Models and Wind Tunnel Measurements

Contribution per participant for three years: 30,000 EUR (39,540 USD) plus in-kind effort. Total value of shared labor received: 2,775,600 EUR (3,658,241 USD).

By the close of 2012, 20 IEA Wind research tasks had been successfully completed and two tasks had been deferred indefinitely. Final reports of tasks are available through the IEA Wind Web site: www.ieawind.org. Table 3 shows participation by members in active research tasks in 2012.

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

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. International organizations may join IEA Wind as sponsor members. The contracting party may designate members or alternate members from other organizations in the country.

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.

Table 3. Member Participation in Research Tasks During 2012

Participant *	Research Task Number										
	11	19	25	26	27	28	29	30	31	32	33
Australia					X						
Austria		X									
Canada		X	X			X			X	X	
CWEA, China	X	X	X		X		X	X	X	X	X
Denmark	X	X	X	X		X	X	X	X	X	
European Commission											
EWEA			X	X							
Finland	X	OA**	OA			X		X			
Germany	X	X	X	X		X	X	X	X	OA	OA
Greece								X	X	X	
Ireland	X		X		X	X					
Italy	X		X			X			X	X	
Japan	X		X		X	X	X	X	X	X	
Korea, Republic of	X				X		X	X			
México	X										
Netherlands	X		X	X		X	OA	X	X	X	X
Norway	X	X	X	X		X	X	X	X		X
Portugal			X					X		X	
Spain	OA		X	X	OA		X	X	OA	X	
Sweden	X	X	X	X			X		X		X
Switzerland	X	X		X		OA			X		
United Kingdom	X		X						X	X	
United States	X	X	X	OA	X	X	X	X	OA	X	X
Totals	16	10	16	9	7	11	10	12	14	12	6

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

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 2012, Hannele Holttinen (Finland) served as chair. Joachim Kutscher (Germany) and Jim Ahlgrimm (United States) served as Vice Chairs. Jim Ahlgrimm was elected Chair beginning in 2013. Tetsuya Kogaki (Japan), Brian Smith (United States), and Joachim Kutscher (Germany) were elected as vice chairs.

Participants

In 2012, there were several personnel changes among the members and alternate members representing their organizations (See Appendix B IEA Wind Executive Committee). For the latest and most complete ExCo member contact information, please click the IEA Wind Members tab at www.ieawind.org.

Meetings

The ExCo met twice in 2012 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 69th ExCo meeting was hosted by the Norwegian Water Resources and Energy

Directorate (NVE) on behalf of the Government of Norway, 22–24 May 2012. Twenty-four representatives from 17 of the contracting parties attended, along with nine operating agent representatives of the tasks. The Common Fund audit report for 2011 was approved. The meeting included a technical tour to the Sarecta wind farm under construction outside of Rorvik. Before the ExCo meeting, the Norwegian wind power industry association (Norwea) hosted a pre-conference on Monday 21 May where OAs presented information about IEA Wind research activities.

The 70th ExCo meeting was hosted in Tokyo, Japan, 23–25 October 2012 by the New Energy and Industrial Technology Development Organization (NEDO), the National Institute of Advanced Industrial Science and Technology (AIST), and the Japan Electrical Manufacturing Association (JEMA). Twenty-nine participants from 16 contracting parties were present. OA representatives from all of the active tasks gave reports. And observers from the IEA Secretariat and from Japan were present. The ExCo approved The National Renewable Energy Centre to replace the Department of Energy and Climate Change (DECC) as contracting party to IEA Wind. Budgets were approved for the ongoing tasks and for the Common Fund for 2013. The ExCo elected officers for 2013. On 25 October, the technical tour included the NEDO offshore wind turbine and wind and wave measurement platform and the offshore wind farm with downwind turbines that survived the tsunami.

4.0 Decisions and Publications

In 2012, IEA Wind approved publication of five final technical reports:

- *IEA Wind Task 19 State-of-the Art Report of Wind Energy in Cold Climates*
- *Design and operation of power systems with large amounts of wind power: Final summary report, IEA Wind Task 25, Phase two 2009–2011*
- *The Past and Future Cost of Wind Energy, IEA Wind Task 26 Work Package 2 Report,*
- *Final Report IEA Wind Task 28 on Social Acceptance of Wind Energy Projects 2008–2011*
- *Final report of IEA Wind Task 29, Mexnext (Phase 1): Analysis of MEXICO wind tunnel measurements.*

IEA Wind issued a new recommended practice *Recommended Practices 13. Wind Energy Projects in Cold Climates.* The ExCo approved extending three research tasks (Task 11 Base Technology Information Exchange, Task 26 Cost of Wind Energy, and Task 28 Social Acceptance of Wind Energy Projects).

An important new research task was approved: Task 34 Assessing Environmental Effects and Monitoring Efforts for Land-Based and Offshore Wind Energy Systems.

The *IEA Wind 2011 Annual Report* was published in July 2012; 2,200 copies were printed and distributed to member organizations; and press releases were issued with links to the electronic version on the website.

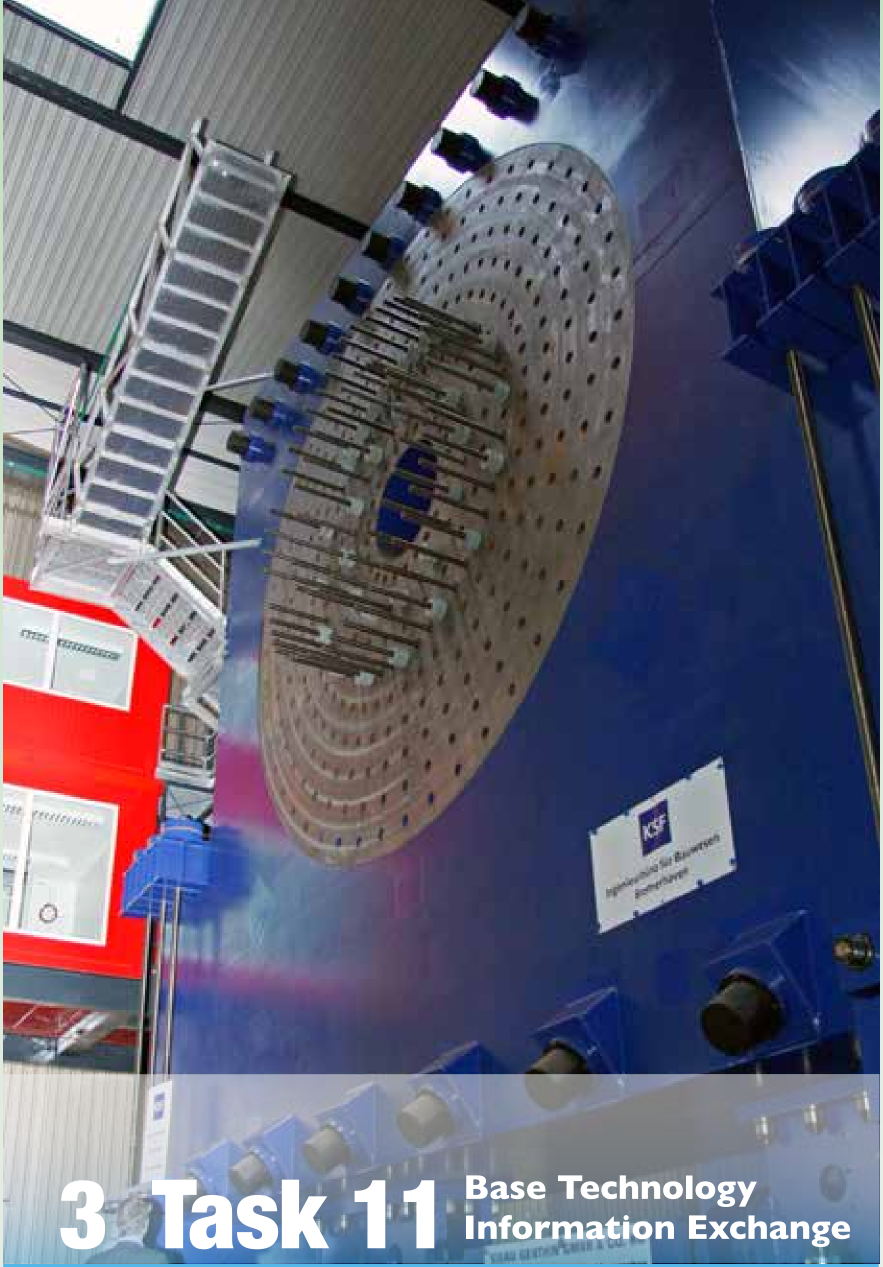
The website, www.ieawind.org, continued to expand coverage of IEA Wind activities. Four Task 11 Proceedings of Experts Meetings from 2011 were posted on the public website. In addition to the five technical reports approved for publication and the Recommended Practice 13 on cold climate, countless journal 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. In addition, Recommended Practices are under development in Task 25 on integration studies, Task 28 on social acceptance, and in Task 32 on remote sensing.

In response to requests for IEA Wind Annual Reports prior to 1999, the Secretary had the old reports scanned and posted to the IEAWind.org website. All reports from 1978 to the present are now available in searchable form.

5.0 Outreach Activities

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

Invitations to attend ExCo meetings were extended to 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.



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 co-operative activities and information exchange on R&D topics of common interest to the Task members. These co-operative activities have been part of the Wind Implementing Agreement since 1978. Table 1 lists the countries participating in this Task in 2012. 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 IEA Wind. Task 11 is also an important catalyst for starting new tasks within IEA Wind. Documents produced are available to organizations in countries that participate in the Task immediately following the meetings. 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. To participate in Task 11 meetings, experts must be in the countries listed in Table 1. The meetings are hosted by organizations within countries participating in the task.

Four meetings on different topics are arranged every year. These meetings are attended by invited, active researchers and experts from the participating countries. The topics are selected by the IEA Wind ExCo and have covered the most important topics in wind energy for decades. A TEM can also begin the process of organizing new research tasks as additional annexes to the IEA Wind Agreement. Table 2 lists the TEMs arranged in the last five years (2008–2012).

A second activity of Task 11 is to develop IEA Wind Recommended Practices (RPs) for wind turbine testing and evaluation. So far, 13 IEA Wind Recommended Practices have been issued. Many of the IEA Wind Recommended Practices documents have served as the basis for both international and national standards.

3.0 Progress in 2012

3.1 Topical expert meetings

Four TEMs were organized in 2012. Proceedings were published on the internal ftp-server for participating countries. Proceedings will be available to the public after one year on www.ieawind.org.

TEM 68: Advances in Wind Turbine and Components Testing included 28 participants from 7 countries—Denmark, China, Germany, Norway, Spain, Sweden, and USA. A total of 18 presentations were given. The participants represented a great variety of stakeholders related to the topic: manufacturers, wind farm operators, research organizations, universities and consultants. After the two days of presentations the floor was opened and a general discussion took place. After the discussion it was decided to launch a new Task Force under the umbrella of the IEA Wind Implementing Agreement on "Full-Scale Testing." Task 35 was approved at ExCo 71.

TEM 69: Operation and Maintenance Challenges scheduled for 2012 was cancelled because only one expert outside China registered in time to attend the meeting. This TEM will be hosted by The Chinese Wind Energy Association in October 2013.

TEM 70: Social Acceptance of Wind Energy was organized in cooperation with IEA Wind Task 28. The local host was the Swiss Federal Office of Energy (SFOE), and the venue for the meeting was Biel, Switzerland. In conjunction, a Swiss expert session was organized together with the Swiss Wind Energy Association Suisse Eole. A total of 19 presentations were given. Following the two days, a general discussion of IEA Wind Task 28 took place. Participants identified issues to

Table 1. Countries and Organizations Participating in Task 11 During 2012

	Country	Institution
1	Canada	National Resources Canada (NRCan)
2	Republic of China	Chinese Wind Energy Association (CWEA)
3	Denmark	Technical University of Denmark (DTU) Risø National Laboratory
4	EC	European Commission (EC)
5	Finland	Technical Research Centre of Finland (VTT Energy)
6	Germany	Bundesministerium für Unwelt , Naturschutz und Reaktorsicherheit (BMU)
7	Ireland	Sustainable Energy Ireland (SEI)
8	Italy	RSE S.p.A. and ENEA Casaccia
9	Japan	National Institute of Advanced Industrial Science and Technology (AIST)
10	Republic of Korea	Korea Energy Management Corporation (KEMCO)
11	Mexico	Instituto de Investigaciones Electricas (IEE)
12	Netherlands	NL Agency
13	Norway	Norwegian Water Resources and Energy Directorate (NVE)
14	Spain	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)
15	Sweden	Energimyndigheten - Swedish Energy Agency
16	Switzerland	Swiss Federal Office of Energy (SFOE)
17	United States	U.S. Department of Energy (DOE)

be addressed in the possible extension of IEA Wind Task 28 into a second period.

TEM 71: Wind Farm Control Methods was hosted by Vattenfall on 27–28 November 2012 in Solna, Sweden. It was attended by 18 participants from six countries (China, Denmark, Germany, the Netherlands, Spain, and Sweden). Following the 11 presentations, the floor was opened and a general discussion took place among the participants.

Meeting topics for 2013 have been selected by the IEA Wind ExCo (Table 3).

3.2 Development of recommended practices

The IEA Wind Recommended Practices activity was initiated to satisfy the need for standard procedures for testing wind turbines. When this action began, no standards for wind energy systems were available. Fortunately, the situation has changed dramatically, and now there are a large number of International Electrotechnical Commission (IEC) standards available in the wind energy sector. Much work is going on under the umbrella of IEC for developing new standards. However, many in the industry point to the problem of the long time required (years in most cases) for elaboration of new IEC standards. IEA Wind Recommended Practices can be prepared in a shorter period of time and will be an important input for the future elaboration of IEC standards.

As a final result of research carried out in the IEA Wind Tasks, Recommended Practices, Best Practices, or Expert Group Reports may be issued. These RP documents are developed and reviewed by experts in the specialized area they address. They are reviewed and approved by participants in the research Task, and they are reviewed and approved by the IEA Wind Executive Committee. They serve as guidelines useful in the development and deployment of wind energy systems. Use of these documents is completely voluntary. However, these documents are often adopted in part or in total by other standards-making bodies. IEA Wind RP 12 Consumer Label for Small Wind Turbines was approved in 2011 and has been incorporated as an appendix in draft standards documents of the IEC as an approach to collection test data and presenting consumer labels.

3.2.1 RP 13 Wind Energy Projects in Cold Climates

The large-scale exploitation of cold climate sites has been limited by our lack of knowledge about their special challenges and the lack of proven and economical technological solutions. The purpose of RP 13 Wind Energy Projects in Cold Climates is to provide the best available recommendations on this topic, reduce the risks involved in undertaking projects in cold climates, and accelerate the growth of wind energy production in these areas. This document addresses many special issues that must be considered over the lifetime of a wind energy project in cold climate. The importance of site measurements, project design, and system operation is emphasized. RP 13 Wind Energy Projects in Cold Climates was approved at the ExCo 70 Meeting in 2012.

3.2.2 RP 14 Social Acceptance of Wind Energy Projects

These Recommended Practices were elaborated by the IEA Wind Task 28 participants. They present strategies from around the world that have been successfully used to improve wind power projects for the benefit of all. These strategies have been used to implement projects that are acceptable to a majority of citizens. The Recommended Practices on "Social Acceptance of Wind Energy Projects" RP was approved at the ExCo 71 Meeting in early 2013.

3.2.3 RP 15 Ground-Based, Vertically-Profiling Remote Sensing for Wind Resource Assessment

The purpose of this RP is to document the steps required to collect high-quality, well-documented remote sensing data for use in wind resource assessments on land. Recommendations are made that apply to both lidar and sodar because of the similarities between these technologies and the sources of uncertainty that are observed when they are used

Table 2. Topical Expert Meetings (2008–2012)			
No.	Meeting Title	Year	Location
71	Wind Farm Control Methods	2012	Solna, Sweden
70	Social Acceptance of Wind Energy	2012	Biel, Switzerland
69	Operations and Maintenance Issues of Wind Farms (cancelled)	2012	Beijing, China
68	Advances in Wind Turbine and Components Testing	2012	Aachen, Germany
67	Long Term R&D Needs on Wind Power	2011	Brussels, Belgium
66	Offshore Foundation Technology and Knowledge, for Shallow, Middle and Deep Water	2011	Esbjerg, Denmark
65	International Statistical Analysis on Wind Turbine Failures	2011	Kassel, Germany
64	Wind Conditions for Wind Turbine Design	2010	Tokyo, Japan
63	High Reliability Solutions and Innovative Concepts for Offshore Wind Turbines	2010	Trondheim, Norway
62	Micrometeorology inside Wind Farms and Wakes between Wind Farms	2010	Pamplona, Spain
61	Wind Farms in Complex Terrain	2010	Pohang, S. Korea
60	Radar Radio and Links with Wind Turbines	2009	Amsterdam, The Netherlands
59	Remote Wind Speed Sensing Techniques Using Sodar and Lidar	2009	Boulder, United States
58	Sound Propagation Models and Validation	2009	Stockholm, Sweden
57	Turbine Drive Train Dynamics and Reliability	2008	Jyväskylä, Finland
56	The Application of Smart Structures for Large Wind Turbine Rotor Blades	2008	Albuquerque, United States
For proceedings and previous meetings visit ieawind.org/task_11/topical_experts.html			

to measure winds. RP 15 Ground-Based, Vertically-Profiling Remote Sensing for Wind Resource Assessment was approved at the ExCo 71 Meeting in early 2013.

4.0 Plans for 2013 and Beyond

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

The process for selecting topics for 2013 meetings started in August 2012. The OA solicited topics of interest from IEA Wind members and from Task 11 participants. The resulting high-priority topics are listed in Table 3.

Table 3. Topical Expert Meetings for 2013			
No.	Meeting Title	Date	Host Country
72	Forecasting	23–24 April	RSE S. p. A. Milano, Italy
73	Noise Reduction Technologies	11-12 June	VTT Energy, Tampere, Finland
74	Operation and Maintenance Challenges	21–22 October	CWEA, Beijing, Republic of China
75	Wind Energy in Complex Terrain	12–13 November	University of Stuttgart, Germany

Following up on recommendations from TEM 67 Long-Term R&D Needs for Wind Power, a working group was assembled to develop updated Long-Term R&D Priorities for 2012–2030. The working group has developed a draft document for planning new research activities that is undergoing extensive review and should be issued in 2013. This document will present long-term R&D priorities from IEA Wind countries in a condensed way.

Recommended Practices for conducting grid integration studies have been drafted in Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power will be reviewed and approved in 2013. The OA of Task 11 will work with the OAs of ongoing tasks to develop additional IEA Wind Recommended Practices.

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

Courtesy VTT: M. Tiihonen

4 Task 19 Wind Energy in Cold Climates

1.0 Introduction

Deployment of wind energy in cold climate areas is growing rapidly. Wind resources in cold climate areas are typically good, but icing of turbines and low ambient temperatures pose additional challenges for wind energy projects. Experience has shown that icing of wind turbine rotor blades reduces energy yield, shortens the mechanical life time of turbines, and increases safety risks due to risk of ice throw. However, these challenges can be taken into account in turbine design and by using appropriate materials. An expert group under IEA Wind research collaboration Task 19 Wind Energy in Cold Climates has been working to solve the additional challenges in cold climates since 2002.

Cold climate areas have gained more focus compared to the earlier years as national wind energy targets have been raised. Also, increased experience, knowledge, and improvements in cold climate technologies have improved the economics of wind projects making them competitive with standard wind projects. The current wind generation capacity in cold climates is approximately 60 GW in Scandinavia, North America, Europe, and Asia, although 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 grow more especially in Canada, the northern United States, China, and in northern Scandinavia. In 2011, participants in IEA Wind Task 19 estimated that about 4,000 MW of wind energy is being installed annually on cold climate sites. However, recent data show that figure to be an underestimate.

Turbine manufacturers have developed technical solutions for low temperature versions of their standard turbines, and 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 of atmospheric icing and low temperatures. These activities aim at improving the economics of wind power in new areas around the globe. It is important to validate the latest theories and models, and to analyze the performance data of the adapted technologies being used in wind energy projects. It is also essential to gather more information to be publicly available.

Table 1 shows the countries and organizations participating in Task 19 during 2012. The group collects, evaluates, and creates information covering all aspects of wind energy in cold climates. For example, the group has published procedures for site assessment in icing conditions, worked to clarify the economics of cold climate wind projects, and examined ways to improve health and safety surrounding wind energy projects operating in cold climate areas. A major milestone for Task 19 was the publication in 2012 of the IEA Wind Recommended Practices 13: Wind Energy Projects in Cold Climates.

2.0 Objectives and Strategy

The objectives of Task 19 for 2012 were as follows:

- Determine the current state of cold climate solutions for wind turbines, especially anti-icing and de-icing

Table 1. Countries and Organizations Participating in Task 19 During 2012		
	Country	Institution(s)
1	Austria	Energiewerkstatt
2	Canada	Natural Resources Canada
3	Finland	VTT Technical Research Centre of Finland
4	Germany	Fraunhofer IWES
5	Norway	Kjeller Vindteknik
6	Sweden	WindREN AB
7	Switzerland	Meteotest
8	United States	National Renewable Energy Laboratory

Table 2. IEA Wind ice classification system			
IEA Wind ice class	Meteorological icing (% of year)	Instrumental icing (% of year)	Production loss (% of annual production)
5	>10	>20	>20
4	5-10	10-30	10-25
3	3-5	6-15	3-12
2	0.5-3	1-9	0.5-5
1	0-0.5	<1.5	0-0.5

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 to improve the commonly used standard tools that do not address cold climate specific issues

• 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 standalone 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 cold climate wind power development. The ongoing national R&D activities in task participant countries are contributing to tackling of these challenges and provide new information and know-how on the subject. The results of the ongoing national activities will improve the overall economy of wind energy projects in cold climates and thus significantly lower the risks of developing in areas where low temperatures and atmospheric icing are occurs.

The collaboration actively disseminates results through the Task 19 website and through conferences and seminars (ieawind.org).

3.0 Progress in 2012

The main activities during 2012 were the finalization and publication of the Recommended Practices report, see Figure 1, and update of State-of-the-Art of Cold Climate Wind Energy report. The recommended practices report was well received by the industry. One of the most important items in the report was a classification system of wind energy sites regarding icing conditions. The recommended IEA Wind ice classification is shown in Table 2. Using this classification, a wind power developer can get an early understanding of the severity and consequences of a particular site under interest. Also, a set of recommended practices can be chosen based on the ice classification. And finally, the IEA Wind ice classification can be used for comparing different sites when choosing the most promising site for the wind project.

Figure 1. Recommended Practices 13—Wind Energy Projects in Cold Climates cover

An important step for developing wind energy in cold climates was taken in 2012 when standardization work began under IEC to incorporate cold climate issues as a part of wind turbine design standard (IEC 61400-1). The evolving dedicated design load case for wind turbines representing extra loading from ice accretion on turbine blades, will allow wind turbine manufacturers to design turbines for these adverse conditions. This in turn leads to better technologies, reduction of O&M costs, and lower cost of energy from wind projects in cold climates.

4.0 Plans for 2013 and beyond

Task 19 enters its fourth three-year period in 2013, to continue coordinating research into cold climate wind development. The main goals of the new term are:

• Execution of a market study for cold climate wind technology

• Updating the third-term recommendations: verification of the recommendations, especially cold climate site classification and methods for energy yield estimation, as well as health and safety recommendations aiming to harmonize safety regulations with respect to icing conditions

• Update of the State-of-the-Art report of cold climate wind energy.

It is expected that Denmark and China will join Task 19 for the period 2013–2015 in addition to the countries participating in 2012.

New results, publications, and reports can be found online (ieawind.org).

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

5 Task 25 Power Systems with Large Amounts of Wind Power

Courtesy: PWT Communications LLC

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 will be need for more flexibility in the power system. How much extra flexibility is needed depends on the one hand on how much wind power there is and on the other hand how much flexibility exists in the power system.

The existing targets for wind power anticipate a quite high penetration 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. The integration of wind power into regional power systems was first 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 penetration 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 methodology, data, and tools, as well as different terminology and metrics in representing the results. Task 25 has worked on summarizing results from its participating countries, as well as formulating recommendations on best practices for integration studies. Because system impact studies are often the first steps taken towards defining wind penetration targets within each country, it is important that commonly accepted standard methodologies are applied in system impact studies.

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, with also transmission system operators (TSOs) participating in the meetings.

The participants are collecting and sharing information on the experience gained in 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 have been formulated in 2012–2013 on how to perform wind integration studies. The recommended practices report is currently in review process.

Task 25 of the IEA Wind Implementing Agreement was approved at ExCo 56 in September 2005 for three years, 2006–2008.

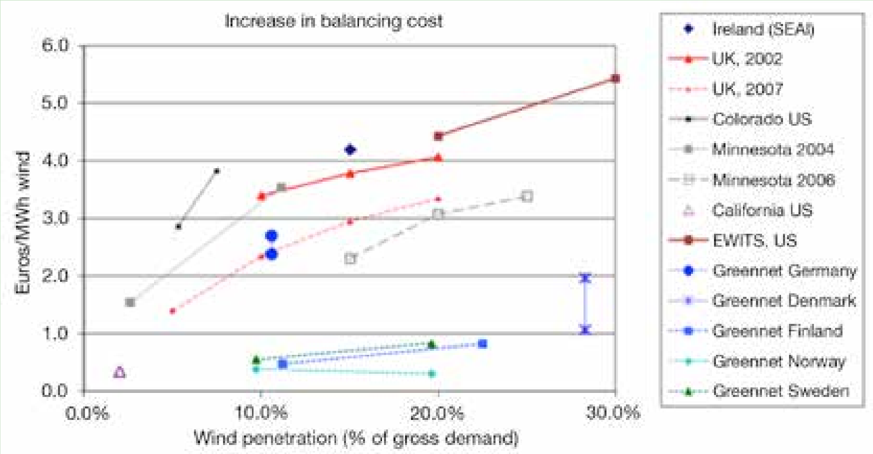


Figure 1. Results from estimates for the increase in balancing and operating costs due to wind power (The currency conversion used here is 1 EUR = 0.7 GBP and 1 EUR = 1.3 USD. For the UK, 2007 study, the average cost is presented here)

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, there were 11 countries plus EWEA participating in the Task. For the second term, Canada, Japan, and Italy have also joined Task 25. For the third term, a Chinese participant from SGERI has joined.

3.0 Progress in 2012

The meetings organized by Task 25 have established an international forum for exchange of knowledge and experiences. The spring task meeting in 2012 was organized in Rome hosted by Italian system operator Terna. The autumn meeting was hosted by AIST and JEMA in Tokyo, and also a workshop on wind integration was organized where Task 25 participants presented experience on wind integration.

Coordination with other relevant activities is an important part of the Task 25 effort. Links between TSO organization working groups at CIGRE and the European Wind Integration Study (EWIS project) were formed in the beginning of Task 25 work; observers have been joining Task 25 meetings in 2008–2009. Task 25 has organized workshop sessions for TSO organizations in Europe (ENTSO-E) and America (UWIG). The system operators of Canada (Quebec), Denmark, Germany, Ireland, Italy, Portugal, and the UK have joined the meetings through 2012. Task 25 has joined the advisory group of the IEA Secretariat work on integrating renewable energies (GIVAR project).

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: EWEC 2007 Milan, EWEC 2008 Brussels, EWEA 2012 Copenhagen, and Bremen and Quebec Integration Workshops in 2009 and 2010.

Task 25 work and results were presented at several meetings in 2012. First, findings on recommendations were presented in the EWEA Copenhagen conference and May Wind Integration Symposium in Frankfort. Collaborative papers were presented at the IEEE Power and Energy Society General Meeting in July 2012 in San Diego, and Wind Integration Workshop WIW12 in November 2012 in Lisbon. Titles include: Market Structures to Enable Efficient Wind and Solar Power Integration; Energy Storage for Wind Integration: Hydropower and Other Contributions; Recommendations for Wind Integration Studies; Contribution of Energy Storage for Large-Scale Integration of Variable Generation; Wind Power Forecasting Error Distributions, an International Comparison.

Collaborative journal articles were published in IEEE Transactions on Sustainable Energy, Volume 3 on Methodologies to Determine Operating Reserves due to Increased Wind Power; Short Term Energy Balancing with Increasing Levels of Wind Energy, and Experience and Challenges with Short-term Balancing in European Systems with Large Share of Wind Power. An article was published at WIREs Energy Environ 2013, No 2. on transmission planning for wind energy in the United States and Europe: status and prospects.

Work on a simplified assessment of wind integration effort and power system flexibility, has been made in collaboration with the IEA secretariat study on integrating renewable energy sources (GIVAR project).

The Task 25 website is at www.ieawind.org under Task Web Sites. The public portion of the site contains the Task 25 publications as well as literature bibliography, updated in

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

	Country	Institutions coordinating work in countries (TSO participating in some meetings in parenthesis)*
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	ECAR; (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	National Renewable Energy Laboratory (NREL); Utility Variable Generation Integration Group (UVIG)

*In some countries like Finland and Sweden, the TSO follows the national advisory group. CIGRE JWG C1, 3, 6/18, IEA Secretariat in Paris and European TSO consortium EWIS have sent observers to meetings.

early 2012. The members-only section details the meeting presentations and information relevant to task participants.

3.1 Summary of recent wind integration studies

The national case studies address impacts that are grouped under 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, the results are 3% of installed wind capacity or less, with penetrations below 20% of gross 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 new investments 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 less requirements on the system. Avoiding allocation of unnecessary reserve is cost effective and can be needed in higher penetration levels of wind power.

Balancing costs: At wind penetrations of up to 20% of gross demand, system operating cost increases, arising from wind variability and uncertainty amounting to approximately 1–4.5 EUR/MWh (1.3–5.9 USD/MWh) (Figure 1). 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 the existing wind power from electricity markets: 1.3–1.5 EUR/MWh (1.7–2.0 USD/MWh) for 16% wind penetration (Spain), and 1.4–2.6 EUR/MWh (1.8–3.4 USD/MWh) for 24% wind penetration (West Denmark). 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. 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 also during significant failures. Dynamic system stability analyses are usually not performed at lower penetration levels unless particular stability issues are foreseen in the system. Wind turbine capabilities are still evolving and may mitigate some potential impacts of wind power. There is 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 for improving 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 of wind integration studies

The methods of wind integration studies are evolving, building on the experiences from previous studies, with more data on system wide wind power production and improved models. Task 25 has made a recommendation report to compile the best practices and instructions on how to perform an integration study. 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 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 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

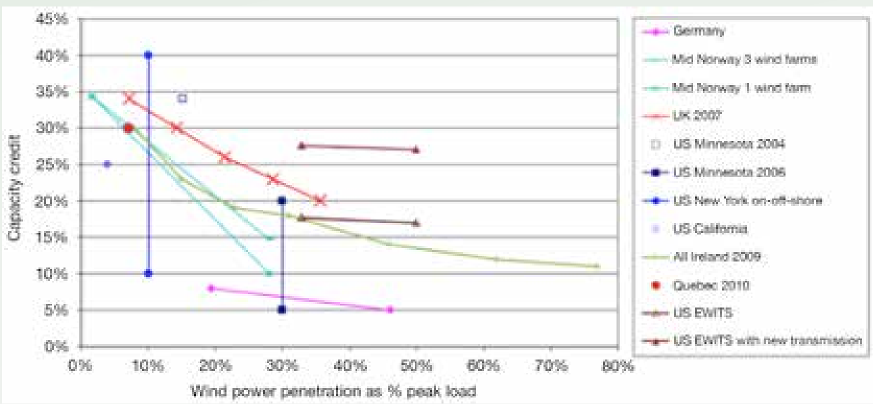


Figure 2. Capacity credit of wind power, results from ten studies, showing reduction of capacity value as penetration level increases. New York on-offshore shows the range of capacity value for wind, when calculated only for onshore sites (10%) or only offshore sites (40%).

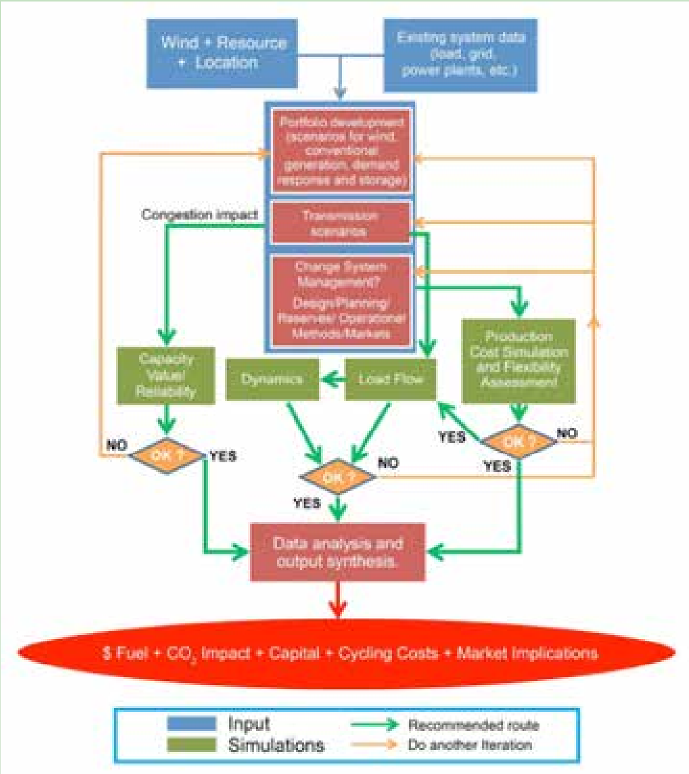


Figure 3. Flow chart of a complete wind integration study, showing relevant iteration loops from simulations to set-up and portfolio development

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 level includes 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.

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 2013

The meetings in 2013 will take place in Finland, hosted by the Operating Agent VTT, and Beijing, hosted by SGERI. Task 25 work and results will be presented also at several meetings in 2013; there will be a session in UVIG workshop in Charleston, U.S. and a session for ENTSO-E working groups is planned for summer 2013.

The Recommended Practices report will be published after the review process. 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. Work will start to make fact sheets of wind integration issues, and collect time series of large scale wind power relevant for integration studies, as basis for the database aimed for during this phase.

The topic being addressed by Task 25 is growing exponentially in importance within the member countries and more broadly. There is a consensus that the work of the task has only just begun. During the third term (2012–2014), participants will expand into more high-penetration studies, and go deeper into the subject of modeling power systems with wind power.

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6 Task 26 Cost of Wind Energy

1.0 Introduction

Wind power generation has come to a "historical" point where, just as installed costs were becoming competitive with other conventional technologies, the investment cost per megawatt has started increasing for new wind power projects. This is believed to be the result of increasing commodity prices (mainly raw material such as copper and steel, plus a bottleneck in certain sub-products), the current 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. 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 future wind deployment.

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 a clear impartial voice regarding the costs of wind systems, organizations without a clear understanding of wind systems are left to determine and publicize the costs of wind systems, often in error. These issues are exacerbated by the diversity of the wind portfolio and variations in international project development cost assumptions. The work undertaken in 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 cost of wind energy in order to understand past, present and anticipate future trends using consistent transparent methodologies as well as understand how wind technology compares to other generation options within the broader electric sector. Task 26 will continue to add data and analysis, develop methodologies, and enhance collaboration.

Expected results include:

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

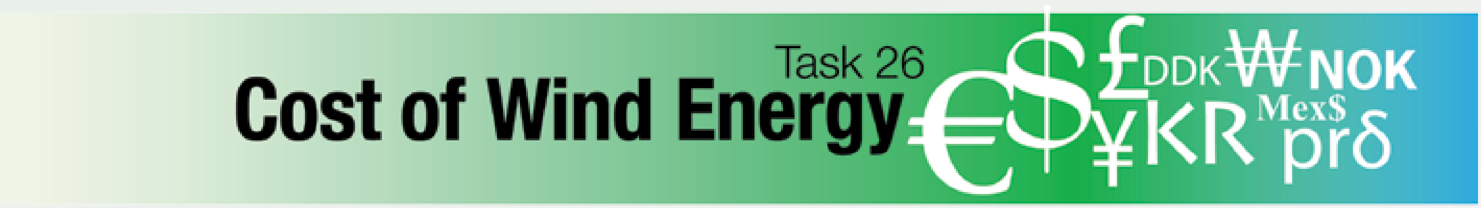
Table 1. Countries and Organizations Participating in Task 26 During 2012

	Country	Institution(s)
1	Denmark	Risoe/DTU, EA Energy Analyses
		European Commission – Joint Research Centre (JRC)
2	Germany	Deutsche WindGuard
3	Ireland	Dublin Institute of Technology (DIT)
4	Netherlands	ECN, TKI
5	Norway	SINTEF
6	United States	NREL, LBNL

3.0 Progress in 2012

A report published in 2012 emphasized 1) the collection of historical cost and performance data from multiple participating countries; 2) analysis of the expected near-term Levelized Cost of Energy (LCOE) from projects in late-stage development in the U.S. and Denmark; 3) evaluation of wind energy cost forecasts in the literature including work to convert existing forecasts of capital costs, capacity factors, and other variables into estimates of LCOE. These data and analysis were compiled into the second report of Task 26 (1). This report also highlighted the importance of considering LCOE relative to an exclusive look at capital costs or performance, discussed the strengths and weaknesses of the existing methods that have been applied to forecast future wind energy costs, and summarized technical sources of future cost reductions described in the literature.

Historical cost and performance data were collected from three participating countries and from the European Wind Energy Association. These data were compiled to illustrate the significant reductions in capital costs achieved by the wind industry from 1980 to the early 2000s and to demonstrate the relative magnitude of the cost increases



observed between the early 2000s and 2010. Historical performance data were used to demonstrate the continual improvements in wind turbine technology that have been realized but also to highlight how trends in siting such as the moving into lower wind resource quality locations can mask the impacts of improvements in technology as has occurred in Spain and to some extent in other countries.

Analysis of near-term wind energy LCOEs in Denmark and the United States revealed that wind energy costs are anticipated to fall dramatically for projects under construction today and into 2013 (Figure 2). In fact, LCOE is expected to be at an historical low over this time period, assuming fixed wind resource quality. However, transmission access, public acceptance, or other variables may push newer projects into lower wind resource quality locales, in which case historical lows in LCOE may not be fully realized in actual wind energy sales contracts. These analyses relied on anticipated project capital costs for projects under development and estimates of energy production from turbines available on the market today. This work was particularly revealing because the achievement of record low LCOE in two countries is likely despite installed capital costs that remain well above their historical low in the early 2000s. The relatively low LCOEs anticipated in the near-term are a result of reductions in capital cost and significant performance improvements from turbines available today, compared to those that were installed roughly ten years ago. This finding highlights the importance of evaluating future LCOE, which considers both capital costs and technology improvements, rather than simply forecasting future capital costs or capacity factors. Such considerations are all that much more critical in the wind industry where the current maturity of the technology suggests that the optimal cost of onshore wind energy may result from little or no further capital cost reductions (and perhaps even modest capital cost increases), but continued performance improvements.

Farther into the future a review of anticipated costs and performance trends suggests reductions in LCOE on the order of 20–30% over the next two decades. As future technology advancement opportunities become increasingly incremental, LCOE reductions are anticipated to slow. This is reflected in forecast data shown in Figure 3 whereby LCOE reductions, across virtually all studies and scenarios in the literature today, fall to less than 1%/yr by 2030. As these studies typically rely on learning curves, expert elicitation, or bottom-up engineering analyses, they do not reflect the potential for short-term turbine supply and demand pressures, competition among manufacturers, or changes in global commodity prices to influence the ultimate delivered cost of wind energy. Moreover, they do not anticipate trends in the quality of the wind resource where projects are sited or potential transmission and integration costs. As such, the delivered price of power may vary, particularly over the short-term from those shown in Figure 3. Nevertheless, over the long-term wind energy's LCOE is expected to continue to decline for some time.

Further improving our understanding of possible future cost trends is anticipated to require additional data gathering and improved modeling capability. Robust data collection is needed across the array of variables that must be factored into estimating LCOE (e.g., capital cost, capacity factor, O&M costs, component replacement rates and costs, and financing costs) and in each of the wind energy markets around the globe. An enhanced capacity to model the cost and performance impacts of new technological innovation opportunities, taking into account the full system dynamics that result from a given technological advancement, is also essential. Together these efforts would enhance our ability to understand future costs, facilitate prioritization of R&D efforts, and help to understand the role and required magnitude of deployment incentives into the future.

4.0 Plans for 2013 and Beyond

In 2012, a task extension proposal was approved by the Executive Committee. The task extension includes the following activities over the next three years (October 2012 through 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 2007 through the present. In addition,

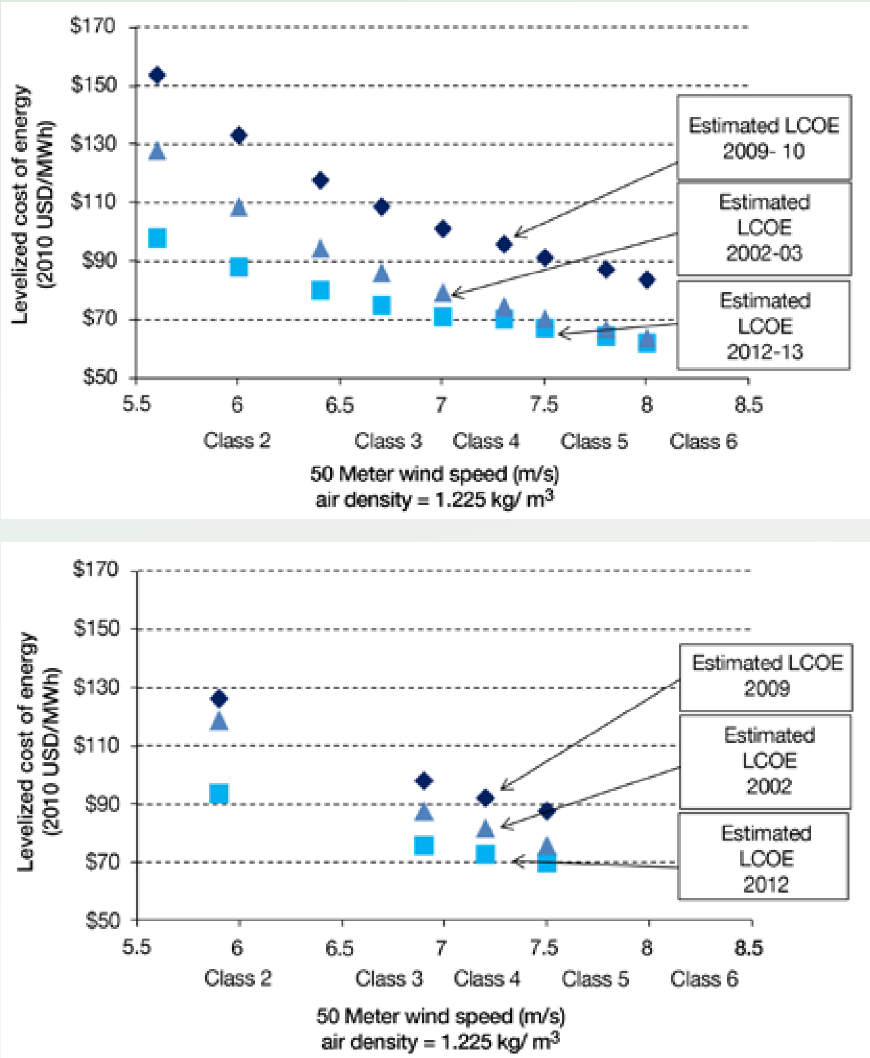


Figure 2. LCOE for wind energy over time in the United States (top) and Denmark (bottom)

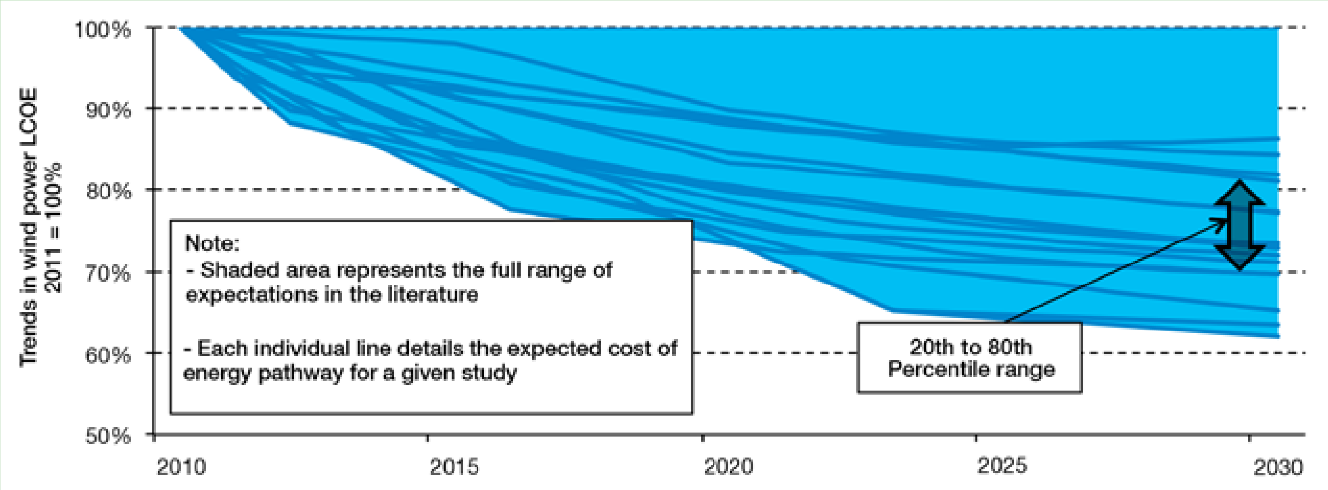


Figure 3. Estimated range of wind LCOE projections across 18 scenarios

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.

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.

Two workshops will be held to assemble experts in the field of valuing wind energy or other generation technologies. The purpose of these workshops is to identify the primary elements of information needed to estimate the value of wind energy and the potential data gaps that may exist. For example, is it more valuable to estimate net employment or wind technology-specific employment impacts? What are current methods used to conduct such analysis and are there data gaps that inhibit accurate comparisons?

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.

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(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.

Author: Eric Lantz and M. Maureen Hand, National Renewable Energy Laboratory, United States.

7 Task 27

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

Source: CEDER-CIEMAT

1.0 Introduction

At the IEA Wind ExCo 61 in 2008, Task 27 was launched with two main objectives:

1) Development and Deployment of a Small Wind Turbine Consumer Label: This subtask included the development of a Recommended Practices: Consumer Label for Small Wind Turbines to provide a label for small wind turbines and to guide testing procedures to generate the data for the label; and

2) Development of the Small Wind Association of Testers (SWAT) to advance the use of the consumer label.

Since 2008, ten IEA Wind Task 27-IEC MT2 liaison meetings have been held in the following locations: Madrid (Spain), London (United Kingdom), Wausau (United States), Toronto (Canada), Tokyo (Japan) (Figure 1), Kaiser-Wilhelm-Koog (Germany), Glasgow (United Kingdom), Boulder (United States), Perth (Australia), and in 2012 in Madrid (Spain).

In 2011, the participants completed development, gained approval, and published the *IEA Wind Recommended Practices for Wind Turbine Testing and Evaluation: RP 12. Consumer Label for Small Wind Turbines*. As a result of the collaborative work between IEC MT2 and IEA Wind Task 27, the Committee Draft of the Third Edition IEC 61400-2 Standard includes an informative annex with the same label requirements and the IEA Wind RP 12.

The labeling activity will start as soon as possible under the guidance of the SWAT, an international network that is still under development. In April 2011, a successful International Conference of SWAT was held in Ithaca (United States). The topic and future of labeling will be undertaken by the TC88 Certification Advisory Council (CAC) Small Wind Turbine subcommittee, who now has purview over the important labeling task.

During the activity to develop the recommended practice on labeling, some new issues were identified related to small wind turbines for in the built environment. There was interest in extending the work of IEA Wind Task 27 participants to better understand the special wind conditions found in the urban environment and in areas of complex terrain, and its effect on wind resources assessment methodology. The new work will develop recommendations for wind resource assessment for areas of high turbulence, develop potential changes to small wind turbine design per IEC 61400-2, and perform power performance tests in urban environments.

The Task 27 extension proposal was drafted in the ExCo 68 in October 2011. During the ExCo 69 meeting held in Norway this extension proposal was defined and issued for approval. The task extension was approved in principal but some questions about the proposal remained. Finally at the ExCo 70 in 2012, the extension of Task 27 was approved with the new title "Small Wind Turbines in High Turbulence Sites." The IEA Wind Task 27 extension will continue for four years (2012–2016).

2.0 Objectives and Strategy

The Task 27 extension has three main objectives:

- Develop a Recommended Practice that provides guidelines and information on micro-siting and possible energy production of small turbines in highly turbulent

Table 1. Task 27 Participants in 2012		
#	Country	Institution(s)
1	Australia	Australian National Small Wind Turbine Centre (RISE) Murdoch University
2	China	Chinese Wind Energy Association (CWEA)
3	Denmark	Danmarks Tekniske Universitet (DTU)
4	Ireland	Dundalk Institute of Technology (DKIT)
5	Italy	University of Napoli (UNINA)
6	Japan	National Institute of Advanced Industrial Science and Technology (AIST)
7	Korea, Republic of	Korean Institute for Energy Research (KIER)
8	Spain	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)
9	United States	National Renewable Energy Laboratory (NREL)
	France (Observer) Argentina (Observer)	Centre Scientifique et Technique du Bâtiment; (CSTB) Instituto Nacional de Tecnología Industrial (INTI)

sites (urban/suburban settings, on rooftops, in forested areas, etc).

• Prepare for the next revision of IEC 61400-2 by developing a new design classification for urban turbines with specific guidance on I15 or similar variables and new external conditions (normal turbulence model and extreme direction change).

• Compare existing power performance test results (typically from accredited power performance test organizations) to power performance results taken in highly turbulent sites.

Four Work Packages were defined:

WP 1: SWAT / Label deployment

WP 2: Analyze and model highly turbulent wind resource

WP 3: Collect wind resource and turbine power performance data from rooftop and complex terrain test sites

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

Since the Task 27 extension was approved, progress has been made in WP1 and WP2.

3.0 Progress in 2012

3.1 Meetings of participants

Two physical meetings and two virtual meetings were held during 2012. The first meeting in 2012 (#8 of the task) was a physical meeting held in Ithaca, New York (United States). Hosted by INTERTEK, USA (28–29 March 2012), twelve experts from research organizations, test centers, and universities represented China, Ireland, Italy, Japan, Spain, the United Kingdom, the United States, and Argentina (observer) (Figure 2). Representatives from Australia and Korea gave presentations. During the meeting, consumer label deployment and round-robin verification tests were planned. Participants discussed governance, development, and deployment of the SWAT organization. The task extension proposal related to Built-Environment Recommended Practice was discussed and refined.

The second and third meetings of 2012 (#9 of the task) were virtual meetings held at two different times of the day to facilitate the participation of partners from different continents. Hosted by NREL, experts from certification bodies, science, and the small wind turbine industry were invited to exchange knowledge on 3-D wind resource data acquisition and analyses. In the first time period, ten experts from seven countries were represented: Argentina, Canada, China, Ireland, Spain, Sweden, and the United States. In the second time period, ten experts from Australia, China, Spain, and the United States participated. The meeting refined the Task 27 extension proposal by separating testing and modeling work relating to the built environment for small wind turbines. With this refinement, each country can participate in select tasks and discussion of the scope of work within the extension proposal. Additionally, participants addressed questions raised during the IEA Wind ExCo meeting about the consumer label. It was reiterated that the consumer label is not a certification. To support this message, disclaimer text was drafted for the website and information explaining accredited and unaccredited test organizations was developed. The governance of the label was reviewed and a reconsideration began about whether the A, B, C, D evaluations (described in the Recommended Practice 12) should be applied for different levels of certification and testing. In particular a "C" evaluation would be for those who are SWAT members.

The third meeting of 2012 (#10 meeting of the task) was a physical meeting held in Dundalk, Ireland (26–28 September 2012), hosted by SEAI in Dundalk in collaboration with the Centre for Renewable Energy Dundalk Institute of Technology. Thirteen experts from Australia, China, Ireland, Japan, Korea, Spain, and the United States (Figure 3) participated. The following topics were discussed.

• The current status of small and medium

Figure 1. IEA Wind Task 27 meetings were held in conjunction with IEC meetings on 61400-2

Figure 2. IEA Wind Task 27 team, Ithaca, New York

wind in Australia, China, Ireland, Japan,. Korea, Spain, and the United States

- IEA Wind Task 27 Extension Proposal
- 3-D turbulence data reduction, analysis, and conclusions
- CFD Analysis of flow around buildings (Kanazawa University)
- Tamkang University of Taiwan building engineering wind tunnel and some modeling results (TIER)
- The experimental design for a building integrated wind turbine testpad
- Consumer labeling and SWAT status

3.2 Reports, conferences and decisions

The first label from the manufacturer of the SOMA Small Wind Turbine appeared on the Task 27 Members Only web page of IEA Wind in 2012. Other dissemination activities include:

- Presentation "Development and Deployment of a Consumer Label for Small Wind Turbines" by Raymond Byrne (DiT/CREDIT - Ireland) at World Summit of Small Wind held in Husum, Germany in March 2012
- Presentation "Development and Deployment of a Small Wind Turbine Consumer Label" by Trudy Forsyth (Wind Advisors Team) at the first Small Wind Association of Testers Conference held in New York, US on 25 April 2012
- Presentation "Development and Deployment of Consumer Label for Small Wind Turbines" by Ignacio Cruz the at the Norwegian Seminar on IEA Wind's research and activities held in Trondheim, Norway on 21 May 2012
- Presentation "Small Wind Turbines for Mini-grids and Islands" by Ignacio Cruz at the World Wind Energy Conference side event held in Bonn, Germany on 3 July 2012.

4.0 Plans for 2013 and beyond

In 2013, the IEA Wind Task 27 Small Wind Annual Report 2012 will be completed. A round-robin test in several sites with different condition (in special TI conditions) is on-going. The labeling activity could be transferred to the new IEC WT CAC Small Wind Turbine subcommittee. A proposal on the methodology of Rooftop Small Wind Turbine Power Performance Tests is being developed. Standardization of measurements for rooftop wind monitoring is being investigated. The deployment of SWAT will be completed, along with governance issues, and organization of the relation between laboratories. Analysis and data collection methodology discussion for rooftop and complex terrain testing and analysis is on-going. Training on the NREL TurbSim Stochastic Simulator will take place as data is required.

The IEA Wind Task 27 extension should last four years (2012–2016). Meetings scheduled for 2013 include: Virtual meeting #2 Research/literature review for papers on rooftops and tool identification and presentation of Progress report #2, due January 2013; Virtual meeting #3 Discussion of measurement strategy for rooftop test site and presentation of Progress report #3, (extra Virtual Meeting not part of original plan); Face-to-face Meeting Second International SWAT meeting and presentations on wind characterization of rooftop test, April 2013; Virtual meeting #4 Discussion of measurement strategy for rooftop test site and presentation of Progress report #4, July 2013; Face-to-face Meeting Presentations on rooftop test data compared to modeling results, October 2013.

References:

Opening photo shows the PEPA 5 Test facility in Soria, Spain.

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

Figure 3. IEA Wind Task 27 team photo, Dundalk, Ireland

8 Task 28 Social Acceptance of Wind Energy Projects

1.0 Introduction

Wind power in some countries is realizing its potential and contributing to the renewable energy targets set by governments in previous years. With wind power growing in contribution to the national energy statistics, knowledge based on long-term wind power deployment is accumulating; project developers are involving local stakeholders, local and regional authorities are taking an active role in the development of the renewable energy sources, planning experts are preparing the basis for renewable energy production by setting the ground rules, etc. The opening photos illustrate workshops addressing social acceptance of wind energy development in Denmark, Germany, and the Netherlands. These and other success stories provide approaches that have proven valuable.

However, the good stories may not reach a broad audience, while some of the bad examples receive widespread coverage. This is where IEA Wind Task 28 comes in: Set up as an interdisciplinary and trans-national working group, practitioners and researchers share their knowledge and experience so that participating countries benefit from successful strategies and innovative ideas. Then by publishing state-of-the-art reports and recommended practices the entire wind community can benefit from the work of the participants.

Early in 2012, the first phase of the task (2008–2011) was completed with the publication of the Final Report (1). Then in June, a Topical Expert Meeting in Switzerland was organized with IEA Wind Task 11. Experts from 13 countries discussed results of IEA Wind Task 28 (2008–2011) and collected ideas and needs for the second phase 2012–2015. This will enable Task 28 working group members to exchange experiences of social acceptance, review current research, define research gaps, and identify possible synergies between participating institutions. The working group members will also develop inputs to IEA Wind, e.g. on topics such as measurement and monitoring of social acceptance or dissemination of good practices. The extension proposal prepared by the working group for the phase 2012–2015 was approved at the IEA Wind ExCo meeting in autumn 2012 (2). Table 1 gives an overview on current participation.

2.0 Objectives and Strategy

IEA Wind Task 28 will support participating countries by

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

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

The intended means to provide these inputs are:
• Working group meetings, national expert meetings, Topical Expert Meeting
• Good Practice Recommendations and other publications
• Reports to IEA Wind ExCo, annual reports
• Participation in conferences, e.g. the annual EWEA conference
• Articles in industry journals and branch magazines, and the
• Task 28 website homepage.

Task 28 will focus on an issue at each meeting to give more detailed recommendations. The main areas of the future work of Task 28 proposed for the next period are summarized as:
• Measurement, monitoring, or assessment of social acceptance respectively quantification and valuation of the phenomenon of social acceptance and the impacts when it has not been sought
• Documentation of existing policies and standards that have been demonstrated to increase social acceptance, including evaluation of checklists and guidelines as well as their use, taking into account the whole life-cycle of wind turbines
• Discussion of current and new issues influencing social acceptance that are being debated in the participating countries, stressing of research gaps and discovering of opportunities for joint research, e.g. (far) off-shore, repowering, electricity grid expansion due to wind energy production
• Deduction, documentation, and dissemination of the lessons learned, good practices, successful strategies, etc. with the aim of improving projects and their implementation and to support the definition of the common understanding of "sustainable, acceptable projects"
• The role of neutral intermediaries, management of controversial projects, "guichet unique" for developers or public authorities.

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

Table 1. Countries Participating in Task 28

	Country	Institution(s)	2008–2011	2012–2015
1	Canada	Natural Resources Canada, CANMET Energy Technology Centre; University of Québec at Montréal	x	-
2	Denmark	Danish Energy Authority; Ministry of Climate and Energy	x	-
3	Finland	Finnish Funding Agency for Technology and Innovation, Energy and Environment Industries (TEKES); wpd Finland Oy	x	-
4	Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety; Martin Luther University; University Saarbrücken	x	x
5	Ireland	Sustainable Energy Authority; Queen's University Belfast	x	x
6	Italy	ENEA Agenzia nazionale per le nuove tecnologie, l`energia e lo sviluppo economico sostenibile; RSE Ricerca Sistema Energetico	-	x
7	Japan	National Institute of Advanced Industrial Science and Technology; Nagoya University	x	x
8	Norway	Norwegian Water Resources and Energy Directorate; Enova SF; Norwegian University of Science and Technology, Centre for Energy and Society	x	-
9	Switzerland	Federal Department of the Environment, Transport, Energy and Communications, Swiss Federal Office of Energy; ENCO Energie Consulting AG,	x	x
10	The Netherlands	Agentschap NL, NL Energy and Climate	x	-
11	United States	U.S. Department of Energy, National Renewable Energy Laboratory Wind Technology Center; Lawrence Berkeley Lab	x	x

3.0 Progress in 2012

The highlight of IEA Wind Task 28 in 2012 was the Topical Expert Meeting (3) that took place in Biel, Switzerland. It united experts from 13 countries for a two-day meeting, followed by a one-day Task 28 working group meeting. It also included a half-day meeting with Swiss practitioners that were invited in close cooperation with the Swiss wind branch organization "Suisse Eole." The target audience for this workshop included IEA Wind Task 28 working group members and national experts from its network; researchers, experts, and practitioners from IEA Wind countries; and countries interested in participation in the second phase of IEA Wind Task 28.

The Topical Expert Meeting on Social Acceptance in 2012 provided feedback on the success of the first phase. The results and the final report of IEA Wind Task 28 stimulated discussion of issues and targets for the second phase. The meeting provided the Task 28 working group and participants from countries in Task 11 new insights from the presentations of current projects and the discussions.

The Final Report of Task 28, phase 2008–2011 was published in 2012 (1). The report summarizes the work of the group, the results of the discussions, and recommendations for further work. It also describes the network established by the Task 28 activities, e.g. by the national expert meetings, and the dissemination activities established.

The extension proposal for continuation of Task 28 in 2012–2015 (2) was approved

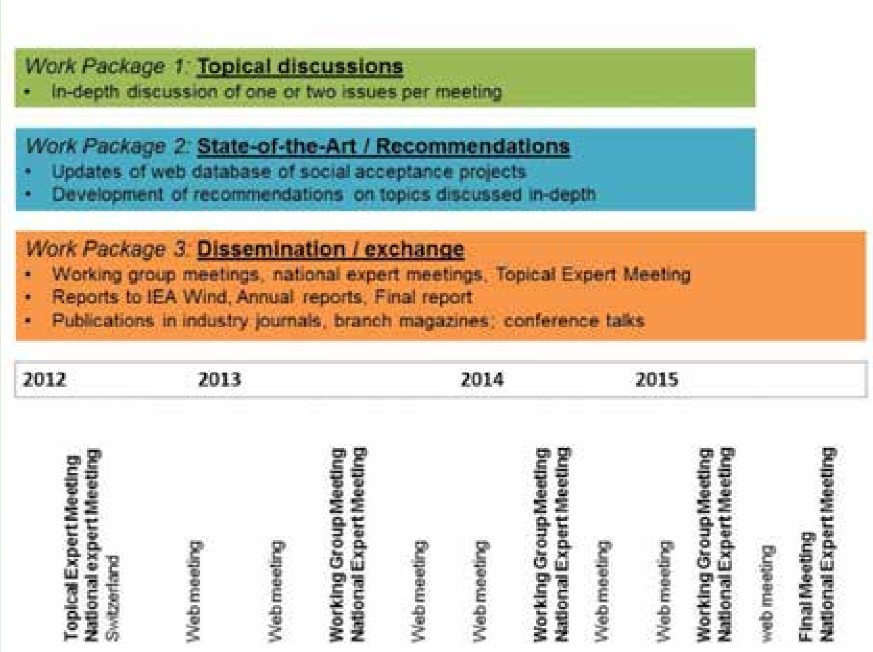

Figure 1. Work packages and timeline for IEA Wind Task 28 (2012–2015)

by the ExCo late in 2012. Exchange with continuing countries continues, while talks with possible new participants are ongoing. Canada and Finland will not participate in the Task 28 second phase; however, Italy has joined and contacts have been established with Australia, Austria, and Sweden.

IEA Wind Task 28 has been working to develop IEA Wind Recommended Practices on the issue of social acceptance of wind energy projects. The Recommended Practices will be published in 2013 and will be available on the IEA Wind website (www.ieawind.org).

Dissemination activities in 2012 also included:

• Publication of the peer-reviewed article in *WIREs Energy and Environment* (3)

• Collaboration for the publication, *Learning from Wind Power: Governance and Societal Perspectives on Sustainable Energy* (4), edited by amongst others Geraint Ellis, working group member of IEA Wind Task 28.

• Participation at the workshop "wind parks for all–increasing social acceptance by citizen involvement" at the Third Forum in St. Gallen, Switzerland, on Management of Renewable Energies (5).

4.0 Plans for 2013 and beyond

In 2013, the working group will focus on the issue of monitoring and quantifying social acceptance. There will be several web meetings and at least one working group meeting. The first meeting is planned for Japan, in connection with a national expert meeting. In parallel, insights from the task work of the last year will be disseminated in the participating countries by the working group members in their teaching or implementation work or by various kinds of publications. IEA Wind Recommended Practice 14. Social Acceptance of Wind Energy Projects, 1. Edition 2013 will be published and widely distributed.

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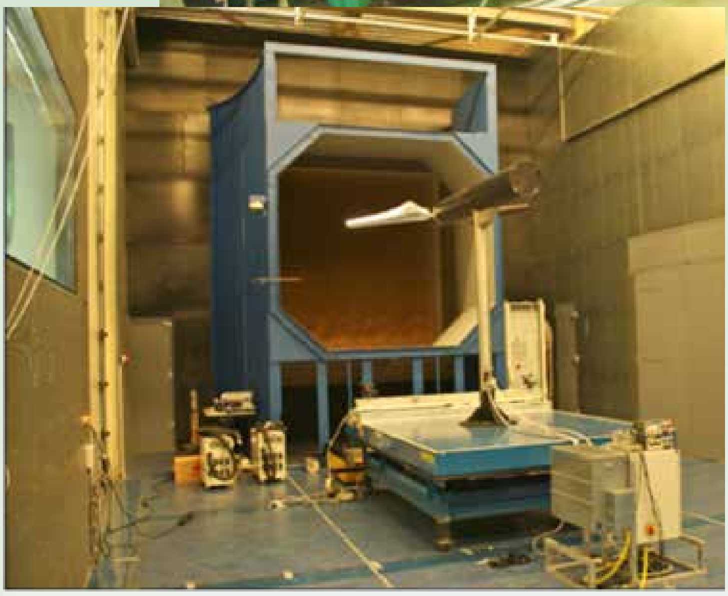
Author: Robert Horbaty and Stefanie Huber, ENCO AG, Switzerland.

Figure 2. Participants of the Topical Expert Meeting on Social Acceptance of Wind Energy Projects in 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 pre-requisite to gain insight into these uncertainties and to validate and improve aerodynamic wind turbine models. The main aim of IEA Wind Task 29 Mexnext: Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models is to analyze the measurements from the European Union (EU) project Model Rotor Experiments In Controlled Conditions (MEXICO) (1), hence the name Mexnext.

In the EU MEXICO project, ten institutes from six countries cooperated in doing experiments on an instrumented, 4.5-m diameter, three-bladed wind turbine placed in the open section of the Large Low-speed Facility of the German-Dutch Wind (DNW) Tunnel in the Netherlands. The measurements were performed in December 2006 and resulted in a large database of combined blade pressure distributions, loads, and flow field measurements, which can be used for aerodynamic model validation and improvement.

In the first phase of IEA Wind Task 29 Mexnext, 20 participants from 11 countries analyzed the EU MEXICO data and found some very interesting results that were reported in numerous journal articles and in the Final Report (40). That first phase of the work began in June 2008 and ended on 1 June 2011. A second phase of Task 29, Mexnext II, was approved through 31 December 2014.

The work of Mexnext-II is still to improve aerodynamic models by analyzing data from measurements. The main difference lies in the fact that the activity will first compile an inventory of all historical aerodynamic wind turbine measurements, from long past to very recent including the EU MEXICO experiment. Then the participants will conduct further analysis of these historical data. This work will take full advantage of existing "lost" data to increase understanding of wind turbine aerodynamics.

Originally, no new measurements were foreseen in Mexnext II. However in 2012, the EU Aerospace program, the European Strategic Wind tunnels Improved Research Potential (ESWIRP), approved a New MEXICO experiment in which additional measurements are performed on the MEXICO model wind turbine in the DNW-Large Low-speed Facility. ESWIRP will fund the costly wind tunnel time using the same instrumented wind tunnel model from the EU MEXICO project. The labor is funded from the EU FP7 project INNWIND.EU. The New MEXICO measurements are scheduled for mid-2014. Then IEA Wind Task 29 Mexnext II participants will use this new data set to approach the questions raised during Mexnext I. The result will be improved understanding of wind turbine aerodynamics that can be used to improve design models.

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

2.0 Objectives and Strategy

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

The approaches in Mexnext I and Mexnext II are very similar but there is a difference in the first Work Package (WP). The first WP in Mexnext II carries out an inventory of the unexplored experiments. In Mexnext I, the attention was focused on the EU MEXICO measurements alone as an unexplored data set. Apart from that difference, both Mexnext I and Mexnext II are carried out along the following WPs.

- 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 that are used by the participants are compared with the data from the various experiments.
- WP4: Deeper investigation into phenomena. In this work package, a deeper investigation of different phenomena takes place. The 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 2012

In 2012, the Mexnext I project was fully completed and the final report (40) was approved by the IEA Wind Executive Committee.

In the framework of Mexnext II the following main activities were carried out:

- A questionnaire was prepared on the experimental facilities in order to assess the usefulness of each experiment. This questionnaire has been completed by the experimental participants on basis of which the usefulness of the various experiment could be established. Apart from the EU MEXICO and NASA-Ames wind tunnel measurements, the wind tunnel experiments from KARI, CARDC, and INTA on scaled down MEXICO and NASA rotors are considered, together with measurements from Mie University (opening photo top) the Open Jet Facilities of TUDelft (opening photo bottom) and along with field measurements from Dan-Aero, Kiel University and measurements taken by TUDelft on the ECN HAT-25 turbine in the 1980s. The latter three experiments also consider boundary layer transition.
- The activities have begun to prepare the New MEXICO experiment. The technical experts who worked on the original EU MEXICO experiment visited the DNW tunnel where the MEXICO model was stored. During the visit, they assessed the status of the model. A limited number of technical problems were found but these are expected to be solvable. The most important conclusion from the visit was that the model can be brought 'alive' again for the new experiment.

Table 1. Countries and Organizations Participating in Task 29 During 2012

	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	Korea	Korea Institute of Energy Research (KIER); Korea Aerospace Research Institute (KARI)
6	Netherlands	Energy Research Center of the Netherlands (ECN); Delft University of Technology (TUDelft); Suzlon Blade Technology (SBT); and the University of Twente
7	Norway	Institute for Energy Technology/Norwegian University of Science and Technology (IFE/NTNU)
8	Spain	Renewable Energy National Center of Spain (CENER); National Institute for Aerospace Technology (INTA)
9	Sweden	Royal Institute of Technology/University of Gotland (KTH/HGO)
10	United States	National Renewable Energy Laboratory (NREL)

* Technion in Israel is a subcontractor to Task 29.

• A meeting of Mexnext II (the seventh meeting of the overall Mexnext project) was held on 5-6 November 2012 at NREL in the United States. This meeting was followed by a meeting of IEA Wind Task 31 Wakebench: Benchmarking Wind Farm Flow Models. Wakebench and Mexnext are related; Mexnext works on rotor aerodynamics and the near wake, which act as starting conditions for the so-called far wake. The far wake is the subject of Wakebench). At the meeting, the usefulness of the New MEXICO experiments to the work of both tasks was discussed. This input helped prepare the strategy of the New MEXICO experiment.

During the activities of IEA Wind Task 29, results have been published and presented in at least 27 papers and articles; see references 10, 11, and 15–39. Moreover, the results from Mexnext together with results from previous aerodynamic IEA Wind Tasks 14, 18, and 20 formed the basis for a PhD thesis defended in November 2012 at TUDelft (41). Another PhD thesis defended in December 2012 at TUDelft contains knowledge on detailed wind turbine rotor flows based in part on the EU MEXICO rotor experiments (42).

4.0 Plans for 2013 and beyond

The main activities in 2013 will involve the analysis of various measurements in WP4, the simulation of measurements in WP3, and the preparation of the New MEXICO experiment in WP1. More specifically:

• Task leaders have been appointed for various WP4 activities. These task leaders have prepared a more detailed work plan of their task, which will form the basis for the activities in their tasks.

• Several meeting and activities are planned to prepare the New MEXICO experiment, which is now scheduled for mid-2014.

• TUDelft offered a 2-D test of the MEXICO model blades in the Delft Low Speed Low Turbulence Tunnel. This tunnel slot is scheduled for September 2013.

• A new calculation round on axial flow will be defined. The first calculation round will concern NASA-Ames measurements at a rotational speed, which is higher than commonly addressed in this experiment. Such conditions go together with a higher induction and less stall than experienced in most NASA Ames measurement data.

• The next plenary meeting of Mexnext II will be held in September 2013 at CENER, Spain. The meeting will be combined with a meeting from the subgroup aerodynamics of European Energy Research Alliance (EERA).

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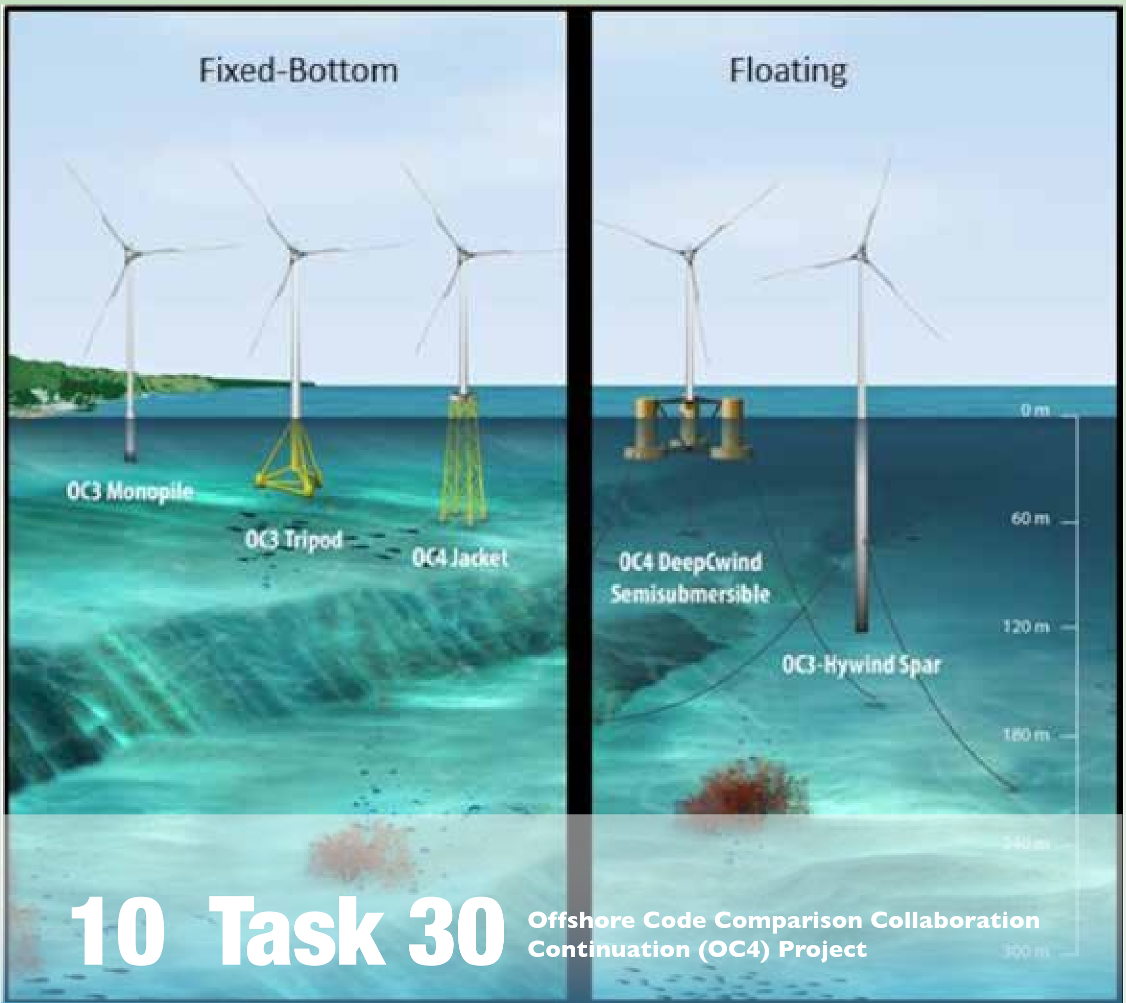
Author: J. Gerard Schepers, Energy Research Center of the Netherlands (ECN), the Netherlands.



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 (opening graphic). 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 to validate them 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) and the Fraunhofer Institute for Wind Energy and Energy Systems Technology (IWES).

Since the project began, 130 participants from 50 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 needs.

Table 1. Countries and Organizations Participating in Task 30 During 2012		
	Country	Institution(s)
1	China	China General Certification Center; Goldwind
2	Denmark	DTU Wind Energy; campus Risø; DHI; Rambøll
3	Finland	VTT Technical Research Centre
4	Germany	Fraunhofer IWES; Germanischer Lloyd; Leibniz Universität Hannover; Repower; University of Stuttgart
5	Greece	Aristotle University of Thessaloniki; National Technical University of Athens
6	Japan	University of Tokyo; National Marine Research Institute
7	Korea	Pohang University of Science and Technology; University of Ulsan
8	the Netherlands	Energy Research Centre of the Netherlands (ECN); The Knowledge Centre WMC; GustoMSC; TU Delft
9	Norway	Center for Ships and Ocean Structures at Norwegian University of Science and Technology (NTNU); FEDEM Technology; Institute for Energy Technology, Marintek; 4subsea; University of Stavanger
10	Portugal	Wave Energy Centre; Instituto Superior Tecnico
11	Spain	Acciona Energia; ALSTOM Wind; CENER; LMS; IREC
12	United States	ABS Consulting; National Renewable Energy Laboratory (NREL); Principle Power; MSC Software; Texas A&M University; Clear Path Energy; Penn State University
Observers		
	Belgium	LMS
	Canada	McGill
	France	Principia
	Italy	Polytechnico Di Milano
	Sweden	GE Wind; Teknikgruppen
	United Kingdom	GL Garrad Hassan; Lloyd's Register

Such verification work, in the past, led to dramatic improvements in model accuracy as 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 simulated 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) a 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 and (II) analysis of a wind turbine on an offshore floating semisubmersible (Figure 1). Additionally, in OC4 an experts meeting on the topic of test methods, data availability, and code validation is planned as a stand-alone meeting.

3.0 Progress in 2012

Task 30 had one physical meeting in 2012 at the International Offshore and Polar Engineering (ISOPE) Conference in Rhodes, Greece in June. In between physical meetings, progress was made through e-mail communication and Internet-meetings scheduled every one to two months.

A number of tasks have been addressed since the project's inception and 12 countries have joined IEA Wind Task 30.

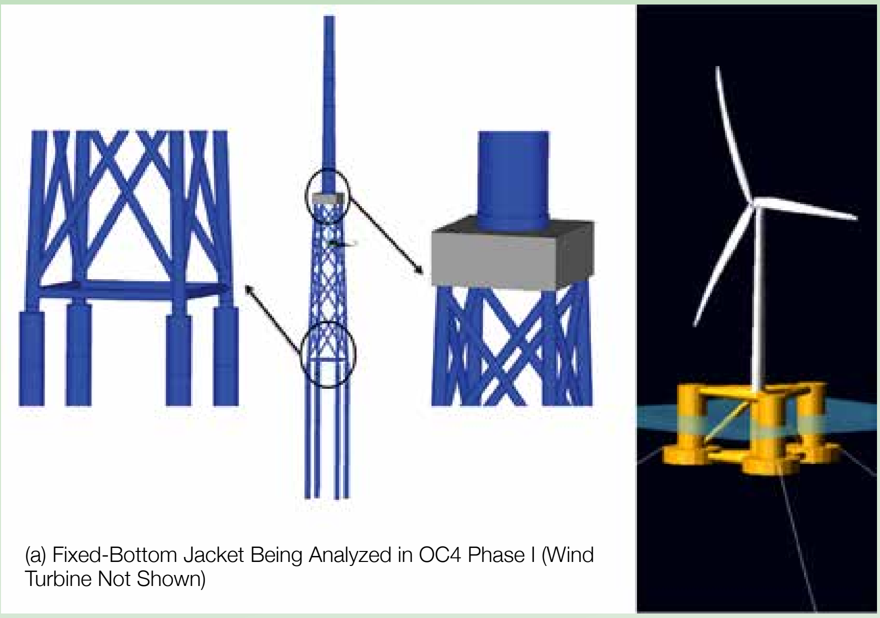
Phase I of the project, the analysis of a wind turbine on an offshore fixed-bottom jacket was completed. Sixteen organizations ran some or all of the load cases prescribed for this phase. Comparison of the results was made through component masses, system eigenfrequencies, static loads, time histories, spectra, statistics, and damage-equivalent loads. Participants made several rounds of revisions in an attempt to converge to similar values. With a few exceptions, the results have compared well among the various models. The lessons learned so far have improved our understanding of the modeling and dynamics of offshore jacket support structures applied to wind turbines. A summary paper of the Phase I analysis was written and presented at the ISOPE conference (3).

A Topical Experts Meeting under IEA Wind Task 11 was held on Offshore Wind Model Validation in Boulder, Colorado (United States) on 15-16 May 2012. The purpose of the meeting was to begin development of a plan for international collaboration on validating the codes used for modeling and designing offshore wind turbines. The meeting was attended by 60 experts from national laboratories, industry, and academia. Invited speakers gave 17 presentations and NREL moderated four discussions. A report summarizing this meeting was distributed to participants.

Work began on Phase II of the project, the analysis of a wind turbine on an offshore floating semisubmersible platform. A specification document was developed describing the semisubmersible design. The specification consists of the geometry, mechanical properties, hydrodynamic coefficients, and mooring design of the system. Several modifications have been made to this document, based on feedback and discussion with participants.

The load cases to be analyzed in Phase II were developed and disseminated to the project participants. The specifications consist of the model features, wind conditions, wave conditions, analysis type, and output parameters appropriate for each case. Using the Phase II semisubmersible design and load cases, models were developed by 12 of the project organizations, and initial simulation results were compared for Load Case (LC) 1.X. This load case focuses on identification of the system properties and includes an eigenanalysis of the system and simulations of the static equilibrium and free decay from various offset positions.

The IEA Wind Task 30 operating agent representative, Walt Musial, presented the



(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

idea of extending the OC4 project for another three years at the October meeting of the IEA Wind Executive Committee. The focus of the extension would be on the validation of offshore wind modeling tools through the comparison of participant simulations to experimental data from actual offshore wind systems. The committee expressed support for this extension.

4.0 Plans for 2013 and Beyond

The first three-year term of IEA Wind Task 30 will end in December 2013. Each phase (I analysis of a wind turbine on an offshore fixed-bottom jacket and II analysis of a wind turbine on an offshore floating semisubmersible) will last about two years, with overlap in the middle year. Phase I of the project was completed in the summer of 2012, with a paper presented at the ISOPE conference. A report summarizing the topical experts meeting on model validation was written. An additional paper will be presented on the results of the Phase II analysis. A final report encompassing the entire project will be published at the end of the task.

Work has begun on Phase II. Three sets of load cases will be run for this design, including system identification (1.X), wave-only simulations (2.X), and combined wind/wave cases (3.X). The simulation work for this phase began in August of 2012 and is anticipated to be completed in 2013. At the conclusion of this work, a conference paper will be written summarizing the findings, to be presented in 2014.

Following the enthusiasm expressed by task participants and the ExCo, NREL and Fraunhofer IWES will pursue the idea of extending the OC4 project for another three years. In the coming months, NREL will identify available datasets for use in a validation project. Then, a formal proposal for the task extension will be presented at the next IEA executive committee meeting in October of 2013.

The next physical meeting for the project will be held in Nantes, France in June of 2013 in conjunction with the Ocean, Offshore and Arctic Engineering (OMAE) Conference.

The verification activities performed in OC3 and continuing in OC4 are important because the advancement of the offshore wind industry is closely tied to the development of accurate 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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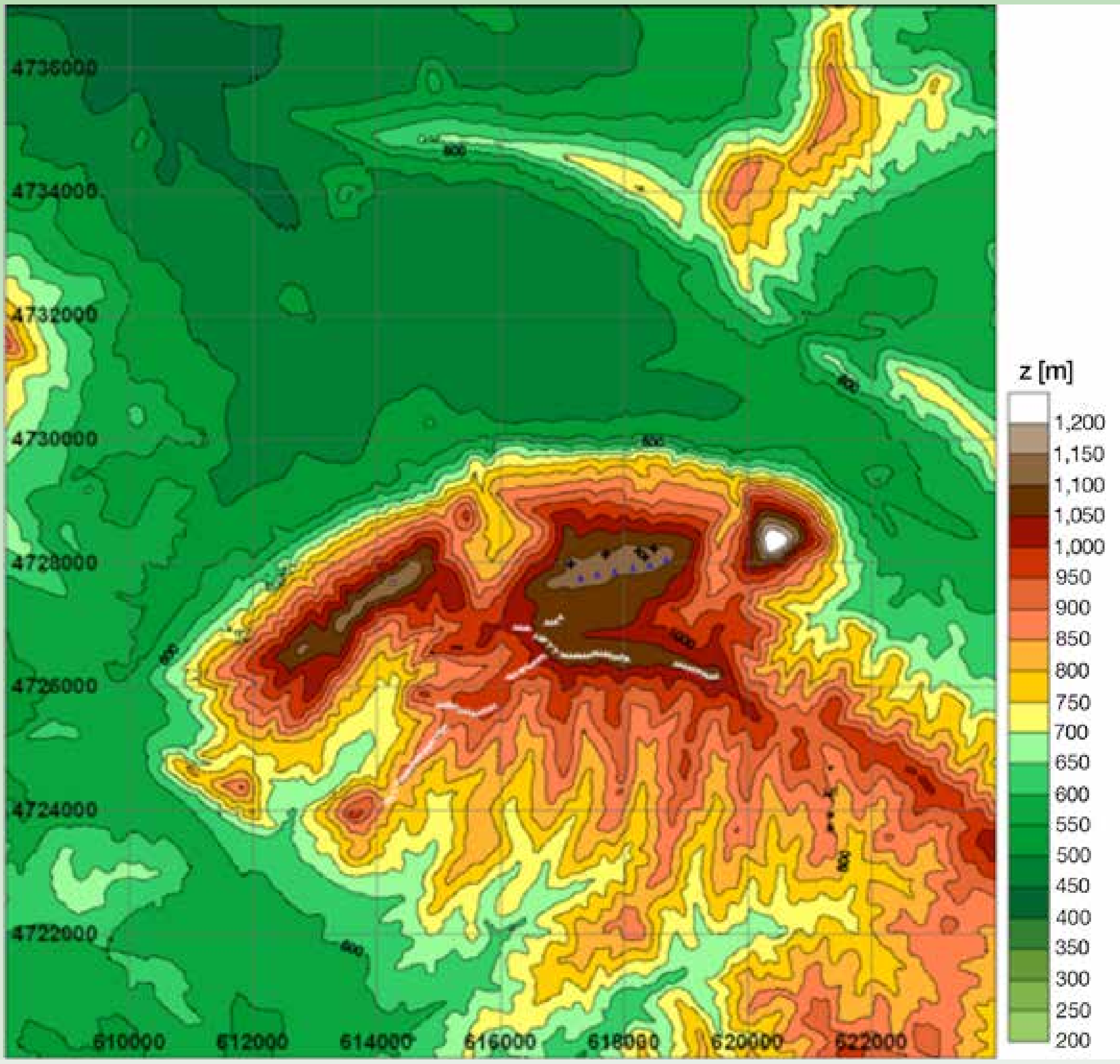

11 Task 31 WAKEBENCH: Benchmarking Wind Farm Flow Models

Source: CENER

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 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 extend 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 average Navier Stokes (RANS), unsteady RANS, detached eddy simulations (DES) (which is a hybrid between RANS and large-eddy simulation (LES), and even full 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 (VV&UQ) are fundamental problems in the development of any engineering model. This process allows a comprehensive transition from experience and test-based design to simulation-based design, producing more efficient and cost-effective design solutions (3). The adoption of VV&UQ procedures is an unresolved issue in wind resource assessment due to the inherent complexity of the system to model.

As stated in the COST 732 Action (2009) report on micro-scale model evaluation (4), there is not a distinct definition of the requirements of a validation test case dataset and the procedure to use it in a consistent and systematic way. A basic requirement for any validation exercise is that the model and the validation dataset share the same or a very similar hypothesis. This basic rule is already difficult to fulfill since most of the micro-scale 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 clever strategy for VV&UQ that combines field and laboratory measurements will be developed in this IEA Wind Task. To this end, a set of verification and validation test cases will be selected for benchmarking of models with increasing levels of complexity. Some test cases are readily available from the literature 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 VV&UQ strategies.

2.0 Objectives and Strategy

Task 31 WAKEBENCH aims at providing a forum for industrial, governmental, and academic partners to develop and define quality-check procedures, as well as to improve atmospheric boundary layer and wind turbine wake models for use in wind energy. The working methodology (Figure 1) will be based on the benchmarking of different wind and wake modeling techniques in order to identify and quantify 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 will be organized around benchmark exercises on validation test cases. In order to facilitate the management of these exercises, the "WINDBENCH" model validation web platform will be made available by CENER, which will act as the administrator. 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

Table 1. Countries and Organizations Participating in Task 31 During 2012

	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 Tokyo; 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
14	Other IEA Wind countries under negotiation for participation: The Netherlands	

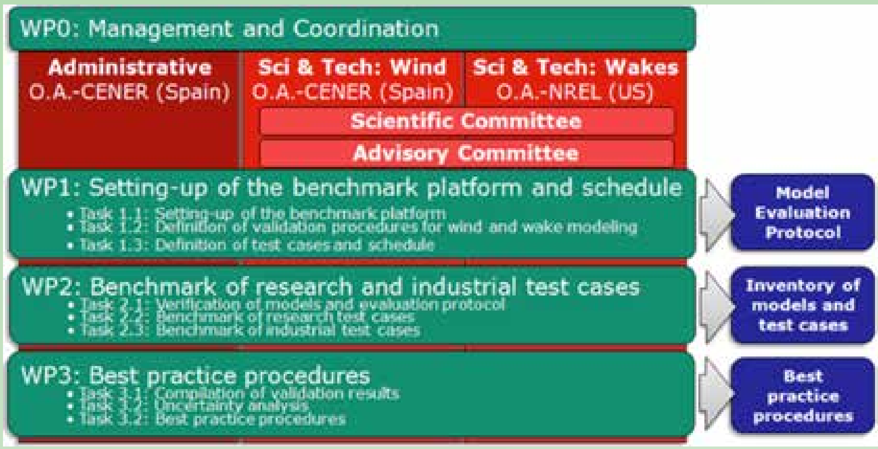

Figure 1. Structure of Task 31 and deliverables

case, schedule the benchmark exercise, and administer access to the data. A set of questionnaires will compile 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 2012

In 2012 Task 31 gathered participants from 14 IEA Wind member countries. The distribution list counts with more than 200 people with different backgrounds and levels of interest. In order to facilitate the structure of such a large group, ten working groups (WG) have been configured, each one dealing with a specific sub-domain of the building-block model chain (Table 2).

Each WG has a number of associated test cases and model inter-comparison benchmarks already identified (opening graphics). During 2012 the first benchmarks where initiated, namely: Monin-Obukhov and Leipzig for surface layer and ABL models in flat terrain; Askervein and Bolund for flow over hilly terrain; Waving Wheat and Furry for wind tunnel flow over homogeneous canopy over flat terrain and two-dimensional hill in a wind tunnel; Sexbierum single-wake and double-wake; and Horns Rev multiple-wake under various inflow conditions. For now, most of the benchmarks are based on neutral stratification.

In November 2012 the first annual meeting took place at NREL (Boulder, U.S.) with focus on the Model Evaluation Protocol (MEP) for wind farm flow models. The first benchmark results were presented and discussions on evaluation procedures were initiated.

4.0 Plans for 2013 and Beyond

The MEP will be the first deliverable of the task. It will be published during in 2013 together with CENER's Windbench model validation web portal. The website will be used to manage user accounts, test case and benchmark guides as well as input, validation and simulation data. From this platform, an inventory of test cases and benchmarks will be published as interim deliverables of the task. Both the MEP and the inventory reports will be updated throughout the duration of the task as new information is produced.

In 2013 the first benchmarks launched in 2011 will be finished in the form of summary reports and new benchmarks will be started to complete the first phase of test cases mostly based on research experiments. The second phase of the task will focus on test cases from industry making use of data coming from wind resource measurement campaigns and supervisory control and data acquisition (SCADA) data from operational wind farms. To this end, a call for test cases will be launched in 2013 in order to guide potential data contributors.

The second annual meeting will take place at the University of Frankfurt (Germany) in November 2013 with focus on complex terrain and uncertainties.

References:

Opening graphics: (top) Initial Benchmarks: WG5 – Mountains; (bottom) Initial Benchmarks: WG3 – Hills.

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

Table 2. Thematic working groups in Task 31

Working Groups	Theme
WG1-Flat_ABL	Flow over flat terrain
WG2-Hills_WindTunnel	Flow over hills in wind tunnel
WG3-Hills_Field	Flow over hills in the field
WG4-Forest	Flow in and above forest canopies
WG5-Mountains	Flow over Mountains
WG6-Wakes_Theory	WT Wakes. Theoretical verification
WG7-Wakes_WindTunnel	WT Wakes. Wind tunnel experiments
WG8-Wakes_SmallWindFarm	Small wind farms / Individual wind turbines
WG9-Wakes_LargeWindFarm	Large wind farms
WG10-New_TestCases	Requirements for validation experiments

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

Courtesy: Leoshere, France

1.0 Introduction

IEA Wind Task 32 aims to address the very fast development of wind lidar technologies, and their use in providing more accurate measurement of wind characteristics that are required for reliable deployment of wind energy power systems (opening photo). The purpose is to bring together the research community and wind industry to create synergies in the many R&D activities already on-going in this new and very promising remote sensing-based measurement technology.

The Task has three main drivers. Firstly, no consolidated multi-lateral and international exchange on lidar technology has taken place up to now, despite several research projects during the last years. Secondly, the availability of new commercial lidar systems with a range of specifications makes it very difficult for the community to keep up with the advances of this specific technology. Finally, new applications that are only possible with wind lidar systems are being developed. However, their real potential cannot be assessed nor exploited without strong cooperation between the research community and the industry (Figure 1).

The Operating Agent is ForWind – University of Oldenburg, Germany. Five countries are currently formal participants of the Task (Canada, Denmark, Germany, Japan, and the United States). In addition, another three countries are in the process of officially joining (Norway, Switzerland, and the United Kingdom) and some others have shown active interest (Table 1).

2.0 Objectives and Strategy

The main objective of the Task is the publication of experimentally tested recommended practices for wind lidar measurements. This should build up based on the joint experience of the participants. The recommendations will be benchmarked with measured data collected at various meteorological and lidar operational conditions. The selected data and the analysis results are mutually shared by the participants.

The activities build upon the discussions and work already performed in regards to lidar technology during IEA Wind Topical Expert Meetings in 2007 and 2009 on remote wind speed sensing techniques using sodar and lidar. 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. This is because sodar- and lidar-based techniques differ both in the nature of the signals emitted (sound vs. light) and in their specific applications related to wind energy utilization. For instance, sodar systems are not yet

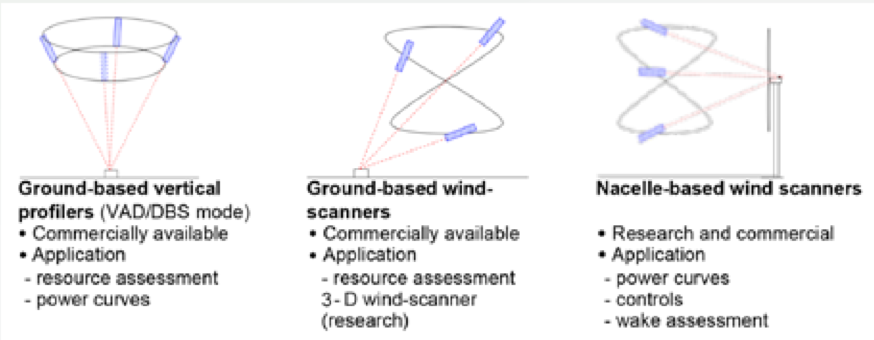


Figure 1. State of the art of lidar technology

Table 1. Countries and Organizations Participating in Task 32 During 2012

	Country	Institutions
1	Canada	Garrad Hassan, AXYS Technologies, et al.
2	Denmark	Alpha wind metrum / alpha wind energy; DONG Energy; DTU Wind Energy; Vestas Technology R&D; Windar
3	Germany	Deutsche WindGuard; DEWI; ForWind - Univeristy of Oldenburg; Fraunhofer IWES; GL Garrad Hassan; SWE - University Stuttgart; WIND-consult
4	Japan	ITOCHU Techno-Solutions Corporation, Mitsubishi Electric Corporation
5	United States	NOOA/ESRL; DnV KEMA; NREL; University of Massachusetts; U. Colorado at Boulder, LLNL; PNNL; et al.
Potential participants		
6	Belgium	3E
7	China	CWEA
8	France	Avent Lidar; Leosphere
9	Israel	Pentalum
10	Netherlands	ECN
11	Norway	Meventus; NORCOWE - University of Bergen
12	Switzerland	EPFL, MeteoSwiss
13	United Kingdom	Carbon Trust; Oldbaum Services Co.; SgurrEnergy Ltd; ZephIR Ltd./Natural Power Consultants

suitable for power curve assessment, are not useful for nacelle-mounted approaches, and do not include a scanner system.

To set the stage for research on remote sensing, IEA Wind under Task 11 developed and approved in 2012 the *Recommended Practice RP: 15. Ground-Based Vertically-Profiling Remote Sensing for Wind Resource Assessment* (Figure 2). This was also reviewed by participants of Task 32. The understanding gained in Task 32 will be collected and summarized in a second edition of this Recommended Practice that will include recommendations to improve lidar-measured wind and turbulence accuracy. It will also contain recommendations for lidar applications suitable for both flat terrain and complex flow conditions as well as turbine assessment (to be published in 2014).

Task 32 is organized in work packages gathered in three subtasks:

- Subtask I: Lidar calibration and classification (Table 2)
- Subtask II: Lidar procedures for site assessment (Table 3)
- Subtask III: Lidar procedures for turbine assessment (Table 4)

One additional subtask is dedicated to the data management. The subtasks have been rediscussed and revised during the first year of the Task. The final scope of each one is described and listed below.

Table 2. Work Packages and Goals of Subtask I

Subtask I: Lidar calibration and classification Coordinator: DTU Wind Energy, Denmark	
1.1 Shear and turbulence effect on the calibration	
Goals	• Better understand the way turbulence affects the scalar means of both cups and lidars
	• Understand how and by how much shear can influence our calibration results
	• If necessary to propose a modified calibration procedure to mitigate these effects
1.2 Classification and uncertainty	
Goal	Evaluation of the classification scheme in IEC 61400-12-1 ed. 2, Annex L
1.3 Calibrating nacelle lidar	
Goals	• Define calibration procedure
	• Understand uncertainties
	• Define how to proceed with different lidar types
1.4 Lidar calibration in complex terrain Merged with Work Package 2.2	
1.5 Calibrating floating lidar	
Goals	• Evaluation of onshore calibration on simulators versus offshore calibration next to a metmast
	• Assess uncertainty budget adding wave height sensitivities
1.6 Novel idea: line of sight calibration Parked until later date	

2.1 Subtask I: Calibration and classification of lidar devices

The main concern of this subtask is the accuracy of wind lidars. At the same time, it aims to assess and develop calibration methods and uncertainty budgets based on the concepts presented in IEC 61400-12-1 ed. 2 CD, Annex L. The work of the subtask will be made available in expert reports and will hopefully contribute significantly to future revisions of IEC 61400-12-1 Annex L.

As lidars become more routinely used in more novel applications such as floating offshore or nacelle-mounted, Subtask I will act as a forum to try and form consensus concerning calibration techniques for these new devices. Expert reports will be prepared as appropriate and it is hoped that these will form a useful starting point for future standardization efforts.

2.2 Subtask II: Procedure for site assessment

Subtask II is evaluating the performance of lidar systems for resource assessment: wind speed, turbulence, stability, and boundary-layer characteristics in flat as well as complex terrain and offshore. Furthermore, the subtask is studying new ways to make a more comprehensive description of turbulence, which will be directly usable at the industrial level. In addition, in the near future, features that will be considered in the prediction of the annual power production of a specific site will include the speed at hub height as well as the entire vertical wind profile and possible additional parameters like stability. For such purposes, new data analysis guidelines will be needed to make use of lidar vertical wind speed profiles in an appropriate manner.

Table 3. Work Packages and Goals of Subtask II	
Subtask II: Lidar procedures for site assessment Coordinator: NREL, United States	
2.1 Review of RP 15: Ground-based vertically-profiling remote sensing for wind resource assessment	
Goals	• Inclusion of reviews of RP 15 given by Task 32 participants to the final document
2.2 Wind field reconstruction methods in complex flow with wind lidars	
Goals	• Formulation of guidelines on how to use wind lidars in complex terrain and when flow correction is necessary
2.3 Measurement of Wind Characteristics	
Goals	• Understanding point- and profile measurements from lidar versus traditional methods
2.4 Using Lidar as part of a wind resource assessment	
Goals	• Estimate of uncertainties in AEP using lidar data

2.3 Subtask III: Procedure for turbine assessment

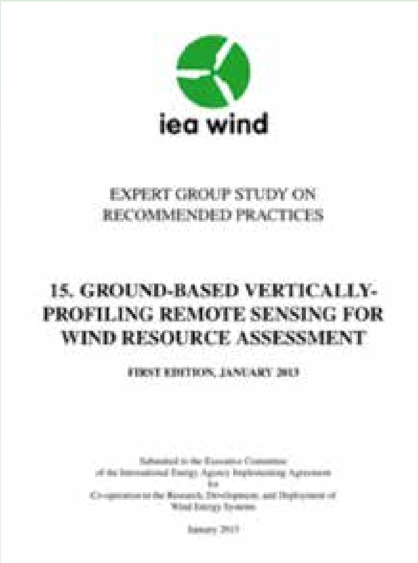
The integration of wind lidar in the standard procedures for the assessment of wind turbines is the focus of this subtask. In particular it is intended to extend to loads estimation the already aknowledged application of lidars for testing the power performances of wind turbines. The activity of this task is divided in nacelle- and ground-based topics as well as in power performance and load estimation issues. Additionally, possible methods for wind field reconstruction from nacelle-based lidar data are going to be reviewed and disseminated.

2.4 Subtask IV: Data management

This cross-cutting activity provides and coordinates a platform for the exchange of the data required to meet the objectives of the entire Task 32. Two types of data have been identified as necessary for the work. Firstly, pure vertical wind speed profile measurements, and secondly, wind speed measurements plus turbine power and load data. The exchange of data is expected to take place in a "give-and-take" manner, where receivers of data also have to provide some data in return.

3.0 Progress in 2012

During this year two plenary meetings took place one at DTU/Wind Energy and the other at Oldenburg University. The first meeting started the Task and interests from participants were collected. Attendees included 41 experts from 27 institutions in 11 countries. Nearly 50% of the participants are from industry, which is important to the success of the work plan. At the second meeting, 30 experts from 19 institutions in 10 countries established the detailed work of the four subtasks and 12 work packages.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EXPERT GROUP STUDY ON RECOMMENDED PRACTICES

15. GROUND-BASED VERTICALLY-PROFILING REMOTE SENSING FOR WIND RESOURCE ASSESSMENT

FIRST EDITION, JANUARY 2013

Figure 2. Cover of the approved IEA Wind RP 15

In 2012, all reviews to the draft IEA Wind Recommended Practice RP 15 "Ground-based vertically-profiling remote sensing for wind resource assessment" (Figure 2) were collected and incorporated into the document which was approved by the ExCo and published in early 2013.

Furthermore, a website (www.forwind.de/IEAAnnex32/) has been hosted to publicize the work and serve the participants.

4.0 Plans for 2013 and beyond

On the timeline the publication of the first edition of IEA Wind RP 15 was completed in February 2013. Next steps foresee the kick-off of the different work packages mainly in the form of telephone-conferences. A data-exchange platform will be developed to support these meetings as well as to facilitate a flexible interaction among the participants. The next progress meeting is scheduled for May 2013 at NREL in Boulder, United States.

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

Table 4. Work Packages and Goals of Subtask III	
Subtask III: Lidar procedures for turbine assessment Coordinator: University of Stuttgart, Germany	
3.1 Exchange of experience in power performance testing using a ground-based Lidar acc. to 61400-12-1 ed. 2	
Goals	• Evaluating the practical experience with the new IEC 61400-12-2 Ed. 2 standard
3.2 Wind field reconstruction from nacelle based lidar measurements	
Goals	• Define procedures to calulate the wind components u,v,w out of the line-of-sight wind speed vector by using assumptions or an estimator
3.3 Nacelle-based power performance testing	
Goals	Measure the wind field from the nacelle for on- and offshore power performance testing and validation
3.4 Load estimation using a lidar system	
Goals	Measure the wind field from the nacelle for load estimation

13 Task 33

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

Source: Paavo Blåfield

1.0 Introduction

IEA Wind Task 33 addresses the different developments of data collection and failure statistics in the wind energy sector to agree on standards and overall structures. 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.

The purpose is to bring together people in the industry and research community to create synergies and agreements in the many ongoing R&D activities in the field of statistical failure and O&M analysis. Table 1 lists countries and organizations active in Task 33.

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 an IEA Wind Recommended Practices for collecting and reporting reliability data
- Identify research, development, and standardization needs for collecting and reporting reliability data.

1.1 Background

High reliability of wind plants translates to a high degree of operating and personal safety, high system availability, and lower maintenance needs. Therefore, achieving high reliability is one of the overriding aims of development work in wind energy technology. Modern land-based wind turbines attain high technical availability of up to 98%. Evaluation of maintenance work in previous projects shows, however, that achieving this high wind turbine availability requires additional maintenance work.

Experiences of some lower availabilities on land and the commissioning of several offshore wind farms has stimulated the demand for improved reliability and maintenance strategies. Figure 1 illustrates that while offshore farms can achieve availabilities equal to the average on land, many have fallen behind that objective. The restricted accessibility and tough offshore environmental factors mean that reliability, maintenance, and service management strategies used on land may need to be adapted for offshore wind plants.

There is a considerable scope for optimizing maintenance procedures and improving reliability. Maintenance of wind turbines is currently being planned and carried out according to statutory requirements and

Table 1. Countries and Organizations Participating in Task 33 During 2012

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

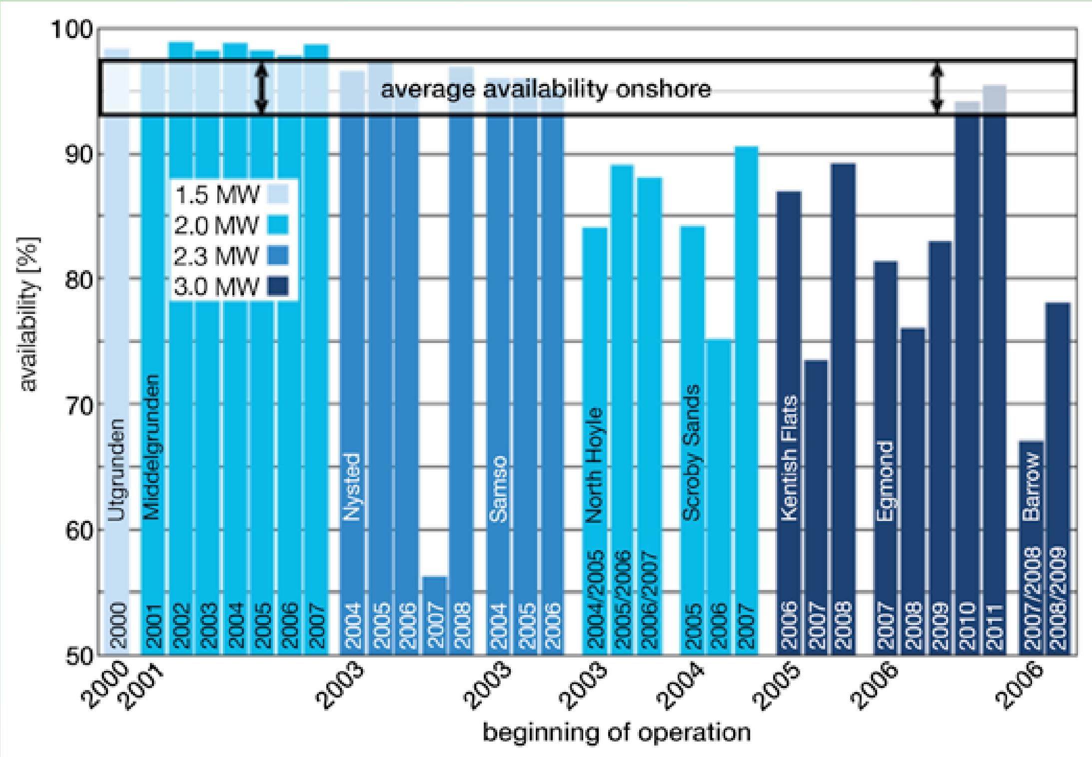

Figure 1. Offshore wind turbine availability (North and Baltic Sea) over time compared to average availability onshore (Germany) (1)

rough guidelines from the original equipment manufacturers. Unplanned maintenance measures due to sudden malfunction of components can cause serious economic losses especially offshore. O&M organization should be shifted from response to crisis to more preventive measures.

Defining preventive maintenance strategies requires statistical analyses of O&M data of turbines and their components to identify weak points and to define maintenance services at an early stage. Effective analysis must consider experience represented by data from many locations. Collecting useful data is possible only through semi-automated and highly simplified data management. Also, for effective analysis more parameters, data, and information are needed than are being collected today. A higher level of detail demands electronically supported reporting by service teams.

Gathering more, and especially more detailed, data while reducing overall maintenance effort is the long-term goal of Task 33. Necessary steps have to be introduced for O&M of wind turbines to bring together available knowledge and to use experience for improvements. At this point, information coming from databases, statistical methods, as well as expertise is essential.

2.0 Objectives and Strategy

IEA Task 33 is dealing with standardized, well-structured databases for optimizing reliability and maintenance procedures for wind plants. The aim is to address the different developments of data collection and failure statistic to agree on standards and overall structures. To accomplish this, the effort will bring together experienced personnel in the wind industry and research community to benefit from the many R&D activities on-going in the field of statistical failure analysis.

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

- Extensive national research projects dedicated to reliability analyses on wind turbine failures have been performed in Denmark, Finland, Germany, Netherlands, Sweden, the UK, and the United States. However, this effort will be the first consolidated multi-lateral and international exchange to take full advantage of these national projects.
- Improving the reliability and profitability of wind energy use, especially offshore, requires the optimization of wind turbine maintenance. For this, appropriate reliability data management and sophisticated decision-support tools are needed.
- National working groups have been launched to develop appropriate standards for O&M of wind power plants for wind energy on land. Joint activities on standardizing O&M measures, documentation, and data structure will multiply the effectiveness of these national activities.

Task 33 will apply the experience of reliability analyses and failure statistics from the wind industry and from other relevant industries to determine data collection and analysis based on defined structures and standards. Task 33 has three subtasks, which have been selected as the most relevant: I Experience, II Data Collection, and III Data Analysis. (Figure 2). Each subtask will generate a State-of-the-Art Report to present its results.

The task participants will establish recommended data collection techniques and procedures, database structures (e.g. database layout, component designation, and event description), and reliability analysis (e.g. mean time between failures (MTBF), mean time between repairs (MTBR), etc.), based on international standards. This work will involve the following activities and results.

- 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 the IEA and other organizations
- Start a broad dialogue on an international level between operators, manufacturers, service, component suppliers, designers, and researchers
- Simplify the monitoring process of wind turbines, to improve the financial and technical reporting and to cooperate with similarly oriented businesses

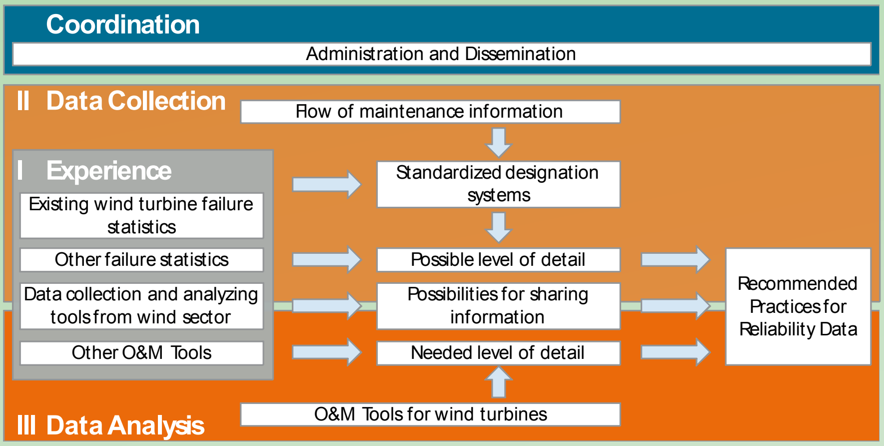

Figure 2. IEA Wind Task 33 scope and contents of the subtasks

- Provide a basis for sound conclusions based on 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 2012

IEA Wind Task 33 began work in October 2012. A kick-off meeting was held in Kassel, Germany in November 2012 (Figure 3) to begin the process of providing an international open platform for regular and continuous exchange of experience and progress from individual research activities and existing measurement projects on failure statistics on wind turbines. All Task 33 participants reviewed and agreed on the proposed work plan.

As the foundation for developing Recommended Practices for Reliability Data, three different State-of-the-Art Reports are planned. The first State-of-the-Art Report, "Initiatives Concerning Reliability," will summarize the numerous activities and initiatives in the wind energy sector as well as relevant experience from other sectors (See references 2–11). Work on this report began in late 2012 when a survey was prepared and distributed to all participants and countries.

The first State-of-the-Art Report will create an overview of the extensive national research/commercial projects dedicated to reliability data. It will describe those performed recently and those which are being developed in each participating country. The report will include a close-up view of existing failure databases worldwide, including their architectures, the standards used for gathering the data, and the method of data management. The report will consider the analyses possible with the aid of each one of the described databases.

4.0 Plans for 2013 and Beyond

The completion of the first State-of-the-Art Report has been set for the end of April 2013. A meeting will be held in Trondheim, Norway on 6–7 March 2013 to discuss the status of the work so far and what is needed to finish the first subtask. Further preparation will start concerning the second State-of-the-Art Report, "Flow of Maintenance Information," and according to the agreed schedule another meeting will be held.

Some countries or organizations have expressed interest but have not yet definitely committed to participation in Task 33. In 2013, the final team will be assembled, and effort will be made to involve more knowledge and experience.

Figure 3. Task 33 kick-off meeting in Kassel, Germany, November 2012

As soon as possible, IEA Wind Task 33 will commission the setup of an Internet home page. This homepage shall provide public information as well as an internal forum for information interchange and discussion.

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(3) Offshore WMEP – Monitoring offshore wind energy use; funded by the German Federal Ministry for the Environment, Nature Conversation and Nuclear Safety; www.offshore-wmep.de

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(5) Continuous Reliability Enhancements for Wind Database and Analysis Program (CREW) at Sandia National Laboratories and funded by U.S. Department of Energy; energy.sandia.gov/crewbenchmark

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(9) Quality Investigation of the Wind Turbines Operation in Chinese Wind Farms; funded by National Energy Administration of PRC

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Authors: Paul Kühn, Berthold Hahn, and Philipp Lyding, Fraunhofer Institute for Wind Energy and Energy System Technology (IWES), Germany.

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

Source: Lance McNew

1.0 Introduction

The vision of IEA Wind Task 34 is to form the leading international forum to exchange and disseminate up-to-date, robust knowledge on peer-reviewed scientific research and methods for assessing and monitoring the environmental effects of wind energy development. This collaborative will focus on wildlife and their habitats as they relate to wind project development, both on land and offshore.

As wind development expands, concern for impacts to wildlife and habitats must be addressed. The availability of scientifically sound environmental practices and data will help wind farm development interests avoid problematic project siting decisions or project choices and can reduce development costs and the risk of failure in the permitting process. The risk of restrictions on wind farm operations or decommissioning due to adverse impacts on protected species or habitats would also be reduced.

The development of good environmental data and practices will enable responsible development of wind energy projects worldwide and ultimately reduce overall project costs, by mitigating risk. This can be accomplished by sharing tested and proven monitoring methods for wildlife, habitat, and ecosystem processes and by sharing lessons from related studies. The large number of studies conducted in countries with significant wind development can contribute to developing internationally recognized best practices for assessment and proven methodologies to assess cumulative impacts on specific species. International collaboration becomes more important with the expansion of offshore wind deployment, where monitoring procedures and identification of species of greatest concern are in the early stages of development.

2.0 Objectives and Strategy

The following points about the impact of wind development on wildlife, habitat, and ecosystem processes frame the need for international collaboration in IEA Wind Task 34.

Wind turbine deployment has measurable environmental impacts, and these impacts (or effects) differ by technology, the number and density of turbines, location, habitats, and species. The risk of unanticipated adverse impacts may increase with expanded wind deployment, particularly where there is a data deficit. Limited data on the populations of avian and bat species, marine mammals, and sea turtles make it hard to determine cumulative impacts of wind deployment. Mitigation strategies for wildlife mortality are evolving rapidly for land-based wind but require wide-scale testing and validation. Useful knowledge may be gained by considering data collection and methodologies from studies of avian, bat, and marine mammal species on different continents. Due to the close ties of environmental impact and social acceptance, Task 34 work will collaborate with IEA Wind Task 28 Social Acceptance of Wind Energy Projects.

Comprehensive monitoring procedures (before and after construction) have been employed at both land based and offshore projects, however the utilization of these approaches is not universal. While there is a history of land based and offshore wind deployment amongst a large number of countries, the history varies, while other countries are in the early stages of wind deployment (either land based and or offshore). Additionally, the environmental effects of offshore wind development are less well understood than those for land-based wind due to a shorter history and fewer offshore turbines deployed. Fewer monitoring approaches and mitigation strategies have been developed for offshore applications than for wind on land. Collaboration with the IEA Ocean Energy Systems Annex 4: Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal and Current Energy Systems may provide some insight to the species and or habitat issue in the water that may need to be addressed in offshore development.

2.1 Objectives

To address the state of environmental assessment and monitoring for wind energy development, the following objectives will be addressed by Task 34.

Table 1. Potential Countries and Organzations Participating in Task 34

	Country	Institution(s)
1	Germany	Berlin Institute of Technology
2	Norway	Research Council of Norway; Norwegian Institute for Nature Research; Statkraft; Norwegian Water Resource and Energy Directorate
3	Sweden	Swedish Energy Agency; Arwen konsult
4	Switzerland	Federal Office of Energy
5	United States	Department of Energy; National Renewable Energy Laboratory; Pacific Northwest National Laboratory

- Expand knowledge of environmental effects, mitigation and monitoring methods, and research being conducted to assess risk that is occurring around the world;
- Increase accessibility of information on assessment methodologies, cumulative impact studies, and impact mitigation strategies;
- Develop an internationally accepted framework for pre- and post-construction assessments (including assessment during the operational phase);
- Collaborate to develop and test mitigation strategies;
- Assess and develop methodologies for cumulative impact assessments, especially for species for which there is limited understanding of population effects or effects on their habitats;
- Assess and develop methodologies for impact assessments and data collection for avian and bat mortality, including new technology-based assessment options;
- Develop an understanding of the effects of offshore wind on marine animals.

2.2 Strategy

The Task will draw upon current efforts within member countries related to the development of procedures and specific assessment of the environmental impacts of wind technology deployment in both offshore and land-based applications. An initial kick-off meeting will be held to draft a detailed workplan to address the specific issues under the Task. Participants will contribute to the task based on their national program activities related to the task objectives. A detailed work plan, identification of specific deliverables, and a timeline will be completed by a coordinating body following the physical meeting of the participants in 2013.

Because some countries are more interested in land-based deployment than in offshore issues, meetings and work packages will be structured to cover offshore assessments, general cumulative study issues, and land-based specific topics at different times.

2.3 Expected results

Task 34 is expected to publish the following documents and outreach activities based on the international collaboration through 2016.

- State-of-the-Science Report on accepted methodologies for environmental assessments with a focus on land-based, offshore, and, potentially, distributed wind topic areas
- Research compendium of publically available data and studies - which could include geospatial metadata on species or other important aspects
- Guideline documents on research methodologies and/or mitigation strategies
- Webinars and direct outreach to the wind development community, environmental community, and government regulation organizations explaining the results of the task
- Publicly available, online accessible, information on the effects of wind development on wildlife and their habitats.

3.0 Progress in 2012

This task was first presented at ExCo 70, in September 2012 with the National Renewable Energy Laboratory of the United States as Operating Agent. It was approved in principle by the ExCo with the United States and Germany as the initial participants. Potential participants developed a revised proposal that was approved early in 2013 at ExCo 71.

4.0 Plans for 2013 and beyond

Virtual and in-person meetings are planned to confirm formal membership and to identify leads for each Work Package. Germany and the United States have a particular interest in offshore wind collaboration, but are also interested in the environmental impacts of land-based projects. The full participant list will be completed at or before the in-person kick off meeting. Work efforts will begin and a website for the public and for participants will be active in 2013.

References:

Opening photo: Greater Prairie Chickens and wind facility in background, Kansas, United States

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

2012 IEA Wind Country Reports

15 Australia

Source: Infigen Capitol

1.0 Overview

Wind energy continues to increase its stake in Australia's clean energy mix following another year of growth in 2012. Wind energy now makes a significant contribution to Australia's energy mix, supplying over 7,700 GWh annually. This equates to around 3.4% of the nation's overall electricity needs and the equivalent of more than one million average Australian households.

Australia's 20% by 2020 Renewable Energy Target (RET) continues to provide the greatest incentive for the development of wind energy in Australia and has driven installed wind capacity from approximately 71 MW in 2001 to 2,584 MW as at the end of 2012. The RET is now complemented by Australia's carbon price mechanism, which commenced on 1 July 2012 with the aim of reducing emissions in the stationary energy sector.

At the close of 2012, Australia had 62 wind farms with a total production capacity of 2,584 MW. Five new projects were commissioned in 2012, adding 358 MW of capacity to the Australian electricity grid. Eleven projects are currently under construction at the end of 2012. These projects will contribute 638 MW of capacity in 2013, and approximately 1,000 MW in the following two years. A further 18,000 MW of projects are currently proposed for Australia and are either in the evaluation phase or going through the development approval process.

2.0 National Objectives and Progress

2.1 National targets

The Australian government's Renewable Energy Target (RET) scheme aims to bridge the gap between the cost of generating renewable energy and the cost of generating electricity from traditional fossil fuel sources. The RET is designed to deliver 20% of Australia's electricity supply from renewable sources by 2020, or more than 45,000 GWh of renewable energy.

Because wind power is one of the lowest cost large-scale technologies, it has been the dominant form of renewable generation to receive support under the RET. Wind energy has accounted for approximately 38% of all renewable capacity installed since 2000, and has attracted over 5 billion AUD (3.9 billion EUR; 5.2 billion USD) in investment since 2001 (1). It is expected that new investment in wind energy will be largely driven by the RET until 2020, after which the carbon pricing scheme will likely act as the major incentive for investment.

The RET which began operating in its current form in 2010, was the subject of a comprehensive review in 2012. The independent Climate Change Authority resisted calls from some parties to reduce the scheme's target in order to save on the costs of moving away from fossil-fuelled energy generation. The Australian government is currently considering the recommendations of the review, but has indicated it is likely to leave the target in its current form.

2.2 Progress

The cumulative installed wind capacity in Australia has increased markedly since 2000 (Figure 1). The amount of installed capacity of wind power has doubled in the past five years.

At the close of 2012, there were 62 wind farms (with two or more turbines) in Australia, with a total of 1,397 operating turbines. The estimated annual wind generation output in Australia from the 2,584 MW of installed wind power capacity was 7,700 GWh or 3.4% of national electrical demand.

Five new projects were commissioned in 2012 (Table 2) adding 358 MW of new wind capacity to the Australian electricity grid. This is an increase of 50% on the 234 MW of new wind projects commissioned in 2011.

An additional eleven projects (Table 3) with a total of 1,627 MW are under construction and expected to be fully commissioned within the next three years.

At the close of 2012, Australia had 62 wind farms with a total production capacity of 2,584 MW.

Table 1. Key National Statistics 2012: Australia	
Total installed wind capacity	2,584 MW
New wind capacity installed	358 MW
Total electrical output from wind	***7.7*** TWh
Wind generation as % of national electricity demand	3.4%
Average capacity factor	***35%***
Target:	The enhanced Renewable Energy Target will deliver 45,000 GWh (approximately 20% of demand) from renewables by 2020
Bold italic indicates estimates.	

2.3 National incentive programs

The main incentive program for wind farms is the national renewable energy target of 20% renewable energy by 2020, as discussed above. In addition to this, the South Australian state government has set a renewable energy target of 33% by 2020 which provides an additional incentive for investment in the state.

Some states and territories (including the Australian Capital Territory, New South Wales, Western Australia and Victoria) have a feed-in tariff or buyback scheme that includes micro-wind as an eligible technology for some level of payment or credit towards electricity bills.

South Australia has a payroll tax rebate that allows developers of renewable energy projects with capacities greater than 30 MW to receive a rebate for payroll tax incurred during project construction. Payroll tax in South Australia is currently 4.95% of wages and the rebate is capped at 1 million AUD (788,000 EUR; 1.04 million USD) for wind farms. The scheme commenced in July 2010 and is valid for a period of four years.

Australia's new carbon price mechanism, designed to reduce emissions from the stationary energy sector, commenced operating on 1 July 2012. The mechanism involves a fixed carbon price of 23 AUD (18.12 EUR; 23.89 USD) per ton of carbon dioxide equivalent emissions for three years, after which there will be a transition to an emissions trading scheme from July 2015. Half of the income raised is being spent on assisting households to adjust to the impacts of the carbon price and the rest of the funds will be used to accelerate the deployment of clean energy sources.

2.4 Issues affecting growth

Wind energy is the fastest growing large scale renewable energy source for electricity generation in Australia and several projects are currently proposed or under development across Australia. The size of projects is also increasing with some very large projects of up to 1,000 MW proposed.

In the past few years, policy uncertainty around the introduction of the carbon price mechanism, amendments to planning regulations and low Renewable Energy Certificate (REC) prices, coupled with global financial uncertainty has made it challenging for many developers to secure financing for new projects and the RET review only added to this uncertainty.

In 2011 and 2012 a number of changes were made to planning laws in different states. Victoria adopted a policy that gives residents living within 2km of a proposed wind farm the right to veto the development and the New South Wales Government released draft planning guidelines requiring additional consultation and development activities for residents living within 2km of a proposed wind farm.

The New South Wales government is yet to finalize these guidelines but is expected to finalize them in 2013. Changes in planning

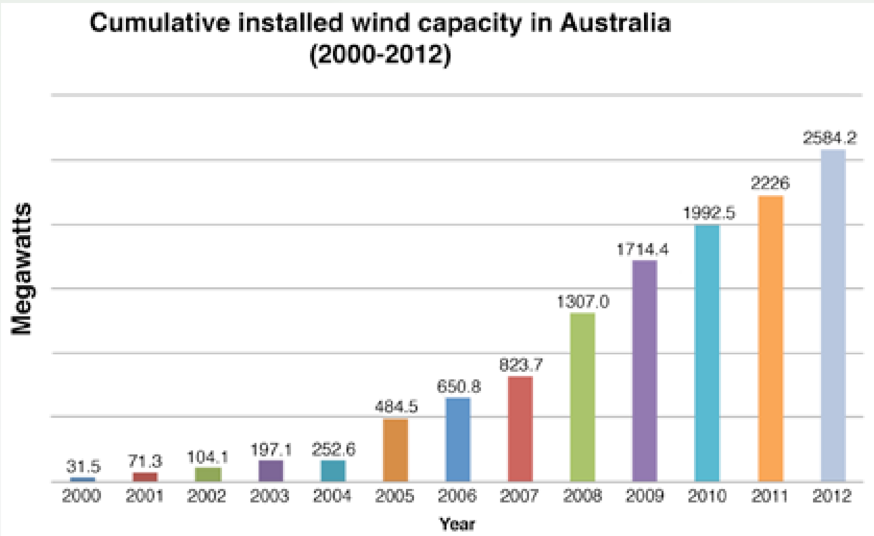


Figure 1. Cumulative installed wind capacity 2000–2012

Table 2. New wind farms 2012

Owner	Location	State	Installed Capacity
UBS IIF/ REST	Collgar	Western Australia	205.4 MW
AGL	Oaklands Hill	Victoria	67.2 MW
AGL	Hallett 5 (Bluff Wind Farm)	South Australia	52.5 MW
Goldwind Australia	Morton's Lane	Victoria	19.5 MW
Verve Energy	Albany 2 (Grasmere)	Western Australia	13.8 MW

Table 3. Wind farms under construction

Owner	Location/Name	State	Expected Commission Year	Installed Capacity
AGL / Meridian Energy	Macarthur	Victoria	2013	420.0 MW
TrustPower Ltd	Snowtown 2	South Australia	2014	270.0 MW
Acciona Energy	Mt Gellibrand	Victoria	2015	189.0 MW
Hydro Tasmania	Musselroe	Tasmania	2013	168.0 MW
Goldwind Australia	Gullen Range	New South Wales	2014	165.5 MW
Union Fenosa	Ryan Corner	Victoria	2014	134.0 MW
Union Fenosa	Crookwell 2	New South Wales	2014	92.0 MW
Union Fenosa	Hawkesdale	Victoria	2014	62.0 MW
Verve Energy & Macquarie Capital	Mumbida	Western Australia	2013	55.0 MW
Wind Farm Developments	Woolsthorpe	Victoria	2013	40.0 MW
NewEn	Salt Creek	Victoria	2015	31.5 MW

laws such as these have caused some wind farm developers to reassess their planned projects in the affected areas.

South Australia finalized a statewide development plan in late 2012 which provides increased certainty for both the wind industry and communities. Its key policy is to ensure wind farms are an 'envisaged' form of infrastructure development in certain rural council areas, so that they cannot be opposed purely on visual grounds.

3.0 Implementation

3.1 Economic impact

The Australian wind power sector continues to make a significant contribution to Australia's economy, particularly in regional areas. Bloomberg New Energy Finance estimated that there was 935.3 million AUD (737 million EUR; 972 million USD) of new financial investment in Australian wind power in the 2012 calendar year.

There are wind projects spread across most states in Australia, (Figure 2) with the exception of the sparsely populated Northern Territory, and just one small wind farm in Queensland. South Australia remains the state with the highest wind power capacity, accounting for 47% of the total national capacity. South Australia produces more than 20% of its electricity from wind power.

Wind farm project development generates employment nationally and within the local regional area. Over 1,800 people are employed in the wind sector directly and this figure is expected to grow as more wind farms are implemented. In addition to the direct employment generated by the construction of wind farms, there are flow-on effects to the wider economy in relation to local retail and services in the locality of the wind farm. Another 5,400 people are estimated to be employed in these indirect services.

A study on the economic benefits of wind farms in Australia (2) found that the construction of a 50-MW wind farm could contribute between 0.1% to 2.6% to gross regional product; employ between five and six full-time equivalent staff for operations and maintenance with a potential on-going expenditure of 125,000-150,000 AUD (98,500-118,200 EUR; 129,875-155,850 USD) per annum; and provide up to 250,000 AUD (197,000 EUR, 259,750 USD) in payments to farmers and an ongoing community contribution up to 80,000 AUD (63,040 EUR; 83,120 USD) per annum for the life of the project.

3.2 Industry status

There are a wide variety of developers participating in the Australian market including large energy utility companies, investment banks, superannuation funds and specialist wind development companies. Firms include Acciona Energy, AGL, EnergyAustralia, Hydro Tasmania, Infigen Energy, Pacific Hydro Goldwind, RATCH Australia Corporation and Verve Energy. In addition, companies such as Epuron, Union Fenosa Wind Farm Developments, and Wind Prospect all also have proposals in the pipeline.

Australia also has a small number of privately and community owned wind farm projects currently operating and under development. These projects are small and examples include the recently commissioned Hepburn Community Wind Farm in Victoria and the Mt Barker Wind Farm in Western Australia.

The majority of wind turbine towers are locally manufactured, however all nacelles and blades are manufactured internationally and imported. A number of new turbine suppliers have entered the Australian market recently, but the market remains dominated by two main suppliers—Vestas and REpower. REpower merged with Suzlon's Australian operation in 2011 (Figure 3).

3.3 Operational details

The size of Australian projects also continues to increase. Australia's largest wind farm, Collgar, was commissioned during 2012 and has a capacity of 205.4 MW. The project, located in Western Australia, is owned jointly by Investment Bank UBS International Infrastructure Fund (UBS IIF) and the Retail

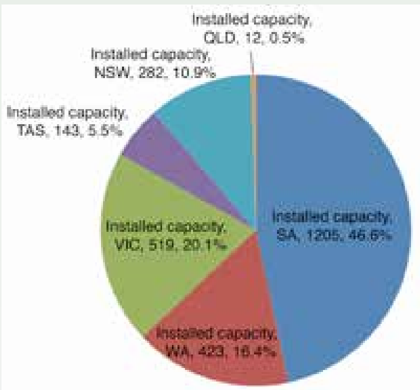


Figure 2. Installed wind capacity in Australia by state

Table 4. Australian wind energy industry 2012—environmental benefits	
Installed megawatts	2,584
Number of wind turbines	1,397
Average number of Australian households powered by wind energy	1,088,000
Number of wind energy projects (two or more turbines)	62
Annual greenhouse gas emissions displaced (tons CO_2/yr)	7,700,000
Equivalent number of cars taken off the road/yr	1,717,000
Note: All figures are estimates only, based on current available information obtained by the Clean Energy Council.	

Table 5. Indicative development costs for Australian wind farms

Cost Item	Million AUD	Million EUR	Million USD	Contribution to capital costs
Turbine works	1.10–2.00	0.86–1.57	1.14–2.07	60–75%
Civil and electrical work up to the point of connection	0.35–0.60	0.28–0.22	0.36–0.62	10–25%
Grid Connection	0.05–0.35	0.04–0.27	0.05–0.36	5–15%
Development and consultancy work, wind speed monitoring	0.15–0.42	0.12–0.33	0.15–0.43	5–15%
Total	1.7–3.4	1.3–2.6	1.7–3.5	100%
Source: Review of the Australian Wind Industry for the Clean Energy Council, Garrad Hassan, 2011				

Employees Superannuation Trust (REST). AGL and Meridian Energy's Macarthur Wind Farm in Victoria is likely to be commissioned in 2013, and at 420 MW, is double the size of Collgar wind farm.

There are also proposals under evaluation for larger wind farms such as AGL's 900 MW wind farm at Silverton and Epuron's proposal for a 1,100-MW wind farm at Liverpool Range, both of which are in New South Wales.

Currently there are 10,000 MW of wind farms under development which includes wind farms that have received all approvals or are in the process of seeking planning and environmental approvals (Table 5). Another 8,700 MW of projects are undergoing feasibility studies. All of the proposed projects are onshore wind farms.

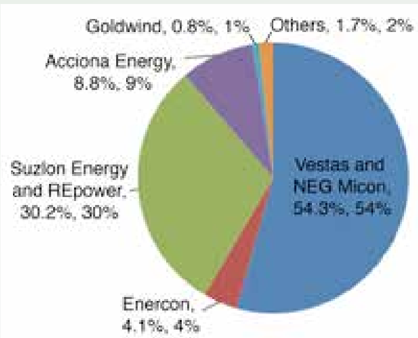


Figure 3. Installed wind capacity in Australia by turbine supplier

Source: CEC Renewable Energy Database and Review of the Australian Wind Industry for the Clean Energy Council, Garrad Hassan.

3.4 Wind energy costs

The contribution of capital costs to total wind farm production costs can vary significantly from site to site. Table 5 shows a typical breakdown of the major development costs associated with wind farm projects.

4.0 R, D&D Activities

Two new programs were established in 2012, the Clean Energy Finance Corporation (CEFC) and the Australian Renewable Energy Agency (ARENA). The 10 billion AUD (7.88 billion EUR; 1.039 billion USD) CEFC will operate independently of government to provide loans for promising clean energy initiatives and to help unlock sources of private sector capital. It is aimed particularly at assisting pre-commercial clean energy technologies meaning that wind energy projects are less likely to attract funding. ARENA will provide 3.2 billion AUD (2.5 billion EUR; 3.3 billion USD) of financial assistance to promote research and development, demonstration, commercialization and deployment of renewable energy projects.

5.0 The Next Term

While the wind industry was quieter in the first half of 2012 due to investor uncertainty surrounding the RET, carbon price and other policy developments, the market gained momentum in the second half of 2012. There were several new power purchase agreements finalized, projects reaching financial close and several commencing construction. Wind energy is still the fastest growing large-scale renewable energy source for electricity generation in Australia, and Bloomberg New Energy Finance predicts another two GW of wind capacity will be built by 2015.

In this past year, the Australian wind industry has been working extensively to ensure communities are engaged and informed about the economic benefits wind projects can bring to the community. In 2012, the Clean Energy Council published Community Engagement Guidelines for the Australian Wind Industry, which is a best practice approach to community engagement and is finalizing *Wind Industry Best Practice Technical Guidelines* for the implementation of wind energy projects in Australia.

References:

Opening Photo: Courtesy of Infigen Capital Wind Farm, New South Wales

(1) SKM (2012) Benefits of the Renewable Energy Target to Australia's Energy Markets and Economy, http://www.cleanenergy-council.org.au/policyadvocacy/Renewable-Energy-Target.html

(2) See <http://www.abc.net.au/news/2012-02-17/wind-farm-rules-may-lead-to-higher-power-prices/3835458>

Author: Felicity Sands, Clean Energy Council, Australia.

16 Austria

Source: Micheal Rothauer

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. Due to the new Green Electricity Act (GEA 2012) (Ökostromgesetz 2012), annual wind power installations in Austria increased to 296 MW in 2012. This represents an annual growth rate of 27% compared to the previous year.

By the end of 2012, nearly 1,400 MW of wind power was operating in Austria. An additional 420 MW of wind power will be constructed in Austria in 2013. Burgenland, the easternmost of Austria's nine federal states, will generate enough electricity from wind power to cover more than the overall annual energy usage in 2013.

2.0 National Objectives and Progress

The GEA 2012 launched a significant expansion in wind power installations and the reduction of a massive project backlog in 2012. 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. The tariff is applicable only for the year 2012, bringing some uncertainty for investors. The purchase obligation is limited to a specific amount of capacity (depending on the available funds for new projects). The FIT for 2012 was fixed at 0.095 EUR/kWh (0.125 USD/kWh), for 2013 it is fixed at 0.0945 EUR/kWh (0.1245 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). But GEA 2012 establishes a new long-term target of adding 2,000 MW 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. In this National Renewable Energy Action Plan (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 estimates 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 2012, 1,378 MW of wind capacity were installed in Austria, counting for an annual production of around 2.9 TWh of electricity production. This is equivalent to more than 5% of the Austrian electricity demand (end energy consumption of households). This way wind electricity avoids 1.8 million tons of CO_2 emissions every year. With the estimated increase in installations of about 419 MW in 2013 the annual production of all Austrian wind turbines counts for an equivalent of more than 6.2% of the Austrian electricity demand and avoids approximately 2.4 million tons of CO_2.

Most wind turbines (679.1 MW) are in Lower Austria, followed by Burgenland (612 MW), Styria (52.7 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 (Ökostromgesetz), adopted in 2002, triggered investments in wind energy in 2003–2006 (Figure 2). Then, an amendment in 2006 brought uncertainty to green electricity producers and new restrictions for projects. This led to nearly four years of stagnation of the wind power market in Austria. A small amendment to the GEA in 2009 and a new FIT set in 2010 (0.097 EUR/kWh; 0.126 USD/kWh) improved the situation. However, there was still one major problem: there were not enough support funds for new projects, so many projects that had obtained all planning permits had applied for a contract (granting the FIT) at Ökoabwicklungsstelle OeMAG, but could not get a contract and had to wait in their queue position.

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. Furthermore all

By the end of 2012, nearly 1,400 MW of wind power was operating in Austria. An additional 420 MW of wind power will be constructed in 2013.

Table 1. Key National Statistics 2012: Austria	
Total installed wind capacity	1,378 MW
New wind capacity installed	296 MW
Total electrical output from wind	2.5 TWh
Wind generation as % of national electric demand	5%
Average capacity factor	30%
Target:	N/A

wind power projects that were queuing for a contract at OeMAG got the possibility to get contracts immediately (those with a queue position in the years 2012 and 2013 got the original FIT of 0.097 EUR/kWh (0.0126 USD/kWh); those with a queue position in 2014 and 2015 got a FIT of 0.095 EUR/kWh (0.123 USD/kWh).

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 Ökostromabwicklungsstelle is the institution that is in charge of buying green electricity at the FIT and selling it to the electricity traders. The Ökostromabwicklungsstelle OeMAG has to give contracts to green electricity producers as long as there are enough funds for new projects (that is 50 million EUR/yr; 66 million USD/yr for new projects—enough for approximately 120 MW–350 MW of new wind capacity per year depending on the market price for electricity and the applications from PV and small hydro power plants). Applicants have to submit all legal permissions in order to be able 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.

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 1,306.8 MW supported by a FIT under the Green Electricity Regulation, producing more than 2.39 TWh/yr. The FIT for 2012 was fixed at 0.095 EUR/kWh (0.125 USD/kWh), for 2013 it is fixed at 0.0945 EUR/kWh (0.1245 USD/kWh). This tariff is valid for all turbines with valid approval by the authorities.

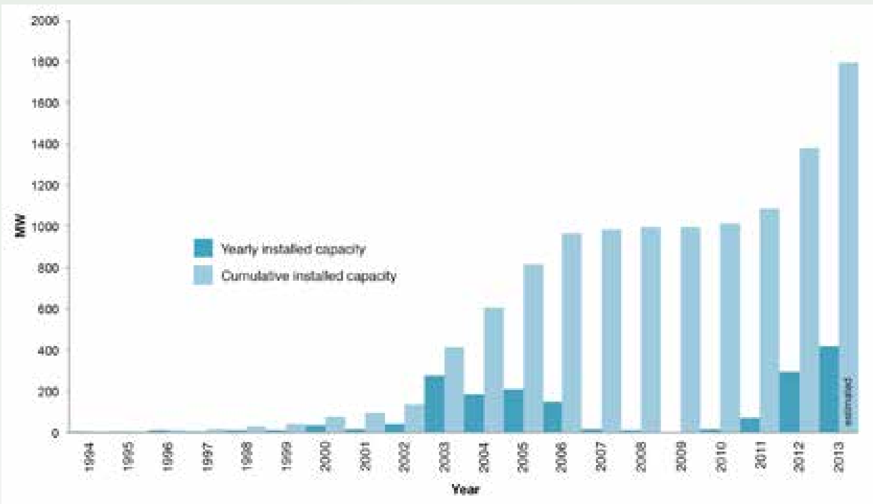


Figure 1. Cumulative wind power installation in Austria 1997–2013

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 2012, the determining factor for wind power growth will be the amount of the FIT. The FIT will be fixed year by year, but for technologies like wind power can also be fixed for a longer period.

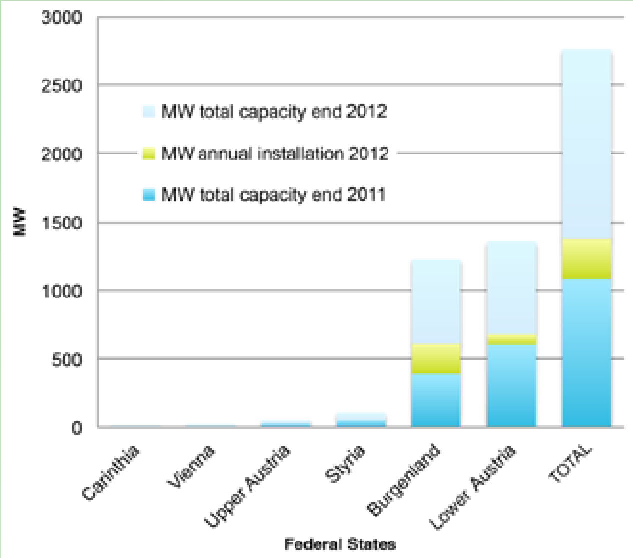


Figure 2. Wind power capacity of the federal states

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 to international wind turbine manufacturers on the other hand. In 2010 the annual turnover of operators of existing wind parks was over 150 million EUR (197.7 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. One third of the Austrian supplier industry obtains an export volume of more than 500 million EUR (659 million USD). This strongly increasing tendency reflects in growth rates between 20–25%.

3.2 Industry status

Cooperatives own 40% 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. Today the most active operators planning new wind projects are cooperatives and traditional electricity utilities. The Austrian operators are very active in the neighboring countries of central and eastern Europe, and some independent companies have also started businesses outside Europe.

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, 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 expanded its production of generators in 2009 and established a joint venture with Suzlon in India. Wind energy also gives highly specialized small and medium enterprises the possibility to enter a new, growing market. Especially in the Austrian market such companies count for a growing share of revenues generated from wind energy. For customers these firms develop customized wind turbine concepts and work advisors for technology transfer.

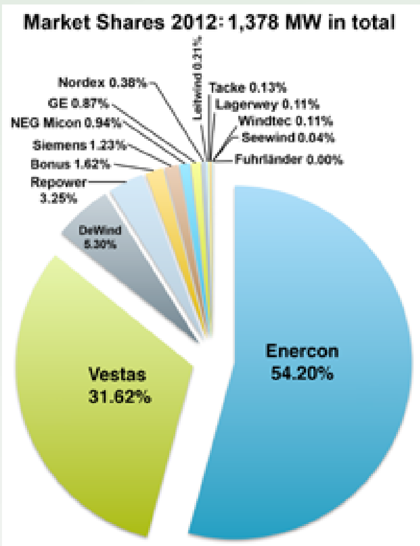


Figure 3. Market shares of suppliers in Austria

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–2.3 MW in capacity, but since 2012 more than 60% 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. With an annual yield of 15 million kWh, each turbine covers the energy requirements of around 4,000 private households since the beginning of 2012.

3.4 Wind energy costs

Table 2 shows estimated costs for wind energy project elements (Price basis 2012).

4.0 R, D&D Activities

4.1 National R, D&D efforts

Due to the importance of better knowledge as to the risk of ice fall from wind turbines, the Austrian Climate and Energy Fund supports a research project on that issue. The project has a duration of two and a half years and aims at a model to estimate the risk zones in the close vicinity of wind turbines, taking into consideration site specific parameters.

National research funds have also been allocated to investigate the usability and economics of small wind turbines to accommodate growing demand in this field. Five Small Wind Power projects are funded by the Austrian Research and Development Program "Neue Energien 2020" of the Austrian Climate and Energy Fund. Four of these were finalized in 2012. The fifth project called 'Kleinwindkraft' started at the beginning of 2011 and focuses on the following challenges: uncertainty about the quality and about the energy harvest, open questions about power quality and applicable inverters, as well as uncertainties about the legal framework and gaining permissions. The objective of this project is to resolve technical, legal, and organizational questions. From the results of the analyses, specific information packages will be prepared targeting all groups of stakeholders involved in the process of

Table 2. Cost of new wind energy projects		
Total investment costs	1,675 EUR/kW	2,207 USD/kW
Turbine costs	1,375 EUR/kW	1,812 USD/kW
Incidental costs (planning, logistics, connection to grid and grid reinforcement, etc.)	300 EUR/kW	395 USD/kW
O&M costs years 1–4	0.009 EUR/kWh	0.0119 USD/kWh
O&M costs years 5–15	0.021 EUR/kWh	0.0277 USD/kWh
O&M costs years 16–20	0.028 EUR/kWh	0.0369 USD/kWh

planning, permitting, constructing, grid-connecting, and operating small wind power stations.

In 2011, another two projects were launched and funded by the Climate and Energy Fund. The project "Holzwind" is designed to demonstrate wood as a sustainable material for the construction of wind turbines. The second project aims to improve productivity by managing icing of blades.

In total, the Climate and Energy Fund supported wind energy projects with a funding amount of 2.8 million EUR (3.69 million USD) since 2007.

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 its long experience with projects in the Austrian Alps. The research activities will continue until the end of 2015 and focus on the following three research aspects:

- Evaluation and comparison of the licensing process and the legislative requirements in each partner country in terms of the assessment concerning the risk of down-falling ice chunks from wind turbines
- Evaluation of the operational performance of a stand-alone power supply unit for an intelligent, demand-oriented energy supply of heated wind measurement sensors
- Evaluation of operational data of a wind farm in Sweden in terms of performance and vulnerability of a Siemens rotor blade heating system

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 has ten partners from six European countries and a budget of 9.6 million EUR (12.9 million USD). SEEWIND will install one pilot wind turbine each in Bosnia Croatia, Herzegovina, and Serbia. The project began in May 2007 and will last six 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 is a solid basis for the further development of wind power in Austria. Crucial for the growth of wind power capacity will be the amount of the FITs in the coming years and measures taken for grid reinforcement and enlargement in the eastern part of Austria.

Reference:

Opening Photo: Global Wind Day 2012, Austrian Photo Competition Winner, Michael Rothauer

Authors: Irmgard Poisel and Florian Maringer, Austrian Wind Energy Association, Austria; Andreas Krenn, Energiewerkstatt, Austria.

17 Canada

1.0 Overview

Canada is the ninth largest producer of wind energy in the world. It has more than 6 GW of wind energy capacity, which produces enough power to meet about 2.8% of the country's total electricity demand. Canada has more than 170 wind farms, spread across ten provinces and two territories.

In 2012, Canada placed ninth globally, in terms of new wind energy capacity installed. Nearly 940 MW of new wind capacity were installed in six provinces and one territory. The province of Quebec led the way, with 430 MW of new installations. The world's most northern large-scale wind-diesel hybrid power facility was commissioned in Canada's Northwest Territories.

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 or will undergo reviews and changes. Ontario, for example, completed a scheduled two-year review of its Feed-in Tariff (FIT) program. A rate reduction in the price paid for wind generated electricity was one of several recommendations put forward, as a result of the review. In Nova Scotia, a review of the province's Community FIT (COMFIT) program is under way.

Community power was given a boost in 2012 with the approval of 46 community projects under Nova Scotia's COMFIT program. The projects range in size from 50 KW–6 MW, and are located in over 40 different communities across Nova Scotia. In Ontario, the M'Chigeeng First Nation Band celebrated the grand opening of its 4-MW Mother Earth Renewable Energy (MERE) wind farm in northern Ontario. MERE is Ontario's first wind farm owned entirely by a First Nation Band.

Canada's federal departments and research organizations are working together in R, D&D areas that are particularly relevant to Canada, including: reducing the cost per kWh of wind generated electricity, assessing cold climate effects on wind energy production, mitigating the environmental impacts of wind development, wind and ice forecasting, and addressing the issues of variable energy supplied to the electrical grid.

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% below 2005 levels by 2020. However, some provinces have set renewable production targets. Details on provincial targets can be found in Canada's chapter of the *IEA Wind 2011 Annual Report*.

2.2 Progress

Electricity supply in Canada is becoming cleaner. The electric system is transitioning to lower emission intensity, with the retirement of coal plants in Ontario and growth in renewable energy generation facilities. In fact, Ontario's wind energy facilities are playing an increasingly important role in meeting the province's demand for electricity. They supplied 4.6 TWh in 2012, which represented 3% of all the electricity generated in the province.

In British Columbia, the 144-MW Dokie wind farm (the second wind farm operating in the province), exceeded its projected annual forecasted production in its first year of operation. Under the province's last Clean Power Call, BC Hydro (the province's electric utility) awarded Power Purchase Agreements (PPAs) to six additional wind projects. The projects are under development.

In Alberta, the province's system operator—the Alberta Electric System Operator (AESO) —launched a six-month pilot project designed to test the ability of wind energy generators to be equivalent to other generators in terms of energy dispatch requirements and participation in the energy market. The "Wind Dispatch Pilot Project" began with two wind farms owned by TransAlta. After six months, AESO extended

Canada has more than 6 GW of wind capacity, which produces enough power to meet about 2.8% of the country's total electricity demand.

Table 1. Key National Statistics 2012: Canada

Total installed wind capacity	6,201 MW
New wind capacity installed	936 MW
Total electrical output from wind	16.3 TWh
Wind generation as % of national electric demand	2.8%
Average capacity factor	31%
Target:	N/A

participation in the project to all other existing wind generating facilities. The project will continue and a new timeline will be set once new participants have been brought onboard.

Manitoba's largest wind farm—the St. Joseph Wind Project—reached its first full year of operation. The 138-MW wind power project, supplied the region with more than 500 MWh, and produced more than 1 million CAD (760,000 EUR; 1 million USD) in property tax revenue for the region.

In July 2012, the government of Québec announced its plan to procure 700 MW of wind energy capacity. A 450-MW block would be procured through a new request for proposal, and the remaining 250-MW block would be procured from Aboriginal communities through a dedicated purchase program. As in previous Requests for Proposals (RFPs), the Québec government intends to maximize regional and provincial economic benefits through domestic content requirements. The formal call for proposals is pending.

In August 2012, Nova Scotia selected three proposals for wind projects totaling 116 MW, completing the province's RFP for 300 GWh of renewable energy from Independent Power Producers (IPPs). The procurement process administered by the Renewable Electricity Administrator (REA) was kicked off in September of 2011. The REA received proposals for 19 projects in response to the RFP—about eight times the target. The winning proposals include two phases of the South Canoe Wind Project totaling 102 MW and the 13.8-MW Sable Wind Project led by the Municipality of the District of Guysborough.

The COMFIT program is part of Nova Scotia's 2010 Renewable Electricity Plan. COMFIT supports the development of local renewable energy projects by municipalities, First Nations, and other community and non-profit groups. Projects approved for COMFIT support will be connected to the grid at the distribution level, and they must fall within the capacity of the local distribution grid. COMFIT began accepting applications on 19 September 2011. Since then, a total of 120 COMFIT applications have been submitted to Nova Scotia's Department of Energy, and a total of 46 projects have now received COMFIT approval. The projects range from 50 kW–6 MW and are located in more than 40 communities.

2.3 National incentive programs

The government of Canada launched the 1.48 billion CAD (1.12 billion EUR; 1.48 billion USD) ecoENERGY for Renewable Power (ecoERP) program in 2007. Through this program, the government has committed close to 1.014 billion CAD (0.771 billion EUR; 1.017 billion USD) for 67 qualifying wind energy projects, representing 3,518 MW. These projects will receive funding of 0.01 CAD/kWh for ten years or until the end of the program (fiscal year 2020–2021). In addition, the federal government continues to provide an accelerated capital cost allowance for wind energy equipment through the Federal Income Tax Act. Start-up expenses may also qualify under the tax system as Canadian renewable and conservation expenses.

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 August 2011, the program received an injection of 20 million CAD (15.2 million EUR; 20 million USD) over the following five years to support pre-feasibility and feasibility studies of renewable energy projects as well as the design and construction of energy projects integrated within community buildings. In the fiscal year 2011–2012, the program provided 285,000 CAD (216,600 EUR; 285,855 USD) to three wind projects. Applications for funding for the next fiscal year (2012–2013) were accepted until 1 May 2012 and the selection process is underway.

Provinces across Canada continue to offer a range of incentives for renewable power, including wind. In Ontario for example, the Ministry of Energy announced that the province would add 150 million CAD (114 million EUR; 150 million USD) to its Aboriginal Loan Guarantee Program. The program provides loan guarantees of up to 75% of an Aboriginal community's investment in eligible renewable energy projects. The loan helps to reduce financial barriers and encourage Aboriginal participation.

The province of Ontario also completed a scheduled two-year review of its FIT program. A cut of about 15% to 0.115 CAD/kWh (0.087 EUR/kWh; 0.115 USD/kWh) from 0.135 CAD/kWh (0.102 EUR/kWh; 0.125 USD/kWh) in the price paid for wind generated electricity, was announced in March of 2012. The rate reduction was one of several recommendations put forward, as a result of the review. Other recommendations included new incentives for community and Aboriginal participation, changes to streamline the project approvals process, and a plan to examine the potential for continued procurement of non-hydro renewable energy generation beyond the current 10.7-GW target.

In Saskatchewan, the province's electric utility SaskPower did not hold its annual Green Options (GO) Partners Program lottery. The GO Partner Program was suspended in order to allow SaskPower to assess, evaluate, and potentially enhance the program for the future.

In Nova Scotia, a review of the province's COMFIT program was announced during the Canadian Clean Energy Conferences FIT Forum in September 2012. The review will include public consultation and discussions with those in the program and will examine applicant eligibility, geographical distribution, eligible technologies, quantity of energy being offered, community engagement and support, things learned from previous projects, and administration.

3.0 Implementation

3.1 Economic impact

Wind energy is generating affordable, clean electricity while creating new jobs and economic development opportunities in communities across Canada. According to the Canadian Wind Energy Association (CanWEA), every 1,000 MW of new wind energy drives 2.5 billion CAD (1.9 billion EUR; 2.5 billion USD) in investments, creates 10,500 person-years of employment, and provides enough clean power for over 300,000 Canadian homes. Nearly 940 MW of new wind energy capacity were added in 2012.

3.2 Industry status

CanWEA is the voice of Canada's wind energy industry and represents over 450 companies. The wind industry is present throughout Canada, with manufacturing facilities in provinces such as Ontario, Quebec, and Nova Scotia.

3.2.1 Ownership

In Canada, wind farms are typically owned by IPPs, utilities, or income funds (CanWEA maintains a list of wind farm owners/operators at www.canwea.ca). However, in recent years, the provinces of Nova Scotia, Ontario, and Quebec have introduced policies to encourage community ownership, including First Nation communities.

Ontario's revised FIT rules contain explicit provisions for cooperatives and First Nations who are developing renewable energy projects, with the goal of greater citizen support through community participation, ownership and profit-sharing. In response, community power cooperatives have come together under a new umbrella organization—the Federation of Community Power Cooperatives (FCPC). FCPC will facilitate renewable energy project development by setting standards and sharing experiences and resources. The Cooperative expects to support at least 100 MW of community-controlled projects by 2015.

On 15 June 2012, the M'Chigeeng First Nation Band celebrated the grand opening of its 4-MW Mother Earth Renewable Energy (MERE) wind farm on Manitoulin Island, in northern Ontario. The wind farm's two Enercon E82 2-MW turbines are located on M'Chigeeng First Nation Band lands. The MERE wind farm is expected to generate 300,000 CAD (228,000 EUR; 300,900 USD) a year net for the first 14 years while loans are being repaid and 1.2 million CAD (912,000 EUR; 1.2 million USD) a year for the remaining six years. MERE is Ontario's first wind farm owned entirely by a First Nation Band.

3.2.2 Manufacturing

Canada continues to attract wind power equipment manufacturers. The country's manufacturing capacity is primarily based in Ontario and Quebec. The past year has seen the province of Ontario open another new manufacturing facility and plan for the construction of two more.

In June 2012, Automodular Corporation celebrated the official opening of its new assembly facility in Brantford, Ontario. The facility will service Automodular's agreement with Vestas Nacelles (a subsidiary of the publicly-traded Danish company Vestas Wind Systems) to sub-assemble wind turbine components. The work undertaken at the facility helps Vestas to meet the Domestic Content Requirements under Ontario's FIT Program.

Shanghai Taisheng Wind Power Equipment Co. Ltd. (TSP) plans to open a wind tower manufacturing facility in Thorold, Ontario through a joint venture with British Columbia-based Top Renergy Inc. The facility will be TSP's first outside China. The first phase will be the manufacturing of wind towers for onshore wind farms. Approximately 150 people will be hired to work in the plant by 2013. The second phase will add offshore wind tower production. TSP is expected to begin manufacturing its first towers in January of 2013. The company has secured its first multimillion dollar order—a trial order for 58 wind towers to be exported to an undisclosed location.

German wind turbine manufacturer Enercon has plans to open a new Ontario manufacturing facility that will produce electrical parts for converters and control panels. The 38,000-square-foot factory will be located in the community of Beamsville in the province's Niagara region, and employ 50 people. Up to 60 different types of electrical components for Enercon's wind turbines and solar products will be manufactured in the facility—the first of its kind for Enercon outside of its home market of Germany.

3.2.3 Applications

In December 2012, NaiKun Wind Energy Group Inc. announced that it signed a preferred supplier Agreement with Siemens Canada Limited. Siemens and NaiKun Wind will work together to move forward on a proposed 396-MW project off the northwest coast of British Columbia. The NaiKun Wind project is at an advanced stage of development, and is in a position to begin construction within two years, pending a PPA with the province's utility.

On 28 September 2012, Diavik Diamond Mine's four 2.3-MW wind turbines began delivering power to the mine's grid. The mine is located on East Island in a sub-arctic lake called Lac de Gras, in the Northwest Territories. At 62° North, the 9.2-MW wind farm is the world's most northern large-scale wind-diesel hybrid power facility and first large-scale wind farm in Canada's Northwest Territories. Temperatures at the mine site drop as low as -40°C in the winter. All the turbine's blades have therefore been fitted with de-icing technology. The facility represents a new benchmark for the production of wind power in low temperatures. Rio Tinto, the mine's owner, invested 33 million CAD (25 million EUR; 33 million USD) in the wind farm and estimates that the mine's annual diesel fuel consumption will decrease by 10% and its carbon footprint will be reduced by 6%.

Table 2. Statistics for new wind farms commissioned in 2012	
Smallest wind farm	2.3 MW—Lingan Wind Facility, Nova Scotia
Largest wind farm	149.4 MW—Halkirk Wind Farm, Alberta
Wind farm locations (provinces/ territories)	Alberta, British Columbia, Manitoba, Nova Scotia, Ontario, Quebec, Northwest Territory
Turbine manufacturers	Enercon, GE, Suzlon, Siemens, RE Power, Vestas
Turbine sizes (range)	1.5–2.3 MW
Average turbine size	1.975 MW

3.3 Operational details

Eighteen wind farms were commissioned across six provinces and one territory in 2012.

4.0 R, D&D Activities

The focus of Canada's wind energy R&D activities is 1) the integration of wind energy technologies into the electrical grid and into remote community applications, and 2) the advancement and development of safe, reliable, and economic wind turbine technology.

Several departments of the federal government are active in wind energy R&D. Natural Resources Canada's (NRCan's) R&D priority areas include: reducing the cost per kilowatt-hour of wind generated electricity, and assessing cold climate effects on wind energy production. Environment Canada conducts research on the environmental impacts of wind development, including potential impacts on migratory birds and bats and other wildlife. The department also conducts research on wind and ice forecasting.

Health Canada is working with Statistics Canada and other external experts possessing expertise in areas including noise, health assessment, clinical medicine and epidemiology, to conduct a research study that will explore the relationship between wind turbine noise and the extent of health effects reported by, and objectively measured in, those living near wind power developments. The study aims to support the government of Canada and other stakeholders by strengthening the evidence base that supports decisions, advice and policies regarding wind turbine development proposals, installations and operations in Canada. For more information and updates on the study, go to (http://hc-sc.gc.ca/ewh-semt/consult/_2013/wind_turbine-eoliennes/index-eng.php).

A number of other organizations active in wind energy research are, in part, government funded. 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 the critical technical issues confronting the Canadian wind sector, strengthening broad-based partnerships among researchers and with industry, and training highly qualified personnel. In December 2012, WESNet's program was extended by one year, with remaining funds. The original 5-year program was scheduled to be completed by 31 March 2013. During this final year (2012–13), the Network will focus on moving the technology solutions developed by researchers down the innovation chain, towards demonstration and commercialization. WESNet will actively seek opportunities for technology transfer to the Canadian wind industry, and disseminate research results to the wind energy community. For more information see (www.wesnet.ca).

TechnoCentre éolien (TCE) is a not-for-profit institution whose mission is to conduct research in cold climate issues and contribute to the development of an industrial wind energy network in Quebec. TCE (www.eolien.qc.ca) 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. In February 2012, TCE installed and commissioned Canada's tallest weather mast at its Site Nordique Expérimental en Éolien CORUS (SNEEC). The 126-m mast was equipped with more than 30 weather sensors, located at 15 different heights. TCE plans to erect two additional masts at SNEEC, in partnership with Cégep de la Gaspésie et des Îles. The Cégep was awarded a 480,000 CAD (364,800 EUR; 481,400 USD) grant from the College-Industry Innovation Fund. The grant will be used to erect two 120-m masts and equip them with pressure sensors, anemometers, precipitation collectors, and icing-rate meters.

TCE works with companies to validate and test instruments at SNEEC. For example, TCE has agreed to have two companies (NRG Systems and Catch the Wind) install and validate their instruments (condition-based turbine health monitoring system and optical control system, respectively) on TCE's Repower MM92 wind turbines.

The Wind Energy Institute of Canada (WEICan), located at North Cape, Prince Edward Island is a not-for-profit, independent research and testing institute. WEICan is recognized as a preferred non-accredited test site for small wind turbines by the Small Wind Certification Council (SWCC) for the North American market; and a non-accredited test site by TUV-NEL (www.tuvnel.com), for Microgeneration Certification Scheme (MCS) certification for the United Kingdom market. The Institute is collaborating with Riamwind Co. of Japan on the testing of Riamwind's 3-kW Wind-lens horizontal axis wind turbine

Figure 1. Riamwind turbine under test in winter. Credit: WEICan

Figure 2. Arthur Wind Farm. Credit: Jimmy Royer, Natural Resources Canada

(Figure 1). The turbine was installed at the Institute's site and is undergoing testing for power performance, duration, safety and acoustic emissions, in accordance with the American Wind Energy Association Small Wind Turbine Performance and Safety Standard and the British Wind Energy Association Small Wind Turbine Performance and Safety Standard. The Institute is conducting the tests for eventual certification by the SWCC and MCS, as well as Nippon Kaiji Kyokai (Class NK) certification in Japan. Construction of WEICan's new 10-MW Wind Energy R&D Park, with installation of five DeWind model D-9.2 wind turbines, was completed in December 2011. For more information and updates, visit (www.weican.ca).

4.1 National R, D&D efforts

Research efforts conducted by federal government researchers include an assessment of cold climate effects on electricity production of commercial wind farms across Canada. The study took a comparative approach—actual production data from 24 wind farms were compared with reference data generated using a combination of wind data from Environment Canada's weather stations, a Measure-Correlate-Predict algorithm (MCP), and a data analysis program called Windographer. The results indicate that in Canada, cold climate effects on annual wind energy production average 6.6%, which is equivalent to 100 million CAD (76 million EUR; 100 million USD) in lost revenue. The highest losses occur in eastern Canada where the average annual production loss is 15.7%. Further research is being undertaken to gain a better understanding of the losses associated with cold climate operation, and in areas such as icing characterization and icing maps, as well as ice detection and protection.

The Université du Québec à Chicoutimi received 394,000 CAD (299,400 EUR; 395,182 USD) from the Canada Foundation for Innovation Leaders Opportunity Fund for a research project on ice-phobic coatings. The investment will enable the university to obtain the tools needed to study how ice builds up on equipment, structures and other surfaces in order to make coatings that are practical and cost-effective.

EcoENERGY Innovation Initiative (ecoEII) is a federal program that received 97 million CAD (73 million EUR; 97 million USD) in budget for 2011, for a comprehensive suite of R, D&D projects. EcoEII's objective is to support energy technology innovation to produce and use energy more cleanly and efficiently. In May 2012, the government of Canada announced that it was investing a further 184 million CAD (139 million EUR; 184 million USD) in the Initiative, bringing the total to 281 million CAD (213 million EUR; 281 million USD).

EcoEII supports activities in five strategic priority areas: energy efficiency, clean electricity and renewables, bio-energy, electrification of transportation, and unconventional oil and gas. The initiative consists of two separate funding streams: one for R&D projects, and one for demonstration projects. Both streams were launched with requests for Letters of Expression of Interest (LOIs) followed by invitations to submit Full Project Proposals (FPPs). Successful proposals were selected to proceed to the next stage of consideration, a rigorous due diligence process, which includes confirming that the proponent's offered funding is secured over the lifetime of the proposed project. This stage has been completed, and proponents of those proposals that passed the due diligence assessment have been invited to sign a contribution agreement.

The ecoEII program also supports government research initiatives, of which there are three wind related projects:

- Mitigating ecological impacts of clean energy project—Previous studies have indicated that wind energy projects result in relatively low impacts on birds, but potentially significant impacts on bats, including some species currently proposed for listing as endangered. Currently, there is limited ability to predict risks to wildlife specifically concentrated in certain geographic areas and time frames. This project uses technology (radar and acoustic monitoring tools) to improve the ability to predict these high risk areas and time periods such that cost-effective mitigation procedures may be developed.

• Mesoscale modeling of wind speed time series project—This project will produce a data set that provides a five-year, ten-minute interval data set across Canada for wind, solar radiation and a variety of other meteorological data. The data set will standardize with a U. S. data set, enabling cross-border integration studies. The data will also provide information for assessing ice formation on wind turbines, solar radiation, and other renewable energy resource studies.

• Wind forecasting in support of the deployment and integration of wind power projects—This project will create a wind forecasting model for use by industry for applications such as wind power plant operation and maintenance, electric grid balancing, electricity trading, etc. The probabilistic forecasting system will be based on an ensemble forecasting approach.

In 2009, the government of Canada announced a five-year, 795 million CAD (604 million EUR; 795 million USD) Clean Energy Fund (CEF). Up to 146 million CAD (110 million EUR; 146 million USD) are being invested in small-scale renewable and clean energy demonstration projects. Two of these are wind projects and are underway. The CEF also invested in renewable and clean energy R&D projects within the federal government. Approximately 918,000 CAD (697,680 EUR; 920,754 USD) were invested in three wind projects, which are now completed. Descriptions of the demonstration and R&D projects can be found in Canada's chapter of the *IEA Wind 2010 Annual Report*.

4.2 Collaborative research

Canada participates in IEA Wind Task 31 (Wakebench), as well as in Technical Committee-88 (TC-88) of the International Electrotechnical Commission.

5.0 The Next Term

Another record year is expected in 2013, with the addition of over 1 GW of new capacity. More than 5 GW of new wind energy capacity have been contracted to be built over the next four years.

References:

Opening photo: Caribou Wind Park, Paul D

Author: Melinda Tan, Natural Resources Canada, Canada.

18 CWEA

1.0 Overview

In 2012, 12,960 MW of new wind capacity was installed in China, increasing the accumulated capacity to 75,324.2 MW. During the year, wind power generated 100.4 TWh of electricity replacing nuclear power as the third largest electricity source in China. But compared to conventional power, wind power only accounted for 2% of generation, so there is a high potential for growth. In the future, wind power could and should play a more important role in the clean and sustainable energy and electricity supply.

After years of rapid development, China's wind power industry has entered an adjustment period and development has slowed. The industry has shifted from expansion of quantity to the improvement of quality. The government and enterprises are paying attention to improving the quality of the Chinese wind power industry. In 2012, grid integration and consumption were the most important bottlenecks that restrict China's wind power development. The government is taking policy, management, and technical measures to overcome these problems.

The *12th Five-Year Plan for Renewable Energy Development* and the *12th Five-Year Plan for Wind Power Industry Development* were released in 2012. They set clear wind power development and technology goals for 2015 and 2020. The report at the *18th CPC National Congress* clearly stated that the Chinese government will promote the construction of ecological civilization, work hard to build a beautiful country, and support the development of energy-efficient and low-carbon industries, as well as new and renewable energy sources. *China's 2012 Energy Policy* states that by the end of 2015 the consumption of non-fossil energy will account for 11.4% of primary energy consumption and the proportion of non-fossil energy installed capacity will reach 30%. Compared to 2010, the energy consumption per gross domestic product (GDP) will be reduced by 16% and the emission of CO_2 per GDP will be reduced by 17%.

2.0 National Objectives and Progress

2.1 National targets

In 2012, the *12th Five-Year Plan for Renewable Energy Development* and the *12th Five-Year Plan for Wind Power Industry Development* were released by the Chinese government. It is written in these development plans that in 2015 the accumulated grid-integrated capacity of wind power will be 100 GW (5 GW offshore), and annual electricity generation will be 190 TWh, representing more than 3% of the national generation. In 2020, the accumulated grid-integrated capacity will be 200 GW (30 GW offshore), and annual electricity generation will be 300 TWh, accounting for more than 5% of national generation. Wind power will be a major electricity source for China.

Meanwhile, developing wind technology and equipment during 2011 and 2015 is also addressed in *12th Five-Year Plan for Renewable Energy Development*. The plan identifies manufacturing of 6–10 MW wind turbines and their key components, developing grid-friendly wind integration technology, optimizing the design of large wind farms, improving wind power forecasting, and enhancing related grid operation control.

2.2 Progress

By the end of 2012, according to CWEA's statistics, 7,872 new wind turbines with generation capacity of 12,960 MW were installed in China (Taiwan excluded), which accounted for 29% of the new global capacity for the year. China's total wind generation capacity reached 75,324.2 MW, the most for any country in the world (Figure 1). The accumulated offshore wind power capacity reached 389.6 MW, with the addition of 127 MW (46 new offshore wind turbines) in 2012. The new capacity added in 2012 was 26.5% less than was added in 2011. However, total installed capacity still increased by 20.8%. The wind power electrical generation of 2012 reached 100.4 TWh, which accounted for 9.4% of renewable energy electricity for the year.

2.3 National incentive programs

In 2012, the Chinese government formulated or adjusted policies to promote stable development of wind power. These policies are aimed at quickly addressing the scientific and technical problems and trends of the wind power industry. For example, to solve the bottleneck of grid integration, the government summarized the experience of wind power dispatch timing, carried out policies to improve wind power forecasting, and built ultra-high voltage (UHV) DC transmission projects to improve the transmission ability of grid. To explore and utilize wind energy more rationally, the government carried out policies to approve and plan wind farm projects, and encouraged the exploration of distributed wind resources. To encourage the development of renewable energy, the government not only

During the year, wind power generated 100.4 TWh of electricity replacing nuclear power as the third largest electricity source in China.

Table 1. Key National Statistics 2012: China	
Total installed wind capacity	75,324.2 MW
New wind capacity installed	12,960 MW
Total electrical output from wind	100.4 TWh
Wind generation as % of national electric demand	2%
Average national capacity factor	18.4%
Targets for wind:	18,000 MW new capacity in 2013; 100 GW total capacity (5 GW offshore) and 190 TWh/yr electrical output by 2015; 200 GW (30 GW offshore) total capacity and 390 TWh/yr electric output by 2020

clarified the requirements of the renewable energy tariff subsidy, but also pre-appropriated 5.8 billion Yuan (708 million EUR; 928 million USD) to the wind electricity in coincidence with the standards..

In the mean time, the Chinese quota system is being discussed. Electricity generating enterprises, grid enterprises, and provincial governments are all responsible for the generation and consumption of wind-generated electricity. The generating enterprises are mainly responsible for generating; grid companies are responsible for purchasing; and provincial governments are in charge of renewable electricity consumption with the help of the grid enterprises. Renewable electricity generating enterprises could get green certificates, which could be used in carbon emission trading. And the Chinese government will carry out green certificate trading in the future.

To make sure offshore wind power is developed, local governments drew up offshore wind power development plans and designated key develop zones according to their specific situations. In 2012, Shandong and Hebei released offshore wind power development plans. So far, nine coastal provinces have released offshore wind power development plans.

2.4 Issues affecting growth

After several years of extremely rapid growth, wind power in China has entered an adjustment period. During this period, problems such as difficulties with grid integration, consumption, and wind power curtailed have emerged and become the main bottlenecks to limit the development of Chinese wind power. In addition, structural overcapacity and wind equipment quality control are also problems needing to be solved to realize the goal of sustainable development.

3.0 Implementation

3.1 Economic impact

In 2012, China invested 27.2 billion USD (20.618 billion EUR) in wind farm development. Wind generation contributed 100.4 TWh, which could satisfy the electrical needs of 62.75 million households in China.

3.2 Industry status

3.2.1 Developers

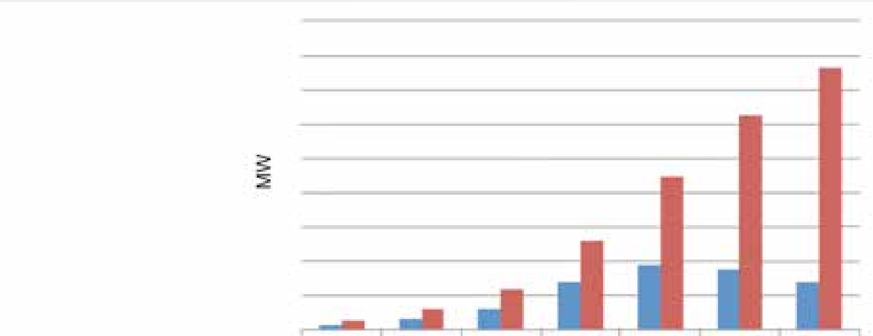
In 2012, the top five developers in China accounted for 56% of new wind projects (Table 2). This list did not change much from those active in 2011.

3.2.2 Manufacture industry

In 2012, the top five manufactures of newly installed capacity were Goldwind (2,521.5 MW), United Power (2,029 MW), Sinovel (1,203MW), Mingyang (1,133 MW) and XEMC-wind (893 MW). There were seven manufactures whose newly installed capacity in 2012 was over 500 MW (Table 3). And the top 10 manufactures accounted for 81% of China's new wind turbines.

3.3 Wind farm operation

By the end of 2012, the Chinese mainland completed construction of more than 1,000 wind farms, and the accumulated installed



	2006	2007	2008	2009	2010	2011	2012
newly installed capacity	1287.6	3311.3	6153.7	13803.2	18928.0	17630.9	12960
accumulated installed capacity	2537.1	5848.4	12002.1	25805.3	44733.3	62364.2	75324.2

Figure 1. New and accumulated installed capacity from 2006–2012 in China

Table 2. Top ten developers of new wind capacity in China in 2012

Rank No.	Developer	Capacity/MW	Share
1	Guodian Group	2,895.0	22.3%
2	Datang Group	1,546.6	11.9%
3	Huadian Group	1,040.5	8.0%
4	Huaneng Group	815.5	6.3%
5	Huarun	751.5	5.8%
6	Guohua	704.0	5.4%
7	China Power Investment Group	611.3	4.7%
8	CGN Wind	572.6	4.4%
9	Tianrun	265.5	2.1%
10	The Three Gorges	223.5	1.7%
	Others	3,534.2	27.3%
	Total	12,960.0	100%

capacity exceeded 75 GW. The top three provinces installed the following amounts in 2012: Inner Mongolian Autonomous Region (1,119.4 MW), Hebei (908.8 MW), and Gansu (1,069.8 MW). The annual full load hours were 1,890 in 2012.

3.4 Capital expenditures

Compared to 2011, average wind farm capital expenditure increased a little in 2012. On one hand, this was partly caused by the increase of average price of wind turbines (Figure 2); on the other hand, with the development of southern market, special wind turbines with longer blades became the focus of the market, which caused an increase in turbine price, transportation costs, and installation fees in 2012.

4.0 R.D&D Activities

4.1 National R.D&D efforts

4.1.1 Fundamental Research

In 2012, China continues to support the fundamental research work of wind energy. Several wind power projects have been put into the National High Technology Development Program 863, including

- Advanced wind turbine airfoil family design and application technology
- Key technology research on offshore wind farm construction
- Research on super large-scale offshore wind turbine design technology
- Key technology research on front speed wind turbine design and manufacture
- Key technology research on the wind turbines suitable for low speed, high altitude, and low temperature conditions
- Key technology research and demonstration on offshore wind power transmission, construction, and floating foundations.

4.1.2 Application research

In 2012, according to the restricting factors in the development of China's wind power in application research, China focuses on solving wind power grid-integration and consumption so that wind power can develop with the power grid coordinately. In addition to solving problems by planning and system integration, the State Grid also approved a number of UHV AC and DC transmission projects, including the +800 UHV transmission project from South Hami of Xinjiang Autonomous Region to Zhengzhou of Henan province. By 2015, the national UHV power grid will cover the regions of north China, east China, and central China, and the transmission capacity will reach 150 GW to meet the needs for wind power installed capacity of 100 GW.

To improve power quality, ensure safe transmission, and stable operation of the power grid, research projects were carried out in 2012 to address the no reactive voltage control problem that exists in the large-scale wind power grid-integration of Northwest Power Grid. A pilot project was completed at a 330-kV wind power cable station of the China Northwest Power Grid. Bi-directional regulation was realized for the reactive power output of 34 units of 1.5-MW wind turbines from AVC master. Also, the automatic adjusting control was realized of the wind farm dynamic wattles power compensation device.

4.1.3 Offshore wind power technology

Offshore wind power is an important aspect of wind power development in China. In 2015, installed capacity of offshore wind power will reach 5 GW (including wind power in inter-tidal areas). In recent years, the Chinese government is encouraging the development of offshore wind power technology. The government supports basic research in the 973 and the 863 Research Programs. Research and development also continues on large-scale offshore wind turbines in the 7-MW size range and above. Offshore wind farm

Table 3. Top ten manufactures of newly installed capacity in China in 2012

Rank No.	Manufacturer	Capacity/MW	Share
1	Goldwind	2,521.5	19.5%
2	United Power	2,029.0	15.7%
3	Sinovel	1,203.0	9.3%
4	Mingyang	1,133.5	8.7%
5	XEMC-wind	893.0	6.9%
6	Shanghai Electric	822.0	6.3%
7	Envision	544.0	4.2%
8	Gamesa	493.2	3.8%
9	Dongfang Electric Corporation	466.5	3.6%
10	Vestas	414.4	3.2%
	Others	2,439.9	18.7%
	Total	12,960.0	100%

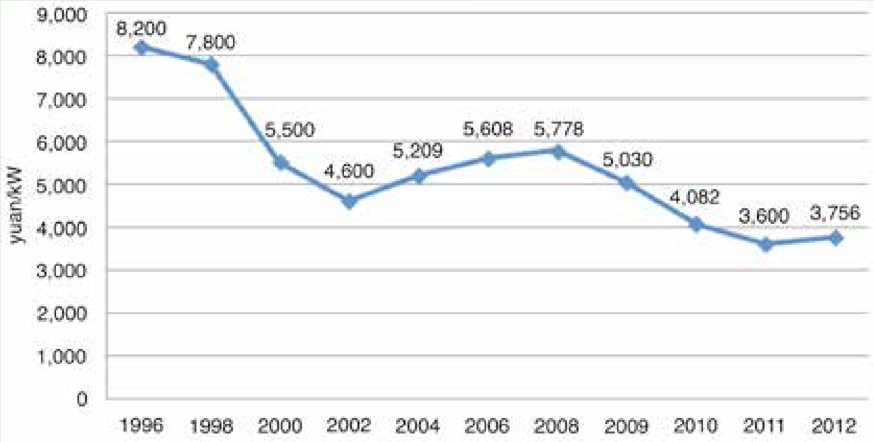


Figure 2. Price trends of wind turbines in China; 1,000 yuan = 122 EUR or 160 USD

engineering equipment has also been developed with government support. In addition, the nation's largest offshore wind power installation vessel has been put into use recently (Figure 3). China Ming Yang Wind Power Group Co., Ltd. invested 450 million Yuan (55 million EUR; 72 million USD) on this research. A new type of offshore wind turbine, the SCD 3-MW, with a new transmission system has also been industrialized.

4.1.4 Decentralized access wind power

In recent years, 10-MW class wind plants have been built in the rich wind energy resource areas, such as in the northwest, northeast, northern, and southeast coastal regions. At the same time, decentralized wind farms are being constructed in areas where the wind resource is not very rich but where the electricity grid is near. Wind turbines suitable for low wind speed running have also been developed for these situations. Envision Energy Co., Ltd. has developed low wind speed type turbines of 2.1 MW with a 110-m diameter. This kind of wind turbine uses intelligent dual-mode electric drive chain technology, optimized and integrated double-fed and direct drive technology to harvest at a low wind speed of 7 m/s. In the low wind speed areas with 60% wind energy resource utilization, the climate and geographical environments are very complicated, including high altitude, sandstorms, freezing rain, lightning, and earthquakes. These places require special study.

4.1.5 Small wind turbines

China is a developing country, and the Chinese government supports developing small wind turbines and wind/solar hybrid systems to solve the problem of electricity shortage in rural areas. In recent years, small wind turbines can be used off-grid, but also in grid-integration or miro-grid system combined with PV and other energy sources.

A series of small wind turbines manufactured by HY Energy Co., Ltd. (models HY-400, HY-600, HY-1000, HY-1500, HY-3000) have passed through the CE, ETL, Rohs, and other international certifications. In 2012, HY Energy Co., Ltd. exported 9,756 units of small wind turbines, a total of the 8.86 MW of capacity. Of these, 6,630 were sold in the French market, accounting for 60% of the total amount of imported wind turbines in France. According to data from Chinese customs, the small wind turbine export turnover of HY Energy Co., Ltd. accounted for 30% of the total small wind turbine export turnover of China.

Figure 3. The largest offshore wind power installation vessel in China

4.2 Collaborative research

In 2012, CWEA organized manufactures, research institutions, and universities to participate in the following IEA Wind cooperative research tasks: Task 11 Base Technology Information Exchange, Task 25 Power Systems with Large Amounts of Wind Power, Task 30 Offshore Code Comparison, Task 31 Wakebench and Task 33 Reliability Data. In 2013, CWEA plans to apply to participate in Task 27 Small Wind in Turbulent Sites, and Task 29 Aerodynamics. Furthermore, CWEA took part in the activities organized by Technical Committee 88 (TC88) of the International Electro-technical Commission.

5.0 The Next Term

The Chinese wind energy industry has moved from a rapid development period into a stable development period. In 2013, new wind power connected to the grid will reach 18 GW. Policy, system, and technical measures will be taken to reduce the proportion of wind power curtailed, thereby allowing expansion. At the same time, enhancing the reliability of wind power equipment, strengthening capacity building, and training wind power operation and maintenance personnel are still key goals.

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

Source: Siemens Press

19 Denmark

1.0 Overview

Approximately 23.7% of Denmark's energy consumption came from renewable sources in 2012, 38.3% from oil, 19.4% from natural gas, and 13.8% from coal. The production from wind turbines alone corresponded to 30% of the domestic electricity supply, compared to 28.2% in 2011. The total domestic supply was nearly the same in 2012 as in 2011.

Wind power capacity in Denmark increased by 210 MW in 2012, bringing the total to 4,162 MW (Table 1). There were 220.6 MW in new turbines installed while 10.7 MW were dismantled. Most of the installed wind turbines in 2012 were onshore, while 14 of the 111 planned 3.6-MW turbines were installed offshore in the Kattegat project Anholt. The largest rated turbine to be installed in 2012 was the 6-MW Siemens turbine at the Oesterild Testsite (opening photo).

In March 2012, a broad majority of the Danish Parliament approved a new political agreement on energy. This Energy Agreement is an important step towards fulfilling the 2050 target. The plan includes installation of 1,500 MW of new offshore turbines and 500 MW of new land-based turbines in addition to an expected 1,300 MW of repowering.

2.0 National Objectives and Progress

In March 2012, a historic new Energy Agreement was reached in Denmark. The Agreement contains a wide range of ambitious initiatives, bringing Denmark a good step closer to the target of 100% renewable energy in the energy and transport sectors by 2050.

In many ways Denmark has started the green transition well. However, the Agreement moves the country forward with large investments up to 2020 in energy efficiency, renewable energy, and the energy system. Targets for 2020 include approximately 50% of electricity consumption supplied by wind power and more than 35% of final energy consumption supplied from renewable energy sources.

No energy agreement has ever been reached by a larger and broader majority in the Danish Parliament than this one (95%); and no Danish energy agreement has previously covered such a long time horizon. In other words, a solid framework has been provided for the huge private and public investment to be made in the years ahead.

More details of the agreement can be found in the in the report "Accelerating Green Energy Towards 2020" (1) and in the

Wind generation met 30% of Denmark's national electric demand. The 870 MW of offshore wind supplied more than one-third of the total with a capacity factor of 34.6%.

Table 1. Key National Statistics 2012: Denmark	
Total installed wind capacity	4,162 MW
New wind capacity installed	210 MW
Total electrical output from wind	10.3 TWh
Wind generation as % of national electric demand	29.9%
Average capacity factor	22.6%
Target:	50% of electricity from wind by 2020; 100% of electricity from renewables by 2050

report to Parliament in May 2012 (2) and the publication "Energy Policy in Denmark," Danish Energy Agency, December 2012 (3).

2.1 National targets

The Agreement contains 62 ambitious actions to be taken up to 2020 bringing Denmark closer to the target of 100% renewable energy in 2050. The Agreement itself covers the period 2012–2020.

By 2020, the Agreement will achieve the following main results:

- More than 35% renewable energy in final energy consumption
- Approximately 50% of electricity consumption to be supplied by wind power
- 7.6% reduction in gross energy consumption in relation to 2010
- 34% reduction in greenhouse gas emissions in relation to 1990

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 2017–2018)
- Krieger Flak 600 MW (EU support to grid connection 1.1 billion DDK (1.5 million EUR; 1.9 million USD) (in operations before 2020)
- 500 MW near-coast offshore installations
- 500 MW added capacity on land before 2020
- 1,800 MW new onshore including 1,300 MW for repowering

2.2 Progress

As shown in Table 1 and Figure 1, the contribution from wind alone to the domestic electricity production was close to 30%, compared to 28% in 2011.

The newly commissioned wind capacity in Denmark was 210 MW in 2012, bringing the total to 4,162 MW (Table 1). There were 220.6 MW of new turbines installed, while 10.7 MW were dismantled. Most of the installed wind turbines were onshore, but 14 of the planned 111 3.6-MW turbines were installed offshore in the Kattegat project Anholt. The largest rated turbine to be installed in 2012 was the 6-MW Siemens at the Oesterild Testsite.

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

The environmental benefits due to the 2012 wind energy production, assuming coal is being substituted, are (2): saved coal: 3,457,577 tons (3378 g/kWh); CO_2: 7,961,661 tons (776 g/kWh); SO_2: 718 tons (0.07 g/kWh); NOX 2,360 tons (0.23 g/kWh); Particles 205 (0.02 g/kWh); Cinder/Ash 543,773 tons (53 g/kWh) (5).

2.3 National incentive programs

In 2012, the Danish incentive program was still based on the act passed at the end of December 2008 (Law No. 1392 of

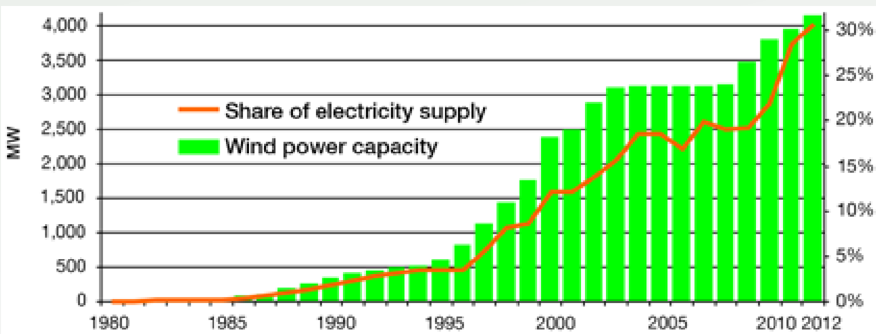


Figure 1. Danish wind power capacity and its share of domestic electricity supply in 2012

27/12/2008) and took effect 1 January 2009 and the 2010 Micro VE support scheme.

In order to meet the targets for a fossil-free Denmark by 2050, new incentives and measures focusing on energy efficiency, electrification, expansion of renewable energy, and RD&D was discussed in 2012 (see Section 2.1) a new energy agreement was signed in March 2012 with a broad political support.

3.0 Implementation

The Danish wind turbine industry (6) publishes an annual report on the industry status and economic impact. The information in the latest annual report "Branchestatistik 2012" (7) is for 2011.

3.1 Economic impact

The wind industry's turnover in Denmark decreased by 6.3% in 2011 to cumulatively 7 billion EUR (9 billion USD), compared to 7.4 billion EUR (9.7 billion USD) in 2010. A reduction in the production of wind turbines influenced the rest of the Danish wind industry, causing a decrease in exports. The average annual growth rate in the period 2006–2011 was 10%. The global turnover rose to almost 14 billion EUR (18.5 billion USD), up 4.1% from 2010.

The Danish wind industry exported goods worth 5.2 billion EUR (6.9 billion USD) in 2011. That is a decrease compared to 2010 when the total export was worth 6.2 billion EUR (8.2 billion USD).

During the last five years, the average annual export has increased by 8%. In 2011, the Danish wind industry contributed 6.4% of the total Danish export.

The number of employees in the industry rose slightly in 2011 to a cumulative of 25,520 people. Figure 2 shows the types of employment in the Danish wind industry.

3.2 Industry status

The major Denmark-based manufacturers of commercial 1-MW or larger wind turbines of are still Siemens Wind Power (formerly Bonus Energy A/S) and Vestas Wind Systems A/S.

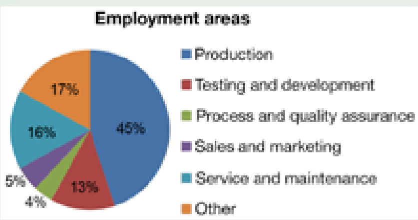


Figure 2. Employment areas in the wind industry

Location (year installed)	Number of Turbines, Total Capacity
1. Vindeby (1991)	11 wind turbines, 5 MW
2. Tunø Knob (1995)	10 wind turbines, 5 MW
3. Middelgrunden (2000)	20 wind turbines, 40 MW
4. Horns Rev I (2002)	80 wind turbines, 160 MW
5. Rønland (2003)	8 wind turbines, 17 MW
6. Nysted (2003)	72 wind turbines, 165 MW
7. Samsø (2003)	10 wind turbines, 23 MW
8. Frederikshavn (2003)	3 wind turbines, 7 MW
9. Horns Rev II (2009)	91 wind turbines, 209 MW
10. Avedøre Holme (2009/2010)	3 wind turbines, 10 MW
11. Sprogø (2009)	7 wind turbines, 21 MW
12. Rødsand II (2010)	90 wind turbines, 207 MW
13. Anholt (2012/2013)	111 wind turbines, 400 MW
Areas for wind farms up to 2020 (Green: near shore)	

Figure 3. Existing offshore wind farms and proposed areas for development up to 2020

3.3 Operational details

The largest projects are the four offshore farms Horns Rev I and II in the North Sea and Nysted and Roedsand II in the Baltic Sea. Figure 3 shows the locations of existing offshore wind farm locations in Denmark.

In 2013, Anholt (400 MW) will come online (Figure 4). The next large offshore wind farms planned are Horns Rev III and Krieger's Flak, with a combined capacity of 1,000 MW (8). For more detail please refer to the *IEA Wind 2011 Annual Report*.

In 2012, 4,700 turbines with a capacity of 3,855 MW operated the whole year producing nearly 10 TWh. The average capacity factor was 22.6 (average wind index 95.6). The 870 MW offshore wind farms alone counted for more than one-third of the production with a capacity factor of 34.6. The newest turbine installed commercially is the 3.6-MW Siemens direct drive. Onshore testing of 6-MW turbines is ongoing. The total penetration rose to nearly 30% in 2012, compared to 28.2 % in 2011.

The average rated capacity of turbines installed is now over 2.7 MW (Figure 5), continuing the trend to larger machines.

As mention 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

Figure 4. Anholt offshore wind farm. Credit: DONG Energy

the results 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, as shown in Figure 6. 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 electricity consumers via their general charges.

The Danish Energy Agency will conduct a tendering procedure for large offshore wind farms, which will be published before the end of 2013. Since the near-shore wind farms will be visible from shore, local joint ownership of 20% of each project will be introduced (as is done on land) in order to maintain local support. If 30% local ownership is achieved, there will be a further price supplement of 0.13 EUR/kWh (0.17 USD/kWh) for the full subsidy period.

In addition to the 450 MW to be installed under the government plan, a further 50 MW of test turbines will be open for applications. The test turbines will be established at a fixed settlement price of 0.094 EUR/kWh (0.124 USD/kWh) for a period corresponding to 50,000 peak-load hours. The test turbines are not tied to the designated areas, and can be located anywhere conditions allow it. The test projects can include up to eight turbines. The projects must have a clear technological development objective aiming at reducing the future costs of offshore wind turbines.

3.4 Wind energy costs

The average turnkey prices for wind is estimated by EA Energi Analyse to be at the

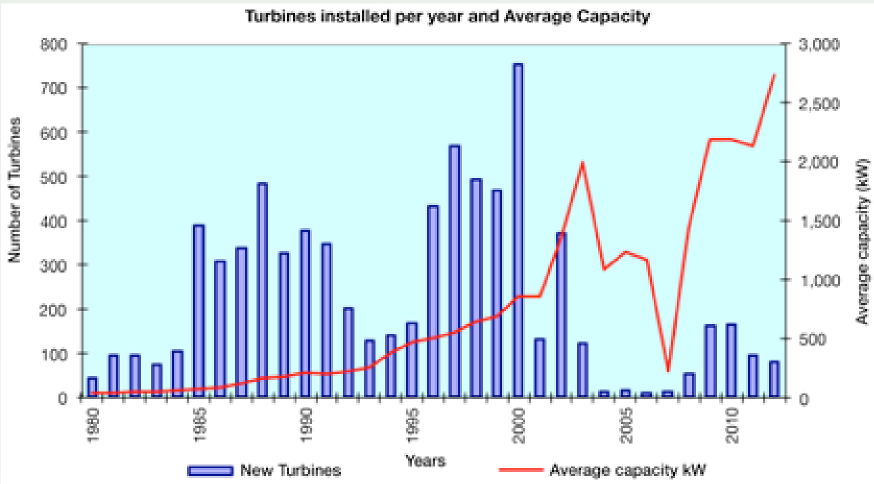


Figure 5. Number of turbines installed per year and average capacity

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

focus areas (9). The component strategy includes activities within four research areas:

- Value chain cooperation: Cooperation in the supply chain between energy companies, original equipment manufacturers (OEMs), and suppliers, as well as supplier to supplier.
- The individual company: Each individual company's resources and competencies, including development of new competencies and business areas.
- Framework conditions: Includes a number of different conditions that determine the companies' development opportunities (markets, competition, advanced demand, knowledge from R&D, education, standardisation and information infrastructure, test and demonstration facilities).
- Optimization of functions: Technical research areas that holds a potential for cost of energy reduction.

same level in 2012 as in 2011, and thereby lower than 2008 (see Figure 7).

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 with Energinet.dk; the Energy Technology, Development and Demonstration Programme (EDDP); the Danish Council for Strategic Research (DCSR); the European Commission (EC) representation in Denmark; and the Danish Advanced Technology Foundation. An updated list of Danish funded energy technology research projects is also available online at (http://dev.energiforskning.omega.oitudv.dk/en?language=en).

4.1 National R, D&D efforts

Since 2007, the main priorities for R, D&D in wind have been defined in cooperation with the partnership Megawind. The Megawind partnership consists of representatives from Vestas Wind Systems A/S, Siemens Wind Power A/S, DONG Energy, COWI A/S, Fritz Schur Energy A/S, DTU Wind Energy, and Aalborg University. The national Transmission System Operator (TSO), Energinet.dk, and the Danish Energy Agency participate as observers.

In 2012, Megawind's strategy for components and systems in wind power plants began a framework for cooperation in the supply chain and a number of technological

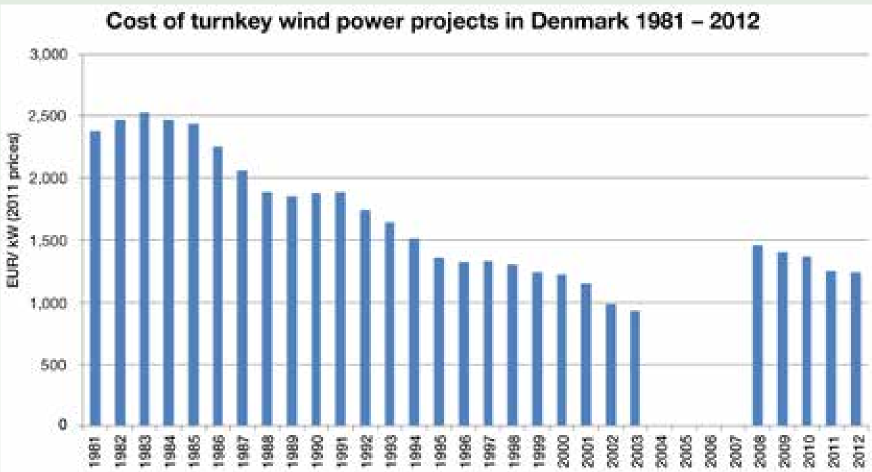


Figure 7. Development of cost of wind power projects 1981–2012

It is expected that suppliers of components and systems will be able to present a significant part of the possible cost of energy improvement through optimization and efficiency improvement in the four areas listed above. The main question is what activities are needed in order to create those improvements in function, reliability, and life span, which ultimately result in reduced cost of energy.

Also in 2012, Megawind initiated a process of updating several earlier published strategies, including an update of "Wind Power Plants in the Energy System" from 2008 (10). The report describes and recommends strategic targets that create new solutions to large-scale integration of wind power including R, D&D of power plant functionality. The recommended targets are aimed at making turbine production more cost-effective and hence contribute to an increased competitiveness both for Denmark and the companies that participate in development activities. All the Megawind Strategies can be downloaded from (6). The latest report is from 2012 (11).

In 2012, 8.7 million EUR (11.5 million USD) of public funding was distributed to the projects listed in Table 2.

4.2 Test centers

The onshore and offshore test and demonstration facilities at Oesterild and the component test center Lindoe Offshore Renewables Center (LORC) were described in more detail in earlier IEA Wind annual reports. The national test center at Oesterild

Table 2. Supported wind energy R&D projects in 2012		
Title	Company	Funding (Million EUR*)
Participation IEA Wind Task 26: Cost of Wind Energy—task extension, phase 2	EA Energianalyse A/S	0.12
Forecasting of electricity production from wind and wave energy	SPOK Consult ApS	0.04
Regain of operational life time of installed wind turbine blades with structural defects	Bladena	0.64
OffWindChina - Research and development of optimal wind turbine rotors under offshore wind conditions in China	DTU Wind Energy	0.81
Participation IEA Wind Task 29 Mexnext-II—task extension, model validation	DTU Wind Energy	0.10
Improved wind turbine efficiency using synchronized sensors	Delta A/S	0.38
PossPOW	DTU Wind Energy	0.64
Retrofit yaw control kits for higher power output	ROMO Wind A/S	1.58
Offshore cable installation	Siemens Wind Power A/S	0.42
Bucket foundation trial installation in multi-layer soil profile (CT Trial)	Universal Foundations A/S	2.15
Low-cost semiconductor laser wind sensor	Windar Photonics A/S	0.99
Standardized power packs for improved aerodynamics of wind turbines—PowerPack	Sander A/S	0.80
IEA Wind coordination	DTU Wind Energy	0.02
Total support		8.70
*Conversion factor from EUR to USD is 1.318		

was opened officially in October 2012 and the first two turbines from Siemens have been set up (opening photo) and will be followed by more test turbines in 2013 and 2014 (12). At the Lindoe Offshore Renewables Center the planning has continued and funding is now guaranteed. There will be two test bends for nacelles of up to 10 MW (13).

5.0 The Next Term

The proposed initiatives for reaching a fossil-free Denmark by 2050 and 50% wind energy by 2020 agreed on in Parliament March 2012 will boost wind energy deployment in Denmark in the coming years.

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The opening photo shows Siemens new 6-MW direct-drive turbine at DTU Oesterild test station.

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(6) The Danish Wind Industry Association Web site, www.wind.windpower.org.

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Author: Jørgen K. Lemming, DTU Wind Energy, Denmark.

20 European Union/EWEA

1.0 Overview

The European Union's (EU) total installed power capacity increased by 29.2 GW in 2012 to a net value of 931.9 GW. Of this total generation capacity, wind power reached a share of 11.4%, up from 10.5% in 2011. Since 2000, 27.7% of new electrical capacity installed has been wind power, 51.2% renewables, and 91.2% renewables and gas combined. The EU power sector continues its move away from fuel oil, coal, and nuclear, with each conventional technology continuing to decommission more than it installs.

Wind power accounted for 26.5% of total 2012 power capacity installations. Renewable power installations accounted for 70% of new installations during 2012: 31.3 GW of a total 44.9 GW of new power capacity, down 4% from the share in 2011.

The rate of EU wind power installations for 2012 does not show the negative impact of market, regulatory, and political uncertainty that has swept across Europe since the beginning of 2011. The turbines installed during 2012 were generally permitted, financed, and ordered prior to the crisis feeding through to a destabilization of legislative frameworks for wind energy. The stress being felt in many markets across Europe throughout the wind industry's value chain should become apparent in a reduced level of installations in 2013, possibly continuing well into 2014. Nonetheless, 2012 was a record year for offshore wind energy installations in the EU, with 1,166 MW of new capacity grid-connected. Offshore wind power installations represented 10% of the annual EU wind energy market, up from 9% in 2011.

1.1 Overall capacity increases

During 2012, 12,744 MW of wind power was installed across Europe, 11,895 MW of which were in the EU. Of the 11,895 MW installed in the EU, 10,729 MW were onshore and 1,166 MW were offshore. Investment in EU wind farms was between 12.8–17.2 billion EUR (16.9–22.7 billion USD).

The opening figure and Table 1 illustrate annual installations in the EU. Germany was the largest market in 2012, installing 2,415 MW of new capacity, 80 MW of which (3.3%) was offshore. The United Kingdom (UK) came in second with 1,897 MW, 854 MW of which (45%) was offshore. Italy installed 1,273 MW, Spain (1,122 MW), Romania (923 MW), Poland (880 MW), Sweden (845 MW), and France (757 MW).

Among the emerging markets of Central and Eastern Europe, Romania and Poland both had record years—each installing around 7.5% of the EU's total annual capacity. Both markets are now consistently in the top ten in the EU for annual installations (Figure 1).

Table 1. Wind power installed in EU by end of 2012 (cumulative, MW)				
EU Capacity (MW)				
	Installed 2011	End 2011	Installed 2012	End 2012
Austria	73	1,084	296	1,378
Belgium	191	1,078	297	1,375
Bulgaria	28	516	168	684
Cyprus	52	134	13	147
Czech Republic	2	217	44	260
Denmark	211	3,956	217	4,162
Estonia	35	184	86	269
Finland	2	199	89	288
France	830	6,807	757	7,564
Germany	2,100	29,071	2,415	31,308
Greece	316	1,634	117	1,749
Hungray	34	329	0	329
Ireland	208	1,614	125	1,738
Italy	1,090	6,878	1,273	8,144
Latvia	17	48	21	68
Lithuania	16	179	46	225
Luxembourg	1	45	0	45
Malta	0	0	0	0
Netherlands	59	2,272	119	2,391
Poland	436	1,616	880	2,497
Portugal	341	4,379	145	4,525
Romania	520	982	923	1,905
Slovakia	0	3	0	3
Slovenia	0	0	0	0
Spain	1,050	21,674	1,122	22,796
Sweden	754	2,899	846	3,745
United Kingdom	1,298	6,556	1,897	8,445
Source: EWEA				

It is also important to note the amount of installations in the UK, Italy, and Sweden. These three markets represent respectively 16%, 11%, and 7% of total EU installations in 2012.

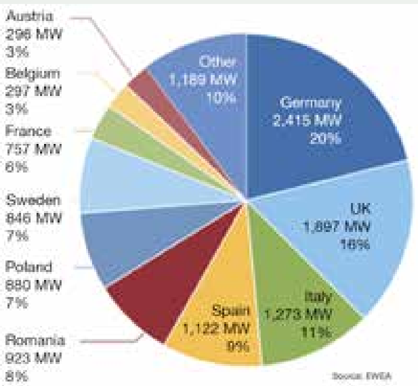

Figure 1. EU Member State market shares for new capacity installed during 2012

Finally, offshore wind accounted for 10% of total EU wind power installations in 2012, an increase of one percentage point from 2011.

Wind power accounted for 26.5% of new installations in 2012, the second biggest share after solar PV (37%) and before gas (23%) (Figure 2). Solar PV installed 16 GW (37% of total capacity), followed by wind with 11.9 GW (26.5%), and gas with 10.5 GW (23%).

No other technologies compare to wind, PV, and gas in terms of new installations. Coal installed 3 GW (7% of total installations), biomass 1.3 GW (3%), CSP 833 MW (2%), hydropower 424 MW (1%), waste 50 MW, nuclear 22 MW, fuel oil 7 MW, ocean energy technologies 6 MW, and geothermal 5 MW.

During 2012, 5.5 GW of gas capacity was decommissioned, as were 5.4 GW of coal, 3.2 GW of fuel oil, and 1.2 GW of nuclear capacity (Figure 3). After two years of installing more capacity than it decommissioned, coal power installations reduced by almost 2.4 GW in 2012.

Wind power's share of total installed power capacity has increased five-fold since 2000; from 2.2% in 2000 to 11.4% in 2012 (Figure 4). Over the same period, renewable capacity increased by 51% from 22.5% of total power capacity in 2000 to 33.9% in 2012.

1.2 Offshore wind

It was a record year for offshore installations, with 1,166 MW of new capacity grid-connected in 2012. Offshore wind power installations represent 10% of the annual EU wind energy market, up from 9% in 2011.

A total of 1,662 wind turbines are now installed and connected to the electricity grid in 55 offshore wind farms in ten countries across Europe. Total installed capacity at the end of 2012 reached 4,995 MW, producing 18 TWh in a normal wind year, enough to cover 0.5% of the EU's total electricity consumption.

The UK has the largest amount of installed offshore wind capacity in Europe: 2,948 MW (58.9% of all installations) (Figure 5). Denmark follows with 921 MW (18.4%). With 380 MW (7.6% of total European installations), Belgium is third, followed by Germany (280 MW: 5.6%), the Netherlands (247 MW: 4.9%), Sweden (164 MW: 3.3%), Finland (26 MW: 0.6%), Ireland (25 MW), Norway (2.3 MW) and Portugal (2 MW).

With the completion of the wind farms that were not fully grid-connected during 2012, around 1,400 MW of new capacity is due to come online in 2013 (Figure 6). The forecast for 2014 is even higher, as completion of wind farms already under construction, and not completed in 2013, would lead to 1,900 MW of new installations. Moreover,

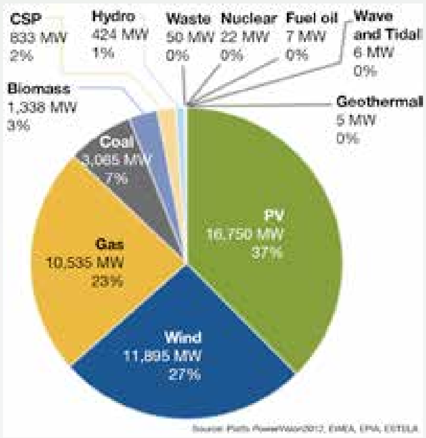

Figure 2. Share of new power capacity installations in the EU in 2012

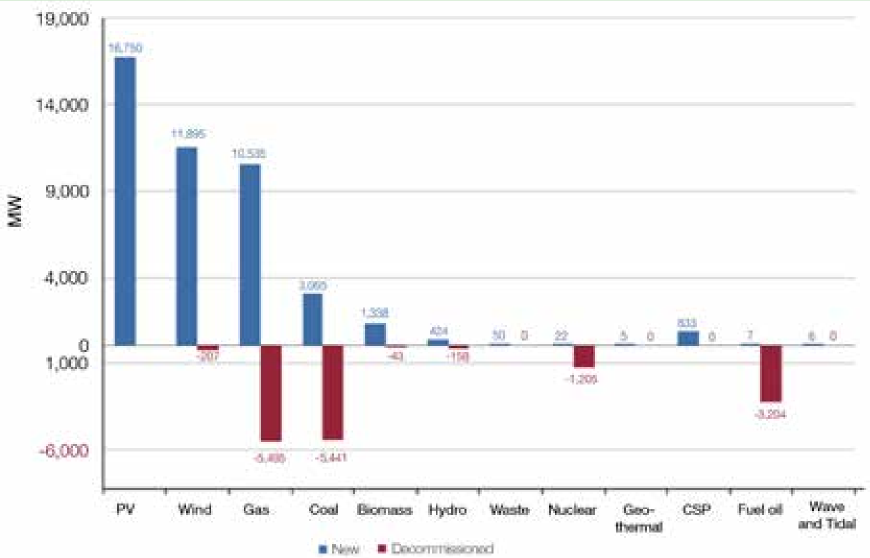

Figure 3. New installed and decommissioned power capacity in 2012.
Source: Platts PowerVision2012, EWEA, EPIA, ESTELA

the European Wind Energy Association (EWEA) has identified 18.4 GW of consented offshore wind farms in Europe and future plans for offshore wind farms totaling more than 140 GW.

2.0 R, D&D Wind Energy Projects

In 2012, around 28 R&D projects were started with the support of the Seventh Framework Programme (FP7) of the EU (the Framework Programmes are the main EU-wide tool to support strategic research areas). In addition, five offshore demonstration projects funded by the European Energy Programme for Recovery (EEPR) are under construction and three more are in the pipeline. Finally, six other innovative demonstration projects were awarded funding by the New Entrants Reserve program in late December (1). The following paragraphs summarize both the nature and main objectives of EU R, D&D funded projects started after January 2012 and managed by the European Commission (EC).

2.1 Basic research projects

ACTIVEWINDFARMS looks at whether wind in the Atmospheric Boundary Layer (ABL) is slowed down as a result of a large deployment of gigawatts-level wind farms, and the claims of significant underperformance in large wind farms compared to a single turbine standalone. The project will employ optimal control techniques to control the interaction between large wind farms and the ABL, and optimize overall farm-power extraction.

EERA-DTOC (EERA Design Tools for Offshore Wind Farm Cluster) aims at improving knowledge of the behavior of the wind farm wake, in particular far-field wake and/or affecting clusters of wind farms. For this EERA-DTOC will carry out a small measurement campaign and use new data available from the industry partners for creating an integrated software tool for the optimized design of offshore wind farms and wind farm clusters acting as wind power plants.

WALiD (Wind Blade Using Cost-Effective Advanced Composite Lightweight Design) will combine design, material, and process developments using thermoplastic materials to create cost-efficient, lightweight, and recyclable blades which will be demonstrated by industrial end-users. A particular focus is future offshore wind blades: weight reduction, protection against harsh environmental conditions (e.g. extreme temperatures, humidity and salt conditions), cost-efficiency, and recyclability.

Other wind-only basic research projects focus on making data more usable and readily available (SOPCAWIND for datasets needed for wind farm and turbine sitting), or support research education and networks (ECOWindS or MARE-WINT). Other basic research projects impacting on wind energy include ROMEO (Replacement and Original Magnet Engineering Options), iGREENGrid (integratinG Renewables in the EuropEaN Electricity Grid), UMBRELLA (Toolbox for Common Forecasting, Risk assessment, and Operational Optimisation in Grid Security Cooperations of Transmission System Operators (TSOs), and COCONET (Towards COast to COast NETworks of marine protected areas).

ROMEO aims at greatly reducing the need for heavy rare earths in permanent magnets. It will first research and develop several novel microstructural-engineering strategies that will dramatically improve the

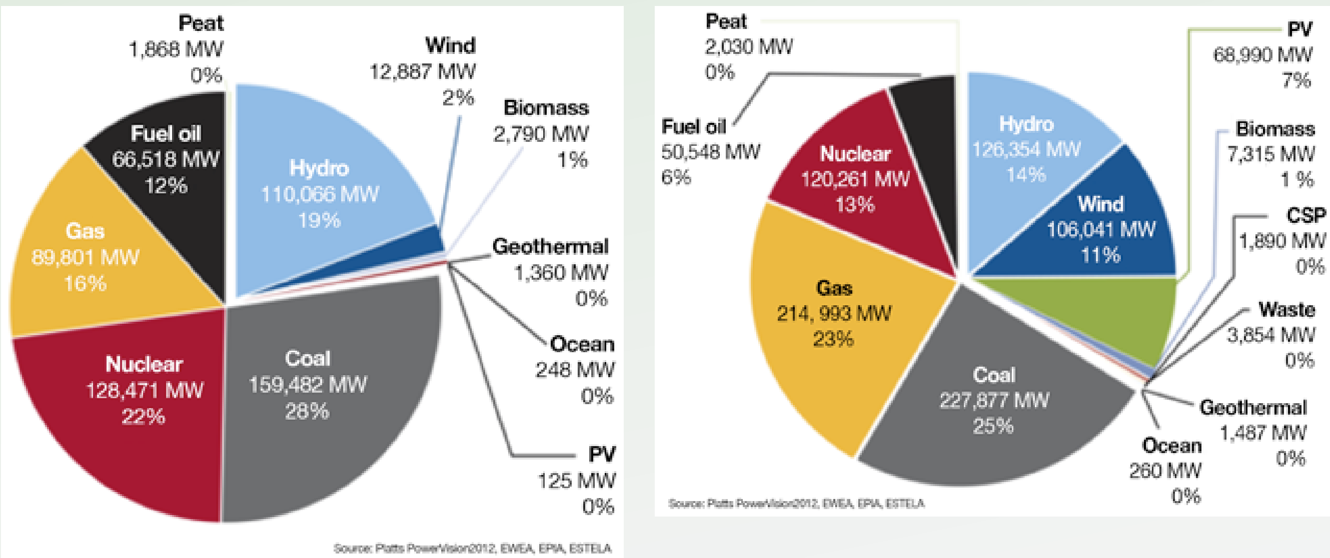

Figure 4. EU power mix (MW and %) in 2000 (on the left) and 2012 (on the right)

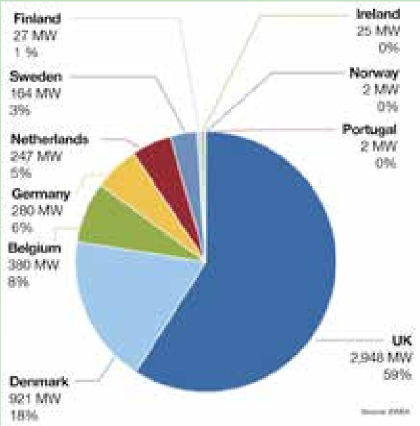

Figure 5. European countries' shares of EU cumulative offshore wind power capacity at end 2012

properties of magnets based purely on light rare earths elements, especially the coercivity (magnetic intensity), which will enable them to be used for applications above 100°C. ROMEO's second ambitious goal is to develop a totally rare-earth-free permanent magnet.

iGREENGrid focuses on increasing the hosting capacity for distributed renewable energy sources (DRES) in power distribution grids without compromising the reliability or jeopardizing the quality of supply. Its main final result will be a set of guidelines: most promising solutions; recommendations for appropriate integration of small and medium size variable DRES in distribution grids; methodologies and tools; criteria to establish hosting capacity and to manage curtailment procedures; and technical requirement to DRES, equipment manufacturers, and technology providers.

UMBRELLA will develop a toolbox to enable TSOs to ensure secure grid operation also in future electricity networks with high penetration of intermittent renewables. It will enable TSOs to act in a coordinated European target system where regional strategies converge to ensure the best possible use of the European electricity infrastructure.

COCONET will explore where offshore wind farms (OWF) might be established, producing an enriched wind atlas both for the Mediterranean and the Black Seas. OWF locations will avoid too sensitive habitats but the possibility for them to act as stepping-stones through marine protected areas, without interfering much with human activities, will be evaluated.

2.2 Applied research projects

Applied research projects are considered here as to include the development of e.g. the hardware components of a wind turbine including prototypes but where the component prototype is not installed in a full-size working wind turbine.

MERMAID (Innovative Multi-purpose off-shore platforms: planning, Design and operation) will develop concepts for the next generation of offshore platforms which can be used for multiple purposes, including energy extraction, aquaculture and platform related transport. The project does not envisage building new platforms, but will theoretically examine new concepts, such as combining structures and building new structures on representative sites under different conditions.

WINTUR DEMO (In-situ wireless monitoring of on - and offshore WINd TURbine blades using energy harvesting technology – DEMOnstration) will demonstrate the structural health monitoring system that was developed successfully in the WinTur R4S project, in order to show that such a system is viable for blade monitoring and can realize the full life-cycle term of blade components.

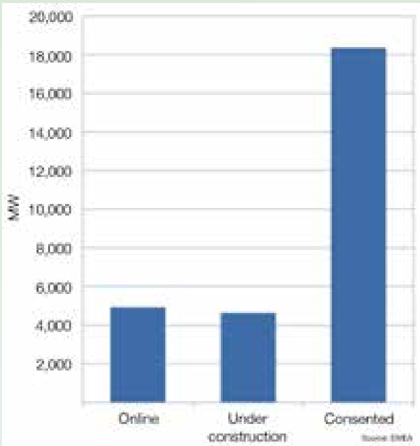

Figure 6. Offshore market: projects online, under construction, and consented

INNWIND.EU (Innovative Wind Conversion Systems (10–20 MW) for Offshore Applications) has as overall objectives the design of a 10–20 MW offshore high performance innovative wind turbine and of hardware demonstrators of some of the critical components. Secondary objectives are constituted by the specific innovations, new concepts, new technologies and proof of concepts: (i) a light weight rotor having a combination of adaptive characteristics from passive built-in geometrical and structural couplings, and active distributed smart sensing and control, (ii) an innovative, low-weight, direct drive generator and (iii) a standard mass-produced integrated tower and substructure that simplifies and unifies turbine structural dynamic characteristics at different water depths.

WINDSCANNER (the European WindScanner Facility) focuses on detailed high-resolution remote sensing measurement methodologies of wind and turbulence for wind energy. This ESFRI WindScanner Preparatory Phase (PP) project develops the governance scheme, legal model, and the final technological design and associated budget and financing models for its construction by 2016. The operational WINDSCANNER facility will be designed around: (i) a central facility with the functions of handling the data management, hosting servers, hosting of website, administrative office, training of technicians and researchers who will operate the WindScanners, training of users, etc.; (ii) six new partner nodes are anticipated which will be equipped with mobile WindScanners used at existing or planned test facilities all over Europe (in different climate conditions and terrains).

SUPRAPOWER (SUPerconducting, Reliable, lightweight, And more POWERful offshore wind turbine) aims at developing a new compact superconductor-based generator that is installed in a 10-MW-class offshore wind turbine. All the essential aspects of electric conversion, integration and manufacturability will be taken into account. In addition, SUPRAPOWER will pursue the following objectives: (i) to reduce turbine head mass, size, and cost of offshore wind turbines; (ii) to reduce O&M and transportation costs and increase life cycle; (iii) to increase the reliability and efficiency of high power wind turbines. The main outcome of the project will be a proof of concept for a key technology to scale wind turbines up to power levels of 10MW and beyond.

WETMATE (33-kV Subsea Wet-Mateable Connector for Offshore Renewable Energy) will design self-monitoring connectors to eliminate routine maintenance at greater depths, and develop ROV-installable wet-mate connectors. The project will deliver a prototype 33-kV hybrid wet-mate connector with a connectivity monitoring system and future-proof features for higher voltage connector technologies.

WIND TURBARS (On-line Intelligent Diagnostics and Predictive Maintenance Sensor System Integrated within the Wind Turbine Bus-Bar structure to aid Dynamic Maintenance Scheduling) attempts to reduce the rate of electrical system faults and the corresponding downtime per fault. To achieve this, the project aims to develop an advanced diagnostics and predictive maintenance intelligent sensor system network for wind turbine (with particular focus on faults, failures, and breakdowns relating to the electrical system of the wind turbine).

WINDHEAT (Opening New Markets for SMEs: Intelligent Ice Sensing and De-icing System to Improve Wind Turbine Efficiency in Cold Climates) will tackle ice formation on the wind turbine blades which significantly reduces their performance, and creates safety and economic issues. The project will develop a state of the art understanding of ice formation on wind turbine blades which will lead to the development of an accurate ice detection system (based on a novel multi-wavelength inter-digital frequency wave-number dielectrometry sensor) and a low power localised heating system based on graphite coatings.

HYDROBOND (New cost/effective superHYDROphobic coatings with enhanced BOND strength and wear resistance for application in large wind turbine blades). The main objective of HYDROBOND is the development of a highly innovative process for application of superhydrophobic coatings onto large offshore turbine blades that will contribute to minimize the power losses and mechanical failures. Novel thermal spray technologies will be the way to achieve the nanostructured coatings with tailored anti-icing properties and enhanced bond strength, in a cost effective manner for very large, composite material surface.

WINDRIVE (Industrialization of a 3-MW medium-speed brushless DFIG drive-train for wind turbine applications) attempts the development and industrialization of a novel medium-speed wind turbine drive-train (WTDT) designed to have an intrinsically higher reliability than the current most widely used based on a 3-stage gearbox and a high-speed doubly-fed induction generator. The proposed innovation aims at improving reliability by adopting (a) medium-speed brushless DFIG, excluding brush-gear and slip-rings, known to be the highest failure rate components in the generator; (b) partially-rated converter, identical to the high-speed WTDT; and (c) 2-stage gearbox, excluding the third high-speed stage, known to be the highest failure rate section of the gearbox.

Other new applied research projects include early-detection condition monitoring systems (CMSWIND focuses on gearboxes, generators, yaw system, and bearings), a maximum power point tracking device for small wind turbines (OPTIWIND), and a wind-wave power open-sea platform equipped for hydrogen generation with support for multiple users of energy (H2OCEAN).

2.3 Advanced research projects

Advanced research projects include the development of hardware to the point of installing a full-size prototype.

INFLOW (INdustrialization setup of a FLoating Offshore Wind turbine) objectives are: (i) to optimize the prototype developed in the previous phases, and (ii) to manage all aspects required to initiate a viable industrialization phase, in order to launch a 26-MW wind farm and to develop even larger farms in the future (150 MW by 2018). The INFLOW project relies upon the results of the first deep offshore wind turbine prototype of the VERTIWIND project, from which it draws in order to optimize blades and arm profiles of the turbine along with arm-to-blade and arm-to-mast connections. The project is a precursor for the 26-MW VertiMED demonstration project which obtained funding from NER300 (see section 2.4).

The FLOATGEN FP7 project, reported last year by Spain, started on 1 January 2013. This project is now expecting to install two floating turbines in the horizon 2016.

TROPOS (Modular Multi-use Deep Water Offshore Platform Harnessing and Servicing Mediterranean, Subtropical and Tropical Marine and Maritime Resources). The key objective of the TROPOS project is the development of a floating modular multi-use (e.g. transport, energy, aquaculture and leisure sectors) platform system for use in deep waters, with an initial geographic focus on the Mediterranean, tropical and sub-tropical regions but designed to be flexible enough not to be limited in geographic scope.

2.4 Demonstration projects

In addition to the FP7 projects a number of other European Union funds managed by the European Commission support the demonstration of innovations in first-of-a-kind wind farms. These include the European Energy Programme for Recovery (EEPR) and the New Entrant Reserve (NER300).

The offshore part of EEPR funded the following projects: the Baltic – Kriegers Flak multi-terminal HVDC connection with double purpose: wind and grid interconnection; the BARD Offshore 1 OWF with support of tri-pile foundations manufacture plus cable feed-in systems; the Borkum West II OWF with support of first 15 tripod foundations and first five turbines; the Nordsee Ost OWF installation of the new REpower 6.15-MW turbine on jacket foundations; and the Thornton Bank OWF with support of five jacket foundations. A project (new gravity foundations to significantly reduce offshore installation work) is currently pending whereas another, the Aberdeen offshore testing facility is undergoing the permitting process. Finally, two HVDC connections which will support the integration of offshore wind energy into the grid will be funded as well.

2.5 Intelligent Energy Europe

The Intelligent Energy Europe Programme promotes EU energy efficiency and renewable energy policies, with a view to reaching the EU 2020 targets by creating better market conditions for a more sustainable energy future in areas as varied as renewable energy, energy-efficient buildings, industry, consumer products, and transport. Within the renewable energy projects, wind energy is very prominent. Recently, IEE has funded projects addressed to facilitate the integration of renewable energy in electricity systems such as BESTGRID and NorthSeaGrid.

BESTGRID (Renewables Grid and Public Acceptance) aims to facilitate faster development of (high voltage) electricity grids to integrate renewable energies by increasing public acceptance and speeding up permitting procedures. Through the involvement of key TSOs in UK, Belgium, and Germany, the best practices identified would be applied in 'projects of common interest' as defined in the new EU Regulation on trans-European energy infrastructure.

NorthSeaGrid (Offshore Electricity Grid Implementation in the North Sea) will be centered around three case studies for offshore interconnections integrating offshore wind energy, located in the North Sea. These case studies will be chosen through close co-operation between the consortium, the European Commission and the North Sea Countries' Offshore Grid Initiative (NSCOGI), ensuring they are both relevant to the advancement of development of an offshore grid, and that they support the work being performed by the relevant decision makers. The goal of the policy recommendations will be to facilitate efficient and timely project implementation.

2.6 Future R, D&D projects

Overall, R, D&D trends in Europe focus on:

- On- and offshore test centers
- Demonstration of floating technologies
- Large machines: esp. reduce fatigue loads and improve reliability
- HVDC demonstration plus development of technology
- Superconductor generators

New FP7 projects to start in 2013 will address the building of a new European wind atlas and the topics of innovative designs to reduce fatigue loads and improve reliability of multi-MW turbines, advanced aerodynamic modeling, design and testing for large rotor blades, small to medium size wind turbines, and large-scale demonstration of innovative transmission system integration and operation solutions for (inter)connecting renewable electricity production, and innovative transport and deployment systems for the offshore wind energy sector.

3.0 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 will be launched this year covering the 2013–2015 period.

The European Wind Initiative, will integrate the following elements:

1. 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

2. Putting an automated wind manufacturing capacity in place

3. 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 on and off-shore wind electricity, and

4. Accelerating market deployment through a deep knowledge of wind resources and a high predictability of wind forecasts.

4.0 European Commission Contacts

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5.0 The European Wind Energy Technology Platform

5.1 Description

The European Wind Energy Technology Platform (TPWind) was officially launched on 19 October 2006, with the full support of the EC and the European Parliament. TPWind is an industry-led initiative. The Secretariat is composed of the EWEA, GL Garrad Hassan, and the Technical University of Denmark (DTU Wind). Its objectives are to identify and prioritize areas for increased innovation, new and existing research, and development tasks and formulate 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 has an Advisory Board composed of external stakeholders that acts as a quick access point to the expertise and know-how developed by other sectors, which is 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. Altogether, TPWind is composed of approximately 200 high-level experts representing the whole wind industry.

5.2 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 2008);

• 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 EC in 2009 and is now being implemented by EU institutions, Member States, TPWind, and the EERA. The budget of the EWI for the 2010-2020 period is 6 billion EUR (7.9 billion USD), composed of both public and private resources;

• A Training Report, looking at skills' gap in the EU wind energy sector and potential corrective actions. The report is expected to be launched in the summer of 2013. Its main findings and recommendations were presented at EWEA 2013 wind energy exhibition and conference, held on 4–7 February 2013 in Vienna.

5.3 TPWind Secretariat contact

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References:

(1) http://ec.europa.eu/clima/news/docs/c_2012_9432_en.pdf

Source: Tuuliwatti

21 Finland

1.0 Overview

In Finland, 32% of electricity consumption was provided by renewables in 2012. Finland's generating capacity is diverse. In 2012, 26% of gross demand was produced by nuclear, 20% by hydropower, 27% from combined heat and power (coal, gas, biomass, and peat), 7% from direct power production from mainly coal and gas, and 20% from imports. Biomass is used intensively by the pulp and paper industry, raising the share of biomass-produced electricity to 12% in Finland. The electricity demand, which is dominated by energy-intensive industry, was 85 TWh in 2012.

Finland aims to increase the share of renewables from 28.5% to 38% of gross energy consumption to fulfill the EU 20% target by 2020. The national energy strategy foresees biomass as providing most of the increase in renewables. Wind power is the second largest source of new renewables in Finland, with a target of 6 TWh/yr by 2020. The new energy strategy set a target of 9 TWh/yr for 2025.

A market-based feed-in system with a guaranteed price of 83.50 EUR/MWh (110.05 USD/MWh) entered into force in 2011. There will be an increased tariff of 105.30 EUR/MWh (138.80 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 2012, 90 MW were installed, reaching a total of 288 MW at the end of year, producing about 0.5 TWh, or 0.6% of gross demand in Finland. At the beginning of 2012, there were 5,900 MW of wind power projects in various phases of planning onshore and 3,000 MW of announced projects offshore.

Wind power technology in Finland employs more than 2,000 persons mainly in component and sub-system manufacturing (Moventas, ABB, The Switch, Hydroll), sensors (Vaisala and Labkotec) and material production (Ruukki, Ahlstrom). There are two Finnish wind turbine manufacturers, WinWinD and Mervento, producing multi-MW turbines. 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) in 2020. This would be about 6% of the total electricity consumption in Finland. This reflects the increased targets for renewables arising from the EU target of 20% of energy consumption from renewable sources in 2020. The target for Finland is 38% of final energy consumption by Renewable Energy Sources (RES) (current RES share 28.5%). The new energy strategy published at the beginning of 2013 has an increased target of 9 TWh/yr in 2025.

2.2 Progress

The development in wind power capacity and production is presented in Figure 1. In 2012, there were seven wind farms installed: six 3-MW turbines in Simo, two 1.8-MW turbines in Huittinen, four 2-MW turbines in Hamina, one 2-MW turbine in Kemi, eight 3-MW turbines in Ii, ten 3-MW turbines in Tervola, and one 3.6-MW pilot plant in Vaasa. Several other wind farms are in the building phase, so the new installed capacity during 2013 will be 120–130 MW.

At the end of 2012, the total capacity was 288 MW and 162 wind turbines were operating in Finland (Figure 2). The average wind turbine size installed in 2012 was 2.8 MW, and for the total installed capacity the average is 1.8 MW. About 26% of the

The wind power target in Finland is 6 TWh/yr by 2020 and 9 TWh/yr in 2025 (9% of electricity consumption).

Table 1. Key National Statistics 2012: Finland	
Total installed wind capacity	288 MW
New wind capacity installed	90 MW
Total electrical output from wind	0.49 TWh
Wind generation as % of national electric demand	0.6%
Average capacity factor	24%
Target:	6 TWh/yr by 2020; 9 TWh/yr by 2025

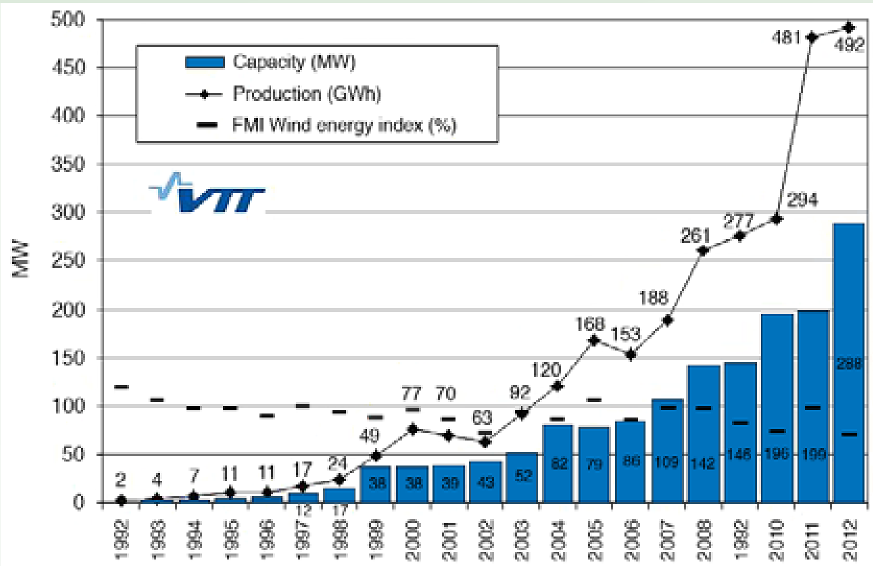


Figure 1. Wind power capacity and production: FMI Wind energy index is calculated from Finnish Meteorological Institute (FMI) wind-speed measurements and converted to wind power production; 100% is average production from 1987 to 2001.

capacity is from turbines originating from Finland, 55% from Denmark, 13% from Germany, 4% from South Korea, and 2% from the Netherlands (Figure 3). Turbine sizes range from 75 kW–3.6 MW. In early 2013, there were already 21 MW installed.

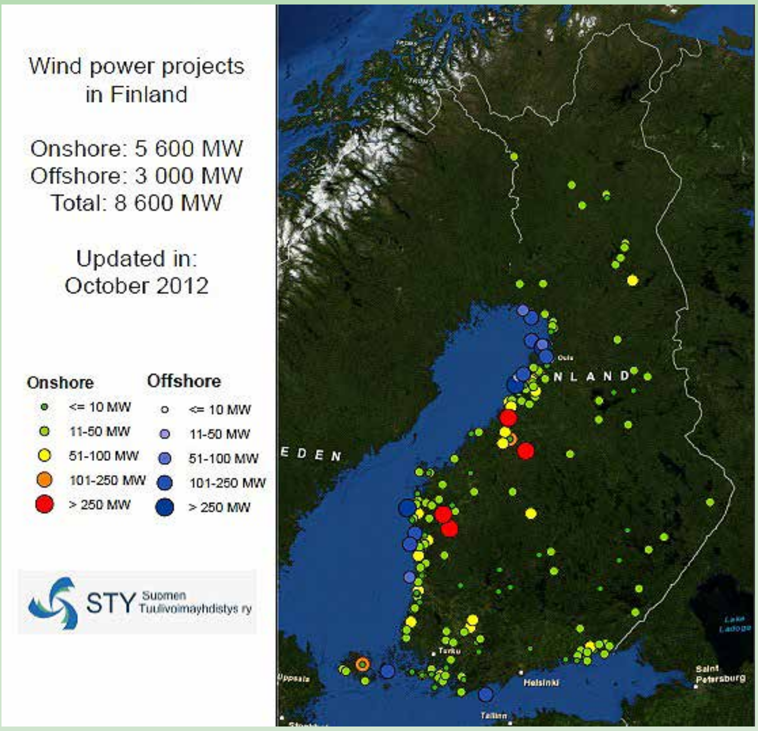
Most of the new wind farms began operation late in 2012, and the wind resource was only 88% of an average year (Figure 1). As a result, production increased only 2%, to 492 GWh. This corresponds to 0.6% of the annual gross electricity consumption of Finland (Table 1). The environmental benefit of wind power production in Finland is about 0.3 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 21% of electricity consumption in 2012 with 22 MW of installed capacity. However, the region is still waiting to be included in the price guarantee mechanism so that investments can be planned for new wind power plants. A 100-MW transmission line to mainland Finland was contracted to be completed in 2015, and this will help deployment of wind power in this wind-rich region.

2.3 National incentive programs

A feed-in premium entered into force on 25 March 2011 in Finland. Previously, an investment subsidy scheme with limited amount of funds was available, with a tax refund of 6.90 EUR/MWh (8.90 USD/MWh). The small tax award subsidy (for older projects) was stopped in 2011.

The feed-in premium scheme means that a guaranteed price of 83.50 EUR/MWh (110.05 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. A higher guaranteed price level of 105.30 EUR/MWh (138.80 USD/MWh) until the end of 2015 encourages early projects. A three-month average spot price (day-ahead electricity market price at the Nordic market Elspot) will be the comparison price



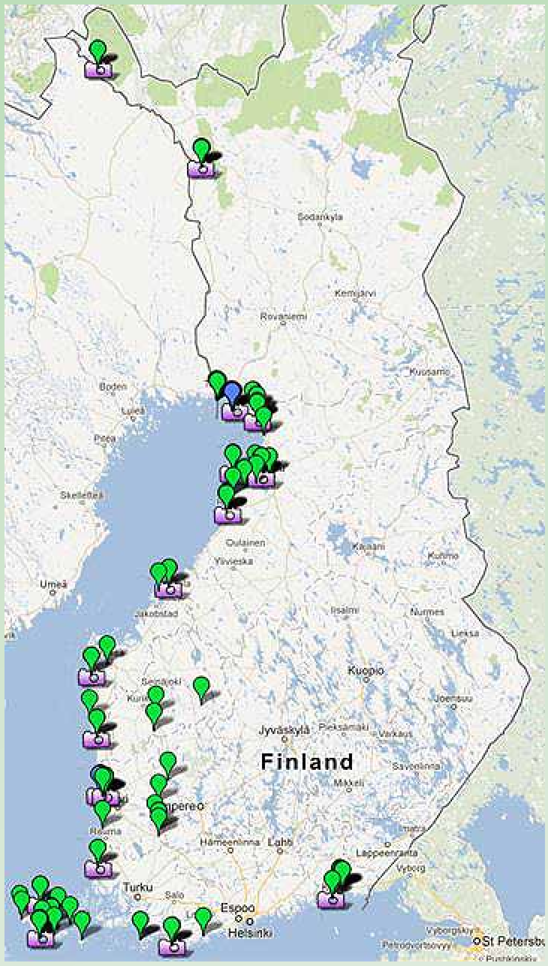


Figure 2. Wind turbines operating in Finland by the end of 2012 (right) and wind power projects published (left)

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. If the average spot price rises above the guaranteed price, the producers will get this higher price. If the price is 0, the producers will not get payments. Shutting down wind power plants will help the power system in cases of surplus power production. These situations have only happened in Denmark where wind shares are larger than are planned for Finland. Wind power producers will also be responsible for paying the imbalance fees from their forecast errors. This has been estimated to add 2.00–3.00 EUR/MWh (2.63–3.95 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, the payments for this subsidy will be reduced because the producers will get more from the electricity markets. The Energy Market Authority is the regulator managing the system.

A special subsidy for offshore wind power will still be considered. A tender for an investment subsidy for the first offshore demonstration wind power plant is planned for autumn, 2013. A 20 million EUR (26 million USD) demonstration subsidy is included for an offshore wind farm in the budget frame in 2015.

2.4 Issues affecting growth

The progress in wind power capacity in Finland was slow up until 2011, due to lack of subsidy system to enable large scale building. 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. At the beginning of 2012, there were 205 wind power projects totaling 5,900 MW in various phases of planning onshore, and 16 announced projects offshore totaling 3,000 MW. The guaranteed price is not sufficient to start offshore projects. Tender for first demonstration offshore wind project is planned for 2013.

Permitting has proved to be a challenge for many of the planned projects. Concerns have been raised about birds (especially eagles) and bats, safety distances to roads, railways and airplane landing zones, radar, and low frequency noise. The planning process with environmental impact assessment is considered lengthy by developers. To overcome planning and permitting problems, the Ministry of Economy and Employment appointed an investigator Justice Lauri Tarasti. He proposed improvements in April 2012, and already some of the measures have been taken.

1. To improve local acceptance: Increase the municipality´s incomes through real estate taxes; Pay compensation to the landowners in the neighborhood (within 500 m) as well as paying rent to the landowner where wind plant is located.

2. To overcome airport limitations: Allow exception permits for Aviation Act limitations for wind turbines in the vicinity of commercial airports. These limitations include a safety area—the runway must have 30 km (lengthwise) and 12 km (widthwise) = 360 km^2, and a flexibility area: a radius of 40 km round the airport = about 5,000 km^2—these cover 1/3 of Finland´s surface; The Ministry of Traffic and Communication has acted to relieve limitations, now the

safety area is only 15 km lengthwise and 6 km widthwise.

3. To reduce impact on radar systems: Radar influence became an issue in 2010 stopping all building permits until a procedure and modeling tool was developed in 2011 to help the Ministry of Defense to estimate the impacts. By February 2013, 118 sites were given permission from radar interference point of view, and 20 sites received a negative decision. In another approach, a working group has investigated necessary changes to radars. New radar for the Raahe municipality has been proposed (20 million EUR; 26 million USD) and similar solution for South-East Finland. Sharing of financial costs between the government and wind power developers is under negotiation.

4. To reduce objections to noise from about 500,000 summer cottages: Follow the same planning guideline values for noise as in Sweden (35–40 decibels) but apply them flexibly, because these values are not norms but recommendations; If a wind turbine is <500 m from a house, specify in the building permit that turbines will be stopped or operated at lower speeds during the main holiday season (from midsummer to early August) if the strength of wind is less than 8–10 m/s; Apply measurement guidelines for sound being developed in a project funded by Ministry of Environment.

5. Processes in planning authorities: Combine the processes of wind power general plan and environmental impact assessment; Allow exception from the plan to build wind turbines in industrial, harbor, or mining areas; Reduce required distance between wind turbines and roads/railways (use the model from Sweden); Forbid the extension of a complaint from the decision of the regional administrative court to the Supreme administrative court if original and regional court decisions are compatible.

A working group has been established to follow-up on the work of Investigator Tarasti towards addressing barriers to wind energy. All regional plan updates by the authorities are adding sites for wind power plants. This will help in permitting future wind power projects. The Ministry of Environment revised the guidelines for planning and building permission procedures for wind power in 2012. Currently the ministry is revising the guidelines for wind power noise modeling and measuring. It is also updating the guidelines for impacts on birds and land scape in 2013 and 2014.

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 2,000 people. More than 100 companies are involved in the whole value chain from development and design of wind farms to O&M and other service providers.

Maintaining the 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 wind power is estimated to create employment of at least 12,000 person-years.

3.2 Industry status

3.2.1 Manufacturing

The Finnish manufacturer WinWinD has been in the market since 2001. Their 1- and 3-MW turbines operate at variable speed with a slow speed planetary gearbox and a low-speed, permanent-magnet generator. By the end of 2012, WinWinD had installed 314 MW in seven countries including Estonia, Finland, France, Portugal, and Sweden. WinWinD has manufactured 25% (73 MW) of the installed wind power capacity in Finland (Figure 3).

In 2009, a new turbine manufacturer, Mervento, started to develop its first prototype that is especially designed for offshore applications. The 3.6-MW direct-drive pilot turbine was erected early in 2012 and has a guyed tower. Mervento is planning an assembly line in Vaasa with annual capacity of 100 nacelles. Mervento's long-term goal is to be a global actor in the wind energy sector. It is currently seeking capital funding.

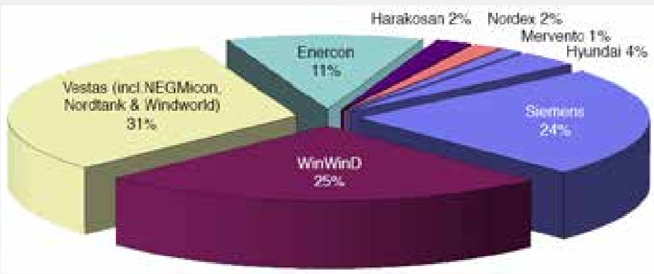


Figure 3. Market shares of turbine manufacturers in Finland as a percentage of total capacity at the end of 2012 (288 MW)

Several industrial enterprises have developed as world suppliers of components for wind turbines. For example, Moventas is the largest 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 for wind turbine applications, including harsh conditions. In addition, materials such as cast-iron products, tower materials (Rautaruukki), and glass-fiber products (Ahlstrom Glasfiber) are produced in Finland for the main wind turbine manufacturers. Sensors especially for icing conditions are manufactured by Vaisala and Labkotec. Bladefence offers inspection, repair, and maintenance of wind turbine blades also in harsh environments. STX Finland has developed foundation solutions for ice infested waters.

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.

Most of the turbines have been located along the coast but new projects are seen also in the forested inland locations. Inland sites are using towers up to 140 m. The supply of used turbines has encouraged some farmers to acquire second-hand turbines, but at heights below 60 m the wind resource is limited inland due to forested landscape.

The first semi-offshore projects were built in 2007. Total offshore capacity is 24 MW. Environmental impact analyses have begun for several larger offshore wind power plants and the first of them (Suurhiekka, 288 MW) received a building permit according to the water act early in 2011. Six other offshore projects (almost 1,200 MW) have finished their environmental impact assessments. The first offshore demonstration will need extra subsidies to be realized, and the tendering process for 20 million EUR (26 million USD) of investment will probably enable a mid-size demonstration in 2014–15.

3.3 Operational details

The average capacity factor of wind turbines operating in Finland was 24% in 2012. The capacity factor has ranged from 17–28% in previous years. The wind resource in 2012 was much lower than in 2011, and the wind power production index ranged from 86–103% of normal in different coastal areas in Finland (turbine capacity weighted average 87%). As reported in the annual wind energy statistics of Finland, the capacity factor of the MW-size turbines is considerably higher than for turbines less than 50 m high. Higher turbines produce significantly more in the forested landscape of Finland. The average availability of wind turbines operating in Finland was 89% in 2011, compared to 89% to 96% in 2001 to 2011.

3.4 Wind energy costs

For the feed-in tariff (FIT) working group in 2009 the cost of wind energy production was estimated for coastal sites in Finland to range between 60–80 EUR/MWh (79–105 USD/MWh) without subsidies. This calculation assumes 2,100–2,400 h/a full load hours for yearly average production; 1,300–1,400 EUR/kW (1,713–1,845 USD/kW) investment cost; 20 years, 7% internal rate of return; and 26–28 EUR/kW/yr (34–37 USD/kW/yr) O&M cost. A balancing cost of 2.00 EUR/MWh (2.60 USD/MWh) was assumed—this would apply for 2010 prices for distributed wind power production; for a single site, the cost would be 3.00 EUR/MWh (3.90 USD/MWh). The estimated cost of offshore production could exceed 100.00 EUR/MWh (131.80 USD/MWh).

The average spot price in the electricity market Nordpool was 37 EUR/MWh (48 USD/MWh) in 2012 (49 EUR/MWh; 65 USD in 2011). Wind power still needs subsidies to compete even on the best available sites and the guaranteed price system has been introduced to open the onshore market.

All wind energy installations are commercial power plants and have to find their customers via a free power market. In most cases, an agreement with a local utility is made that gives market access and financial stability. The new guaranteed price, feed-in premium for wind energy fits the Nordic electricity markets, as the producers will sell their energy in the market or by bilateral contracts, and account for the balancing costs for their production.

4.0 R, D&D Activities

4.1 National R, D&D efforts

The Finnish Funding Agency for Technology and Innovation (Tekes) is the main public funding organization for research, development, and innovation in Finland. Tekes funds R&D and innovation activities by companies and research organizations registered in Finland. Tekes invested 552 million EUR (727 million USD) in R&D projects in 2012, of which energy an environment sector takes about 40%.

Tekes funding for wind power in the last seven years is presented in Figure 5. Tekes granted close to 2 million EUR (2.6 million USD) in wind power R&D projects in 2012. Since 1999, Finland has not had a national research program for wind energy. Individual projects can receive funding from Tekes, and some projects are linked to the research programs Groove, Serve, and Concepts of Operations. Benefit to industry is stressed, as is the industry's direct financial contribution to individual research projects. Tekes is the main source of funding for Finnish co-operation with IEA.

In January 2013, 21 ongoing wind power connected R&D projects were funded by Tekes, most of them industrial development projects. The main technologies were power electronics, generators, permanent-magnet technologies, gearboxes, wind turbines (large

Figure 4. Olhava wind power plant. (Source: Tuuliwatti)

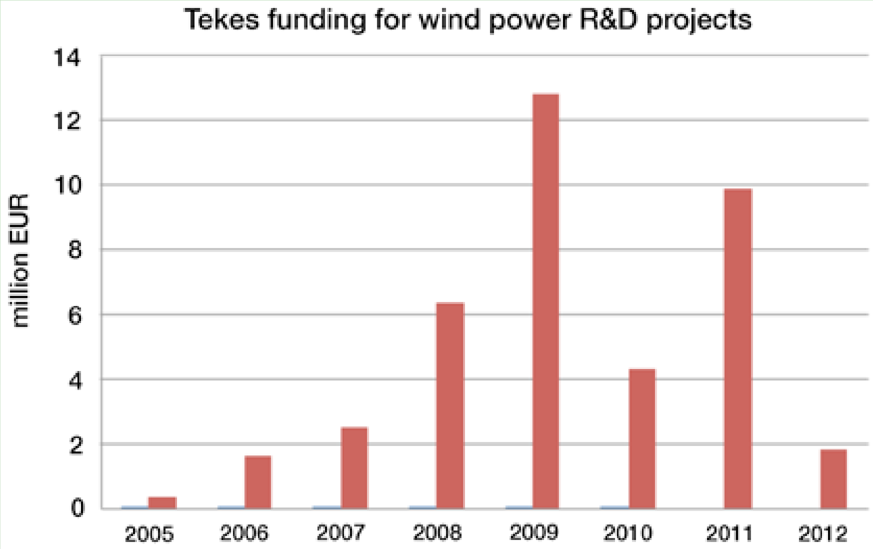


Figure 5. Tekes funding for wind power R&D projects in the last eight years

and small), sensors, blade manufacturing, foundry technologies, construction technologies, automation solutions, offshore technology, and services.

The wind atlas, launched by FMI in 2010 was amended by adding an icing atlas in March 2012. The icing atlas includes monthly average values for time of instrumental icing, time of structural icing, and production losses due to icing.

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. Several technical universities also carry out R&D projects related especially to electrical components and networks (including Lappeenranta, Tampere, Vaasa, and Aalto).

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 utility system services being provided from wind power are studied to help wind integration. VTT is participating in two new Nordic Energy Research projects—Offshore DC Grid and IceWind.

Finland is taking part in the following IEA Wind research tasks with VTT:

- Task 11 Base Technology Information Exchange
- Task 19 Wind Energy in Cold Climates (operating agent)
- Task 25 Power Systems with Large Amounts of Wind Power (operating agent)
- Task 30 Offshore Code Comparison Collaboration Continuation OC4

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.

5.0 The Next Term

Approximately 120–130 MW of new capacity is anticipated for 2013 for Finland, as projects try their best to get as many years as possible of operation at the higher guarantee price period, which expires at the end of 2015. A huge number of projects are planned, under feasibility studies, or have just been proposed: 5,600 MW onshore and 3,000 MW offshore.

Large wind turbine pilot projects are expected to be developed and built, including turbines with high towers and larger diameters. The blade heating system developed in Finland is now in commercialization. Further research and development in this area will continue.

The statistics of wind power in Finland can be found at www.vtt.fi/windenergystatistics.

References:

Opening photo: inauguration ceremony of the Olhava wind power plant with the god children of the turbines. Each turbine has been named for a child.

Authors: Hannele Holttinen and Esa Peltola, VTT Technical Research Centre of Finland, Finland.

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The use of wind energy in Germany has avoided 35.8 million tons of greenhouse gas emissions in 2012.

Table 1. Key National Statistics 2012: Germany (1) (2)	
Total installed capacity	31,315 MW
New wind capacity installed	2,440 MW
Total electrical output from wind	46.0 TWh
Wind generation as % of national electric demand	7.7%
Average capacity factor	---
Target:	35% of electrical energy consumption by renewables and 10 GW offshore wind by 2020; 80% electrical energy consumption by renewables in 2050

1.0 Overview

Wind energy continues to be the most important renewable energy source in Germany in medium term. Within the German federal government, the Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU) is in charge of renewable energy policy as well as of the funding of research for renewable energies.

The share of renewable energy sources in Germany's gross electricity consumption rose significantly in 2012 to reach 22.9%. This represents an increase of nearly two and a half percentage points against the previous year (20.5%). At 136 billion kWh, electricity generation from solar, wind, hydro, and biomass was around 10% higher than in 2011. This upward trend was largely due to the sharp increase in electricity generation from photovoltaic systems. Biogas was another growth area, and generation from hydropower increased from the previous year due to high rainfall.

Relatively poor wind conditions led to a decline in electricity generation from wind (2012: 46 TWh; 2011: 48.9 TWh) despite of the fact that 2012 also saw a strong upward trend in the expansion of wind energy capacity, and 675 MWh were generated by offshore wind. Construction of new turbines added 2,440 MW, a clear increase from the previous year (2,007 MW). Repowering measures accounted for 541 MW, while installations with a capacity of 196 MW were dismantled, giving a net capacity in 2012 of 2,244 MW. At the end of the year total installed wind capacity in Germany was nearly 31,315 MW, of which 280 MW were offshore (1).

Nevertheless, with a share of 7.7% (2011: 8.1%) wind energy maintained a strong position as the main source of renewable electricity. The share of offshore wind energy remained still low in 2012, at 1.5% of total wind power generation. Even so, the offshore generation was around 19% more than in the previous year (1).

In 2012, a breakthrough took place in offshore installations. At the end of 2012, six wind farms with 350 wind turbines and a total capacity of 1,700 MW were under construction in the German Exclusive Economical Zone (EEZ) of the North Sea (2). Including the wind farms projects starting construction in 2013 and 2014, a total offshore capacity of about 3,000 MW will be installed in 2015 (3).

The use of wind energy has avoided 35.8 million tons of greenhouse gas emissions in 2012 (3).

An important issue that will further influence wind energy development and grid technology during the next ten years is the federal government's decision to phase out completely nuclear energy production by 2022.

2.0 National Objectives

2.1 National targets

In September 2010, the German federal government decided on a new energy concept. The scenarios upon which the energy concept is based show that in 2050 wind energy will play a key role in electricity generation (4). The energy concept consequently emphasizes the expansion of onshore and offshore wind energy and explicitly formulates the target of 25 GW of offshore wind power installed by 2030. More general policy objectives are to increase the share of renewables in electrical energy consumption to 50% by 2030, 65% by 2040 and up to 80% by 2050 (4).

2.2 Progress

The wind capacity development in Germany is shown in Figure 1. The main difference from the previous years is the considerable growth in repowering capacity and the highest total new installed capacity since 2004.

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 in the German Parliament voted for an amendment of the EEG, which became active from 1 January 2012.

For onshore wind, the premium tariff is 89.3 EUR/MWh (117.7 USD/MWh). In order to further stimulate cost reductions the

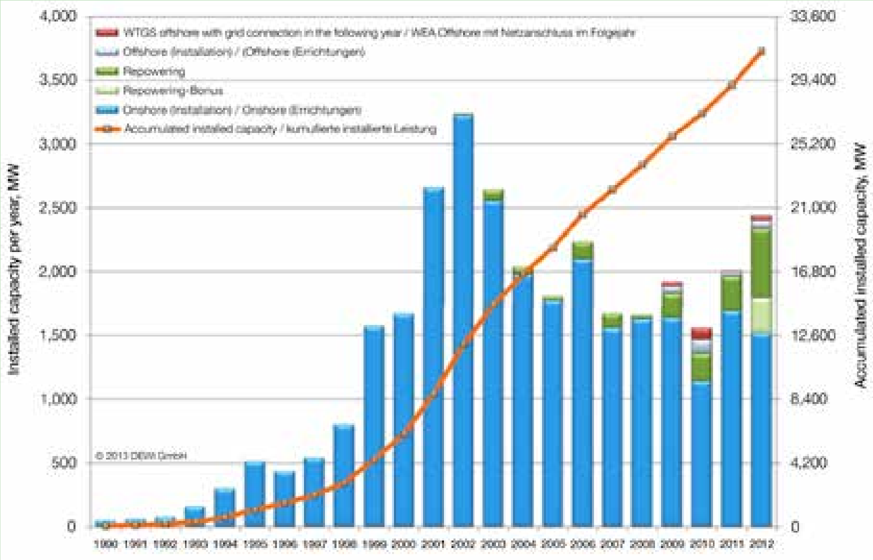

Figure 1. New installed capacity per year and accumulated wind energy capacity since 1990 © 2013 DEWI GmbH (5)

degression amounts to 1.5%. The Repowering Bonus (5 EUR/MWh; 6.6 USD/MWh) as well as the Ordinance on System Services by Wind Energy Plants (5 EUR/MWh; 6.6 USD/MWh) stayed the same. The latter one will be prolonged by one year, meaning that any project connected to the grid before 2015 is eligible.

The tariff for offshore wind energy is 150 EUR/MWh (198 USD/MWh) including the Sprinter-Bonus of 2 EUR/MWh (2.6 USD/MWh) if the turbine was connected to the grid before 1 January 2016. Due to delays in project starts the degression was postponed by three years and will only become active from 2018. In return the degression increased from 5% to 7%. To stimulate investments in offshore wind energy an optional, no additional costs compression model was introduced. Instead of 150 EUR/MWh (198 USD/MWh) for a period of 12 years, operators of offshore wind farms may chose 190 EUR/MWh (250 USD/MWh) for a period of just eight years.

2.4 Issues affecting growth

The electricity grid expansions turned out to be a major issue affecting the growth. For offshore wind energy, the situation became critical when the Transmission System Operator (TSO) responsible for connecting the offshore wind farms in the North Sea announced serious problems in realizing all offshore grid connections in due time. Task forces such as the working group "Acceleration" consisting of all relevant stakeholders had been implemented to work out possible solutions. As a result, the German Parliament adopted in December 2012 the Third Act Revising the Legislation Governing the Energy Sector (EnWG). According to this act, a wind farm operator that did not receive the grid connection in time after the wind farm was finally constructed (or experiences a severe grid failure) can claim 90% of the missed EEG feed-in–tariff (FIT) from the TSO. Depending on the degree of its own responsibility for the delay the TSO may spread these compensation costs to all other TSOs (equalization of burden) and finally pass them to the electricity end-consumer. According to §17f, No. 5 EnWG the resulting extra tariff for the end-consumer is limited to a maximum of 0.0025 EUR/kWh (0.0033 USD/kWh, and 0.0005 EUR) kWh (0.000659 USD/kWh) for energy intensive companies (6).

Furthermore, the EnWG regulates that TSOs have to develop a yearly offshore grid development plan to be approved by the Federal Network Agency and become a part of the Federal Network Demand Plan. This new regulation is an important contribution to improve security for offshore investments and planning conditions for TSOs.

3.0 Implementation

With an added capacity of 2.44 GW, 2012 has been the fourth most successful year with respect to wind power installation. The sector employs approximately 100,000 people and is an important part of the German economy. However, uncertainties with respect to grid expansion led to delays of offshore projects.

3.1 Economic impact

Investment in wind energy in Germany was 3.75 billion EUR (4.89 billion USD) in 2012, an increase of 27.1% compared to the previous year. At the same time, the additional turnover from wind turbine operations increased just by 2.1% to a less constant 1.43 billion EUR (1.86 billion USD) (1).

With an export share of well above 60%, the 2012 production volume of German manufacturers (domestic and export) is above 9.38 billion EUR (12.21 billion USD).

The number of turbine manufactures stayed constant in 2012. However, due to the financial crisis and resulting project delays some of the companies even had to file for insolvency in order to recapitalize and get back on a sound track.

3.2 Industry status

The diversity of owners and operators of wind projects is clearly divided between land-based and offshore wind energy. While onshore wind energy is owned and operated by a broad mix of utilities, cooperatives, and investors, offshore wind energy is dominated by utilities. Nevertheless different models of participation exist for offshore too.

The turbine manufacturers market shares of newly added capacity varied slightly. Compared to the previous year Bard (+2.2%), Vestas (+2.1%), and Repower Systems (+0.9%) gained share. Now e.n.o. energy and Vensys are listed with 1.4% and 1.1% respectively (Figure 2). A part of these market shares came at the expense of the market share of Enercon (-5.2%) and Nordex (-0.4%) (5).

The German market leader, Enercon, had its best year ever. In 2012, Enercon installed 1,647 wind turbines worldwide (565 in Germany) with an aggregated capacity of more than 3.5 GW (1.3 GW in Germany) (7.1). As of 1 October 2012 Enercon owner Wobben transferred all his shares to the Aloys-Wobben-Foundation (7.3). Also in

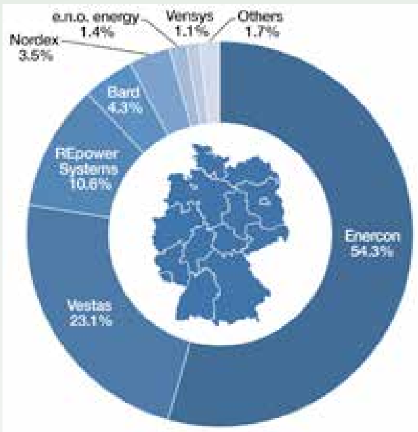

Figure 2. Market shares by manufacturer of newly installed wind capacity in 2012, source DEWI (5)

2012 Enercon started to build its new research and development center, giving space for 400 R&D employees, and test bays for generators and rotor blades (7.2).

REpower acquired the remaining 49% stake in PowerBlades, a joint venture company of REpower and SGL Rotec, which produces rotor blades for wind turbines and is now the single owner of PowerBlades (7.4).

3.3 Operational details

The energy provided from installed wind energy capacity dropped by 5.9% to 46 TWh, compared to the previous year (1). However, the overall trend of the average capacity factor is positive, see Figure 3.

The construction of the offshore wind park Riffgat began in summer 2012. Riffgat is one of the very few German projects within the 12-mile-zone. When finished in 2013, the 30 Siemens 3.6-MW turbines will provide green electricity for approximately 100,000 households. Further offshore wind farms under construction in 2012 were Bard Offshore I (400 MW), Borkum West II Phase I (200 MW), Global Tech I (400 MW), Meerwind Süd/Ost (288 MW), and Nordsee Ost (295 MW).

The averaged power of turbines added in 2012 (on- and offshore) increased to 2.4 MW/unit. Almost all newly installed turbines (98.55%) belong to the +2-MW class (Figure 4). Accordingly, the average hub height increased to 111.48 m, with a broad spread from 81.0 m in the North up to 133.5 m in the South (8) (9).

The most powerful commercially available wind turbines from German manufacturers are the Enercon 126 with a capacity of 7.58 MW and a rotor diameter of 127 m, followed by the REpower 6M with a capacity of 6.15 MW and a rotor diameter of 126 m.

3.4 Wind energy costs

Exact figures for the costs of wind energy projects are very difficult to obtain and depend very much on practical project conditions. The estimated costs for pioneer offshore wind parks currently under construction vary considerably. However, steep learning curves, higher capacity factors, and accompanying research activities will help to make offshore wind energy a competitive success.

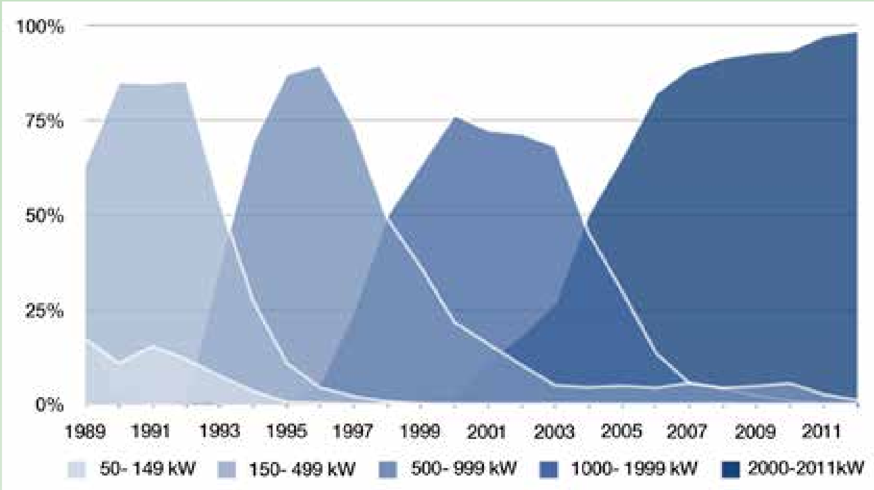

Figure 4. Shares of turbine sizes (capacity) in newly added capacity. Source: IWES (8)

4.0 R, D&D Activities

4.1 National R, D&D efforts

In 2012, German wind energy research saw an outstanding increase in new R&D funds and research projects as well as in capacity building and creation of networks.

Focal areas and activities among the research funded by BMU in 2012 include:

- planning, construction and/or operation of test facilities for rotor blades, drive train, generators, power converters and offshore foundations
- development and test of new turbine conceptions (e.g. for low wind conditions)
- aerodynamic research for the development of flow control methods around blades (smart blades)
- offshore foundation technology with low sound emission during construction and methods for reducing sound emissions
- turbine control methods and improvement of operational data acquisition
- optimization of offshore logistic processes
- research at the FINO 1, 2, 3 offshore platforms, and
- research at the offshore test site alpha ventus (RAVE) (opening photo).

Results of nearly three years of research at the offshore test site alpha ventus were presented at the International RAVE-Conference in May 2012 in Bremerhaven (10).

The substantial increase in governmental funding of R&D motivated many research institutions to form networks and clusters to bundle their competencies and to apply more successfully for publically funded projects and for R&D orders from industry. A powerful research network has been composed by the Fraunhofer Institute for Wind Energy & Energy System Technology (IWES), the university compound For-Wind and the German Aerospace Centre DLR (*Wind Energy Research Alliance*). With 600 scientists involved, the network covers nearly all R&D aspects of wind energy deployment. It is equipped with appropriate research and test infrastructure such as several wind tunnels and LIDAR systems (University of Oldenburg, DLR), two rotor blade test rigs for blades up to 85 m (IWES), a high performance computer cluster (University of Oldenburg), a 300-m wave flume, a 3-D wave basin (University of Hannover), and an automated fiber placement unit (University of Bremen, DLR). Test rigs for 10-MW drive trains (IWES) and large support structure components (University of Hannover) are under construction. A first large joint research project of this Wind Energy Research

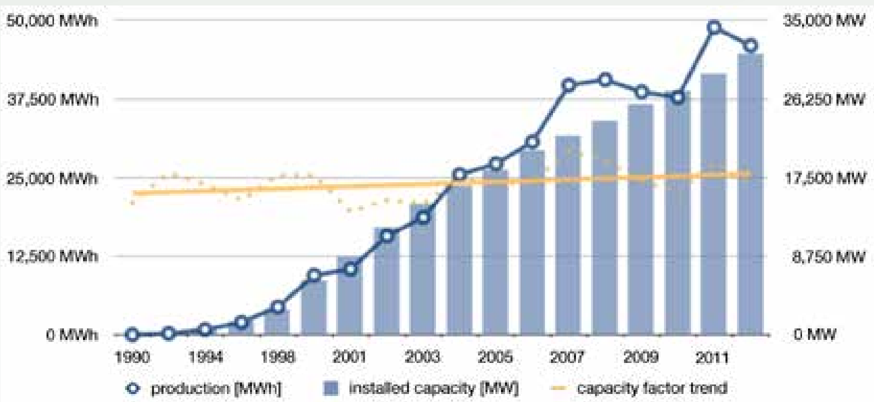

Figure 3. Annual production and cumulative installed capacity. Source: WindGuard (9)

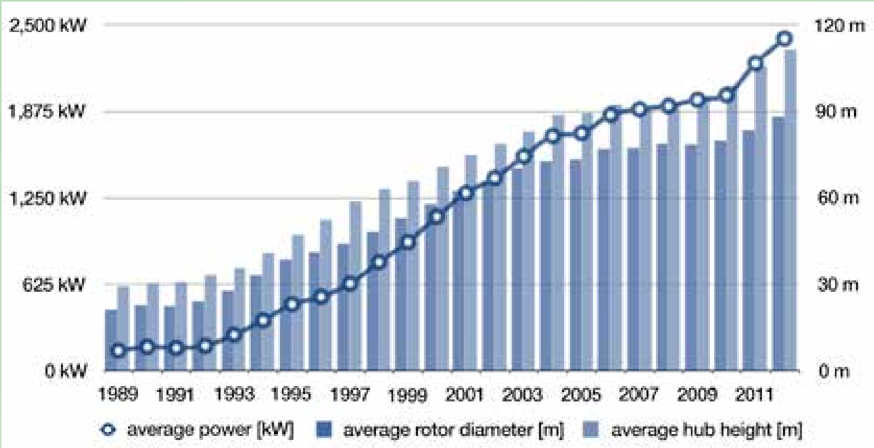

Figure 5. Features of newly added wind turbines. Source: IWES (8)

Alliance is "Smart Blades" which bundles the competencies in wind physics, aerodynamics, active flow control for blades, and turbine load management. This project is supported by the Federal Environmental Ministry by 12 million EUR (15.8 million USD) (11).

The Centre for Wind Power Drives (CWD) was founded in 2011 at the Technical University Aachen. It will be a focal point of cooperation with gear box, bearing, and turbine manufacturers. Until now, it was equipped with a 1-MW drive train test rig for research purposes. A 4-MW drive train test rig is under construction with exerted force in six degrees of freedom and with technology for grid simulation. CWD initiated a new task in IEA Wind (Task 35) for the development of good practices for tests of large wind turbine components. This international cooperation was established in February 2013 (12).

The Competence Centre for Wind Energy Berlin (WIB) comprises the Technical University Berlin, the Federal Institute for Materials Research and Testing (BAM), and the University for Technology and Economics Berlin (HTW). It features laboratories for material testing, large component testing, wave flume, measuring equipment for pile-soil interaction, and long-term foundation stability testing. Key aspects of research are, among others, pile soil interaction and pile stability, condition monitoring systems, sensor based blade material testing, and development of large foundation components (13).

WindForS is the Wind Energy Research Network South performed by the University Stuttgart, University Tübingen, the Karlsruhe Center of Technology (KIT), the Technical University Munich, and others. Research topics are wind energy in complex terrain, wind physics and wind field characterization, load management, LIDAR wind measurement, soil mechanics, data analysis from alpha ventus measurements, and development of design tools for offshore wind turbines as well as wind-PV storage systems (14).

CEwind e.G. concentrates on wind energy research of universities and other research entities in the northern state of Schleswig-Holstein. R&D topics are aerodynamics, small wind turbines, environmental impact analysis of offshore wind farms, scour dynamics, and research activities at the two FINO offshore research platforms located in the North Sea (15).

More information on wind energy research funded by the Federal Environment Ministry can be found at

(http://www.erneuerbare-energien.de/die-themen/forschung) and

(http://www.forschungsjahrbuch.de).

4.2 Collaborative research

German scientists and experts from industry participate actively in 12 IEA Wind tasks. Four tasks are chaired or co-chaired by German researchers. In 2012, a new IEA Wind Task, Full-Size Ground Testing for Wind Turbines and Their Components (Task 35) has been proposed by the Technical University Aachen together with NREL, Clemson University, DTU, IWES and NAREC in 2012. The work plan was approved at the ExCo 71 meeting in early 2013. The aim of this task is to develop recommendations and good practices for drive train and rotor blade testing.

IWES concluded a Memorandum of Understanding with the Norwegian NORCOWE research center in 2012 on exchange of meteorological and oceanographic data and information on ongoing offshore research activities.

5.0 The Next Term

Results and experiences of long term research at the three FINO offshore research platforms will be presented at the FINO-Conference scheduled for late 2013 in Kiel.

The German Maritime and Hydrographic Agency announced the International Offshore Conference: Five Years of Research at alpha ventus - Challenges, Results and Perspectives. It will take place on 30–31 October 2013 at the Lower Saxony State Chancellery, Berlin.

The scope will include:

• Lessons learnt from five years of environmental monitoring and research on ecological effects at the offshore wind farm alpha ventus

• A program of leading scientists of renowned German research institutes covering effects of offshore wind energy development to fish, benthos, birds, and marine mammals (16).

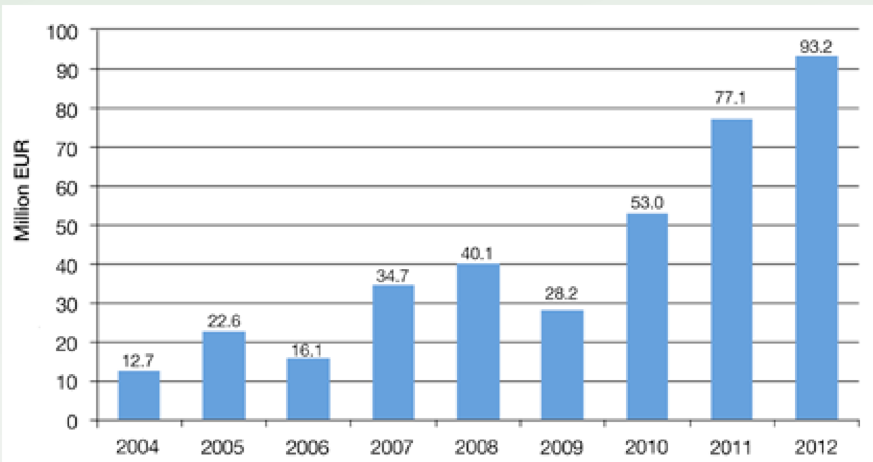

Figure 6. Annual funds spent by BMU for the support of new projects. Data from BMU

References:

(1) Renewable Energy Sources 2012, Data from the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) on trends in renewable energy in Germany in 2012, Provisional data (AGEE-Stat); valid as at 28 February 2013, p. 4-5; http://www.erneuerbare-energien.de

(2) BWE and VDMA-PS at http://www.wind-energie.de/presse/pressemitteilungen/2013/jahresbilanz-windenergie-2012-stabiles-wachstum-deutschland-im

(3) Theses of the 3rd EEG-Dialog "Wind Energy – the central column of the Energy Transformation", p. 2; http://www.erneuerbare-energien.de/die-themen/gesetze-verordnungen/eeg-dialog/3-eeg-dialogforum

(4) Energy Concept for an Environmentally Sound, Reliable and Affordable Energy Supply,

http://www.bmu.de/english/energy_efficiency/doc/46516.php

(5) Ender, Carsten: Wind Energy Use in Germany - Status 31.12.2012; DEWI-Magazin (2013) Nr. 42, S. 31-41

(6) Energiewirtschaftsgesetz (EnWG), Teil 3 - Regulierung des Netzbetriebs, Abschnitt 2 – Netzanschluss, §§ 17e bis g

(7.1) WINDBLATT 01/13, p. 4 http://www.enercon.de/en-en/205.htm

(7.2) http://www.enercon.de/p/downloads/PM_Spatenstich_FE_Zentrum_en.pdf

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(13) http://www.wib.tu-berlin.de

(14) http://www.windfors.de

(15) http://www.cewind.de/de/organisation

(16) Any questions about the International Offshore Conference should be directed to anika.beiersdorf@bsh.de.

Authors: Joachim Kutscher, Forschungszentrum Juelich GmbH, ETN; Stephan Barth, ForWind Center for Wind Energy Research, Germany.

23 Greece

Courtesy: Iberdrola

1.0 Overview

In 2012, 117 MW of new wind capacity were installed in Greece (Table 1). The total installed wind capacity is 1,749 MW, a 7% increase from 2011. There are 121 wind farms in Greece. Almost 150 million EUR (197 million USD) was spent in the wind energy industry in 2012 (1).

The Hellenic Wind Energy association (HWEA) still expects roughly 150 MW of new capacity could be added in Greece in 2013 after capacity increased 117 MW to 1,746 MW in 2012. 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.

Table 1. Key National Statistics 2012: Greece	
Total installed wind capacity*	1,749 MW
New wind capacity installed*	117 MW
Total electrical output from wind**	2.714 TWh
Wind generation as % of national electric demand**	4.0%
Average capacity factor	27.5%
Target:	7,500 MW by 2020
*Global Wind Energy Council Global Wind Statistics 2012. ** Data from 2011	

In 2012, Greek wind energy installations were outpaced by solar photovoltaic (PV) power, which saw more than 1,000 MW in new capacity installed. Investors focused on PV projects due to an attractive incentive price and a 31 December 2012 grid connection deadline for receiving the most generous tariffs. The new 10% tax was initially only for PV projects but was extended to cover wind as well (2).

References:

Opening photo: Skopies wind farm. Courtesy: Iberdrola

(1) www.investingreece.gov.gr/

(2) www.windpowermonthly.com/

24 Ireland

1.0 Overview

Ireland's official commitment to achieving ambitious 2020 renewable electricity targets primarily from wind power remained unchanged in 2012. A significant challenge in 2012 was the proposed implementation of arrangements for curtailment of wind farms. The associated market uncertainty may have contributed to the relatively low new wind capacity addition of 153 MW. This is below the estimated 200 MW/yr required to deliver upon the 2020 targets. Although production capacity increased (slightly), wind energy output in 2012 did not exceed 2011 levels.

A number of unprecedented GW-scale proposed onshore wind projects with direct connections to the British electricity system were also announced in 2012. The UK and Irish governments have embarked upon negotiations to put in place arrangements for such projects as defined in the cooperation mechanisms in EU Directive 2009/28/EC.

2.0 National Objectives and Progress

Ireland is committed to meeting an EU target of 20% of its energy demand from renewable electricity 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 bulk of this renewable electricity target will be met from onshore wind energy because it is the most abundant, least cost resource with a mature conversion technology.

According to the National Renewable Energy Action Plan's (NREAP) First Progress Report (January 2012) 3,521 MW of wind capacity will need to be installed onshore in Ireland to meet 40% renewable electricity as set out in the NREAP (2). This will mean around 1,700 MW of additional capacity is required in the next eight years.

2.1 National targets

2.2 Progress

The installed wind capacity at the end of 2012 was 1,826.5 MW, which is an increase of 153 MW from 2011 (1). This is well below the annual capacity additions of over 200 MW/yr estimated to be required to achieve Ireland's 2020 renewable energy targets. Figure 1 and Figure 2 show the trends of capacity additions and number of turbines installed since 1992 in Ireland.

2.3 National incentive programs

The primary support scheme for renewable electricity in Ireland is the Renewable Energy Feed-in Tariff (REFIT) scheme (3). This scheme has been in place since 2006 and the REFIT 1 tariff arrangements applied to 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 energizing 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 (PPA) counterparties are modified under REFIT 2.

In January 2012, it was announced that a previously announced offshore wind FIT would not be implemented.

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 2012 was approximately 50 million EUR (66 million USD). This cost does not consider the depression of electricity prices by wind power which, a Sustainable Energy Authority of Ireland (SEAI)/Eirgrid study found, in 2011 almost exactly balanced the cost of the levy (5). The average wholesale market price during 2012 was 77.93 EUR/MWh (102.72 USD/MWh),

Proposals for Irish GW-scale, onshore wind projects with direct connections to the UK electricity system were announced in 2012.

Table 1. Key National Statistics 2012: Ireland	
Total installed wind capacity	1,827 MW (1)
New wind capacity installed	153 MW (1)
Total electrical output from wind	***4.03 TWh***
Wind generation as % of national electric demand	***14.5%***
Average national capacity factor	28.4%
Target:	***3,521*** MW by 2020 (2)
Bold italic indicates estimates	

as compared to an inflation adjusted REFIT tariff of 68.078 EUR/MWh (89.727 USD/MWh) for wind farms larger than 5 MW and 70.467 EUR/MWh (92.876 USD/MWh) for wind farms smaller than 5 MW (3 and 4).

2.4 Issues affecting growth

Uncertainty regarding the arrangements for the curtailment of wind power within the electricity system dispatch rules may have caused delays in financial close-out of some new wind farm projects in 2012. The regulatory authorities initially decided that curtailment should be allocated across wind farms on a "grand-fathered" basis according to "firm" and "non-firm" connection status. This arrangement had the potential to severely disadvantage "non-firm" projects and result in this important category of wind farm projects not being executed to meet 2020 targets. The regulatory authorities subsequently revised their decision to defer the implementation of "grandfathering" of curtailment until 2018 and to allocate curtailment on a "pro-rata" basis across all wind generation until this date (6). This is likely to encourage execution of "non-firm" wind projects during this period while the full implementation of measures to reduce curtailment is completed.

3.0 Implementation

3.1 Economic impact

A 2012 SEAI report estimated wind energy related employment at 1,300 in 2010 rising to 3,490 in 2020. The 2020 estimate was based upon total installed capacity increasing to 4,650 MW in 2020 (4,100 MW onshore, 550 MW offshore) (7).

A 2012 survey 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. The latter figure assumes 2020 target capacity is exceeded through the execution of large projects connected directly to the UK.

3.2 Industry status

The development ownership of wind farms in Ireland involves a range of types and scales of wind farm development. Around 50% of wind farms are owned and operated by, mostly vertically integrated, energy utilities. The balance of wind farm ownership is a mix of small, privately-owned wind farm operators, individual landowners, and groups/cooperatives. Small project developers, who bring a wind farm site through the permitting steps and then sell the project to larger wind energy companies for execution, are also significant players. Apart from wind farms developed by groups of adjacent landowners, there have been few successful developments of wind farms on a community or cooperative basis in Ireland. While there have been a small number of notable wind auto-production projects executed on industrial and commercial sites, this model of development has yet to see widespread uptake in Ireland.

The average size of a wind farm project phase in Ireland in 2012 was 21 MW, small by international standards. This reflects the significant involvement of small players in the Irish wind energy sector. It may also reflect the nature of available wind farm sites, which is influenced by a highly dispersed, low density, pattern of rural settlement. In some regions, this pattern may effectively restrict wind farm development to small packages of marginal land.

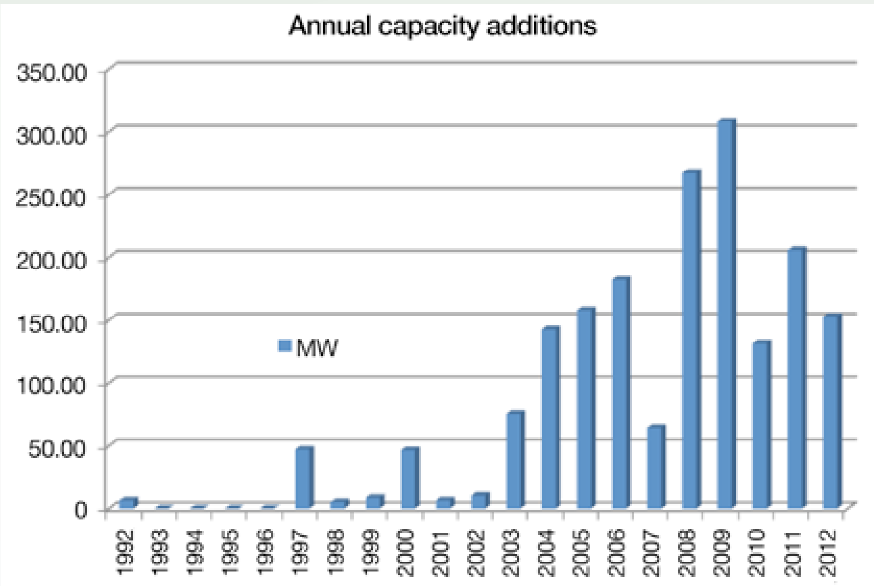

Figure 1. Annual wind farm capacity additions 1992–2012

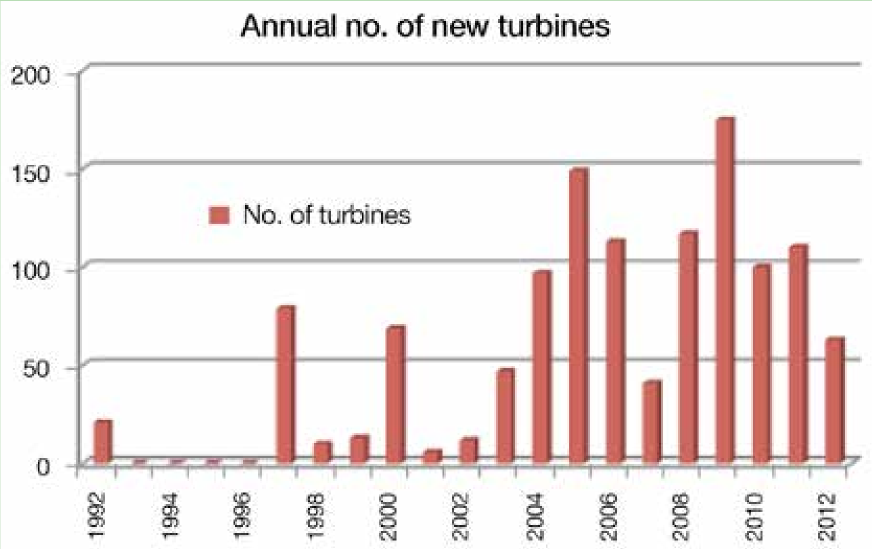

Figure 2. Annual new wind turbine additions 1992–2012

In 2012, the main suppliers of large wind turbines were Enercon (79.4 MW) and Nordex (73.2 MW). Figure 3 shows the manufacturer market share of the total capacity in Ireland. To date, no manufacturing of utility-scale wind turbines or any of their main components is taking place in Ireland. However, there have been significant developments in small wind turbine manufacturing. C&F Wind Energy, a division of the Irish industrial manufacturing company C&F Tooling, has developed a new product range of wind turbines ranging from 6 kW upwards in size. The C&F wind turbines have some innovative features not commonly found on small wind turbines including intelligent controls and electronic pitch control. Their largest model is a 50-kW wind turbine launched in 2012. The company has captured a significant share of the small wind turbine market in both Ireland and Britain.

3.3 Operational details

The average size of onshore wind turbine installed in 2012 was 2.41 MW, a significant increase over the 2.0 MW average in 2011 and a continuation of a long-term trend of increasing onshore wind turbine size (Figure 4).

The average capacity factor of wind farms in Ireland in 2012 was 28.4% (from the TSO, Eirgrid, based upon the actual capacity in operation throughout the year), which is somewhat below the long-term trend of 29–30% (Figure 5). That is why, despite significant capacity additions in 2011 and 2012, total wind energy output in 2012, at 4.03 TWh, was 8.5% lower than in 2011.

3.4 Wind energy costs

Turbine prices in 2012 averaged approximately 900 EUR/kW (1,186 USD/kW) for projects involving multiple turbines. Total development costs averaged 1,500 EUR/kW (1,977 USD/kW) for a typical project in 2012. Ireland joined IEA Wind Task 26 Cost of Wind Energy in 2012, and more detailed cost breakdowns and trends will be reported in 2013 as the data from the work within the Task becomes available.

4.0 R, D&D Activities

4.1 National R, D&D efforts

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. Wind energy has received 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 that would argue for government subsidies for industrial and academic R&D supporting wind turbine technology development.

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 program including:

- Birdwatch Ireland — Phase 1 delivery of a fully consolidated bird sensitivity map for Ireland
- NUIG—Study on the greenhouse gas emissions associated with developing wind farms on peatland sites
- TCD—Study to determine the most appropriate international approaches to measure social acceptance of wind projects; measure the factors affecting individuals' perceptions of wind farm projects
- UCD — Study on the interactions of bats with onshore wind farms
- UCD — Study on social acceptance of wind energy projects from the perspective of spatial planning
- Meitheal na Gaoithe (small wind farm representative body) — independent study to evaluate the costs and benefits from the development of small-scale wind energy in Ireland

SEAI also completed monitoring of its small- and micro-scale generation pilot during 2012. Analysis of the data highlighted an inadequate current state of the art in small wind site assessment. The analysis showed that a majority of small wind sites have a turbulent wind regime and energy yield assessment methods are ill equipped to take account of this.

4.2 Collaborative research

Ireland has participated in IEA Wind Tasks 11 Base Technology Information Exchange, Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power, and Task 28 Social Acceptance of Wind Energy Projects. In 2012, Ireland also joined Task 26 Cost of Wind Energy and Task 33 Standardizing Data Collection for Wind

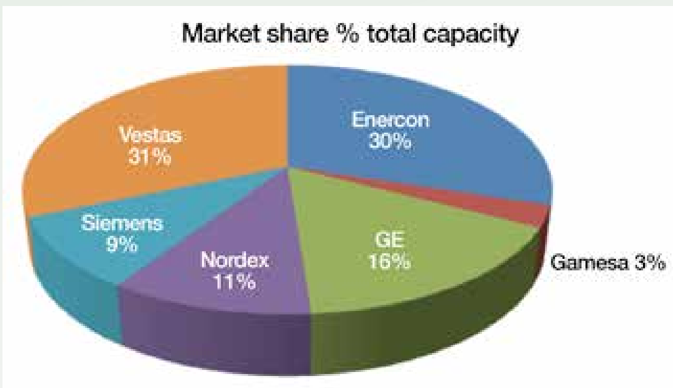

Figure 3. Manufacturer market shares in Ireland 1992–2012

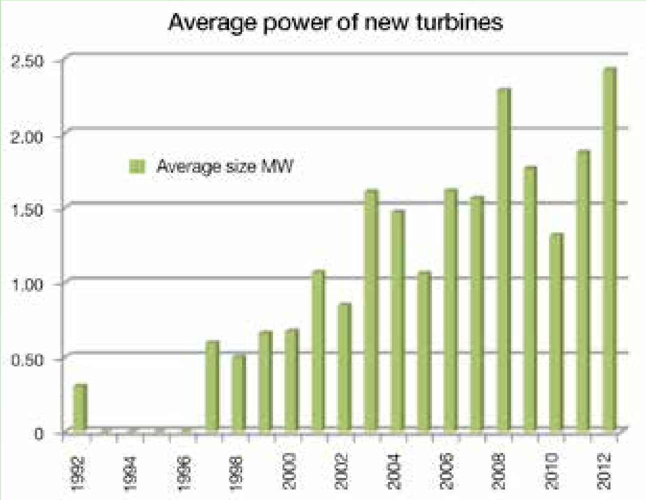

Figure 4. Average wind turbine power in MW 1992–2012

Turbine Reliability, Operation, and Maintenance Analyses. SEAI coordinates Ireland's participation in IEA Wind and provides funding to cover costs incurred by national participants. SEAI actively seeks to maximize the benefits of IEA Wind Task participation to Ireland and other members through seeking participation by the most competent national expert via a competitive tendering process. An objective of IEA Wind Task participation is to stimulate a relevant national research project along with contributing to the international collaboration. For example, in the course of participation in Task 28, a report on the options for enhancing community acceptance of wind farms in Ireland was prepared.

Ireland also participates in the IEA GIVAR project (Grid Integration of Variable Resources), which is concerned with methods for assessing the capability of electricity systems to integrate variable renewables such as wind power. Ireland also participated in the EU GPWIND project, which was completed in 2012 and sought to highlight good practices in developing wind farms across Europe.

While limited research is carried out on wind turbine technology in Ireland, there is a significant research competence in the field of the grid integration of wind power at the Electricity Research Centre in University College Dublin. Details of wind related research projects may be found on the ERC website (8). The Irish TSO, Eirgrid, has also established an advanced program of work entitled "Delivering a Secure Sustainable Electricity System (DS3)" to manage the integration of very high levels of instantaneous renewable penetration on the island supported by a program of supporting research (9).

5.0 The Next Term

The potential for directly connecting Irish wind farms to the British electricity system and crediting their output to the UK is being explored. A Memorandum of Understanding between the Minister for Communications, Energy and Natural Resources of Ireland and the Department of Energy and Climate Change of the United Kingdom on cooperation in the energy sector was signed on 24 January 2013. The cooperation mechanisms provided for in Articles 6–11 of the Renewable Energy Directive 2009/28/EC are the only means whereby renewable energy that contributes to member-state targets may be traded. Any export regime agreed with another country would fall under these articles and would require a legal treaty. If it is decided to pursue an export regime and negotiate a bilateral treaty, information on the treaty and export regime would be made publicly available. These negotiations are likely to be concluded in 2013.

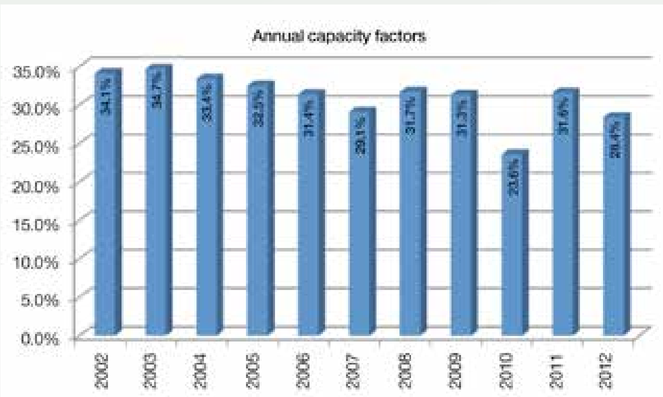

Figure 5. Annual average capacity factors

References:

(1) The installed capacity in 2012 is reported based upon the sum of the nameplate power rating of all commissioned wind turbines. In previous years it was reported on the basis of the sum of the wind farm grid connection maximum export capacities (MEC). Because there has been a growing divergence in MW installed and MEC figures, MEC is no longer an accurate indicator. This will lead to a discontinuity in the reported statistic for Ireland in 2012.

(2) National Renewable Energy Action Plan (NREAP) IRELAND First Progress Report Submitted under Article 22 of Directive 2009/28/EC January 2012 www.dcenr.gov.ie

(3) www.dcenr.gov.ie/Energy/Sustainable+and+Renewable+Energy+Division/REFIT.htm

(4) Quarterly SEM Price Report, Quarter 4 2012, Information Paper, 22nd January 2013, SEM-13-003 Download from: www.google.ie

(5) Impact of Wind Generation on Wholesale Electricity Costs in 2011, SEAI www.seai.ie/Publications/Energy_Modelling_Group_/Energy_Modelling_Group_Publications/Impact_of_Wind_Generation_on_Wholesale_Electricity_Costs_in_2011.pdf

(6) Treatment of Curtailment in Tiebreak situations Single Electricity Market Decision Paper 1 March 2013 SEM-13-010 Download from: www.google.ie

(7) The Case for Sustainable Energy: A review and analysis of the economic and enterprise benefits. SEAI June 2012. Download from: www.seai.ie/Publications/Statistics_Publications/EPSSU_Publications/The_Case_for_Sustainable_Energy.pdf

(8) http://erc.ucd.ie/

(9) http://www.eirgrid.com/operations/ds3/

Author: John McCann, the Sustainable Energy Authority of Ireland (SEAI), Ireland.

25 Italy

Source: Alerion CleanPower

1.0 Overview

In 2012, a record number of new wind farm installations were completed in Italy, due to the opportunity to access to the old (and more favorable) incentive mechanism for plants connected to the grid by 30 April 2013. New wind capacity of 1,266 MW was added (+18.4% with respect to 2011) by deploying 720 new turbines, reaching an overall grid-connected wind capacity of 8,144 MW and a total of 6,166 installed turbines at the end of last year. The provisional 2012 energy production by wind farms was 13.1 TWh, which represents about 4% of total electricity demand on the Italian system.

The scheme for supporting Renewable Energy Systems (RES) in Italy changed at the end of 2012.

The old scheme was based on a RES quota obligation and tradable green certificates (TGCs), allowing to the non-programmable RES producers an extra income with respect to the income deriving from the energy sale. Additional options were considered in this scheme for small plant owners. The new scheme considers three different incentive access mechanisms: direct access, access by registration, and access by auction. Registration and auction access is constrained by established annual quotas. The access mechanism depends on the plant size and characteristics (i.e. integrally rebuilt, repowered, or refurbished plant). Incentive tariffs depend on plant size and characteristics as well (i.e. onshore or offshore plant).

The permitting procedures and wind production curtailments ordered by the transmission systems operator (TSO) still represent issues affecting wind energy growth. To address permitting procedures, acknowledgement by the Regions of the national permitting guidelines issued in 2010 is in progress. As to production curtailments, the TSO TERNA has made noteworthy efforts to upgrade the grid in order to match RES-production dispatching needs and the Italian Regulatory Authority for Electricity and Gas (AEEG) has provided for curtailed production to be estimated and wind farm owners indemnified.

The most critical issue for investors is represented by the annual quotas established for auction in the next three years, 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 plant capacity is also considered to be too low.

Foreign manufacturers supplied most of the new turbines in 2012. Leitwind is the only large Italian turbine manufacturer. Other national firms supply small-sized units. The market for small wind systems is growing rapidly, reaching about 16.7 MW of overall installed capacity (estimated value).

There has been no national R, D&D program running on wind energy, but activities have been carried out by different entities, mainly the National Research Council (CNR) and the National Agency for New Technologies, Energy, and the Environment (ENEA) (the first and second national research institutions respectively), Research on the Energy System (RSE), some universities, and other companies.

2.0 National Objectives and Progress

2.1 National targets

The new RES policy launched by the EU established a target value of 20% of total EU energy consumption coming from RES by 2020. The European Directive 2009/28/EC on RES promotion issued on 23 April 2009 assigned Italy a binding national target equaling 17% of overall annual energy consumption from RES. According to this Directive, the Italian National Action Plan

In 2012, a record amount of new wind capacity was added in Italy and production by wind farms represented about 4% of total electricity demand on the Italian system.

Table 1. Key National Statistics 2012: Italy	
Total installed wind capacity	8,144 MW
New wind capacity installed	1,266 MW
Total electrical output from wind	***13.1 TWh***
Wind generation as % of national electric demand	***4%***
Average capacity factor	---
Target:	National Action Plan: Wind generation 12,680 MW and 20 TWh/yr by 2020 Directive 2009/28/EC:17% of total energy consumption from RES by 2020
Bolt italic indicates estimates	

(PAN) for Renewable Energy issued on 30 June 2010 shared this overall target among sector-based targets. A target of 26.39% contribution from RES was established for the electrical sector, corresponding about to 43.8 GW of RES on-line capacity and 98.9 TWh/yr production from RES to be reached by 2020. In addition to existing hydropower capacity, most of the power growth is expected from wind, biomass, and solar energy sources. The 2020 targets for wind energy were set to 12,680 MW (12,000 MW on land and 680 MW offshore) as installed capacity and 20 TWh/yr (18 TWh/yr on land and 2 TWh/yr offshore) as energy production.

2.2 Progress

A record amount of new capacity, 1,273 MW, was installed in 2012 (Figure 1). After accounting for 6.5 MW of old capacity that was removed, this led to an increase of 1,266 MW since 2011. Overall grid-connected wind capacity was 8,144 MW at the end of 2012. The corresponding growth rate was 18.4%. The largest wind turbines installed in Italy are 3.4 MW (opening photo). Most of the new installations took place in the South. Apulia and Sicily have the highest wind capacities. The annual and cumulative installed wind capacities for the Italian Regions are shown in Figure 2.

According to provisional data by TERNA and the Manager of Energy Services (GSE), in 2012 overall production by wind, photovoltaic, and geothermal plants was about 36.8 TWh. The wind farm contribution was estimated at about 13.1 TWh, which would equal about 4% of total electricity demand on the Italian system (total consumption plus grid losses). The development in wind power production is presented in Figure 3. Total electricity demand (325.3 TWh) decreased by 2.8% in 2012 with respect to 2011. An 87% share of this demand was satisfied by domestic production and 13% by imports.

2.3 National incentive programs

New incentive mechanisms have been introduced and implemented this year. The Italian government issued Legislative Decree No. 28 on 3 March 2011 to implement EU Directive 2009/28/EC on RES promotion and to provide outlines for a new incentive scheme concerning RES plants that will start operations from 1 January 2013 onwards. The old incentive mechanism, mainly based on TGCs, is guaranteed for plants authorized before 11 July 2012 if the condition to get in operation before 30 April 2013 is observed. The current main scheme of quotas

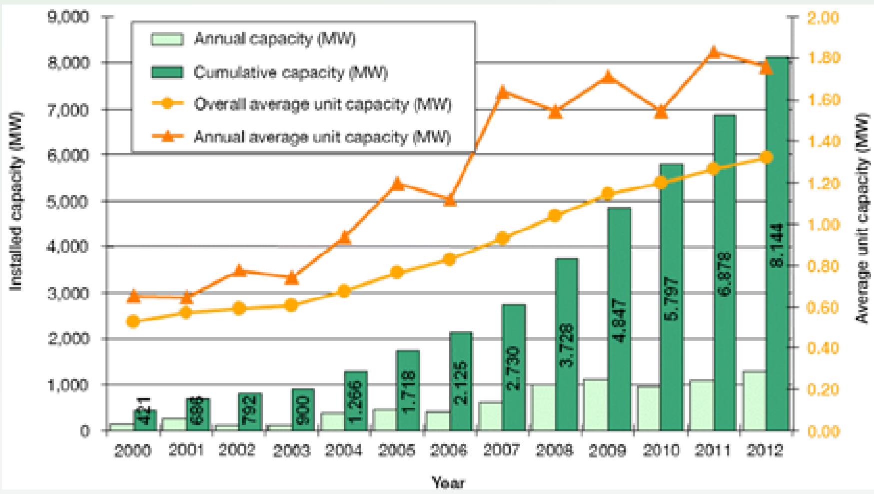

Figure 1. Trend of Italian annual and cumulative wind turbine installed capacity, and newly added and overall average unit capacity

Region	end 2012 (MW)	2012 (MW)
Fruili V. Giulia	0	0
Lombardia	0	0
Marche	0	0
Veneto	1	0
Umbria	2	0
Trentino A. Adige	3	0
Valle d'Aosta	3	3
Piemonte	13	0
Emilia Romagna	16	0
Liguria	47	22
Lazio	51	0
Toscana	84	40
Abruzzo	236	10
Basilicata	360	58
Molise	371	2
Calabria	994	222
Sardegna	1,015	68
Campania	1,208	146
Sicilia	1,746	70
Puglia	1,994	627
TOTAL (onshore)	8,144	1,266
TOTAL (offshore)	0	0

Figure 2. Wind capacities in the Regions of Italy at the end of 2012

and TGCs is to expire by 2015. Entitled plants should then be supported by transient measures.

The main issues of the new mechanisms are special energy purchase prices fixed for RES-E plants below a capacity threshold depending on technology and size (no lower than 5 MW). Special energy purchase prices are assigned to larger plants through calls for tenders (lower bids gain contracts) and prices are granted over average conventional lifetime of plants (20–25 years).

For wind plants, three different access schemes are provided depending on plant size: <60 kW direct access; for new, integrally rebuilt and repowered plants access by registration in the size range 60kW–5MW; access by auction through call for tenders for plant size > 5 MW. For refurbished plant 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) has been established for onshore wind capacity and a quota of 650 MW of offshore wind capacity has been established for the whole period.

For onshore wind plants, conventional plant life is set to 20 years and basic incentive tariff (Tb) set for 2013 depends on plant size P (kW):

- 1< P ≤20: Tb=291 EUR/MWh (378 USD/MWh)
- 20< P ≤200: Tb=268 EUR/MWh (348 USD/MWh)
- 200< P ≤1000: Tb=149 EUR/MWh (194 USD/MWh)
- 1000< P ≤5000: Tb=135 EUR/MWh (175 USD/MWh)
- P >5000: Tb=127 EUR/MWh (165 USD/MWh)

For offshore plants, conventional plant life is set to 25 years and Tb set for 2013 also depends on plant size P (kW):

- 1< P ≤5000: Tb=176 EUR/MWh (228 USD/MWh):
- P >5000: Tb=165 EUR/MWh (214 USD/MWh).

According to these values, new incentives are significantly lower than those assessed in the old scheme. For example, for a plant with size exceeding 5 MW the reduction is around 20%. It has to be noted that small (P<200 kW) and offshore plants still benefit of greater incentives than the onshore ones (P>200kW). Due to the favorable old and new incentives, small plants are growing very fast in Italy. The Italian Wind Energy Association (ANEV) is trying to take a census of these small plants. From preliminary results, 11.7 MW of surveyed and about 5 MW of non-surveyed capacity is already installed. The contribution of small plants is not relevant to the overall capacity, but can stimulate the growth of national small and medium enterprises in this sector (Table 2).

2.4 Issues affecting growth

The most important issue affecting the growth of the wind energy sector in Italy is the annual quota of wind capacity that can benefit from the incentives of the new decree and its implementation. As mentioned above, the quota for new capacity for plants larger than 5 MW is 500 MW/yr in 2013–2015. This means an expected growth-rate reduction for plants connected to grid after 30 April 2013, when the new incentive mechanism will be applied. This reduction is estimated to be half of the new annual average capacity installed in the last four years. In order to benefit from the more favorable incentives, producers installed a large amount of capacity in 2012: the highest annual capacity ever installed.

The first registration and auction was completed by GSE in compliance with the 6 July 2012 Implementing Decrees. For registration,

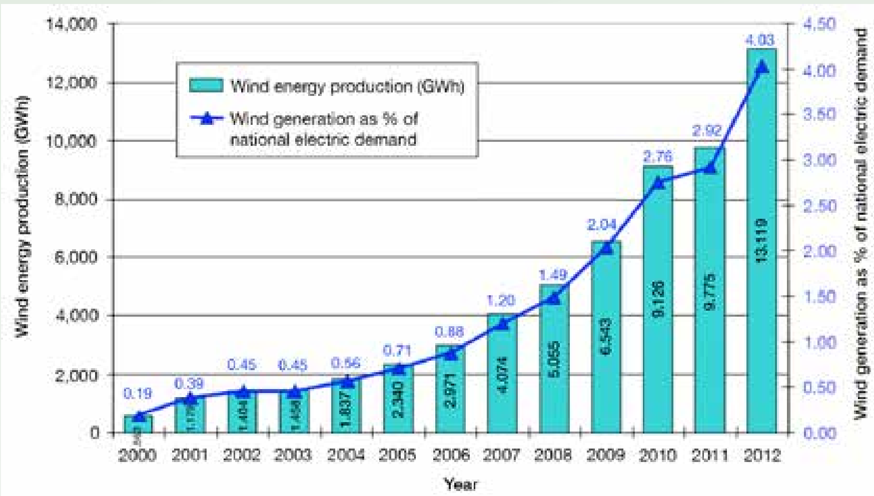

Figure 3. Italian wind energy production and percent of national electric demand

applications totaled 192 MW, more than five times the annual available quota of 60 MW established for 2013. For the auction, onshore applications totaled 442 MW, 10% lower than the quota of 500 MW established for 2013; offshore applications totaled only 30 MW, much lower than the quota of 650 MW set for 2013–2015. The authorization for offshore wind plants in Italy is given by the central government (for onshore parks the authorization is given by Regional governments) after long and complex procedures. At the end of 2012, only three offshore wind projects were determined eligible by the Ministry of Environment after examination of the Environmental Impact Assessment. These projects are now completing the authorization process.

To achieve 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 on Cases of Failed Achievement of the Goals by the Regions and Autonomous Provinces" (called "Burden Sharing" Decree). As a consequence of this decree, significant growth is expected in Basilicata and Sardinia, smaller growth is expected in Sicily and also in central regions with low wind capacity already installed such as Emilia-Romagna, Umbria, Lazio, and Tuscany.

Another important issue affecting growth is the connection of wind farms to the grid. Technical and economic conditions have been set by the 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 are still reported, especially in the permitting of new electrical lines by local Authorities. Moreover, Italy's 2010 National Action Plan (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 (10.4 billion USD). TERNA was sometimes compelled to ask wind farms to stop or reduce output, because of overloads or planned work in grid zones (especially in the south and Sardinia). In 2012, curtailments totaling 150 GWh (1.1% of production by RSE estimate) were claimed by wind farm owners. 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 2012 was around 2.1 billion EUR (2.8 billion USD). This amount includes both preliminary (design and development) and executive (construction, equipping, and grid-connection) activities involved in new wind farm installations.

Despite the fact that most of the new installed wind turbines were made abroad, these activities had a significant impact on employment. Many Italian firms supply components to wind turbine manufacturers based in Italy and abroad. According to ANEV, the positive trend for employment has begun to reverse in the last year, mainly due to the dramatic investment reduction as consequence of the new incentive system. The wind energy sector, which employs about 30,000 people, including direct and indirect involvement, has started to lose employees and a drop of thousands of jobs is feared in 2013.

3.2 Industry status

Foreign manufacturers are prevailing in the Italian market for large-sized wind turbines. This is clear from Figure 4, where the overall market shares of wind turbine manufacturers in Italy at the end of 2012 are shown. The capacities installed in 2012 by manufacturers of the wind turbines are: 434 MW by Vestas (Denmark), 304 MW by Gamesa (Spain), 189 MW by REpower (Germany), 116 MW by Enercon (Germany), 94 MW by Nordex (Germany), 80 MW by Leitwind (Italy), 44 MW by Siemens (Germany), and 13 MW by GE Wind (United States).

Leitner is the only Italian manufacturer of large wind turbines and produces its 1.5–3 MW turbines in factories located in Telfs (Austria) and Chennai (India). Vestas operates in Italy through its corporation Vestas Italy. This corporation has its headquarters and sales office in Rome and two production facilities for blades and nacelles for the V90 turbines in Taranto. Its operations office and a customer service center are also located in Taranto. All the other foreign manufacturers of large wind turbines operate in Italy through their commercial offices. Italian firms also have a significant share of the component market for large wind turbines: pitch and yaw system components, electrical and electronic equipment, bearings, flanges, towers, cast and forged components (hubs, shaft supports), and machine tools.

In 2012, about 60% of the Italian wind energy production market, computed as percentage of overall installed capacity, was held by the top ten producers. The highest capacity is presently owned by Erg Renew, as a consequence of the takeover of IP Maestrale, the Italian wind energy subsidiary of International Power. ENEL Green Power, a corporate company of the ENEL Group, is another leading player in the market. Other substantial capacity shares are held by FRI-EL, Edison Energie Speciali, subsidiary of the electricity utility Edison, IVPC, Veronagest, and E.ON Italia. Other producers hold significant market shares, like Falck Renewables, Tozzi Renewable Energy, and Alerion Green Power.

ANEV is the main association of energy producers and manufacturers in the wind sector in Italy.

Unlike the market for large (MW) wind turbines, the market for small-sized wind plants (having a capacity up to 200 kW) has a significant presence of Italian firms (Table 2).

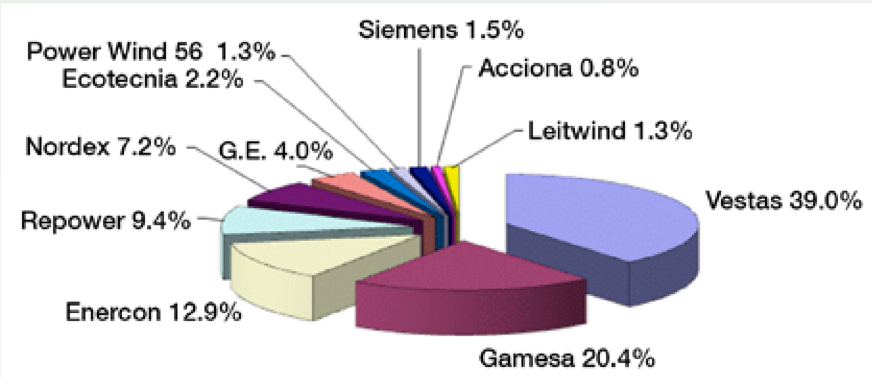

Figure 4. Market shares of wind turbine manufacturers in Italy at the end of 2012 (as percentage of total online capacity)

Table 2. Top small-sized wind turbine manufacturers in the Italian market			
Manufacturer	Nationality	Type*	Capacity (kW)
Aria	Italian	HA	55
Bluminipower	Italian	HA	0.5–200
Deltatronic	Italian	HA	1.5–5
Electria Wind	Spanish	HA	150–200
En-Eco	Italian	VA	3
Eolart	Italian	HA	60
Espe	Italian	HA	60
Italtech Wind	Italian	HA	55–330
Jonica Impianti	Italian	HA	30–60
Klimeco	Italian	HA	0.5–55
Layer Electronics	Italian	HA	0.3–20
Ropatec	Italian	VA	1–20
Salmini	Italian	HA	<1
Sipe	Italian	VA/ HA	3–6/20–100
Southwest Windpower	U.S.	HA	2.4–200
Tekna Energy	Italian	HA	30
Terom	Italian	HA	50
Tozzi Nord	Italian	HA	10
T.R. Energia	Italian	HA	1
Vergnet	French	HA	200
Windstar	Italian	VA	1–5

*Vertical axis (VA); Horizontal axis (HA)

3.3 Operational details

In 2012, 720 new wind turbines were deployed (1,760 kW of average unit capacity), corresponding to 1,273 MW of capacity. This increased the number of online wind turbines to 6,166, with an overall average capacity of 1,320 kW/unit. The corresponding overall capacity is 8,144 MW. All plants are based on land, mostly on hill or mountain sites.

Regarding offshore projects, only three of the applications submitted so far for the permitting procedure have successfully completed the phase of environmental impact assessment (342 MW of overall capacity). Moreover, a very poor response for offshore applications was recorded in the first auction procedure for incentive allocation according to the new support scheme: only 30 MW were allotted out of an available 650 MW.

Many new wind farms were connected to the grid in 2012. Their average capacity is about 23 MW, and the average turbine number in the wind farms is 12. Among the largest plants built in 2012 are those of Bisaccia (Campania—66 MW), Sant'Anna (Calabria—64 MW), and Castellaneta (Apulia—56 MW).

3.4 Wind energy costs

For 2012, an average capital cost of 1,750 EUR/kW (2,307 USD/kW) has been estimated. This cost shows a large variability in the Italian context and is about 20% higher than the average European installation cost, because of the Italian site characteristics and the extra costs induced by the permitting procedures length and complexity. Two typical plants exist in Italy: ones installed in plains of southern regions, and ones built at rather remote hill or mountain sites. In general the hill and mountain sites have better wind regimes, but experience higher costs of transportation, installation, grid connection, and operation.

4.0 R, D&D Activities

4.1 National R, D&D efforts

R, D&D activities have been carried out mainly by CNR, ENEA, RSE S.p.A., and universities.

CNR activity in wind energy involves eight institutes and is in the frame of National and FP7 EU projects. The main topics include 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 farms with ocean circulation and geological risk assessment related to development of offshore wind farms (ISAC, ISMAR, ITAE and INSEAN); wind generator emulators, DC/DC converter, and control schemes for grid integration (ISSIA-ITAE); and innovative materials (ISTEC).

Different activities were carried out in the ENEA's research wind tunnel, such as new-concept wind blade testing and anemometer calibration. Moreover, ENEA has been working on ultrasonic inspection and mechanical characterization of adhesively bonded fiber-reinforced-plastic (FRP) joints, used for manufacturing the blades of small horizontal axis wind turbines. The goal is to correlate the ultrasonic data with the results of the mechanical test.

RSE S.p.A. has been doing research on wind energy mainly under its contract agreement with the Ministry of Economic Development for research on the electrical system. Wind energy has been allotted a total commitment of 2.0 million EUR (2.6 million USD) for 2012–2014. In particular, RSE is conducting a measurement campaign on coastal/island sites in order to improve the knowledge of the offshore wind resource and to better validate the offshore maps of the Italian Wind Atlas (http://atlanteeolico.rse-web.it/viewer.htm) developed by RSE in previous research projects. In June 2012, an offshore buoy (called MOBI) was installed in the Sicily Channel for offshore wind measurements. RSE is also developing information and tools for decision makers in regional administrations to help them to better plan for wind capacity.

The Department of Aerospace Science and Technology of the Polytechnic of Milano has been working on wind turbine aero-servo-elasticity, blade design, load mitigation, and advanced control laws. A four-year project was completed on wind tunnel testing of actively-controlled and aero-elastically scaled wind turbine models. The department also participates in two major FP7 EU-funded projects, which will work on 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 aero-elastic modeling. The Department of Electrical Engineering has been working on generator technology, while the Department of Energy works on grid and wind energy economics. In 2012, the Polytechnic of Milano joined the European Academy of Wind Energy (EAWE) as national node member, and the European Energy Research Alliance (EERA) Joint Program on Wind Energy as associate member.

The Department of Energy of the Polytechnic of Turin has been working on a model of energy conversion (especially in DFIG machines); an experimental analysis of "power quality," reliability, and availability; and a comparison between statistical data of the wind resource and weather forecasts for the prediction of power injection into the grid. The Departments on Mechanical Engineering and Environment Engineering have activities to study floating offshore wind energy systems. They are studying dynamic models of such structures, the rotor aerodynamics, the floater hydrodynamics, the mooring system dynamics, and the design of a collective blade pitch control system.

The DICCA Department of the University of Genoa has been working on the evaluation of wind fields and wind potential in complex areas. They are also looking at the safety and fatigue of wind turbines, and deal with small and medium size installations. The DITEN Department focuses on forecasting and integration of renewable energy sources, with specific reference to micro wind turbines for urban applications. This activity is carried out by resorting to the "Smart Polygeneration Microgrid," a smart grid test-bed installed at the Savona Campus R&D facilities of the University of Genoa, characterized by the presence of ICT technology, long- and short-term electrical storage, and a suitable energy management system.

The CRIACIV – Inter-University Research Center on Building Aerodynamics and Wind Engineering has been involved in collaboration with Polytechnics, Universities, and CNR in three national research projects on deep water structures for wind energy and other RES. Moreover CRIACIV has been working on the FP7 Project MARINET with University of Florence dealing with offshore wind energy structures.

The University of Trento has, for several years now, focused on the testing of small wind turbines at their own test field in a mountain environment. The experimental wind farm provides equipment for the analysis and comparison of structural and functional characteristics of mini and micro wind turbines, with emphasis on vertical axis wind machines.

The Department of Aerospace Engineering of the University of Naples has, for quite some time, been engaged in designing and wind tunnel testing of small wind turbines.

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. The University of Naples joined Task 27 Small Wind Turbines at Turbulent Sites. The Universities of Genoa and Perugia, the CNR-INSEAN Institute, the wind farm developer SORGENIA S.p.A., and the company KARALIT s.r.l. joined Task 31 Benchmarking Wind Farm Flow Models. RSE joined Task 28 Social Acceptance of Wind Energy Projects. Within the EERA, Joint Program on Wind Energy, CNR is member as full participant and ENEA and Polytechnic of Milan are associated partners. CNR and RSE are participating in the Weather Intelligence for Renewable Energy (COST ACTION WIRE) concerning wind energy short-term forecast finalized to grid integration.

5.0 The Next Term

In October 2012, the Ministry of the Economic Development issued the National Energy Strategy (SEN), the official document that defines the national energy strategy up to 2020. The key elements for RES development and deployment are to: overtake the European 20-20-20 target; increase the energy mixing 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; and progressive electric market and grid integration as far as electric RES are concerned. In this strategy RES research is addressed to innovative RES (e.g., concentrated solar power and second generation biofuels) in which there is a stronger national position.

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26 Japan

Source: New Energy and Industrial Technology Development Organization (NEDO)

1.0 Overview

In 2012, the total installed wind capacity in Japan reached 2,614 MW with 1,887 turbines, including 25.3 MW from 15 offshore wind turbines. The annual net increase was 78 MW. Total energy produced from wind turbines during 2012 was 4.5 TWh, and this corresponds to 0.54% of national electric demand (861 TWh).

In response to the great East Japan earthquake and tsunami of March 2011, the decision was taken to dismantle four nuclear power plants in Fukushima Prefecture. In addition, 50 other nuclear power plants were shut down for a time. After careful examination and performance of stress tests, two nuclear power plants were restarted in July 2012. However, the other 48 nuclear power plants were still under suspension at the end of 2012. This loss of nuclear generation capacity caused the dramatic increase of more than 5 trillion JPY (43.5 billion EUR; 58.0 billion USD) of imported of fossil fuel to increase generation at carbon-burning plants in Japan. This shifted the balance of trade and damaged the economy in Japan.

On the other hand, Japan has a large amount of wind energy potential, and the expectation of wind energy as fuel-free electricity is growing. As a sign of that expectation, the R, D&D projects of offshore wind turbines and wind farms are growing rapidly.

2.0 National Objectives and Progress

2.1 National targets

After the Fukushima nuclear power plant accident, an expert committee convened by the Ministry of Economy, Trade, and Industry (METI) began discussions in October 2011 to review the Basic Energy Plan. In the former Basic Energy Plan, the share of nuclear energy was to be increased from 25% to 45%, the share of renewable energy was to be increased from 10% to 20%, and the share of fossil fuels was to be decreased from 63% to 35%. After the fundamental review of the plan, new options or scenarios for energy through 2030 were drafted and published by the National Policy Unit in July 2012. In that draft, there are three scenarios categorized by the share of nuclear energy: 0% nuclear scenario, 15% nuclear scenario, and 20–25% nuclear scenario. In the three new scenarios, the share of renewable energy is expected to be from 25–35%.

The current total installed wind capacity in Japan is about 2,600 MW. More than ten times that amount is expected in 2030 for the new 15% nuclear and 20–25% nuclear scenarios (38,000 MW). In the 0% nuclear scenario, wind capacity of 52,000 MW in 2030 is expected. If constant growth rate is assumed for wind, the grow rates are about 16%/yr for the 15% nuclear and 20–25% nuclear scenarios. Even for the most radical 0% nuclear scenario an 18%/yr growth is needed. Therefore, all three of these scenarios are not so challenging for wind power deployment in Japan. According to these draft scenarios, the formal new Basic Energy Plan was to be decided, and published by the end of 2012. However, at the close of 2012, the new plan was not yet made available to the public.

2.2 Progress

Cumulative wind power capacity reached 2,614 MW (1,887 turbines), with 78 MW of annual net increase in 2012. The slight increase in offshore wind power capacity from 25.2 MW to 25.3 MW is due to the floating offshore wind turbine demonstration project funded by the Ministry of the Environment

In 2012, wind capacity in Japan reached 2,614 MW with 1,887 turbines, including 25.3 MW from 15 offshore wind turbines.

Table 1. Key National Statistics 2012: Japan	
Total installed wind capacity	2,614 MW
New wind capacity installed	78 MW
Total electrical output from wind	4.5 TWh
Wind generation as % of national electric demand	0.52%
Average capacity factor	***19.9%***
Target: (Prospect of wind capacity announced by the government)	Not specified (5 GW by 2020)
Bold italics indicates estimates	

(MOE), which is explained in Section 4.0. Figure 1 shows the history of wind power development in Japan. Wind power generation in 2012 was 4.5 TWh, and the contribution of wind power to the national electric demand accounted for 0.52%.

2.3 National incentive programs

The former main incentive programs were investment subsidies and the Renewables Portfolio Standard (RPS), however, these incentive programs ended in June 2012. The government made a cabinet decision to introduce a new Feed-in-Tariff (FIT) system on 11 March 2011, and the new Renewable Energy Law (Special Measures Law Concerning Procurement by Electric Power Companies of Renewable Energy Electricity) was approved by the National Diet of Japan on 26 August 2011, and promulgated on 30 August 2011. This law obliges electric power companies to purchase electricity generated from renewable energy at a fixed price (procurement price) for a fixed period (procurement period), and came into force on 1 July 2012. The first FIT system that started in November 2009 was only for PV; however this new FIT system covers all practical renewable energy sources such as wind (including small wind), small- and medium-scale hydropower, geothermal, and biomass.

The procurement price (FIT price) and the procurement period were discussed and decided by an independent committee convened by METI. The procurement prices are 20 JPY/kW (191 EUR/MWh, 255 USD/MWh) for wind power greater than or equal to 22 kW of capacity and 55 JPY/kWh (479 EUR/MWh, 638 USD/MWh) for small wind with less than 20 kW of capacity. The above procurement prices do not include the 5% consumption tax. The procurement period is 20 years for wind, including small wind. These procurement prices for wind may

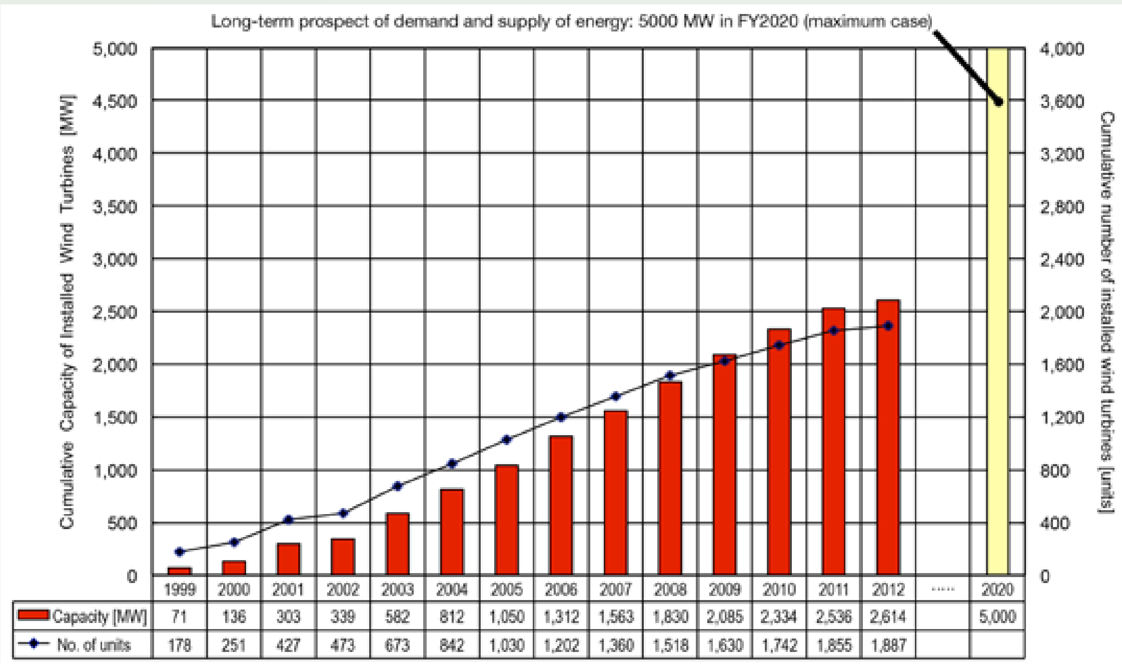

Figure 1. Total installed wind capacity and number of turbine units in Japan.

seem high compared with other countries in which the FIT system has already been introduced; however, the procurement price will be reviewed every fiscal year in consideration of technological innovations and decline in power generation costs. The premium procurement price for offshore wind has not been fixed, and it will be examined based on the experience of ongoing R, D&D projects of offshore wind.

2.4 Issues affecting growth

Good wind resource is expected in the northern part of Japan such as Hokkaido and Tohoku; however, most of these regions are rural areas with sparse population. 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 requested financial help to support the reinforcement of the electric grid in northern Japan. This support program will grant a 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 support program will stimulate wind power development in Japan.

The government made a cabinet decision to amend the Environmental Impact Assessment Law on 11 November 2011. Development projects of wind power plants were subject to this amended law from 1 October 2012. This law requires developers of wind power plants that have total capacity of more than 10 MW to implement an environmental impact assessment of the project. The assessment and approval process takes three to five years, and the wind community fears that this may slow down wind power development in Japan in the next few years.

3.0 Implementation

3.1 Economic impact

In Japan, 75 companies with 2,500 people are manufacturing wind turbines and their components. Annual sales are estimated at close to 181.8 billion JPY (1.582 billion EUR; 2.109 billion USD), according to a research report by the Economic Research Institute in Japan Society for the Promotion of Machine Industry.

3.2 Industry status

Three Japanese wind turbine manufacturers produce turbines larger than 1 MW: Mitsubishi Heavy Industries (MHI), Japan Steel Works (JSW), and Hitachi. MHI produces 1-MW, 2.4-MW, and 2.5-MW wind turbines and is developing a 7-MW offshore wind turbine with hydro drive train. JSW produces 2-MW gearless, permanent-magnet, synchronous generator (PMSG) wind turbines and will begin testing a prototype 2.7-MW wind turbine in 2013. Hitachi, a Japanese multinational engineering and electronics conglomerate corporation, and Fuji Heavy Industries (FHI) have reached a basic agreement on the assignment of FHI's wind turbine business to Hitachi. The assignment of the wind business from FHI to Hitachi was completed in July 2012. Hitachi produces 2-MW downwind wind turbines (Figure 2) and announced plans to develop a 5-MW downwind offshore wind turbine. The prototype testing of the 5-MW offshore wind turbine will begin in fiscal year 2014, and Hitachi will start selling the 5-MW offshore wind turbine in fiscal year 2015.

Toshiba, also a Japanese multinational engineering and electronics conglomerate corporation, has decided to join the wind power generation business by cooperating with the South Korean wind turbine manufacturer, Unison.

Japanese manufacturers are competitive at delivering large bearings and electric devices in the international market. NSK, JTEKT, and NTN are producing large main bearings for wind turbine manufacturers worldwide. They are famous for the high reliability experience coming from Japanese automobile companies. Hitachi, TMEIC, Meidensha, and Yasukawa Electric are producing generators for wind turbines.

3.3 Operational details

The average capacity of new wind turbines was 2.438 MW in 2012, compared to 1.788 MW in 2011. The mean capacity of new turbines from 2005–2007 was 1.459 MW; therefore the size of new wind turbines is increasing. The estimated average capacity factor of wind turbine generation in Japan was 19.9% in 2012, the same as in 2011. However, the mean capacity factor from 2005–2007 was about 17.8%, therefore the capacity factor has increased in the past several years.

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 (2,610 EUR/kW; 3,480 USD/kW)
- COE: 11.0 JPY/kWh (0.096 EUR/MWh; 0.128 USD/MWh)
- O&M costs: 6,000 JPY/kW/unit/yr (52.2 EUR/kW/unit/yr; 69.6 USD/kW/unit/yr)
- Wind electricity purchase price: 7–9 JPY/kWh (0.061–0.078 EUR/MWh; 0.081–0.104 USD/MWh) until June 2012. Thereafter, 22 JPY/kWh (1.91 EUR/MWh, 2.55 USD/MWh) for wind power greater than or equal to 20kW of capacity, and 55 JPY/kWh (4.79 EUR/MWh, 6.38 USD/MWh) for small wind (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 NEDO, METI, and MOE are as follows:

A. NEDO R&D of Next-Generation Wind Power Generation Technology (FY 2008 to FY 2012)

A1. R&D of Basic and Applied Technologies

A2. Natural Hazard Protection Technologies (lightning protection measures)

A3. Natural Hazard Protection Technologies (wind turbine noise reduction)

B. NEDO Research and Development of Offshore Wind Power Generation Technology (FY 2008 to FY 2013)

Figure 2. Kushikino-Reimei wind power plant has ten 2-MW Hitachi HTW 2.0-80 turbines and began operation in December 2012. Source: Kyudenko Co., Inc.

C. MOE Floating Offshore Wind Turbine Demonstration Project (FY 2010 to FY 2015)

D. METI Floating Offshore Wind Farm Demonstration Project (FY 2011 to FY 2015)

E. MOE Environmental Assessment Model Project for Wind Power (FY 2011 to FY 2016)

In the NEDO R&D of Next-Generation Wind Power Generation Technology project (A1 and A2), severe external conditions such as typhoons, high turbulence by complex terrain, and lightning were surveyed in detail. The outcomes in these projects are now proposed as IEC international standards to expand the wind energy market by securing the safety and reliability of wind turbine generation systems in areas with such severe external conditions. In the NEDO project A3, a wind turbine acoustic model was developed and the effectiveness of the model was proved by the field experiments in an operating wind farm.

In NEDO R&D project B for offshore wind, an offshore wind turbine and an offshore measurement platform were planned to be installed at two offshore sites: Choshi in Chiba Prefecture (opening photo) 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 (1). In the Choshi offshore site, an MHI 2.4-MW wind turbine with gravity foundation and offshore platform were installed in the Pacific Ocean 3 km offshore in October 2012. In the Kitakyusyu site, an offshore measurement platform was installed 1.4 km offshore in June 2012. A JSW 2-MW gearless offshore wind turbine will be installed in 2013 in the Kitakyusyu offshore site. A distinctive feature of the Kitakyushu offshore project is the "hybrid gravity type" substructure for both offshore platform and wind turbine (1). R&D of very large offshore wind turbine generation system technology has also been supported in this NEDO offshore project. Innovative hydro-drive train and an 80-m class long rotor blade for very large offshore wind turbines are developed in this project.

Figure 3. A small-scale floating offshore wind turbine (SUBARU 22/100 100-kW) installed 1 km offshore in Nagasaki Prefecture in the MOE Floating Offshore Wind Turbine Project

Figure 4 Conceptual CG image of offshore floating offshore wind farm in the METI Floating Offshore Wind Farm Demonstration Project (Source: Fukushima FORWARD).

In MOE Floating Offshore Wind Turbine Demonstration Project C, a Subaru 100-kW machine small-scale demonstration wind turbine was installed on spar type floater 1 km offshore in Nagasaki Prefecture in June 2012 (Figure 3). At this offshore site, the water depth is about 100 m, and the extreme significant wave height is 7.7 m. The small-scale demonstration wind turbine will be replaced with a Hitachi 2-MW, full-scale, downwind type wind turbine on spar type floater in 2013.

METI published a plan for a Floating Offshore Wind Farm Demonstration Project in 2011 (Figure 4). This project was planned as Fukushima's revival act, and is treated as a symbol of Fukushima's revival by renewable energy. The main contractors are Marubeni, the University of Tokyo, MHI, Hitachi, IHI Marine United, and Mitsui Engineering and Shipbuilding. The general trading company, Marubeni, acts as project integrator, and the University of Tokyo is the technical adviser. In this large-scale floating offshore wind demonstration project, several offshore wind turbines with various types of floaters will be installed in the Pacific Ocean more than 20 km offshore of Fukushima prefecture. In Phase 1 (FY 2011 to FY 2013), a Hitachi 2-MW downwind type wind turbine with a 4-column semi-submersible floater and a 66 kV floating offshore electrical substation will be installed. In Phase 2 (FY 2014 to 2015), 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.

5.0 The Next Term

Drastic changes in the national incentive programs and implementation of environmental impact assessment took place in 2012. These may keep causing confusion in wind energy development in 2013. On the other hand, it is expected that the success of on-going full-scale R,D&D for offshore wind projects will accelerate offshore wind development in Japan.

References:

(1) NEDO offshore wind energy progress, www.nedo.go.jp/content/100515169.pdf?from=b

Author: Tetsuya Kogaki, National Institute of Advanced Industrial Science and Technology (AIST), Japan.

27 Republic of Korea

Source: Korea Energy Information Center

1.0 Overview

The cumulative installed wind power in the Republic of Korea was 406 MW in 2011 and 487 MW in 2012, increasing by 17% from the previous year. Most wind turbine systems installed in 2012 were supplied by local turbine system manufacturers. A Renewable Portfolio Standard (RPS) proposal for new and renewable energy was enacted in 2012. The required rate of RPS in 2012 was 2% and will increase to 10% by 2022. In 2012, the first year of RPS, more than 60% of the target rate was achieved. A nine-year plan for construction of a 2.5-GW offshore wind farm off the west coast was announced in 2010. The first stage of the project, construction of 100-MW wind farm, was initiated in 2011 and is in progress. The 2.5-GW offshore wind farm construction and RPS are expected to accelerate the growth of wind energy in Korea. Since 2009, the government has concentrated on developing Korean production of components to secure the supply chain for wind projects. More government R&D budget has been allocated to localize component supply and develop core technologies for wind power.

2.0 National Objectives and Progress

The Republic of Korea has focused on wind energy as the clean energy resource that could replace fossil fuels and nuclear power, and also as a new area of heavy industry to expand the Korean economy. Therefore, the government has increased the R&D budget continuously to support Korean 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 2012, the total installed wind power (machines rated above 200kW) was 487 MW a 17% growth since 2011 (Table 2).

2.1 National targets

The national target is to promote wind energy to reach 7.3 GW by 2030 and replace 11% of total energy consumption as stipulated in the Third National Energy Plan 2030. That plan also calls for about 12.6% of consumption to be shared among the new and renewables. Another goal is to raise the level of the technology associated with wind energy and lead the wind energy industry.

2.2 Progress

In 2012, 81 MW of new wind power was installed in Korea, increasing total capacity

The new capacity installed in 2012 was three times more than was installed in 2011, and most of the turbines were supplied by domestic manufacturers.

Table 1. Key National Statistics 2012: Korea	
Total installed wind capacity	487 MW
New wind capacity installed	81 MW
Total electrical output from wind	0.863 TWh (2011)
Wind generation as % of national electric demand	0.17% (2011)
Average capacity factor	n/a
Target:	7.3 GW by 2030

Table 2. Total Installed Wind Capacity in Korea

Year	~2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total
Capacity (MW)	12.6	5.4	50	31	79	18	108	44	33	27	81	487
Electrical Output (GWh)	15	23	38	125	234	371	421	678	812	863	-	-

by 17%. The capacity installed in 2012 was three times more than was installed in 2011 and most of the turbine systems were supplied by domestic manufacturers. Domestic manufacturers have developed their systems and are recording turbine operation.

In 2011 (the latest year for which data are available), net sales of the wind energy business decreased 14% from the previous year to an estimated 916 million USD (694 million EUR) (Table 3). This amount was 10% of total renewable energy sales. In contrast, solar energy sales grew in 2011 and comprised 80% of renewable energy sales.

The number of wind turbine manufacturers has increased steadily and in 2011, 38 companies were involved in the wind energy industry. The number of employees were estimated to be 2,456 in 2011. Most manufacturers concentrated on developing products and technologies, and more employees are dedicated to R&D than to production.

The history of wind energy in Korea is short compared to countries with established wind industries. However, Korean communities are striving to catch up with core technologies. Although the level of technology is still behind the cutting-edge technologies, it has been improved and was roughly estimated to be more than 80% of the leading countries.

Table 3. Total Sales of Wind Energy Business in Korea

Year	2007	2008	2009	2010	2011
Total Sales (million USD)	563	1,234	1,076	1,062	916
Ratio (%)	50	40	25	14	10

2.3 National incentive programs

The government subsidizes the installation of NRE (New and Renewable Energy) facilities to enhance deployment and to relieve the end user's burden. The government has especially focused on school buildings, warehouses, industrial complexes, highway facilities, factories, and electric power plants. For wind power installations, 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 renewable energy in residential areas, the government expanded the 100,000 solar-roof program to be the one million green homes program for diversifying and optimizing the renewable energy use. The target is to construct one million homes equipped with the green energy resources by 2020. By the end of 2011, 111,400 homes were equipped with green energy.

• Green requirement to public buildings: New construction, expansion, or remodeling of public buildings having floor area exceeding 3,000 square meters are required to invest more than 5% of their total construction expense in the installation of new or renewable energy systems.

• Feed-in Tariff (FIT): The standard price has been adjusted annually reflecting the change of the NRE market and economic feasibility of NRE. Concerning wind energy, the FIT was 0.092 USD/kWh (0.0697 EUR/kWh) as a flat rate for 15 years in 2012. The FIT is being applied to the wind farms installed by 2011, while new farms constructed from 2012 are supported with RPS.

• RPS: RPS was approved by Congress to begin in 2012. More than 2% of electric power should be supplied by renewable resources in 2012. This regulation applies to electric power suppliers providing more than 500 MW. The required rate will increase to 10% in 2022. The RPS includes weighting factors: for onshore wind farms (1.0), offshore wind farms less than 5 km from shore (1.5), and offshore wind farms more than 5 km (2.0). The RPS began in 2012 and more than 60% of the yearly target was achieved end of 2012.

In addition, a loan and tax deduction program, 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 a 2.5-GW offshore wind farm in the West Sea. According to the roadmap announced by the government, the 2.5-GW farm will be constructed through three stages over nine years, beginning in 2011 (Table 4). For the first four years, 100 MW of wind power will be installed to demonstrate the performance of the technology and of the site design. Then, 400 MW of wind power will be installed to accumulate operational experience and commercial purpose for the next two years. At the final stage, 2 GW of wind power will be constructed with 5-MW wind turbines for commercial use. The total budget is estimated to be 7.5 billion USD (5.685 billion EUR).

Another issue affecting growth is the RPS program starting from 2012. Major electric power suppliers are required to provide 2% of the power with renewable energy including wind power in 2012 and the rate will increase to 10% in 2022. This regulation will stimulate power suppliers to invest in renewable resources.

3.0 Implementation

3.1 Economic impact

As reported in the *IEA Wind 2011 Annual Report,* major shipbuilding and heavy industry companies have developed their own wind turbines and some companies have established track records for these machines. Sales in 2011 were less than 2010 and recorded only 916 million USD (694 million EUR). The export of turbine systems was initiated in 2009, but oversea sales were small. Even employment was slightly decreased and recorded 2,456 employees.

3.2 Industry status

Some manufacturers expand their business into other renewable resources such as solar energy or tidal energy to provide stable renewable energy. However the global economic crisis has deteriorated the vision of the renewable energy and new investment plans are being reviewed seriously.

3.3 Operational details

In 2012, 81 MW of wind power was installed and most turbines were supplied by domestic manufacturers. Twelve 2-MW turbines were supplied by Hyundai, eleven 1.5-MW turbines by Hanjin, five 3-MW turbines by Doosan, five 2-MW by Hyosung, and three 750-kW turbines by Hyosung. Unison installed three 750-kW turbines; STX and DMS each provided one 2-MW turbine.

3.4 Wind energy costs

Newly installed wind turbines, especially those supplied by the domestic manufacturers, are not operated for the commercial purpose but for system checking and demonstration. Therefore, there are not enough electric output records and it is still difficult to estimate the real wind energy cost.

4.0 R, D&D Activities

4.1 National R, D&D efforts

The government has continuously increased the R&D budget and ensured the

Table 4. The 2.5-GW Offshore Wind Farm Construction Plan

	Demonstration	Standardization	Deployment
Objective	Test record set up; accumulation of track record site design	Operational experience; validation of commercial operation	Cost effectiveness; GW site development; and commercial operation
Wind Power	100 MW	400 MW	2,000 MW
Schedule	2011–2014 (4yrs)	2015–2016 (2yrs)	2017–2019 (3yrs)

strong will for wind energy. Even the Korean President mentioned wind energy as one of the candidates to expand the Korean economy at the New Year's news conference in 2011. The government allocated an R&D budget for developing domestic wind turbines but then realized the importance of a stable supply chain. The government, therefore, has increased the budget to develop the technologies for components and several government sponsored R&D projects are under way (Figure 1). More component development projects, as confirmed in Table 5, are launched every year. Table 5 presents the portion of component among the government R&D and 40% of the R&D budget supported component development in 2010. The components being developed for the domestic production are brake calipers, pitch system and controllers, offshore floating simulation codes, condition monitoring, yaw bearings, blade damage smart sensing, low-voltage ride-through converter algorithms, shrink disks, gearboxes, yaw and pitch drives, and others.

5.0 The Next Term

The first stage of the 2.5-GW offshore wind farm was initiated in 2011 and the RPS program was enacted in 2012. These major issues are expected to encourage the electric power suppliers and turbine system manufacturers to plan for profitable wind farm construction. Also, many wind farm projects are planned by private companies and provincial governments; therefore, it is quite difficult to project future activities in detail.

Reference:

The opening photo shows Youngyang wind farm in Korea.

Authors: Cheolwan Kim, Korea Aerospace Research Institute; Ji-yeon Kang, Korea Energy Management Corporation; and Jong Hoon Lee, Korea Institute of Energy Technology Evaluation and Planning, Korea.

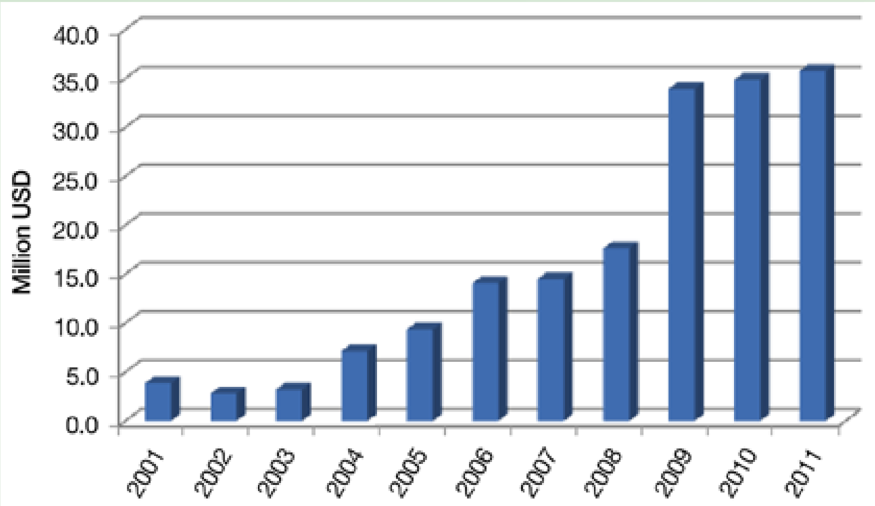

Figure 1. The budget trend of government sponsored R, D&D

Table 5. Government R&D budget allocation in 2009 & 2010

Category	2009			2010		
	No. of Projects	Budget million USD	Rate (%)	No. of Projects	Budget million USD	Rate (%)
System	3	11.6	34	7	5.7	16
Field Test	3	9.2	27	2	12.1	35
Component	11	9.2	27	17	13.9	40
Electric, Controls	5	2.6	8	3	2.2	6
Others	3	1.3	4	3	0.9	3
Total	27	33.9	100	32	34.8	100

28 México

Source: PWT Communications LLC

1.0 Overview

During 2012, 645 MW of new wind turbines were commissioned in México, bringing the total wind generation capacity to 1,212 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 2000-MW, 400-kV, 300-km electrical transmission line was commissioned for wind energy projects in the Isthmus of Tehuantepec. Presently, the construction of 276 MW of new wind power capacity has been secured. This will bring the total generation capacity to at least 1,488 MW by the end of 2013. 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 3,708 MW of wind power capacity. It is estimated that up to 12,000 MW of economically-feasible projects could be implemented in México by 2020. 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, and Tamaulipas, 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 2020 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

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 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 Latin America (owned by CEMEX) and is aimed at supplying around 25% of the CEMEX Company's electricity demand. Eléctrica del Valle de México (opening photo) has the largest wind turbines installed in México, 27 2.5-MW turbines from Clipper Windpower. 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 2012, total electrical output from wind was around 3.4 TWh, which is equivalent to around 1.2% of national electric demand.

2.2.2 Environmental benefits

Reduction of CO_2 emissions due to wind generation for the year 2012 was 1.97 Mtons, considering a mitigation rate of 0.58 tons CO_2 /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

It is estimated that up to 12,000 MW of economically-feasible projects could be implemented in México by 2020.

Table 1. Key National Statistics 2012: México	
Total installed wind capacity	1,212 MW
New wind capacity installed	645 MW
Total electrical output from wind	***3.4 TWh***
Wind generation as % of national electric demand	***1.2%***
Average capacity factor	***30%***
Target:	***12,000 MW by 2020***
Bold italic indicates estimate.	

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; 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

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 2012, it was estimated that the total investment in the construction of wind power plants was around 2.4 billion USD (1.8 billion EUR). Assuming that around 80% of this amount corresponds to the cost of the wind turbines, the rest, around 480 million USD (364 million EUR) could be considered as the economic distribution to México. Nevertheless, a substantial portion of the work is carried out by foreign employees.

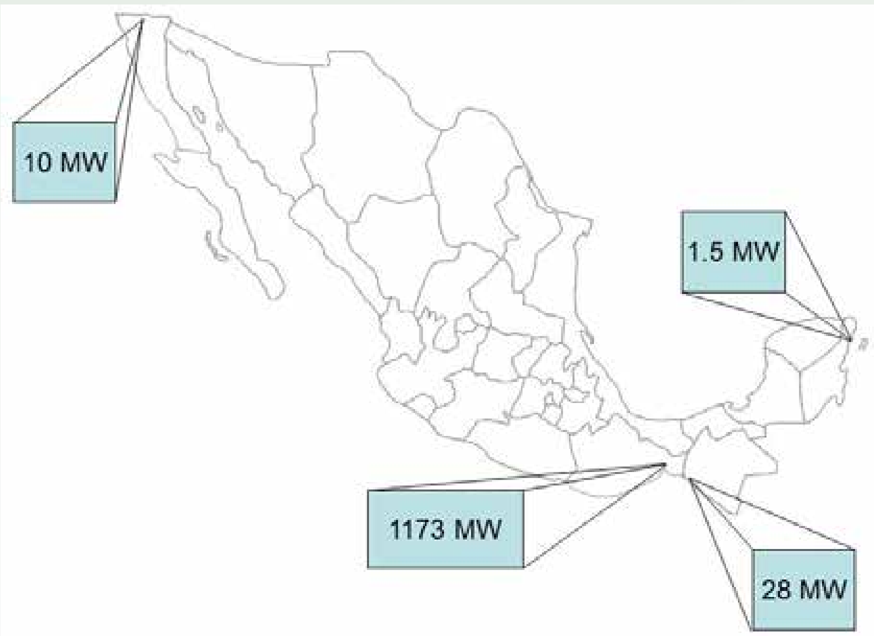

Figure 1. Wind generating capacity installed in México as of December 2012

3.2 Industry status

The Spanish wind turbine manufactures Acciona Windpower and Gamesa Eólica are leading the Mexican wind turbine market, but other companies like Vestas have been awarded important contracts.

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 large- 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.

Table 2. Progress on wind generation capacity in México

Wind power station	No. WT	WT (KW)	WT Manuf.	Station capacity (MW)	Status by the end of 2010	Type (1)	Year (2)	State
La Venta I	6	225	Vestas	1.3	Commissioned	FGOB	1994	OAX
Guerrero Negro	1	600	Gamesa	0.6	Commissioned	FGOB	1998	BCS
La Venta II	98	850	Gamesa	83.3	Commissioned	FGOB	2007	OAX
Parques Ecológicos F1	93	850	Gamesa	79.9	Commissioned	POSS	2009	OAX
EURUS	167	1,500	Acciona	250	Commissioned	POSS	2009	OAX
Bii Nee Stipa	31	850	Gamesa	26.3	Commissioned	POSS	2010	OAX
Certe-IIE (F1)	1	300	Komai	0.3	Commissioned	I+D	2010	OAX
E. Valle de México	27	2,500	Clipper	67.5	Commissioned	POSS	2010	OAX
Mexicali	5	2,000	Gamesa	10.0	Commissioned	SGOB	2010	BC
Fuerza Eólica	20	2,500	Clipper	80.0	Commissioned	POSS	2011	OAX
La Venta III	121	850	Gamesa	102.9	Commissioned	IPP	2012	OAX
Oaxaca I	51	2,000	Vestas	102.0	Commissioned	IPP	2012	OAX
Oaxaca II	68	1,500	Acciona	102.0	Commissioned	IPP	2012	OAX
Oaxaca III	68	1,500	Acciona	102.0	Commissioned	IPP	2012	OAX
Oaxaca IV	68	1,599	Acciona	102.0	Commissioned	IPP	2012	OAX
Stipa Nayaa		850 & 2,000	Gamesa	74.0	Commissioned	POSS	2012	OAX
Eólica de Arriaga	14	2,000	Vestas	28.0	Commisioned	POSS	2012	OAX
DEMSA (F1)	45	2,000	Gamesa	90.0	U. Construction	POSS	2013	OAX
Eoliatec Istmo	82	2,000	Gamesa	164.0	U. Construction	POSS	2013	OAX
DEMSA (F2)	68	2,000	Gamesa	137.5	U. Construction	POSS	2014	OAX
Eólica Mareña	60	3,000	Vestas	180.00	U. Construction	POSS	2014	OAX
Not initiated	-	-	Several	1,902.6	Not initiated	-	-	-
Accumulated				3,708.5				

(1) FGOB=Federal Government, SGOB= State Government, POSS= Private owned self-supply, IPP= Independent Power Producer, I+D= Research and Development

(2) Commissioning year

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 in 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 new 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 it is happening in many parts of the world, some investors are worried because there is too much uncertainty about how much it is going to cost for post-warranty maintenance.

3.4 Wind energy costs

Investment cost for installed wind energy projects in the Isthmus of Tehuantepec are around 2,000 USD/KW (1,500 EUR/kW). In that region, the buy-back price for IPP generators is around 0.065 USD/KWh (0.049 EUR/kWh).

4.0 R, D&D Activities

4.1 National R, D&D efforts

With the economic support of the GEF and the UNDP, the Instituto de Investigaciones Eléctricas (IIE) implemented a Regional Wind Technology Center (WETC) (opening photo). In 2009, a special class of wind turbine prototype was installed in the WETC for testing purposes. The 300-kW wind turbine is manufactured by the Japanese company Komaihaltec, Inc. According to the

Figure 2. La Venta II 83.3-MW wind farm in the Isthmus of Tehuantepec, México

manufacturer's specifications, the potential use for this turbine is distributed generation. It will be appropriate especially where site access is difficult, turbulence intensity is up to 20%, and seismic hazard is high.

With the support of the Sener and the National Council for Science and Technology, the IIE is working on national capacity building on the most relevant topics involved in the implementation of wind energy. The IIE is also carrying out specific studies and projects for CFE. The IIE developed a National Wind Energy Resource Atlas (Figure 4) that was presented by President Calderón during the COP 16 meeting.

4.2 Collaborative research

The IIE participates in IEA Wind Task 11 Base Technology Information Exchange.

5.0 The Next Term

Presently, the construction of 276 MW of new wind power capacity has been secured. This will bring the total generation capacity to at least 1,488 MW by the end of 2013. It is expected that public and private companies will be capable of managing appropriately pending social requirements.

Author: Marco A. Borja, Instituto de Investigaciones Eléctricas (IIE), México.

Figure 3. Mexican Wind Energy Atlas

29 the Netherlands

Source: André de Boer

1.0 Overview

The long history of using the wind for the current and next generation (opening photo) continues in the Netherlands. While 2012 saw a smaller market growth than in previous years, new approaches to incentives and R&D promise more advancement in the coming years.

2.0 National Objectives and Progress

2.1 National targets

In April 2012 the center-right cabinet fell, leading to elections in September 2012 and a new left-right cabinet in November 2012. The previous government reduced the renewable energy target for 2020 from 20% to 14%, but the new cabinet brought it back to 16%. The CO_2 target for 2020 remained unchanged at 20% CO_2 emission reduction compared to 1990. The main tools to achieve these targets are the SDE (stimulering duurzame energie) plus (+) incentive subsidy, Kyoto mechanisms, European mechanisms, a Long-Term Agreement with the industry, government branches for energy efficiency, and more than 140 Green Deals with society aiming at energy efficiency and production of renewable energy.

Within these renewable energy targets, no official targets for wind are currently set. The official vision and ambition in 2012 is that the "national government and provinces will make spatial planning as much as possible suitable for the growth of wind on land to at least 6,000 MW in 2020." Even though there was opposition from lower governments during 2012, this goal to appoint areas for wind energy on land has been reconfirmed by all players and has been backed by all provinces. In addition, the national government will designate enough space for 6,000 MW of wind at sea. Until 2012, the policy was to have offshore wind projects outside of the 12-mile zone. In order to implement renewable energy as cheaply as possible, off shore wind projects might be allowed within the 12-mile zone in the near future.

2.2 Progress

Progress in the Netherlands was limited to a net installation of 115 MW. This value consists of a gross installation of 161 MW of new turbines, while 46 MW of old wind turbines were removed or replaced. All changes happened on land, while offshore remained unchanged at 228 MW.

2.3 National incentive program

In 2011, the SDE+ subsidy was introduced, a subsidy to compensate the gap between the payback-tariff and the price of the renewable energy. SDE+ is meant to implement the cheapest forms of renewable energy first and gives no priority to particular renewable energy technologies.

SDE+ defines three main categories of energy carriers: renewable electricity, renewable heat/power, and renewable gas. Within these three main categories, subcategories and techniques have been defined for specific technologies (e.g. offshore wind, wind on land, wind in lakes, solar PV, waste incineration, geothermal, and solar thermal). For all subcategories and these techniques the Netherlands Research Institute ECN and DNV KEMA determine fixed energy prices (EUR/kWh, EUR/nm3 or EUR/GJ). Within the SDE+ calculations, all energy prices are expressed in kWh (renewable electricity), nm3

Offshore, the average capacity factor in 2012 was 39.5%

Table 1. Key National Statistics 2012: Netherlands	
Total installed wind capacity	***2,431 MW***
New wind capacity installed	***161 MW***
Total electrical output from wind	4.9 TWh
Wind generation as % of national electric demand	4.1%
Average national capacity factor	
Target 2020	16% renewable energy and 20% reduction CO_2 as compared to 1990 level
Bold italic indicates estimate	

(renewable gas) or GJ (renewable heat) but are directly convertible between each other to make energy prices comparable.

To apply for SDE+, a producer of renewable energy has to claim its price of energy and has to report about the payback tariff of the energy company. SDE+ can be received for the difference between the claimed price of energy and the received payback tariff. In 2012, applications could be made in five calls: 1) in March for a price of energy of 0.07 EUR/kWh (0.09 USD/kWh), 2) in May for approximately 0.09 EUR/kWh (0.12 USD/kWh), 3) in June for approximately 0.11 EUR/kWh (0.14 USD/kWh), 4) in September for approximately 0.13 EUR/kWh (0.17 USD/kWh), and 5) in November for approximately 0.15 EUR/kWh (0.19 USD/kWh). Assuming a feed-in tariff of around 0.05 EUR/kWh (0.07 USD/kWh) this means calls for a SDE+ subsidy of ~0.02 EUR/kWh (0.03 USD/kWh), ~0.04 EUR/kWh (0.05 USD/kWh), ~0.06 EUR/kWh (0.08 USD/kWh), ~0.08 EUR/kWh (0.11 USD/kWh) and ~0.10 EUR/kWh (0.13 USD/kWh).

In total, an SDE+ budget was available of 1.7 billion EUR (2.2 billion USD). Since the SDE+ budget has not been partitioned in budgets per energy carrier of techniques, in principle it was possible that the entire budget would be spent on only one (the cheapest) technique. When the process closed it became clear that the whole budget was claimed in the first call. SDE+ will be spent only for projects with a renewable energy price of 0.07 EUR/kWh (0.09 USD/kWh). Of the 1.7 billion EUR (2.2 billion USD), 8.0 million EUR (10.5 million USD) has been granted for electricity; amongst this, 2.0 million EUR (2.6 million USD) was granted for a wind on land project. Of the remaining funds, 1.65 million EUR (2.18 million USD) was granted for renewable heat (half of it for geothermal energy) and 38 million EUR (50 million USD) was granted for renewable gas projects. This means that wind energy received ±1% of the budget.

2.4 Issues affecting growth

The SDE+ incentive program explained above makes it difficult for wind energy to receive subsidies. The cost of wind energy on land generally is generally near or little bit less than 0.10 EUR/kWh (0.13 USD/kWh). The cost of offshore wind energy is approximately 0.16 EUR/kWh (0.21 USD/kWh) and in actual practice cannot receive the SDE+ subsidy. For offshore wind the focus is therefore clearly put first on reducing the cost of energy before large deployment will take place.

Furthermore, the availability of good wind locations 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 2012 can be estimated at 217 million EUR (286 million USD), assuming an average investment cost for land-based wind of 1,350 EUR/kW (1,780 USD/kW) for the 161 MW gross installed. The total investment in wind energy installations built up to 2012 is estimated at approximately 4.1 billion EUR (5.4 billion USD) (price level: 2012). In 2011 a report about the economic impact of the offshore wind sector was published (1). 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% is in construction, 12% in O&M, 11% is 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 (1.1 billion USD), but it is very likely that the real turnover is much more than 1 billion EUR (1.3 billion USD). The report will be updated in 2013.

3.2 Industry status

After some years of near absence, Dutch turbine manufactures are gradually coming back. Lagerweij company has its roots in the late 70s 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, installed its first prototype in the Netherlands (Figure 1), and started taking orders from abroad. The turbine operates at variable speeds. Because it is high efficiency, nature 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 U.K. but also for Alaska in the United States. It is expected that a 2.0-MW turbine will be certified in 2014. All EWT's turbines are meant for IEC61400 wind class IIA or IIIA.

The Dutch-Chinese enterprise XEMC-Darwind has sold its first ten XD115/5-MW offshore turbines. 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, installing services, or delivering 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

Figure 1. The first new L93 Lagerwey 2.6-MW turbine becomes operational

Table 2. Calculated Wind Energy Costs

	Investment Costs EUR/kW (USD/kW)	Fixed O&M EUR/kW x year (USD/kW x year)	Variable O&M EUR/kWh (USD/kWh)	Full load hours/yr	Cost of Energy EUR/kWh (USD/kWh)
Wind on Land (<6 MW)	1,350 (1,779)	25.8 (34.0)	0.011 (0.014)	2,200	0.096 (0.126)
Wind on Land (≥6 MW)	1,950 (2,570)	25.8 (34.0)	0.0095 (0.0125)	3,000	0.096 (0.126)
Wind in Lakes	2,450 (3,229)	15.3 (20.2)	0.022 (0.029)	3,100	0.123 (0.162)
Wind Offshore	4,000 (5,272)	150 (198)	0.00 (0.00)	4,000	0.160 (0.211)

available for prototypes with a maximum tip height of 200 m.

3.3 Operational status

The wind index is a way to evaluate wind plant performance over the year. Although difficult to compare from year to year and wind indices in the long term have a variable basis, 2012 had a wind index of 89%. The 2012 wind index is based on the period 2001–2011, which is known to be a slightly wind poor period, compared to previous periods. Given these facts, the capacity factor on land in 2012 was 20%. This is only slightly lower than the last 10-year average capacity factor of 21.4%. This indicates that, despite lower winds, 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 2012 was 39.5%. Since the first offshore wind farm became operational in 2007, only six years of offshore statistics are available. In these six years, the ratio between the offshore and onshore capacity factors (1.97:1.00) has never been this high.

3.4 Wind energy costs

Every year the cost of wind energy is calculated to determine the SDE+ tariff. Because of initiatives to build wind farms in the Lake IJsselmeer (sea until 1932, 1,100 km^2, maximum depth of 9 m) a new wind category has been defined in the SDE+ systematics: wind in lakes. Besides that, the wind on land category is split up in the categories <6MW and ≥6MW. For all calculations, some basic assumptions are presented in Table 2.

4.0 R, D&D Activities

4.1 National R, D&D efforts

In 2012, R&D programs in the Netherlands experienced major changes. The leading idea behind this was to have the business sector, research centers, and universities directing R&D, instead of having R&D being directed from politics and governmental organizations. To accomplish this change, seven sectors of energy saving and renewable energy generation were chosen as spearheads of R&D policy. These sectors were chosen because of their R&D and industry position and their potential to contribute to sustainability and the national economy.

The sectors have set up their own organization—the Topconsortia for Knowledge and Innovation (TKI)—representing their R&D community and their involved industry. Wind energy is present in the TKI Wind Offshore. The TKI Wind Offshore has written its R&D vision (Dutch: "Innovatiecontract") and has received 7.3 million EUR (9.6 million USD) for a first R&D tender and 800,000 EUR (1 million USD) for strategic activities. 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 HVgrid, transport installation

Figure 2. Fistuca: A test model with a column of water delivering reaction force for the combustion room on top of the monopile

Figure 3. Marin Splash: A test of the impact of breaking waves on support structures in Marin's shallow water basin

and logistics, O&M, and wind farm development. Under the R&D tender, six projects were granted:

- Investigation to connect an offshore wind farm directly to a interconnector at the Northsea
- Development of the technique of driving monopiles (BLUE Piling) using explosives at the bottom of a pile filled with water (Figure 2)
- Development of a motion compensated crane for transferring people and goods up to 5 metric tons
- Modeling the dynamics of extreme wave events (Figure 3)
- Efficiency improvements of Lidar
- Fatigue modeling for metal, leading to mass reduction and extended inspections intervals.

Part of the "Innovatiecontract" is the organizing and setting up of an experimental offshore wind farm (100 MW) by TKI Wind Offshore. This is meant to test innovations, techniques, and work methodologies that are nearly ready for the market. Preparations for a demonstration offshore wind farm (200 MW) are also underway.

Besides this new budget for the TKI Wind Offshore, old budgets from previous R&D programs being are being spent. The main subjects are:

- projects on wind turbine development (XEMC Darwind (5-MW offshore), 2B Energy (6-MW offshore), Emergya Wind Technologies (2-MW onshore)
- 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.)

The extended Far and Large Offshore Wind energy (FLOW) program with an expected 47 million EUR (62 million USD) in project costs is fully operational. In FLOW, 13 parties are involved (industry and utilities) working on more than 40 projects. The main themes here are: wind farm design (projects on cost calculation, wind farm wake modeling, and wind farm controls), support structures (projects on monopiles for depth of 50m, development of design tools for support structures, scour protection study, designing of slipjoints, 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 2Benergy concept to 140-m rotor and IPC), and societal aspects (such as cost assessment) (Figure 4).

The Monitoring and Evaluation Program (MEP) of the Offshore Wind farm Egmond aan Zee (OWEZ), formerly known as NSW, is almost completed. It consists of two parts: technology/economy and ecology/environment. In 2011, the technology/economy part already was completed. In 2012 the ecology/environmental part was completed and the results were presented in a workshop in Amsterdam in October (2). The MEP-OWEZ gave lots of new scientific results and insights. The wind farm has few negative but several positive effects upon marine life. It also became clear that monitoring alone is not enough. Fruitful monitoring can only be done when parallel good models exist to interpret the data. Further measuring under a wide scope is necessary: natural causes and/or human actions also might give changes and are otherwise difficult to recognize.

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). The Netherlands withdrew from Task 28 Social Acceptance of Wind Energy. Participation in the IEA Wind tasks has proven to be a cost-effective way to conduct research. On average, 1 EUR spent in the Netherlands on research gives access to a value of 5 EUR of research spent in the other participating countries.

5.0 The Next Term

5.1 Innovation Contract/TKI

In 2013, further continuation of the work under the guidance of TKI Offshore Wind is foreseen. Expected is new set of tenders, with criteria defined in close cooperation with the market but evaluated by independent experts.

5.2 SDE+ in 2013

The SDE+ 2013 will not be very much different from the 2012 system, but the budget will nearly double to 3.0 billion EUR (3.9 billion USD). Besides, there will be an extra category of 0.08 EUR/kWh (0.10 USD/kWh) and applications on geothermal (which claimed a big part of the budget) will be limited, meaning projects now can apply for 0.07, 0.08 and 0.09 EUR/kWh (0.09, 0.11, and 0.12 USD/kWh). In 2011 and 2012, many applications in the lowest and cheapest category have been granted and market analyses indicate there are not many projects in the pipeline with costs of approximately 0.07 EUR/kWh (0.09 USD/kWh), as the "low hanging fruit already has been picked." It is expected that there will be budget left over for higher categories than in previous years, making successful application of wind on land projects more likely.

5.3 Projects

For 2013, the project Zuidlob (122 MW) is expected to be finished. The construction of project Noordoostpolder (458 MW) will continue in 2013. This project will consist of 38 land-based 7.5-MW turbines, and 48 offshore 3.6-MW turbines in Lake IJsselmeer.

References:

(1) www.agentschapnl.nl/sites/default/files/bijlagen/Sectoronderzoek%20Offshore%20Windenergie.pdf (Dutch)

(2) www.noordzeewind.nl/en/

Author: André T. de Boer, NL Agency, The Netherlands.

Figure 4. The ECN test field where many FLOW and other research projects are being done

30 Norway

Photo: PWT Communications LLC

1.0 Overview

In 2012, 195.3 MW of new wind power capacity was installed in Norway, which is more than has ever been installed in one year before. Total installed capacity was 704 MW at the end of the year and production of wind power in 2012 was 1,569 GWh compared to 1,308 GWh in 2011. The calculated wind index for Norwegian wind farms in 2012 was 103%, corresponding to a production index of 107%. The average capacity factor for Norwegian wind farms in normal operation was 31.2%. Wind generation amounted to 1.1% of the total electric production in the country. Fakken Wind Farm in Norway is shown in the opening photo.

Electric energy in Norway is generated using a very high share of renewable energy. The primary source of electricity is hydropower which in 2012 stood for approximately 97% 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 2012 are shown in Table 1 and Figure 1.

2.0 National Objectives and Progress

2.1 National targets

Renewable sources of electricity amounted to 98% of the national electricity production in Norway in 2012. About 1% of the electricity production came from wind power. Wind and hydropower production in Norway were above average in 2012, and this, combined with increases in installed capacity for both technologies, resulted in a record-high annual energy production of 147.9 TWh in 2012. With electricity consumption in the country totaling 130 TWh for the year this meant a net electricity export of 17.9 TWh.

The already high ratio of renewable energy production combined with concerns about wind power development's local environmental impacts has provided fuel for considerable public debate on the topic of wind power development in Norway in recent years.

As a member of the European Economic Area (EEA), Norway was obliged to accept the EU's renewable energy directive in 2011. The target for renewable energy was set to 67.5% of total energy consumption. This target is to be met through a combination of energy efficiency measures and increased renewable energy production.

The incentive mechanism for increasing renewable energy production in Norway is a joint support scheme with Sweden to finance 26.4 TWh/yr of new renewable energy production by 2020. This market-based electricity certificate scheme is unique in that the targets are both country- and technology-neutral, meaning that the policy does not dictate which country the new renewable energy production comes from or which type of renewable energy is produced. The objective of this policy is rather to allow

The average capacity factor for Norwegian wind farms in normal operation was 31.2%.

Table 1. Key National Statistics 2012: Norway	
Total installed wind capacity	704 MW
New wind capacity installed	195 MW
Total electrical output from wind	1.6 TWh
Wind generation as % of national electric demand	1.1%
Average capacity factor	31.2%
Target:	N/A

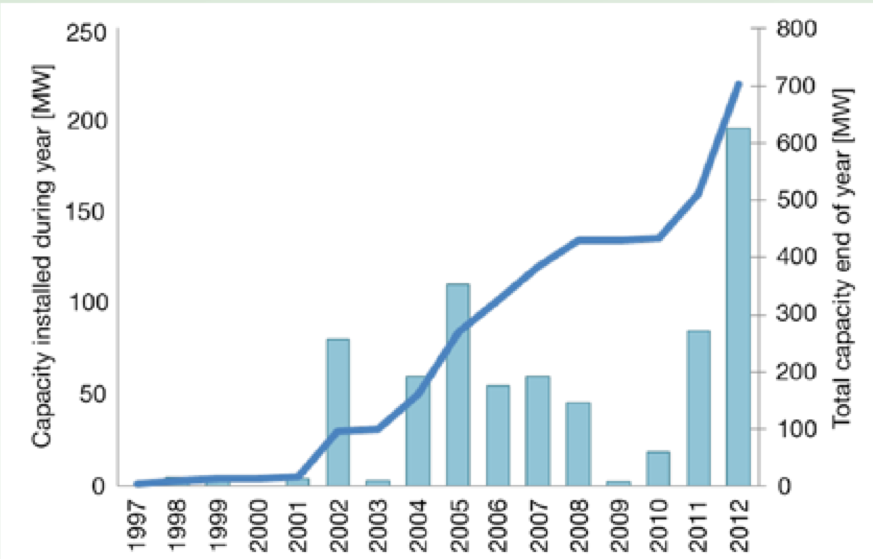

Figure 1. Installed wind capacity in Norway 1997–2012

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; however the record installation of wind power capacity in 2012 consisted almost entirely of projects which received investment support from the previous Enova scheme in 2009 and 2010. These projects had the option of repaying the Enova support and going over to the new support scheme but none chose to do so. Instead the only Norwegian wind farms which were eligible for electricity certificates at the end of 2012 were the Åsen II wind farm and Blaaster prototype turbine at the Valsneset Test Center, which together total only 4.6 MW. The first larger wind farm to be eligible for the electricity certificate scheme will be the 57.5-MW Midtfjellet II wind farm, which is expected to be completed in 2013.

2.3 National incentive programs

From 2001 to 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. Enova will from 2012 focus 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 resources. Hence, owners of approved plants have two products on the market: electricity and certificates. They can be sold independently of each other.

Figure 2. Fakken Wind Farm. (Photo Credit: Svein Erik Thyrhaug, Troms Kraft)

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 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. According to the best estimates, wind power is expected to contribute around half of Norway's 13.2 TWh/yr new renewable energy target by 2020.

3.0 Implementation

3.1 Economic impact

Norwegian industry takes part in component production for wind energy systems, e.g. wind turbine blades and nacelles on a relatively small scale. Companies with experience from the offshore oil industry (e.g. OWEC Tower and Aker Solutions) have widened their scope of interest and engagement to the offshore wind industry. These companies offer offshore wind turbine substructure solutions like Jacket Quatropod and Tripod. Increased construction of wind farms will generate engineering and construction jobs, and ultimately jobs for maintenance personnel.

3.2 Industry status

Production of wind power is dispersed among several energy companies, some of which are small local utilities. The largest wind power projects are operated by large national energy companies. Some Norwegian companies (Fred Olsen Renewables, Statkraft, and Statoil) are also engaged in projects in foreign countries, like offshore wind in the United Kingdom. So far, there is no significant wind turbine manufacturing industry in Norway.

3.3 Operational details

In 2012, the capacity factor of wind farms larger than 5 MW varied between 23% and 4%. The average capacity factor was 31.2%, and the average technical availability was 95.6%. The technical availability of new wind turbines in Norway is usually in the range of 95% to 99%. Annual energy per swept area ranged from 416 to 1,970 KWh/m^{2,} with a national average of 1,330 KWh/m^2.

3.4 Wind energy costs

The total wind farm installation costs are estimated between 11.5–12.5 million NOK/MW (1.5–1.6 million EUR/MW; 1.9–2 million USD/MW). Annual maintenance is reported to be between 0.12–0.16 NOK/kWh (0.014–0.02 EUR/kWh; 0.020–0.026 USD/kWh), with an average cost of 0.15 NOK/kWh (0.019 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 510 NOK/MWh (64 EUR/MWh; 85 USD/MWh), including capital costs (discount rate 6.0%, 20-year period), operation, and maintenance.

4.0 R, D&D Activities

4.1 National R, D&D efforts

In accordance with a broad-based political agreement on climate achieved in the Storting (the Norwegian parliament) and the national R&D strategy for energy (Energi21), the Research Council of Norway has founded eight Centers for Environment-friendly Energy Research (CEER). The goal of the centers is to become international leaders in their respective areas of energy research and to make environmentally friendly energy profitable. Each CEER will receive up to 20 million NOK (2.4 million EUR; 3.4 million USD) annually over a five-year period with the possibility of receiving an extension of funding up to eight years. Two of the CEERs focus on 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. A third CEER, the Center for Environmental Design of Renewable Energy (CEDREN) conducts research on environmental issues within wind energy and other renewable energy production.

The Research Council of Norway also administers a public research program for sustainable energy. In 2012 the previous program, RENERGI, reached its final year and was replaced by a new ten-year program ENERGIX. ENERGIX 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 on proposals to regular calls. The budget and topics are similar to RENERGI, but ENERGIX will focus slightly more on new concepts and long term research. The budget for 2012 was 385 million NOK (52 million EUR; 69 million USD). In total, the Research council granted 126 million NOK (17 million EUR; 22 million USD) to wind energy research in 2012. In December 2012 the following wind energy R&D projects were approved for funding:

- Innovative Mitigation Tools for Avian Conflicts with Wind Turbines (INTACT), Energi Norge
- Integration of Computational Fluid Dynamics (CFD) and Meteorological Modelling Techniques to Optimize Wind Farm Performance, WindSim AS
- Concrete Substructure for Floating Offshore Wind Turbines, Dr.techn.Olav Olsen AS

In addition to this, several projects have been funded through the RENERGI budget the last few years. One of them is a 1:6 scale model floating offshore turbine called SWAY which is being tested in the sea outside Bergen under real conditions.

The world's first full-scale floating wind turbine (Hywind concept developed by Statoil) is operational. Statoil has operated the turbine for over two years and results for both production and technical availability have been positive. Hywind has survived the powerful extratropical cyclone Berit followed by other storms with winds over 40 m/s and maximum waves over 18 m. There are plans to deploy and test a next generation of Hywind in the United States off the coast of Maine.

The Norwegian Energy Agency, Enova offers capital grants for full-scale demonstration projects of ocean renewable energy production including offshore wind. While up to 50% of eligible costs can be covered, Enova's funding measured in absolute figures is limited.

Innovation Norway runs a program supporting prototypes within "environmental friendly technology." Wind energy is included in this definition. Projects are supported with up to 45% of eligible costs.

4.2 Collaborative research

In 2012, Norway participated in the following IEA Wind Tasks: Task 11 Base Technology Information Exchange; Task 19 Wind Energy in Cold Climates; Task 25 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; and Task 33 Reliability Data: Standardization of Data Collection for Wind Turbine Reliability and Maintenance Analyses.

5.0 The Next Term

The next term will be dominated by the impetus given to the wind power industry by the green certificate scheme. This scheme has also contributed to a trend toward the development of wind farms in Norway by large international companies. As of late 2012, two wind farms were under construction.

Authors: Harald Rikheim, Norwegian Research Council; and David E. Weir, Norwegian Water Resources and Energy Directorate, Norway.

Source: Luis Marinho

1.0 Overview

In Portugal, 2012 was an atypical year in Portugal with regards to energy. Due to the efficiency measures implemented in recent years, but also due to the economic recession, electricity consumption in Portugal dropped 3.6% to 49.1 TWh. This represents a reduction of 6% of electricity demand in the last two years (1). It was also an extremely dry year, the fifth driest hydro year of the past 80 years (63% below the normal climate). Therefore, due to the reduced hydro production, the renewable contribution for the energy mix decreased 17% compared to 2011.

The wind sector continued to grow with a wind generation of 10,011 GWh, which accounted for 20% of the country's electric demand (1). Portugal's wind penetration is now only surpassed by Denmark. Portugal is reaching the renewable contribution target for 2020; therefore the rate of capacity installation has slowed considerably. During 2012 only 147 MW of new wind capacity was installed compared to 315 MW in 2011. Despite slowing its deployment pace, Portugal reached the capacity of 4,517 MW. This represents 23% of renewable electricity generation's installed capacity, which accounts for 58% of the total installed capacity (2).

The first offshore wind floating system (the second in the world) installed in the north of Portugal (near Aguçadoura coast) operated smoothly throughout the year and produced more than 1.7 GWh in the first half of 2012 (3).

2.0 National Objectives and Progress

2.1 National targets

The capacity targets currently in place were established in June 2010 by the former government through the Plano Nacional de Acção para as Energias Renováveis (NREAP) (4). This plan established a course of action needed to reach an installed minimum capacity of 6,875 MW by 2020, where 6,800 MW will be installed onshore and 75 MW offshore.

2.2 Progress

In 2012, the new wind generation capacity follows the capacity's saturation trend of the last few years as displayed in Figure 1. A net capacity of 147 MW was added in 2012 (149 MW of new capacity installed and 2 MW decommissioned). This value was the lowest installed since strong wind deployment was initiated in 2004. Cumulative installed capacity until 2012 is distributed over 223 wind farms with 2,408 wind turbines operating across the country, one of them being a floating offshore wind turbine (2). The wind capacity generated 10,011 GWh in 2012 which corresponded to 20% of the Portuguese electricity demand and 50.2% of the renewable generation (2).

The average production at full capacity was 2,313 hours in 2012. The wind energy production by classes of number of hours at full capacity (NEPs) was concentrated in wind farms with NEPs between 2,000 and 2,500 hours (58%). Although the wind index was below 1, the wind parks with NEPs below 2,000 hours reduced their share in 2012 from 19% to 14% and on the higher production range, the wind parks with NEPs from 2,500–2,750 hours and above 3,000 hours experienced an increase of 8% with respect to 2011(2).

With 2012 being such a dry hydro year, it is no surprise that the renewable energy contribution decreased by 6.7% with respect to 2011, meeting 38.4% of this year's electric demand. The largest share of renewable production came from wind energy, which accounted for 50.2% and was 13% above 2011, with the reduction of 17% from hydro power plants (32.3%). The remaining sources were able to increase their contribution where the biomass sector represented 15.7%, and PV grew from 1.1% to 1.8% (2).

2.3 National incentive programs

In 2010, NREAP was approved, providing the strategy and incentives for renewable energy investments in Portugal. The targets defined in that plan are set to 2020 and foresee a quota for the renewables contribution for several economic sectors. The plan considers 2005 as a baseline, where the contributions

Wind generation grew to 10,011 GWh, which accounted for 20% of the country's electric demand.

Table 1. Key National Statistics 2012: Portugal	
Total installed wind capacity	4,517 MW
New wind capacity installed	147 MW
Total electrical output from wind	10.01TWh
Wind generation as % of national electric demand	20%
Average capacity factor	28%
Target:	Onshore: 6,800 MW Offshore: 75 MW by 2020

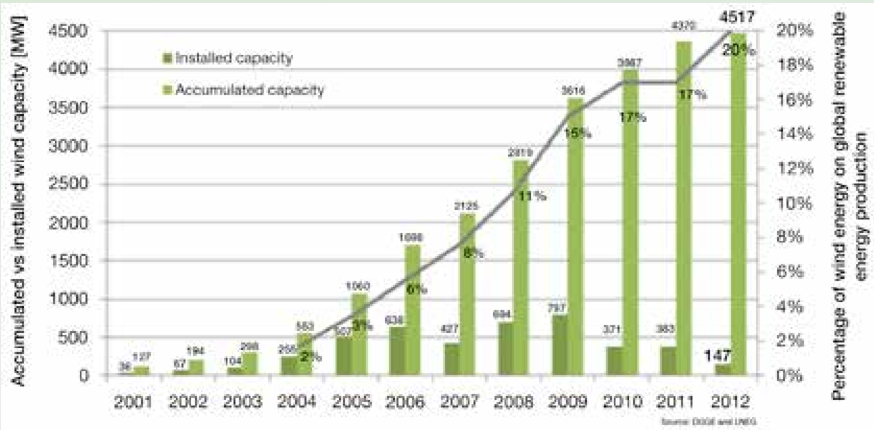

Figure 1. Installed versus accumulated wind capacity (bar graph) and percentage of wind energy production (line graph)

from renewables were 0.2% in transportation, 31.9% in heating and cooling, and 29.3% in electricity. The targets for 2020 are to raise those contributions to 10% in the transportation sector, 30.6% in heating and cooling, and to 60% in electricity (4).

Renewable energy installations for micro-generation and mini-generation continue to be the object of incentive programs in Portugal. The micro-generation law was established by the Decree-law 118-A/2011 that regulates the micro-production of electricity from renewable energy sources (up to 11 kW) and provides a simplified framework and licensing regime for connecting renewable energy producers to the distribution grid (5). In 2012 the reference value for micro-generation's feed-in tariffs (FITs) was 326 EUR/MWh (429.7 USD/MWh) and the annual capacity's cap allowed was 10 MW, in accordance with the Ordinance 284/2011 (6).

Although the mini-generation program was established in 2010 the Decree-law 34/2011 was not published and did not set its rules until March 2011 (7). This program introduces the opportunity for small companies to install renewable-based production centers of up to 250 kW. In 2012, there was a drop in the reference tariff of 14%, reducing the values from a maximum of 250 EUR/MWh (329.5 USD/MWh) to 215 EUR/MWh (283.4 USD/MWh) and a maximum value of 30 MW for annual grid connected power (Ordinance 285/2011) (8).

2.4 Issues affecting growth

In the first month of 2012, the Portuguese government suspended the capacity attribution for grid connection. This decision was justified by the need to reevaluate the legal framework for electricity generation (9). The decision had little direct impact on the deployment of wind projects since the existing and ongoing ones had their permit for grid connection already attributed several years ago.

On the other hand, Portugal reached wind penetration of 20% of the annual consumed energy—a very high value and the second highest in the world, surpassed only by Denmark, the pioneer country in wind deployment.

A limiting design parameter of electric systems like the Portuguese is the extremely high penetration of renewable, non-dispatchable sources (e.g., wind power or river run-off hydropower). On 14 December 2012 at 2:45 PM a new record was set for instantaneous wind penetration of 3,754 MW with 90% of power connection and a wind energy production of 84 GWh (54% of the consumption). The highest daily wind contribution to consumption was recorded on 14 April 2012 with a value of 65%. On 28 October 2012 at 5:30 AM the instantaneous wind penetration of 3,271 MW was recorded with a wind contribution to demand of 86% (1). Figure 2 depicts the wind generation profiles on i) the maximum demand day; ii) maximum daily contribution from wind; and iii) highest instantaneous production.

3.0 Implementation

3.1 Economic impact

In 2012, the wind industry in Portugal, together with the wind deployment activity (147 MW), supported an estimated 3,200 jobs. In 2012, wind generated electricity produced an estimate income of 984 million EUR (1.29 billion USD) and allowed the saving of 3.6 million tons of CO_2 emissions.

3.2 Industry status

In 2012, following the trend of recent years, Enercon consolidated its leadership of the Portuguese manufacturers' market. Of the 70 wind turbines installed in 2012, 44% corresponded to expanding the capacity of existing wind parks (under a process referred as "overcapacity"). Of the remaining 39 new wind turbines, 77% were Enercon, followed by Vestas with a 13% share, and Gamesa with10%.

By the end of 2011, the first offshore wind system, WindFloat, composed of a semi-submersible structure and a Vestas V80 wind turbine with 2-MW capacity was deployed at Aguçadoura. This site is located 6 km offshore of Póvoa de Varzim with a water depth of approximately 50 m. This project is being developed by WindPlus as a joint venture with A. Silva Matos (ASM), Energias de Portugal (EDP), Fundo de Apoio à Inovação (FAI), InovCapital, Principle Power, and Vestas Wind Systems A/S. Using the Windfloat technology, the consortium submitted a proposal for a floating offshore wind park to the European Programme NER 300 targeting the installation of five floating systems. This proposal was approved during 2012.

3.3 Operational details

Reviewing the 223 wind farms installed in Portugal by the end of 2012, 52% have an installed capacity below 10 MW, 40% have a capacity between 10–50 MW, and the remaining 8% are above 50 MW (2). During 2012, four new wind parks were connected in the Portuguese territory: one with a capacity of 2 MW at the North region, two with 8 MW in the Center, and 48 MW at the south of Portugal (1). The remaining capacity (96 MW) was installed under the "overcapacity" process. From these, nearly 42% of wind farms have a capacity between 10–50 MW, 47% above 50 MW and 10% below 10 MW. The tendency to deploy large wind farms was maintained in 2012 (2).

Due to the intrinsic characteristics of the Portuguese territory, the wind turbines operate in two different environments—the coastal or the mountainous region. In 2012, the coastal region had atypical wind availability and production. The Laboratório Nacional de Energia e Geologia (LNEG) indexes show a pronounced decrease on the coastal region with a wind availability of 12% under the average (0.88) and 16% under average on production (0.84). These values are the lowest since 1999. For the mountainous region, the scenario reversed last year's tendency, with production growing 10% (index 1.02) reaching a wind index close to the average (0.99). Data from the Portuguese Operation of Power Systems TSO (1) is in the line with the results presented from LNEG, indicating a range between 1.27 and 0.68 for wind generation indexes, when considering the period between 2001 and 2011.

3.4 Wind energy costs

During 2012, the average cost per MW installed was 1.35 million euro (1.78 million USD/MW), including projects, constructions, grid connections, land contracting and others.

According to the Portuguese energy regulator (ERSE), the mean tariff paid to the wind power plants increased 5.2 EUR/MWh reaching 98.3 EUR/MWh (129.6 USD/MWh) in 2012 (10).

4.0 R, D&D Activities

4.1 National R, D&D efforts

The national R&D efforts during 2012 were mainly focused on offshore wind energy, development of tools and methodologies to maximize the penetration of renewable energy, and promoting energy sustainability. These activities are taking place at the principal institutes and universities of the country financed through national or European programs. The main R&D activities underway in Portugal are described in the following paragraphs.

Project FP7 NORSEWInD: made up of 15 organizations between research institutes and industrial organizations with the Portuguese participation of LNEG funded by EC FP7. The project aimed to characterize and evaluate the wind resource on the northern seas and was concluded in 2012.

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.

Project FCT Fluct.Wind: a Portugal 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 IEE SEANERGY 2020: an EC-IEE project to evaluate and further develop the maritime spatial planning on the European space with the PT participation of LNEG. The project was concluded in 2012.

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 twelve EU countries. It is led by Acciona Energy and funded by EC FP7 with the Portuguese participation

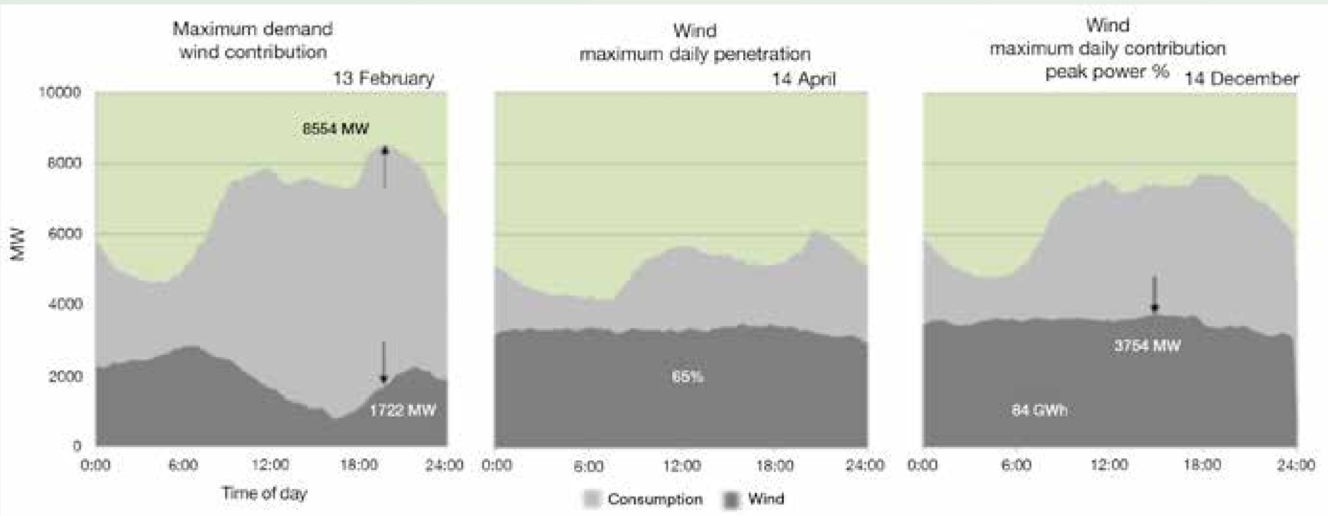

Figure 2. Record wind power penetration and energy generation during 2012 (1)

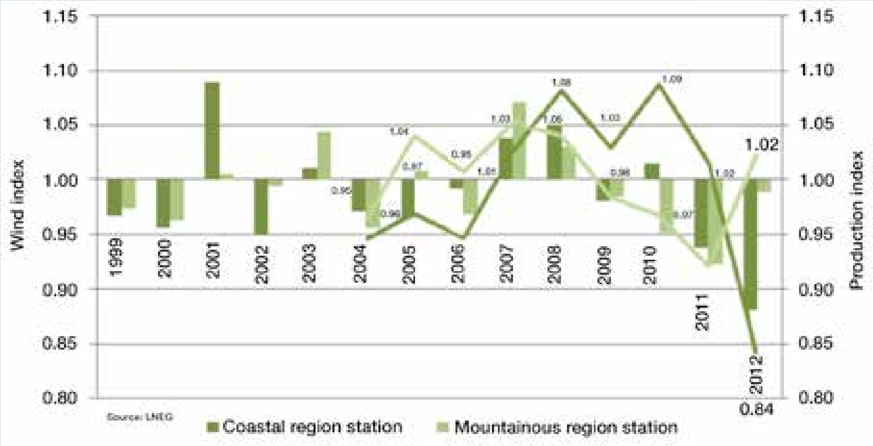

Figure 3. Wind (bar graph) and production indexes (line graph) on coastal and mountainous regions of Portugal

of University do 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 Portuguese participation from 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 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 support technologies increase the competitiveness and the entrepreneurship in this sector.

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 renewables 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).

4.2 Collaborative research

Portugal and LNEG 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 Labeling Small Wind Turbines. 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

Despite the European economic crisis, 2013 is expected to be a promising year for the offshore wind power sector. For the ongoing R&D activities, the next term will bring some important milestones. The DEMOWFLOAT project will begin to demonstrate the sustainability of the WindFloat technology. Combined with the NER300 European incentive, for projects with impact on the reduction of carbon emissions Portugal will deploy five turbines in a floating offshore wind farm with an estimated capacity of 25 MW. This will constitute the first floating offshore wind park in the world.

The trend in 2012, for the onshore wind market will be maintained and it is expected that the key players will continue to invest in the emergent markets like Brazil, Africa, and Eastern Europe. On the economic sector, in the beginning of 2013, it is expected that the FITs will be reviewed through a new Decree Law

In particular for renewable energy installations for micro-generation, the ordinance nº 431/2012 of 31 December 2012 was published, which establishes a new FIT for these systems as well the new capacity limit for 2013 (11).

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(6) Ordinance nº 284/2011. Diário da República 208: Série I. 28 October 2011

(7) Decreto-Lei nº 34/2011. Diário da República 46:Série I. 8 March 2011

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(11) Ordinance nº 430/2012. Diário da República 252: Série I. 31 December 2012

Authors: Raquel Marujo, Teresa Simões, and Ana Estanqueiro, Laboratório Nacional de Energia e Geologia (LNEG), Portugal.

32 Spain

Source: Susana Girón

1.0 Overview

Installed wind capacity in Spain reached 22,785 MW in 2012 with the addition of 1,112 MW, according to the Spanish Wind Energy Association's (AEE) Wind Observatory. The growth has been similar to 2011, which had an increase of 1,050 MW. Spain is the fourth country in the world in terms of installed capacity and produced 48,156 GWh of electricity from wind in 2012.

In 2012, Spain's electrical energy demand decreased 1.8% from 2011 to 269.16 TWh. Wind energy met 17.8 % of this demand and was the third largest contributing technology in 2012. Other big contributors to the system were nuclear power plants (22.2%), coal (19.8%) and gas combined-cycle power plants (13.9%) (Figure 1).

During 2011, the government implemented new decreases to incentives for wind energy so that the wind sector would share the burden of helping the country to reduce its subsidy bill for green energy. Spain's landmark renewable energy law, 661/2007, only governs wind power prices for new projects through 2012. A draft decree sent to the national energy commission in September sets out the proposed regulations after 2012. However, lobbyists are arguing that the 2020 target will not be achieved if the bill is passed.

The decision on the draft decree was deferred to the new government elected in November 2011. The conservative party won the elections and the first decisions will be how to end the national deficit created partially by the feed-in-tariff (FIT) system. A new law came early in 2012, Royal Decree-Law 1/2012, temporarily (the duration was not established) suspending pre-allocation incentives for new energy production projects using, among others, renewable energy. The justification, based on the economic crisis and on the financial difficulties in the electricity industry, was to halt a reward system that involved a substantial cost for the electricity system, causing the tariff deficit; in particular, limiting the impact of renewable premiums in the tariff deficit, reducing costs in this way.

This measure would not affect projects registered in the Pre-Allocation Registry at the time the Law was passed (January 2012). At that time, there were around 1,900 MW of wind projects registered. Slightly more than 1,100 MW were deployed during 2012, so about 800 MW could be installed. For about 450 MW promoters have declared that they cannot be built under the current rules due to problems beyond the control of the promoters (delays in the planning of the transport network and distribution lines, administrative difficulties, etc.). This means that, with valid green moratorium, only around 350 MW of wind power remain installable in Spain under the current rules in 2013 and 2014. However, the Royal Decree-Law 2/2013 adopted by the government in 2013, assumes that all wind farms will compulsorily adopt the regulated rate and reduces the update settings of incentives. Given the loss of return implied by the new rules, the installation of these remaining wind farms is threatened.

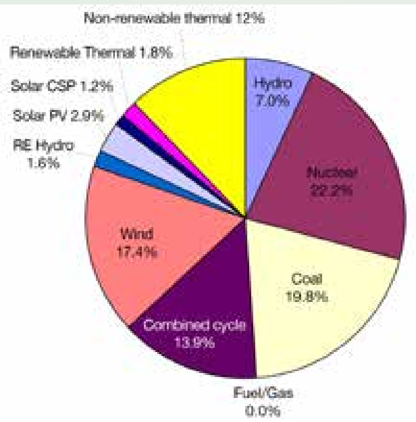

Figure 1. Percentages of the 2012 power supply mix in Spain (Source: REE, AEE)

2.0 National Objectives and Progress

2.1 National targets

On 11 November 2011, the new Renewable Energy Plan (REP 2011–2020) (1) was approved by the Spanish government for the years 2011–2020, establishing the development framework for the renewable energy sector. This plan aims to fulfill and go beyond the EU objectives of covering 20% of total energy consumption by renewable sources by 2020. The REP 2011–2020 establishes Spanish objectives and suggests the measures to be implemented to reach the

Wind energy met 17.8% of Spain's electrical demand and was the third largest contributing technology in 2012.

Table 1. Key National Statistics 2012: Spain	
Total installed wind capacity	22,785 MW
New wind capacity installed	1,112 MW
Total electrical output from wind	48.156 TWh
Wind generation as % of national electric demand	17.8 %
Average capacity factor	24.13 %
Target 1. Official Network Planning	29,000 MW by 2016
Target 2. New National Renewable Energies Action Plan (NREAP)	35,000 MW by 2020

20% goal. It includes the Spanish vision for each type of renewable energy. The public entity charged with implementing the REP 2011-2020 is the Institute for Energy Diversification and Saving.

For wind energy, the objective for 2020 is 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 2011–2022, it is estimated that wind energy will 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.

2.2 Progress

Total electrical generation capacity in the Spanish mainland system increased more than 2,346 MW during 2012 for a total of 102,514 MW, according to the Spanish Transmission System Operator (TSO) Red Eléctrica de España (REE) (3). The technologies that contributed most to this growth were wind (1,112 MW), solar power (968 MW), hydro (192 MW), and renewable thermal (81 MW). With more than 22,785 MW of wind power installed (Figure 2); more than 20,185 turbines are operating in Spain, grouped among 1,055 wind farms. The average size of an installed wind farm in 2012 was 18.5 MW, whereas the overall wind farm size is 21 MW.

Unlike many countries with significant wind development, Spain has increased its distribution throughout the country. Wind energy is present in 15 of the 17 autonomous communities (Figure 3). Castilla-Leon has the highest installed power among them, with 5,510 MW. This autonomous community has had the biggest growth with 277 MW added in 2012. Cataluña experienced 23.1% growth, the second biggest, with 256 MW installed in 2012. It has 1,258 MW of wind capacity. The third biggest growth has been in Andalucia with 18% (196 MW new) reaching 3,263 MW total. Then Asturias with 84 MW (7.6% growth) reached 512 MW. Aragón installed 83 MW for a total of 1,893 MW. Murcia added 72 MW for a total of 262 MW. Then Castilla-LaMancha installed 70 MW in 2012 for 3,806 MW total wind capacity; it stays in second place of total capacity. Galicia added just 31 MW for a total of 3,311 MW. Comunidad Valenciana added 19 MW (for a total of 1,189 MW), and the Canary Islands added 1.8 MW for a total capacity of 146 MW. Finally, Navarra increased its installed power by 3 MW for a total of 979 MW.

Four of the traditional regions did not install any wind power: La Rioja, País Vasco, Cantabria, and Baleares. Only two autonomous regions, Extremadura and Madrid, have not yet installed any wind power capacity. However, they have advanced

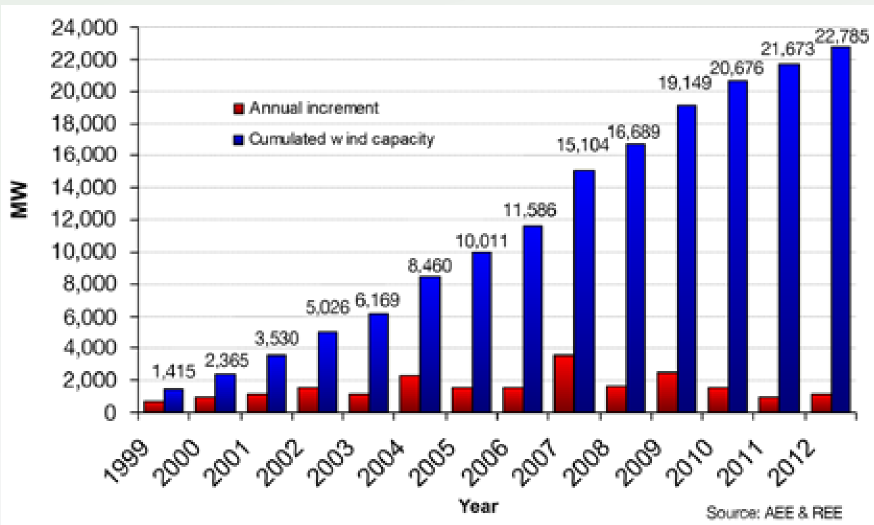

Figure 2. Annual and cumulative installed wind capacity in Spain

projects and regulations to start wind energy activities, especially in the Extremadura region. The two communities of Galicia and Cantabria have not increased their wind capacity despite having their respective development plans approved, due to different political reasons.

The use of wind power has lowered carbon emissions by about 24.6 million tons during 2012. Despite this saving, overall CO_2 emissions of the mainland electric sector in 2012 experienced an 11% increase in relation to 2011, due mainly to the increase in generation from coal. Furthermore, wind generation has saved up to 9.6 million tons of conventional fuels and has supplied the electrical consumption of more than 15.5 million Spanish households.

2.3 National incentive programs

To date, the promotion of renewable energies has been a stable national policy. All political parties have had similar policies regarding support of renewable energies. The main tools within this policy at a national level have been as follows:

- The new NREAP (2011–2020), which included midterm objectives for each technology that could not be achieved due to new regulations.
- Supplemental incentives to facilitate the integration of wind energy into the grid, are based on technical considerations (reactive power and voltage dips). These incentives apply only for existing wind farms (after January 2008), and it is mandatory to satisfy Grid Code P.O.12.3.

Payment for electricity generated by wind farms in Spain is based on a FIT scheme. As stated in Section 1.0, Royal Decree-Law 1/2012 temporarily suspended pre-allocation incentives for new energy production projects using, among others, renewable energy. So the situation at this point is that no renewable installation is allowed if the special regime is sought.

Finally, the approval of a net balance support scheme is expected to complement the existing technical regulation for the grid connection of small power production facilities (up to 100 kW), which is foreseen to be decisive for the development of small wind generation for the owners' use.

2.4 Issues affecting growth

The economic slowdown affected the wind industry in 2012. 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 20,000 jobs have been lost. Installations in 2013 may be as low as 360 MW.

3.0 Implementation

3.1 Economic impact

The number of installations during 2012 demonstrates the maturity of the wind industry, which has increased despite worldwide financial crisis and deployment of the Pre-allocation Register in Spain. Installing and operating wind plants to cover 17.4% of the Spanish electrical demand implies a huge accomplishment by the developers and manufacturers.

3.2 Industry status

During 2012, the largest manufacturers were Gamesa (423 MW new capacity), Vestas Wind Power (338 MW new capacity), Alston Wind (107 MW new capacity), Acciona Wind Power (102 MW new capacity), GE Wind (48 MW new capacity), Nordex (36 MW new capacity), Sinovel (36 MW new capacity) and Enercon (21 MW new capacity).

Gamesa is still the top manufacturer in Spain with 11,925 MW total wind capacity installed (52.3% of the total wind capacity installed). In the second position is Vestas Wind Power with 4,071 MW total wind capacity installed (17.9% of the total wind capacity installed), and Alston Wind moved into third place with 1,737 MW (7.6% of the total wind capacity installed). The Spanish manufacturer Acciona Wind Power is in the fourth position with 1,658 MW (7.3% of the total wind capacity installed), see Figure 4.

Several manufacturers are developing small wind turbines from 3 kW to 100 kW for grid-connected applications (Norvento connected two 100-kW turbines and Del-Valle Aguayo one 100-kW turbine to the grid in 2012), and two manufacturers are working on mid-sized prototypes from 150–300 kW (Electria Wind and ADES).

Iberdrola Renovables, the largest Spanish utility, has the largest accumulated capacity (5,512 MW; 24.2% of the whole wind market) thanks to the addition in 2012 of 174 MW. Acciona Energy, in second place, has accumulated capacity of 4,228 MW with 64 MW installed in 2012. The Portuguese company EDPR, with 2,086 MW total, installed 90 MW during 2012. The Italian utility Enel Green Power España is in the fourth position with a total capacity installed of 1,403 MW with 22 MW installed in 2012. Several other developers have installed wind power in 2012 (Figure 5), but only seven companies installed 50 MW or more, including the ones listed above.

3.3 Operational details

The number of wind turbines in Spain increased by 579 in 2012, and the total number of turbines is more than 20,185. The average size of a wind turbine installed in 2012 was 1.92 MW, and the average size of the total installed capacity is 1.1 MW.

Wind turbines operating in Spain show important seasonal behavior. Annual

Figure 3. Wind energy capacity distributions by autonomous communities (MW). Source: AEE

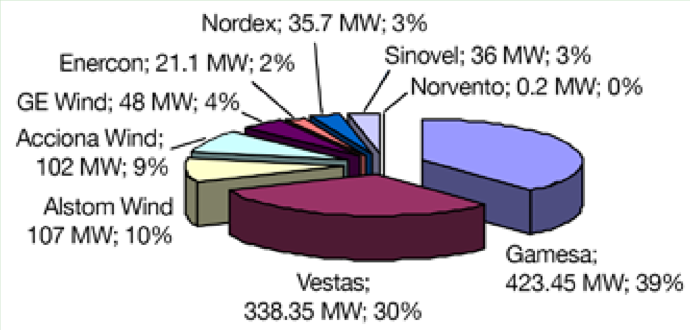

Figure 4. Installed wind capacity in 2012 by manufacturer (in percentages). Source: AEE

electricity generated by wind farms was more than 48,156 GWh. During 2012, equivalent hours at rated power were higher than 2,100 hours for all of the wind farms. This shows that 2012 was a good wind resource year overall. On several occasions, wind power exceeded previous historical instantaneous power peaks and maximum hourly and daily energy production. On 24 September 2011 (3:03 am) 64% of total demand was covered by wind energy. And on 18 April 2012 (4:41 pm) instant wind power generation reached 16.636 MW. That precise day, historic records were reached for hourly (16.455 MWh) and daily (334.850 MWh) wind generation. On the other hand, in November 2012 wind generation had the highest contribution to the energy mix among all the existing technologies, reaching 21.3%.

3.4 Wind energy costs

In spite of the price increases for some raw materials used in wind turbines, the increased use of large wind turbines (2 MW of nominal power), the excess of available main components, and the current limited demand for wind turbines, prices for wind generators have decreased. The official cost at the factory during 2011 in Spain was about 800 EUR/kW (1,054 USD/kW).

4.0 R, D&D Activities

4.1 National R&D efforts

During 2012 the deployment of previously approved Royal Degree-Law RD 1565/2010 was carried out. This Law established the payment of a premium similar to that under RD 661/2007 for wind farms classified as experimental (133.8 MW were registered in 2012). Two types of projects were included: experimental units for testing and assessment mainly by manufacturers, or testing and assessment facilities mainly by public research centers. The main topics addressed in these research projects were: new materials, blade design, mechanical and electrical equipment, control devices, and special resource or site features.

Funding for R&D activities in Spain is structured in two pillars: the National Strategy for Science and Technology at the national level and programs developed by the governments of the autonomous communities. The National Plan for Scientific Research, Development and Technological Innovation, approved by resolution of the Council of Ministers of 14 September 2007, is the programming instrument in establishing the objectives and policy priorities for research, development, and innovation in the period 2008–2011.

Each line of action brings together the coherent set of instruments, which are developed through four different national programs:

- National Program of Fundamental Research Projects (NPFRP)
- National Program of Applied Research Projects (NPARP)
- National Program of Experimental Development Projects (NPEDP)
- National Program of Innovation Projects (NPIP)

NPFRP: In the national fundamental research projects, the scope of the projects and action is not oriented to any topic. Within this program, only four wind related projects have been granted in 2012. 1) Development of a high-resolution tool for the analysis and prediction of offshore wind energy (Coordinator: CIEMAT). 2) Analysis and simulation of new regulatory requirements on wind farms and their integration as complementary services in power systems with high wind presence. (Coordinator: Institute for Research on Renewable Energy, Castilla la Mancha University). 3) Electrical transport systems for large offshore wind power plants. (Coordinator: Center for Technological Innovation in Static Converters and Drives, Polytechnic University of Catalonia). 4) Analysis and development of an isolated network for water desalination variable wind regime. Coordinator Technical School of Industrial and Civil Engineering, University of Las Palmas de Gran Canaria).

The national innovation strategy integrates a packet of programs to promote innovation. The innovation plan (INNOVACCION) was developed to implement the innovation strategy and four programs (INNPACTO, INNCORPORA, INNFLUYE, and INNPALNTA) are designed to stimulate Public-Private Collaboration.

In 2012, from all projects submitted to the INNPACTO Program call, only five projects dealing with wind energy were funded. Three projects concerned onshore wind and two to offshore wind. The total budget of the projects approved has reached 10.9 million EUR (14.4 million USD) and the subsidy has been around 6.7 million EUR (8.8 million USD) (most of the subsidy is based in loans because this program only offers loans as funding solution to the companies. Granting is only available for a research organization). Some of these INNPACTO projects granted in 2012 are described below.

INOFFMET Project: The project aims to develop the first floating platform that allows the installation of a weather station that combines a traditional measurement system using lattice tower with anemometers and Light Detection And Ranging (LIDAR). It

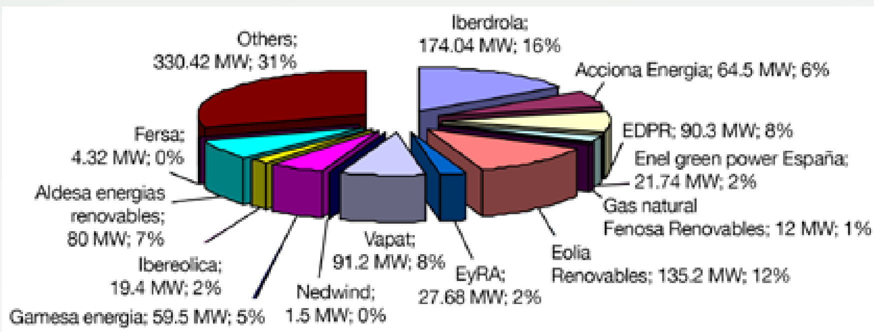

Figure 5. Percentage of installed wind capacity by developer at the end of 2012. Source: AEE

will be used to study the measurement system behavior under conditions of actual operation, contributing to the floating turbine validation. This project is coordinated by Acciona Energia. The partnership is composed of the Spanish shipbuilder company Navantia, CENER-CIEMAT, and Tecnalia Foundation. The duration of the project is four years (July 2012–December 2015).

NANOMICRO Project: The project objective is to develop, through nanotechnology, a new generation of advanced cement with particle size of less than a micron. The advanced cement will have excellent durability and mechanical resistance in both onshore and offshore environments of extreme weather conditions. Nanomicro technology presents a new era in the manufacture of cements. In particular, this new generation of cements could be used in offshore wind turbine floating platforms where use of current concrete technology is unthinkable. In this project, CENER aims to acquire knowledge in the design of concrete for highly dynamic operational structures, and develop a map of possible applications for concrete. The partnership is composed by Cementos Portland Valderrivas, S.A., FCC Construcción, S.A.; Norten Prefabricados de Hormigón, S.L.; Gamesa Innovation and Technology, S.L. Fundación Investigación y Desarrollo en Nanotecnología, and CENER. The fundable budget is around 3.6 million EUR (4.7 million USD).

ERDF-INNTERCONECTA Program: This national program is managed by the NFA CDTI with funding based in the ERDF (Électricité Réseau Distribution France). It is applicable for experimental integrated development projects that are strategic, large-scale and aim to develop innovative technologies. These technology areas have projected economic, trade, technological, and industrial progress relevant to the target regions aid of the "Operational Programme I + D + i by and for the benefit of business –Technology Fund."

SEAMAR Project (Solutions for Andalusia wind at sea): This is an ambitious project, with a consortium of eight industrial partners, led by Navantia, whose experience and skills make possible the technical objectives of the project. The other partners are Acciona Energia, Acciona Infraestructuras, Krefer, Siasa, Tecnoambiente, Cambell Europe S.A., Enerocean; and as research partners, the University of Cadiz, Cehipar, University of Seville, Cetemet, CENER, CSIC University of Malaga, and Tecnalia. The total budget is 9.3 million EUR (12.3 million USD) and it has been granted with 3.9 million EUR (5.1 million USD). The objective is to develop advanced technologies for support structures for offshore wind turbines aimed at mass production. It will lay the groundwork regarding logistical requirements, installation, and maintenance of future offshore wind farms. By demonstrating the technical feasibility and cost of this technology offshore, Andalusia will become a key player in the offshore wind sector.

UE FP 7 Program, SUPRAPOWER Project: This research project is coordinated by the Spanish research center Tecnalia Foundation in collaboration with the Karlsruher Institut fuer Technologie (Germany) Institute of Electrical Engineering, Slovak Academy of Sciences (Slovenska Republika), University of Southampton (UK), Acciona Windpower sa (Spain), Columbus Superconductors Spa (Italy), Acciona Energia s.a. (Spain), Oerlikon Leybold Vacuum Gmbh (Germany), and D2M Engineering Sas (France). The project aims to provide an important breakthrough in offshore wind industrial solutions by designing an innovative, lightweight, robust, and reliable 10-MW class offshore wind turbine based on a superconducting generator. It will take into account all the essential aspects of electric conversion, integration, and manufacturability. The main outcome of the project will be a proof of concept for a key European technology necessary to scale wind turbines up to power levels of 10 MW and beyond.

H2OCEAN Project: The project is to develop a wind-wave power open sea platform equipped for hydrogen generation with support for multiple users of energy. An innovative design will be explored for an economically and environmentally sustainable multi-use open-sea platform. Wind and wave power will be harvested and part of the energy will be used for multiple applications on-site, including the conversion of energy into hydrogen that can be stored and shipped to shore as green energy carrier and a multi-trophic aquaculture farm. The work will build on the R&D and commercial activities of an existing partnership involving 17 leading European industrial and academic partners from five countries (Denmark, Germany, Italy, Spain, and the UK). That R&D is within the fields of renewable energy, hydrogen generation, fish farming, maritime transports and related research disciplines. This project is coordinated by the Spanish company AWS Truewind SLU. H2OCEAN started its activities on 1 January 2012 and will end on 31 December 2014. The project budget is 6 million EUR (7.9 million USD) and the European Union has granted a financial contribution of 4.5 million EUR (5.9 million USD).

TROPOS Project: This European collaborative project aims to develop a floating, modular, multi-use platform system for use in deep waters. The initial geographic focus will be on the Mediterranean, tropical and sub-tropical regions, but it will be designed to operate in other geographic area. The Tropos Project is a 7 million EUR (9.2 million USD) European project in which the European Commission is committed to fund 4.9 million EUR (6.5 million USD). The Project will gather 18 European partners from nine countries (Denmark, France, Germany, Greece, Norway, Portugal, Spain, Taiwan, and the United Kingdom), under the coordination of PLOCAN (Spain) for three years (starting 1 February 2012).

SOPCAWIND Project: The Software for the Optimal Place Calculation for WIND-farms project aims at developing a new service achieved through the development of a software tool for optimal wind farm design. It will be based on a large and heterogeneous set of digitalized data containing information from different fields (wind climate, geography, environment, archaeology, and social-economy), that will be treated, validated, standardized and converted for this application. The project leader is Tecnalia Foundation and the partners are the Basque Country University (Spain), 3E (Belgium), Anemos (Germany), Eurohelp Consulting (Spain), and GeoINDEX (Hungary).

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 Labeling Small Wind Turbines, and most recently a new task led by Spanish experts in wind flow modeling in complex terrain—Task 31 Wakebench: Benchmarking Wind Farm Flow Models.

5.0 The Next Term

Expectations for the Spanish wind energy industry for 2013 are not very optimistic. During 2012, the new wind capacity added in Spain has been reasonable considering the economic and financial situation as well as the decision of the government to establish an indefinite moratorium on the FIT system.

Approximately 300 MW are projected to be installed in 2013. On the industrial side, because the FIT support scheme will likely not continue, other strategies should be applied like promoting the repowering activity, establishing a bidding system, developing the Power Purchase Agreements (PPA) market, and if the electrical links with the central-European power system were reinforced, a transnational FIT system would be developed.

In the technological side, R&D funding from the EU or from local government (central and regional) is not enough. Technology is going to bigger wind turbines and offshore wind farms, especially floating offshore wind technology, which is the solution required in Spain. Because such demonstration projects are costly, specific R&D support programs with FIT for experimental wind farms are needed in order to show off the technology. Moreover, dedicated programs to promote the integration of wind energy in islands will became a solution to fight with the high electricity cost in the islands but also offer a good opportunity to export these solutions to other countries with similar problems.

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Authors: Ignacio Cruz and Luis Arribas, Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Spanish Ministry of Economy and Competitiveness, with the collaboration of the Spanish Wind Energy Association (Asociación Empresarial Eólica, AEE), Spain.

Source: Per Westergård

1.0 Overview

The new wind energy installations in 2012 had a capacity of 755 MW (765 MW were installed in 2011). 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 III, Vindval, and the Swedish Wind Power Technology Center (SWPTC). The technical program Vindforsk III runs from 2009–2012 and has a total budget of about 80 million SEK (9.3 million EUR; 12.3 million USD). Vindval is a knowledge program focused on studying the environmental effects of wind power. Vindval runs from 2009–2012 with a budget of 35 million SEK (4.1 million EUR; 5.4 million USD). The SWPTC at Chalmers Institute of Technology runs from 2010–2014 and has a total budget of 100 million SEK (11.6 million EUR; 15.4 million USD). The center focuses on complete design of an optimal wind turbine, which takes the interaction among all components into account.

2.0 National Objectives and Progress

2.1 National targets

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 compared to the level in 2002.

2.2 Progress

Electricity generation from wind power has increased from 6.1 TWh in 2011 to 7.1 TWh in 2012 (Figure 1).

The Swedish electricity end use in 2012 was 142.0 TWh, an increase of about 2% compared to 2011. The wind power electricity generation share is now 5.0%.

2.3 National incentive programs

There are two main incentive programs for the promotion of wind power: electricity certificates and support for technical development in coordination with market introduction for large-scale plants offshore and in arctic areas. The work done in assessing areas of national interest for wind power can also be considered a sort of "soft incentive."

2.3.1 Electricity certificates

The electricity certificate system came into force on 1 May 2003, and it is intended to increase the production of renewable electricity in a cost-efficient way. The increased deployment of renewable electricity generation will be driven by stipulated quotas that are increased annually, as well as by a quota obligation fee. The principle is that there should be sellers and purchasers of certificates, and a market to bring them together. There are no specific quotas for wind power. Electricity producers receive a certificate from the state for each megawatt hour of renewable electricity that they produce. This certificate can be sold to provide additional revenue above the sale of the electricity, 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.

2.3.2 Support for technical development

In 2003, the Swedish Energy Agency launched a program to support technical development, in coordination with market introduction, for large-scale plants offshore and plants in arctic areas. The aim is to stimulate the market, achieve cost reduction,

In Sweden, electricity generation from wind power has increased from 6.1 TWh in 2011 to 7.1 TWh in 2012... The wind power electricity generation share is now 5.0%.

Table 1. Key National Statistics 2012: Sweden	
Total installed wind capacity	3,524 MW
New wind capacity installed	755 MW
Total electrical output from wind	7.1 TWh
Wind generation as % of national electric demand	5.0%
Average capacity factor	26%
Target:	30 TWh of wind generation by 2020

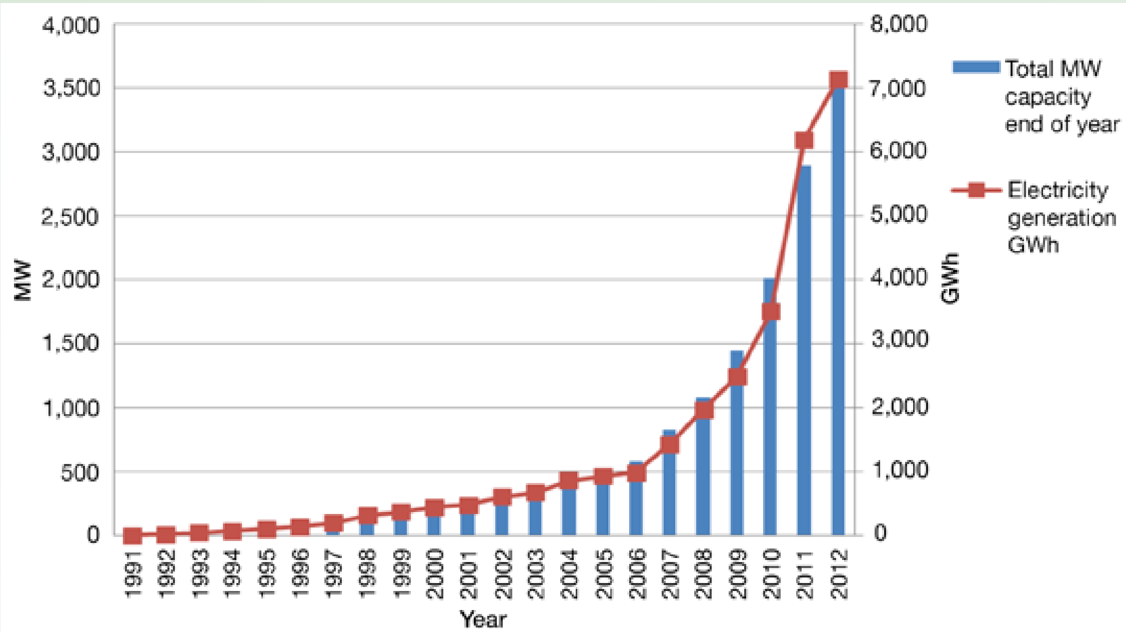

Figure 1. Installed wind power capacity in Sweden 1991–2012

and gain knowledge about environmental effects. For the years 2003–2007, the budget was 350 million SEK (40 million EUR; 54 million USD). The market introduction program has been prolonged another five years with an additional 350 million SEK (40 million EUR; 54 million USD) for the period 2008–2012.

2.3.3 Areas of national interest

According to the environmental code, land and water areas shall be used for the purposes for which the areas are best suited in view of their nature, the situation, and the existing needs. Priority shall be given to the use that promotes good management from the point of view of public interest. These are areas of national interest for fishery, mining, nature preservation, outdoor recreation, wind power, etc.

2.3.4 Network for wind utilization

The Swedish Energy Agency is the expert authority appointed by the government to promote the development of wind power, taking a holistic approach to encouraging the rapid expansion of wind power. 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. (1)

2.3.5 Vindlov.se

One of the key obstacles prolonging the permission process for wind power is the huge number of stakeholders in the process. Therefore, 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 work, and in this process some stakeholders might also be overlooked. (2)

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 20 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. Developers form their application in the web map application including all necessary information. Then they send it to the authority via the system, and the authority handles the status of the application, which is visible on the map for the public to follow the process.

Figure 2. Kastlösa Wind. Credit: Per Westergård

3.0 Implementation

3.1 Economic impact

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.

3.2 Industry status

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 ABB (electrical components and cable), Dynavind (tower production), EWP Windtower Production, SKF (roller bearings and monitoring systems), and Vestas Castings (formerly Guldsmedshytte Bruk AB). Other companies worth mentioning are ESAB (welding equipment), Oiltech (hydraulic systems and coolers), and Nexans (cables). 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.

3.3 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 promote deployment in cold areas the Swedish Energy Agency is supporting a number of projects financially.

In addition to pilot projects, Vattenfall has inaugurated the StorRotliden wind farm, consisting of 48 machines with a total installed capacity of 78 MW. The experience from one year of operation is that production losses due to ice can be considerable. De-icing and anti-icing equipment may help alleviate such losses.

4.0 R, D&D Activities

Publicly funded wind energy research in 2012 was mainly carried out within the Vindforsk (3), Vindval (4), and SWPTC (5) research programs. The present phase of Vindforsk (Vindforsk III) runs from 2009–2012, with a total budget of 20 million SEK/yr (2.3 million EUR/yr; 3.1 million USD/yr). The program is financed 50% by the Swedish Energy Agency and 50% by industry. Vindforsk III is organized in four project packages: the wind resource and establishment; cost-effective wind power plant and design; optimal running and maintenance; and wind power in the power system.

The SWPTC runs from 2010–2014. The program is financed by the Swedish Energy Agency, by industry, and by Chalmers University. SWPTC has organized its work in six theme groups: power and control systems; turbine and wind load; mechanical power transmission and system optimization; structure and foundation; maintenance and reliability and cold climate.

Vindforsk, Vindval, and SWPTC together invited interested actors to a conference where researchers and organizations participated and presented research projects. During 2012, intensive work was carried out by applicants, steering groups, and the Vindforsk and SWPTC organization to formulate and start up new research projects.

The Vindval program is financed by the Swedish Energy Agency and is administrated by the Swedish Environmental Protection Agency. Vindval's objective is to facilitate an increase in the expansion of wind power by compiling basic data for environmental impact assessments and permit application processes. During 2008, the program was extended through 2012 with a new budget of 35 million SEK (4.1 million EUR; 5.4 million USD). Within this time period, the program includes new environmental studies in important fields such as: social studies; animals in the forests; and effects on economic areas like reindeer farming, nature tourism, and outdoor recreation. Other important areas will be to synthesize and spread information to important actors in the industry about the effects from wind power development.

These programs and other R&D projects that have been funded during 2012 include the following:

Fatigue loads in forest regions: the project aims to numerically predict the turbulent fluctuations, characterizing the atmospheric boundary layer approaching the wind turbine.

Sensors for ice detection on wind turbine rotor blades: the project aims to evaluate simple, effective and inexpensive devices for accurate detection of ice and ice accretion tracking on the surface of wind turbine blades.

Efficiency and influence of heating device on wind turbine blades: the project aims to develop models and experimental methods to evaluate the efficiency of de-icing equipment and its influence on the expected life of the turbine blades.

5.0 The Next Term

The research programs Vindval, Vindforsk, and SWPTC will continue during 2013. Vindval and Vindforsk will be extended to 2016 and 2017, respectively. The Vindval research program will also continue synthesizing and spreading knowledge. A lot of the expected growth in wind generation capacity will be in forested areas and also in the northern parts of Sweden in the "low-fields." The interest in those regions is prompted by the rather good wind potential as estimated by Swedish wind mapping. Substantial uncertainty, however, exists in the energy capture and loads of turbines in forested areas. The character of wind shear and turbulence is less explored in these areas and projects in the coming research program will be set up to increase the knowledge in this area. The SWPTC activities will continue developing wind turbines and to optimize maintenance and production costs.

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Opening Photo: Wind turbines at Öland shore, Credit: Per Westergård

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Source: Suisse Eole

34 Switzerland

1.0 Overview

By the end of 2012, 32 wind turbines of considerable size were operating in Switzerland with a total rated power of 49 MW. These turbines produced 88 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 3,343 GWh under the FIT scheme. Due to continuous obstacles in the planning procedures and acceptance issues, only two new turbines with a rated power of 3.9 MW were installed in 2012.

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 (51.3 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/y. Wind energy should contribute 4 TWh/y 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 2012, the energy yield from operating wind turbines was 88 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 1,200 GWh are registered; additional projects with a potential energy yield of 2,135 GWh are on the waiting list.

Projects with possible energy yield of 2,320 GWh have been submitted to planning bodies, and 445 GWh are already authorized (Figure 1).

2.2 Progress

Today, approximately 56% of Switzerland's overall electricity production comes from renewable sources, with hydropower by far the

In 2012, 32 wind turbines of considerable size produced 88 GWh of electricity.

Table 1. Key National Statistics 2012: Switzerland	
Total installed wind capacity	49 MW
New wind capacity installed	3.9 MW
Total electrical output from wind	0.09 TWh
Wind generation as % of national electric demand	0.1%
Average capacity factor	<20%
Target:	4 TWh/yr in 2050

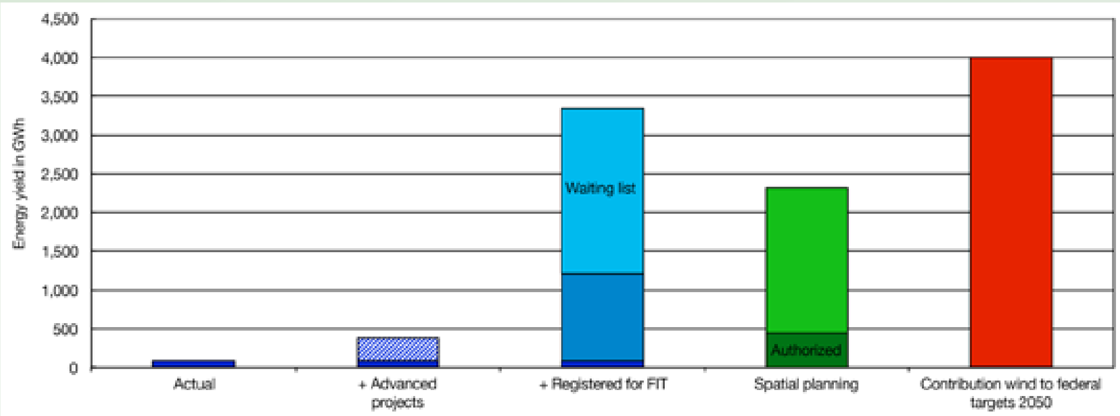

Figure 1. Actual and future energy yield of wind turbines in Switzerland 2012

biggest contributor (96.5%). In 2012, two wind turbines were put in operation with an average rated power of 3 MW (opening photo) and 0.9 MW. In total, 32 wind turbines of a considerable size are installed with a rated capacity of 49 MW. These turbines produced 88 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 0.083 EUR/kWh (0.109 USD/kWh), based on the current electricity consumption in Switzerland. This leads to more than 500 million CHF (414 million EUR; 546 million USD) annually of available funds. At the moment there is a debate in national parliament to raise this levy up to 0.124 EUR/kWh (0.163 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 0.13 EUR/kWh (0.24 to .017 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

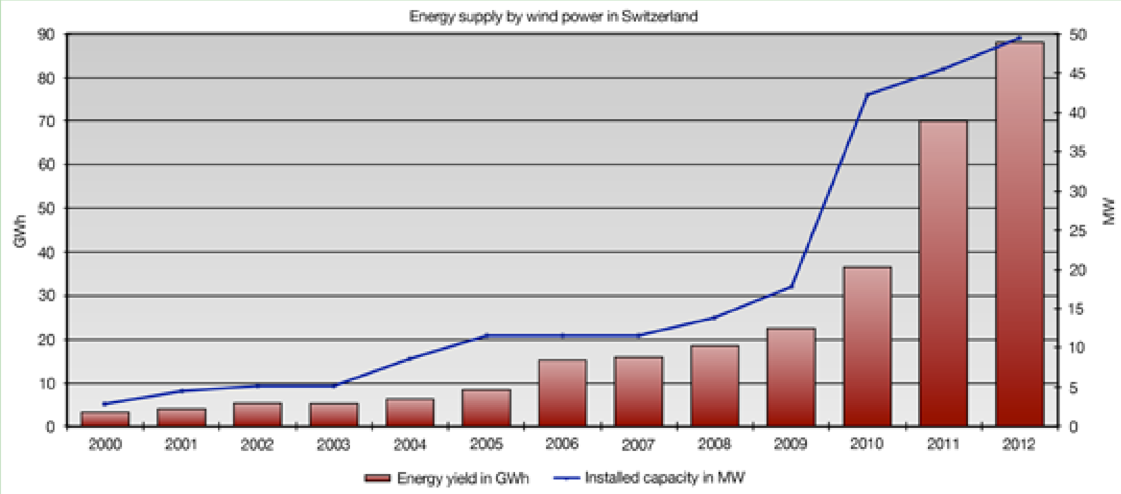

Figure 2. Development of wind energy in Switzerland 2012

A recent study estimates that the total turnover in wind energy in Switzerland in 2010 was about 38.9 million EUR (51.3 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 (11.6 billion USD) and 32,000 employees worldwide.

3.2 Industry status

The Swiss industry is active in several fields of wind energy: development and production of chemical products for rotor blades, like resins or adhesives (Gurit Heberlein, Huntsman, Clariant); grid connection (ABB); development and production of power electronics like inverters (ABB, Integral Drive Systems AG, Vivatec, VonRoll Isola); services in the field of site assessments and project development (Meteotest, Interwind, NEK, New Energy Scout, Kohle/ Nussbaumer, etc.); and products like gearboxes (RUAG).

3.3 Operational details

Due to the specific wind regime in Switzerland (moderate wind speeds, turbulent sites, icing conditions, etc.) the average capacity factor for installations in Switzerland is below 20%. New projects with modern wind turbines are showing substantially higher performance, also thanks to lessons learned within research activities. The turbines in the lower Rhone Valley recorded over 2,500 full load hours, values known from locations in Northern Germany and Denmark.

3.4 Wind energy costs

The specific costs of existing large wind power plants is about 1,450 EUR/kW (1,911 USD/kW), including installation the figure rises to 2,070 EUR/kW (2,728 USD/kW). The regulation for the compensatory FIT scheme provides 0.13–0.18 EUR/kWh (0.17–0.24 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 2012, the budget for wind energy related R&D projects was 410,000 EUR (540,380 USD). An amount of 459,000 EUR (604,962 USD) is spent on promotional activities.

Several innovative research projects were underway in 2012.

Social Psychological acceptance of wind power projects at potential sites (9): This research project focuses on local acceptance of wind energy projects in five Swiss municipalities. An experimental design was used to analyze the influence of three project characteristics on local acceptance. The result of a citizens' vote had a significant effect on local acceptance. Local acceptance was higher if the project developer was a well-known Swiss company and very experienced in the field of wind energy projects in contrast to an unknown project developer acting on behalf of a foreign or unknown investor. Local benefits associated with the project had the highest impact on local acceptance. Wind energy projects that included financial investment opportunities for local citizens or launched a communal fund were perceived significantly more positively by local citizens than wind energy projects that encompassed lease of land as the only local benefit. Only 12% of the respondents

Figure 3. Best performing wind turbine in Collonges: >2,500 full load hours (Source: Suisse Eole, Switzerland)

opposed and 42% supported all presented wind energy projects.

Field measurements of wind turbine wake flows (10): The characterization of the wake flow produced from wind turbines is a fundamental task for the evaluation of wind turbine performance and for an optimized design of wind farms. Besides the continuous improvement of tools for numerical simulations of wind turbine wakes, field measurements of wakes produced by real wind turbines are still required for their deeper physical interpretation and for validation of numerical simulation tools. To this end, the WIRE Lab of EPFL is developing a system based on three synchronized scanning Doppler wind LiDARs in order to measure 3-D wind velocity field over measurement volumes with a maximum width/height of about 3 km. LiDAR measurements of the wake flow produced from a 2-MW Enercon E-70 were carried out (Figure 4).

Figure 4. Field Measurement Campaign in the lower Rhone Valley

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, and Task 26 Cost of Wind Energy, and Task 31 WAKEBENCH, Benchmarking Wind Farm Flow Models.

5.0 The Next Term

If significant economic effects of wind energy for the Swiss industry are to be realized, a substantial rise in research and promotional activities is crucial. In 2012, the energy research concept 2013 to 2016 was being elaborated by the Swiss Federal Office of Energy (SFOE). The following key issues where included:

- Quantifying production losses and downtimes due to icing; and implementation and evaluation of relevant measures, in collaboration with IEA Wind Task 19 Wind Energy in Cold Climates
- Reducing energy production costs by increasing the full-load hours and reliability of turbines in harsh conditions and on sites with low wind speeds
- Increasing the accuracy of energy yield estimates and improving the economics of wind parks
- Reducing planning and installation costs by speeding up planning procedures and considering important acceptance issues
- Maintaining the high degree of wind energy acceptance in Switzerland.

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The opening photo shows a 3-MW wind turbine at Charrat, Switzerland.

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35 United Kingdom

Source: Renewable UK

1.0 Overview

The United Kingdom (UK) has approximately 40% of Europe's entire wind resource and significant potential for both onshore and offshore wind. The UK government has 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. The UK signed up in 2009 to a European Union (EU) target of 20% of primary energy (electricity, heat, and transport) from renewables sources. The UK contribution to that target is 15% by 2020. Wind will be an important contributor to this target. Figure 1 shows Griffin wind farm near Perth, Scotland, completed in 2012 with a total installed capacity of 156.4 MW.

In 2012, total wind capacity in the UK was 8.29 GW, representing approximately 6% of the UK's national electricity demand, an increase of 1.8 GW from the 2011 figure (a 27% increase) (1). A significant increase in electricity generation from wind was seen in 2012 in the UK, from 15.5 TWh in 2011 to 21.8 TWh in 2012 (40% increase) (1).

The 2020 UK Renewable Energy Roadmap was published by the Department of Energy and Climate Change (DECC) in July 2011 (2). The Roadmap sets out a path as to how the country intends to fulfill its obligation to the EU of sourcing 15% of its energy from renewables by 2020. While the Roadmap follows the Renewable Energy Strategy of 2009 and the 2010 update, some notable changes were made in terms of wind energy deployment scenarios. The current central scenario for offshore wind sees scope for 18 GW by 2020. The headline scenario for onshore wind is for 13 GW by 2020.

The publication of the Roadmap led to the formation of a DECC-sponsored Offshore Wind Cost Reduction Taskforce (CRTF), which was tasked with producing a list of actions to ensure that the industry would reach 100 GBP/MWh (112.3 EUR/MWh; 162.6 USD/MWh) by 2020. The CRTF, comprising senior industry professionals, held a series of evidence-gathering meetings focusing on key areas for costs reductions. The group also looked in detail at the results of The Crown Estate's Cost Reduction Pathways Project. The CRTF's report was launched on 13 June 2012 at RenewableUK's Global Offshore Conference and Exhibition. The report found that 100 GBP/MWh (112.3 EUR/MWh; 162.6 USD/MWh) by 2020 was challenging, but achievable if the 28 recommendations in the report were delivered.

The government's response to the Renewable Obligation (RO) Banding Review, published on 25 July 2012, set out support levels for onshore wind from April 2013. The government confirmed its intention to reduce the level of support to 0.9 Renewable Obligation Certificates (ROCs)/MWh from 1 April 2013–31 March 2017. Offshore wind RO banding levels were maintained at 2 ROCs to April 2015, 1.9 ROCs to April 2016, and 1.8 ROCs to April 2017.

In his speech on 11 September 2012, the Department for Business, Innovation, and Skills (BIS) Secretary of State Vince Cable set out his vision for the future of British industry and committed to a long-term, strategic partnership between government and industry. DECC Secretary of State Ed Davey welcomed the proposals, particularly their potential to enhance low-carbon infrastructure in the UK.

As part of this government-wide industrial strategy program, there are plans for a series of collaborative, challenging sector strategies. One of these sector strategies will focus on offshore wind—one of the ten sectors with which government intends to establish a strategic partnership to have real impact on economic growth.

In 2012, wind capacity increased 27% and generation increased 40% over 2011, meeting 6% of the UK's national electricity demand.

Table 1. Key National Statistics 2012: United Kingdom	
Total installed wind capacity	8,292 MW
New wind capacity installed	1,822 MW
Total electrical output from wind	***21.8 TWh***
Wind generation as % of national electric demand	***6.0%***
Average national capacity factor	Onshore: 27.4% Offshore: 36.7%
Target	15% renewables by 2020
Bold italic indicates estimates	

Figure 1. Griffin wind farm near Perth, Scotland, completed in 2012 with a total installed capacity of 156.4 MW. Courtesy: SSE Generation, Ltd.

The Low Carbon Innovation Co-ordination Group (LCICG) will continue to work together, investing in excess of 100 million GBP (112.3 million EUR; 162.6 million USD) in this spending review period, in a number of activities to promote the development of innovative offshore wind technologies. This includes the establishment of the Offshore Renewable Energy Catapult Centre and the ongoing work of the DECC and Technology Strategy Board (TSB) Offshore Wind Components Technology Scheme, offshore wind feasibility studies and knowledge transfer partnerships, with a combined budget of 21 million GBP (23 million EUR; 34 million USD), aimed to bring cost-lowering ideas into the UK supply chain.

2.0 National Objectives and Progress

2.1 National targets

In 2009, the UK signed up to a target of obtaining 15% of its primary energy from renewables sources as part of the EU renewables target of 20% of primary energy, electricity, heat, and transport. 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. In order to meet this target by 2020, the UK predicts that it will need to supply 30% of its electricity and 12% of its heat from renewable sources.

2.2 Progress

UK electricity is generated from a range of sources. Of electricity generated in 2012, provisional data highlights that gas accounted for 30% and coal accounted for 38%. Nuclear energy's share contributed 20% of the total, while renewable energy's share of generation increased to 11% (3).

Generation from wind increased in 2012 due to an increase in capacity. The increase in generation was from 15.5 TWh in 2011 to 21.8 TWh in 2012 (40% increase). In 2012, 1,822 MW of new wind generation capacity was commissioned, bringing the total UK capacity to 8.3 GW, an increase of 28% above the 2011 level. This includes 2.68 GW of offshore wind, maintaining the UK's lead in the development and deployment of offshore wind farms.

Table 2. Wind Projects Prospects at End of 2012	
Description	MW
Planning application submitted	10,767
Planning approved (awaiting/ under construction)	11,345
Total planned and/or in construction	22,112

2.3 National incentive programs

2.3.1 Renewables Obligation (RO)

The RO is currently the government's chief incentive mechanism for eligible renewable electricity generation. 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. It requires licensed electricity suppliers for Great Britain and Northern Ireland to provide a specified and increasing number of ROCs as evidence of the number of megawatt hours of electricity that is produced from eligible renewable sources, or if ROCs are not presented, then suppliers pay a buy-out price.

The government's response to the RO Banding Review, published on 25 July 2012, set out support levels for onshore wind from April 2013. The government confirmed its intention to reduce the level of support to 0.9 ROCs/MWh for new accreditations and additional capacity added in the banding review period 1 April 2013–31 March 2017. Following this announcement, the government launched an onshore wind call for evidence in two parts: 1) community engagement and benefits; and 2) costs, due to close in November 2012 and report in May 2013.

Offshore wind RO banding levels were confirmed at 2 ROCs to April 2015, 1.9 ROCs to April 2016, and 1.8 ROCs to April 2017. The industry considered this to be consistent with the cost-reduction trajectory required for 2020.

The RO system has three complimentary obligations, one covering England and Wales, and one each for Scotland and Northern Ireland. Decisions regarding the details of the ROs, including the setting of RO banding levels are for the Scottish government and Northern Ireland executive. Separate consultations on ROC support have also been held in Scotland and Northern Ireland.

2.3.2 Feed-In Tariff (FIT)

The FIT scheme was introduced on 1 April 2010, under powers in the Energy Act 2008. Through the use of FITs, DECC hopes to encourage 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 first comprehensive FIT review was launched in February 2011. The results of the Phase 2B Review, which considered all non-solar PV technologies including wind, were published on 20 July 2012. Changes resulting from this review, including new generation tariffs and a preliminary accreditation process will come into effect in December 2012. The Review also introduced a degression mechanism, based on which tariff degression between 2.5% and 20% will be triggered depending on deployment in the previous year. The degression mechanism, unlike other changes to FITs, will take effect from 2014. RenewableUK has asked DECC to reconsider these degression thresholds.

2.3.3 Electricity Market Reform (EMR)

As part of EMR, the draft Energy Bill was published in May 2012, along with a draft framework for the Contract for Difference. Pre-legislative scrutiny was conducted by the Energy and Climate Change Committee in summer 2012. Further work is underway following the publication of the Committee's report. EMR's focus is on the development of a long-term vision in which low-carbon technologies are competing on cost.

2.3.4 Transitional arrangements

The current ROC scheme will close in 2017 and be overtaken by Contracts for Difference (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 powers to introduce a capacity market, allowing for capacity auctions from 2014 for delivery of capacity in the winter of 2018/19, 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. Transitional measures will allow renewable investors to choose between the new system and the existing RO, which will remain stable up to 2017.

3.0 Implementation

3.1 Industry status

Although no established wind turbine manufacturer is currently based in the UK, overseas manufacturers continue to show interest in the UK as a base for manufacturing as a result of the 2010 announcement of Round 3 leasing competition. The developers for the large Round 3 offshore wind farms have been confirmed and over the coming years will be placing contracts for work and turbines, that will require UK facilities to progress the build out. A number of wind turbine manufacturers have since signaled their intention to establish UK manufacturing bases.

3.2 Operational details

In 2012, the UK saw key achievements in wind power development. Further large developments took place onshore in Scotland. Griffin was completed at 156-MW wind farm and Clyde Wind Farm came fully online (220 MW). In England, an onshore wind farm of 66 MW was commissioned at Ilfracombe. Offshore wind saw four large farms come on-line: Greater Gabbard with the largest UK offshore farm of 504 MW; Sheringham Shoal with 317 MW, Walney 2 with 183.6 MW; and Ormonde with 150 MW. Figure 2 shows offshore installation for the London Array Offshore Wind Farm.

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 new 100-m wind turbine blade test facility in 2012 and a 15-MW drive train test facility for offshore wind turbines will be commissioned in summer 2013. The UK Energy Technologies Institute (ETI) is investing 25 million GBP (28 million EUR; 40 million USD) in the design, development and commissioning of the offshore wind turbine test rig.

Narec has obtained a 100-MW grid connection and a lease from The Crown Estate to enable an offshore wind demonstration site to be built in deep water, just off the Blyth coast. An Offshore Anemometry Hub was installed offshore in November 2012 as part of the project and the private sector investment required to build out the demonstration site will be in the order of 400 million GPB (449 million EUR; 650 million USD).

Vattenfall is leading plans for an offshore demonstration site at the European Offshore Wind Deployment Centre near Aberdeen, Scotland, and SSE & Scottish Enterprise are investing in an onshore site for offshore machines at the Port of Hunterston in south-west Scotland. Two of the three plots will be managed by SSE, with Siemens and

Figure 2. Installation of final turbine in first 630-MW phase of the London Array Offshore Wind Farm. Courtesy: London Array

Mitsubishi already named as the manufacturers that will use the facilities.

The Low Carbon Innovation Co-ordination Group (LCICG): The LCICG brings together the major public-sector backed funders of low-carbon innovation in the UK. Its core members include DECC, BIS, Carbon Trust, Energy Technologies Institute, Technology Strategy Board, the Engineering and Physical Sciences Research Council, the Scottish government, the Scottish Enterprise, and several other organizations, including the other devolved administrations, have recently joined as associate members.

The group's aims are to maximize the impact of UK public sector funding for low-carbon energy, in order to deliver affordable, secure, sustainable energy for the UK; deliver UK economic growth; and develop UK's capabilities, knowledge, and skills.

4.1 Research Councils UK Energy Programme

The Research Councils UK Energy Programme (4) aims to position the UK to meet its energy and environmental targets and policy goals through world-class research and training. The Energy Programme is investing more than 625 million GBP (701 million EUR; 1 billion USD) in research and skills to pioneer a low-carbon future. This builds on an investment of 839 million GBP (942 million EUR; 1.3 billion USD) over the past eight years. The Energy Programme is led by the Engineering and Physical Sciences Research Council (EPSRC). It brings together the work of EPSRC and that of the Biotechnology and Biological Sciences Research Council (BBSRC), the Economic and Social Research Council (ESRC), the Natural Environment Research Council (NERC), and the Science and Technology Facilities Council (STFC).

The EPSRC established the SUPERGEN Wind Energy Technologies Consortium (SUPERGEN Wind) on 23 March 2006 as part of the Sustainable Power Generation and Supply (SUPERGEN) Programme. The project was renewed for another four years, starting from 23 March 2010. 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 Consortium has 19 industrial partners, including wind farm operators, manufacturers, and consultants.

The Doctoral Training Centre at the University of Strathclyde every October awards ten prestigious EPRSC research studentships to talented engineering and physical science graduates to undertake a four-year PhD. This combines training and research to enable graduates to make the transition into the wind energy sector—a rapidly expanding area in the UK and overseas, with an overwhelming demand for well qualified people.

The Technology Strategy Board (TSB) is an executive, Non-Departmental Public Body (NDPB), established by the government in 2007 and sponsored by BIS. The TSB activities are jointly supported and funded by BIS and other government departments, the devolved administrations, regional development agencies, 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 DECC, the Research Councils, the Regional Development Agencies, 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 Centre development program, including the Offshore Renewable Energy Catapult.

R, D&D projects supported by the technology program during this reporting period included development of in-situ wireless monitoring systems for towers and blades, cost effective manufacture of offshore wind turbine foundations, and a direct-drive superconducting generator for offshore wind application.

4.2 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 BIS, with funding channeled through the TSB and the EPSRC. The DECC are observers on our Board.

The ETI carries out two 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; and 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.

The ETI has the following projects in wind energy: Condition monitoring: Developing an intelligent integrated, predictive package, which will improve the reliability and monitoring of wind turbines, and increase turbine availability by reducing downtime by up to 20%, which leads to potential savings of approximately 16,000 GBP (17,968 EUR; 26,016 USD) per turbine. Launched in September 2009 with 5.4 million GBP (6.1 million EUR; 8.8 million USD) of ETI funding the system is currently being tested on turbines belonging to EDF

Table 3. Offshore Wind Projects Completed by the End of 2012

Wind farm name	Turbine type	Number of turbines	Total capacity (MW)	Date online
Sheringham Shoal	3.6-MW Siemens	88	317.00	Sept 2012
Greater Gabbard	3.6-MW Siemens	140	504.00	Sept 2012
Ormonde	REPower 5M	30	150.00	Feb 2012
Walney 2	3.6-MW Siemens	51	183.6	Jan 2012
Walney 1	3.6-MW Siemens	51	183.6	July 2011
Thanet	3-MW Vestas V90	100	300.0	Sept 2010
Robin Rigg	3-MW Vestas V90	60	180.0	Apr 2010
Gunfleet Sands I + II	3.6-MW Siemens	48	172.8	Apr 2010
Rhyl Flats	3.6-MW Siemens	25	90.0	Dec 2009
Inner Dowsing	3.6-MW Siemens	30	108.0	Nov 2008
Lynn	3.6-MW Siemens	24	86.4	Nov 2008
Burbo Bank	3.6-MW Siemens	25	90.0	Oct 2007
Beatrice	5-MW REPower	2	10.0	Jul 2007
Barrow	3-MW Vestas V90	30	90.0	Jul 2006
Kentish Flats	3-MW Vestas	30	90.0	Oct 2005
Scroby Sands	2-MW Vestas	30	60.0	Mar 2004
North Hoyle	2-MW Vestas	30	60.0	Dec 2003
Blyth Offshore	2-MW Vestas	2	3.8	Dec 2000

in France and E.ON in North Yorkshire. The project is due to be completed by the end of 2013.

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. The ETI invested over 25 million GBP (28 million EUR; 40 million USD) in the project which will see the test rig operational at Narec in Blyth by the autumn of 2013. The test rig has been designed to allow the whole turbine nacelle to be tested, in a purpose-built, onshore test facility before being exposed to the more challenging offshore conditions.

Very Long Blades Project: Blade Dynamics have been commissioned to design, build and test blades in excess of 80 m long that would be used on the next generation of large offshore wind turbines with a capacity of >6MW. The aim of the project is for the first blades to be manufactured and tested by the end of 2014 ready for production scale-up to serve anticipated future demand.

Offshore Wind Floating Platform: Floating turbine technology is of strategic importance to both UK energy supply and industrial strategy. The Floating System Demonstrator project aims to develop, install, and commission a full-scale floating wind turbine system demonstrator by 2016. The demonstrator is aimed at demonstrating technology for the 60 m–100 m water depth. The global market for floating turbines is likely to be significantly greater than for fixed turbines.

4.3 Department for Energy and Climate Change (DECC)

DECC's vision is of a thriving, globally competitive, low-carbon energy economy. DECC's key priorities are to save energy with the Green Deal and support vulnerable consumers; deliver secure energy on the way to a low-carbon energy future; drive ambitious action on climate change at home and abroad; and manage our energy legacy responsibly and cost-effectively.

The Carbon Trust Offshore Wind Accelerator (OWA) is a collaborative R, D&D program involving the Carbon Trust and eight energy companies that aims to reduce the cost of offshore wind by 10% in time for Round 3 (2015). One third is funded by the UK government and two thirds from the industry. The OWA focuses on four research areas—access systems, electrical systems, foundations, and wake effects. Set up in 2009 and running to 2014, the OWA has achieved a number of milestones.

- Access systems: Thirteen leading designs from 450 entries in a competition for improved crew transfer vessels received financial and technical support for design development. These should allow maintenance to take place in much harsher sea states than is possible today, increasing availability.
- Electrical systems: An engineering design study confirmed the potential for higher voltage (66 kV) intra-array cables to reduce the cost of energy.
- Foundations: Following 18 months of concept development and de-risking, the first of four finalists from 104 entries in a 2009 turbine foundation competition was successfully demonstrated. The Keystone 'twisted jacket' was installed in the Hornsea zone, 100 km offshore in 30 m water depths to support a met mast.
- Wake effects: The OWA funded the development of two new wake effects models that forecast wind farm yields more accurately. This will reduce financing costs and allow more efficient wind farm layouts to be adopted.

Britain's first Industrial Doctorate Centre in Renewable Energy was commissioned and funded by the ETI and the EPSRC. It took its first students in January 2012. The Centre will train up to 50 students in the research and skills needed to accelerate the development of renewable energy technologies. Each will spend part of their training with the three universities in the consortium. The students will spend most of their training time at ETI Member companies, as well as in other renewable industry organizations and companies. The students will each gain an internationally-leading engineering doctorate. The drive to meet the UK's ambitious deployment targets for offshore renewable energy technologies requires a steady supply of highly trained engineers, scientists and leaders. This new Industrial Doctorate Centre in Renewable Energy will contribute significantly to that requirement.

5.0 The Next Term

In July 2013, the 'strike price' on the electricity wholesale market will be set in the government's draft Delivery Plan. The current wholesale price for electricity is 50 GBP/MWh (56 EUR/MWh; 81 USD/MWh), while offshore wind is estimated to cost around 140 GBP/MWh (157 EUR/MWh; 227 USD/MWh). The government has already legislated to establish a Carbon Price Floor from April 2013, to underpin the move to a low-carbon energy future. A Final Investment Decision (FID) enabling process will allow investment in low-carbon projects to come forward for early projects, guarding against delays to investment in energy infrastructure.

The government will take additional powers so that if necessary, it can promote greater competition and liquidity in the wholesale market. An Emissions Performance Standard (EPS) will curb the most polluting fossil fuel power stations, ensuring that any new coal-fired power stations will have carbon capture and sequestration (CCS) fitted to be able to operate within limit. Through the Levy Control Framework, 7.6 billion GBP (8.5 billion EUR; 12.4 billion USD) will be invested in clean technologies each year up to 2020—as the price of carbon and imported gases rises, the cost of offshore wind is expected to fall. Gas prices roses by 50% in the five years prior to 2011.

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Opening photo of a rural wind farm courtesy of Renewables UK www.renewableuk.com/en/news/media-galleries/index.cfm

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36 United States

Photo: Campo Band of the Kumeyaay Nation

1.0 Overview

In the United States, 13,131 MW of wind power capacity came online in 2012, more than any other year and nearly twice as much as was installed in 2011 (1). This added wind capacity represented 43% of new U.S. electricity generation capacity for 2012, surpassing the 33% of new generation represented by natural gas (2). Wind energy now accounts for nearly 3.5% of national electricity consumption in the United States (3) and is deployed in 39 states and territories (1). The state of Texas alone has more installed wind power than all but five countries around the world.

The record installations in 2012 represented a rush to complete projects before the pending expiration of a key federal incentive for wind energy—the Production Tax Credit (PTC). In January 2013, as part of the American Taxpayer Relief Act of 2012, the U.S. Congress extended the incentive for one year and changed the eligibility requirement so that rather than being in operation, farms must be under construction by the end of the year.

Moving aggressively to advance offshore wind deployment, the U.S. Department of Energy (DOE) Wind Program is pursuing its 168 million USD (127 million EUR) offshore wind initiative. In 2012, DOE announced seven Phase 1 funding awards to plan and design offshore wind demonstration projects. In Phase 2, three of these technology demonstration partnerships will be selected to move to demonstration of full-scale offshore wind generation facilities (4). Offshore wind facility developments were further facilitated with the adoption of the American Wind Energy Association (AWEA) Offshore Compliance Recommended Practices (5) that address the unique conditions for wind energy development in U.S. waters.

Other important R&D activities support technology development. Tests of large wind turbine blades began at the Massachusetts Wind Technology Testing Center that has been certified by the International Electrotechnical Commission (IEC). Development and testing of advanced drivetrains continues, and researchers are increasing efforts to understand the reliability of wind turbine components and complex flow in wind facilities. The United States is leading a new IEA Wind research task to assess and monitor the environmental impacts of land-based and offshore wind development.

2.0 National Objectives and Progress

Although the U.S. government has no official targets for wind energy, the president is striving to achieve 80% of U.S. electricity from clean energy sources (including renewable energy technologies, nuclear, clean coal, and natural gas) by 2035. After the U.S. achieved a doubling of renewable energy generation (largely driven by wind) between 2008 and 2012, President Obama challenged Americans to double renewable electricity generation again by 2020. Wind energy will contribute significantly to achieving this goal and aiding economic recovery.

2.1 National targets

The potential for wind energy development in the United States is enormous. DOE estimates a potential 8,000 GW of land-based wind resource and 4,000 GW of offshore wind resource off the marine coasts and in the Great Lakes (6). Although not all of this wind resource (land-based and offshore) can be realistically developed because of certain restrictions (e.g., competing uses and environmentally sensitive areas), a cost-effective offshore wind industry could add a substantial amount of electric-generating capacity. The National Offshore Wind Strategy calls for reducing the cost of offshore wind energy and enabling the deployment of 54 GW by 2030 (7).

2.2 Progress

Total U.S. wind capacity at the close of 2012 was more than 60 GW compared to just 2.5 GW in 1999. The U.S. wind fleet generated more than 140 GWh of electricity in 2012, which avoided 79.9 million tons of CO_2 emissions from power generation. This avoided CO_2 is equivalent to reducing national power system emissions by 3.6% or to eliminating the emissions of 14 million cars. In addition, 60 GW of wind plants operating for a full year avoids the consumption of 37.7 billion gallons of water. (1)

Wind generation represented nearly 3.5% of total U.S. electrical consumption in 2012 (3). However, in nine states, wind generation meets more than 10% of demand. In Iowa, wind represents 24.5% of total state electrical consumption (1).

By the end of 2012, 10 offshore wind projects were identified as being more-advanced in the development process. These projects equal 2,840 MW of anticipate capacity and are primarily located in the Northeast, Mid-Atlantic, and Gulf of Mexico (2).

2.3 National incentive programs

Federal tax and grant incentives and state Renewable Portfolio Standards (RPSs) 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. PTCs, loan programs, and various levels of bonus depreciation were effective through 2012. However, uncertainty about their extension spurred the installation of a record 8,380 MW in the fourth quarter of 2012. The PTC was extended for one year as part of the American Taxpayer Relief Act of 2012 and will apply to projects under construction in 2013.

State-based RPSs 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 RPSs. Another seven states have

In the United States, 13,131 MW of wind power capacity came online in 2012, more than any other year and nearly twice as much as was installed in 2011.

Table 1. Key National Statistics 2012: United States	
Total installed wind capacity (1)	60,007 MW
New installed wind capacity (1)	13,131 MW
Total electrical output from wind (3)	140.1 TWh
Wind generation as a percentage of national electric demand	3.5%
Average national capacity factor (9)	33%
Target	80% of electricity from clean sources by 2035. Double renewable electricity generation by 2020 (relative to 2012 levels)

goals for renewables. Utility resource planning requirements, voluntary customer demand for "green" power, state clean energy funds, and state and regional carbon-reduction policies also play a role in supporting wind energy development.

2.4 Issues affecting growth

The wind industry and DOE's Wind Program are addressing barriers to increased deployment of wind energy through R&D and demonstration projects.

2.4.1 Offshore experience

At the close of 2012, no utility-scale wind turbines were operating off of U.S. marine coasts or in the Great Lakes. The experience gained through R&D and advanced technology demonstrations (see Section 4.1) will reduce key barriers to offshore wind, including the relatively high cost of energy, the demands of permitting and approval processes, the mitigation of environmental impacts, and the technical challenges of project installation and grid interconnection.

2.4.2 Cost of energy

In 2012, the lowest cost option for new electricity generation was from natural gas because of historically low natural gas prices. As a result, all other sources, including wind, are striving to reduce their costs. In many markets, wind energy is already the lowest cost renewable source of energy. However, identifying the cost drivers for land-based and offshore wind energy is a key aspect of the DOE Wind Program to direct R&D investment to achieve the greatest cost reductions. The Wind Program has joined with members of IEA Wind Task 26 to evaluate methods for calculating the cost of wind energy. In 2012, a report on the first phase of this work (8) provided information on the historical costs, near-term market trends, methods used to estimate long-term cost trajectories, and range of costs projected for land-based wind. It also highlighted high-level market variables that influence wind energy costs. The next step for this task is to explore costs for offshore wind.

2.4.3 Transmission and integration

AWEA has identified near-term transmission projects that—if all were completed—could carry approximately 45 GW of electric-generating capacity from wind. However, lack of transmission access has been driving project developers to choose sites with less wind potential but with access to transmission, which increases the resulting cost of energy. As a result, the Wind Program conducts grid integration studies to better understand the impact of wind generation on the power grid and to encourage investment in new transmission infrastructure. These studies provide grid integration support for utility owners and operators; wind generation modeling for use by transmission planners; development of active power controls methodologies; and metric development and technical solutions to wind resource variability. States, grid operators, regional organizations, and DOE are also working to improve forecasting and transmission-planning strategies, and increase transmission capacity.

Another barrier to increasing deployment of wind energy has been concern from utilities about wind-induced cycling of fossil-fueled generation. Building on the 2011 Western Wind and Solar Integration Study, DOE researchers examined new industry data and determined that although there are wear-and-tear and emissions impacts from wind-induced generator cycling, these impacts are modest compared to the benefits of replacing fossil-fuel with renewable energy generation. These new data will be used in unit commitment and economic dispatch modeling for the Western Interconnection for four scenarios.

2.4.4 Environmental issues

Siting issues—including wildlife impacts, radar interference, and human impacts (sound and visual)—can push wind development into lower-quality wind regimes and increase the cost of energy. Therefore, DOE continues to fund work to identify, measure, and mitigate the negative impacts that can limit quality wind resource areas from development. In 2012, DOE completed a series of tests to evaluate technologies designed to eliminate radar interference caused by physical and operational effects of wind turbines. DOE also joined with member countries of IEA Wind to strategize and share methods to assess and monitor the environmental impacts of land-based and offshore wind development.

3.0 Implementation

3.1 Economic impact

The wind industry has supply chain or utility-scale wind facilities in all 50 states. The 60

GW of wind capacity operating at the close of 2012 represented more than 120 billion USD (91 billion EUR) in U.S. investment, according to AWEA, and the new installations in 2012 alone represented approximately 25 billion USD (19 billion EUR) in private investment. AWEA estimates that the entire U.S. wind energy sector directly and indirectly employed 80,700 full-time workers; of these jobs, 25,500 were in manufacturing (1).

A 2012 study quantified the annual impact on county-level employment and personal income resulting from wind power installations in nearly 130 counties across 12 states (10). The findings indicated that, on average, wind power installations within the study area (occurring between 2000 and 2008) resulted in an increase in total county-level personal income of approximately 11,000 USD/MW (8,338 EUR/MW). On average, the impact of these wind power installations on total county-level employment was 0.5 jobs/MW.

3.2 Industry status

At the close of 2012, more than 890 wind facilities were operating in 39 states and Puerto Rico with 400 owners using machines from 60 manufacturers, according to AWEA (1). General Electric Company and Vestas Wind Systems A/S each supplied about 5.7 GW of wind turbines for the U.S. market in 2012. Siemens AG, Enercon GmbH, and Suzlon Energy Ltd. were the other major suppliers (11). Wind-generated electricity was supplied to companies through long-term Power Purchase Agreements (PPAs) or from direct ownership of on-site turbines. During 2012, 91% of new capacity was owned by independent power producers and 9% by utilities. Purchasers of new wind power included utilities, power marketers, industrial buyers, schools, universities, towns, and cities, as well as farms, medical centers, and manufacturers of plastics, light bulbs, and semiconductors (1).

As U.S. interest in offshore wind development has increased, industry, regulatory agencies, and stakeholders saw a need for a single set of guidelines for this development. Consequently, AWEA, in collaboration with DOE, the National Renewable Energy Laboratory (NREL), and more than 50 experts, developed and adopted the Offshore Compliance Recommended Practices in 2012 (5). The document recommends practices that leverage standards already in use in Europe and other industries to address the unique conditions for wind energy development in U.S. coastal waters. These guidelines are a first step toward creating mature standards that will reduce uncertainty and project risk and ultimately help lower the cost of offshore wind energy.

In response to the increased use of small wind turbines in the urban environment, NREL published the *Built-Environment Wind Turbine Roadmap* in 2012, a strategy to supply safe, reliable small wind turbines (12). Important performance data from small wind turbine testing programs are being provided to manufacturers and consumers, and more turbines are completing certification tests according to AWEA's small wind turbine performance and safety standard. Developers of small-scale wind also gained access to a specialized resource map developed by NREL and AWS Truepower that shows the wind speed at 30 m, the relevant hub height for these turbines (13).

3.3 Operational details

Figure 1 illustrates the geographic distribution of wind projects operating at the close of 2012. The capacity factor of wind installations varies by region (from 25% to 37%), reflecting variations in the wind resource (9). By the end of 2012, the state of Texas had the most total wind capacity at 12,214 MW, followed by California at 5,542 MW, Iowa at 5,133 MW, and Illinois at 3,568 MW (2).

3.4 Wind energy costs

Turbine prices have fallen 20–35% from their highs in 2008 (2). Data from a preliminary sample of wind power projects being built in 2012 suggest a 13% reduction in average installed project costs since 2009. Among a sample of wind power projects with PPAs signed in 2011 or 2012, the generation-weighted average levelized price was 41 USD/MWh (31 EUR/MWh), down from 61 USD/MWh (46 EUR/MWh) for projects with PPAs signed in 2010 and 67 USD/MWh (51 EUR/MWh) for projects with PPAs signed in 2009 (all in 2012 dollars). A study by Bloomberg New Energy Finance found the cost of power from a large-scale wind project *before subsidies* dropped from 90 USD/MWh (68 EUR/MWh) in 2011 to 80 USD/MWh (60.6 EUR/MWh) in 2012 (14).

4.0 R, D&D Activities

DOE supports the research, development and deployment of wind energy through its Wind Program. The Wind Program's R, D&D activities are applicable to utility-scale, land-based, and offshore wind markets, as well as wind turbines used in distributed applications, which tend to be smaller turbines. The majority of these program activities have cross-cutting benefits for all market types.

Often in collaboration with government and industry partners, the Wind Program conducts R, D&D that addresses high-risk, transformational technological innovations that are essential for the advancement of U.S. wind systems. Federally supported projects engage comprehensive competencies that industry alone cannot tackle. The Wind Program also addresses inter- and intra-governmental agency issues related to wind energy. The Wind Program provides competitive awards to the wind industry, universities, and U.S. national laboratories to increase reliability and reduce the levelized cost of wind energy through innovative research.

4.1 National R, D&D efforts

The Wind Program strives to reduce the cost of wind energy by improving wind plant performance, increasing wind plant reliability, and developing the next generation of wind turbine systems and components for land-based and offshore wind facilities. Areas of research include electrical grid integration, complex flow characterization, wind resource assessment and forecasting, wind turbine component failure mitigation, advanced rotor and drivetrain development, improved manufacturing methods, public acceptance through education, and responsible siting to avoid use conflicts.

The Wind Program budget was 93.5 million USD (70.9 million EUR) in fiscal year (FY) 2012 (October 2011 through September 2012). The approved FY 2013 budget was 88.3 million USD (66.9 million EUR). Details of Wind Program research projects are available on the website (4). Some sample activities are described in this chapter.

4.1.1 Offshore wind

The Wind Program addresses offshore wind because it is an emerging industry in the United States, where the resource is abundant, but technology, infrastructure, financial, and market barriers have slowed progress.

To advance the offshore wind industry, in 2012 the Wind Program announced the start of a six-year, 168 million USD (127 million EUR) offshore wind initiative and selected seven projects to demonstrate next-generation offshore wind technologies. Initially, each project will receive up to 4 million USD (3 million EUR) to complete the engineering, design, and permitting phase of the project. The Wind Program will

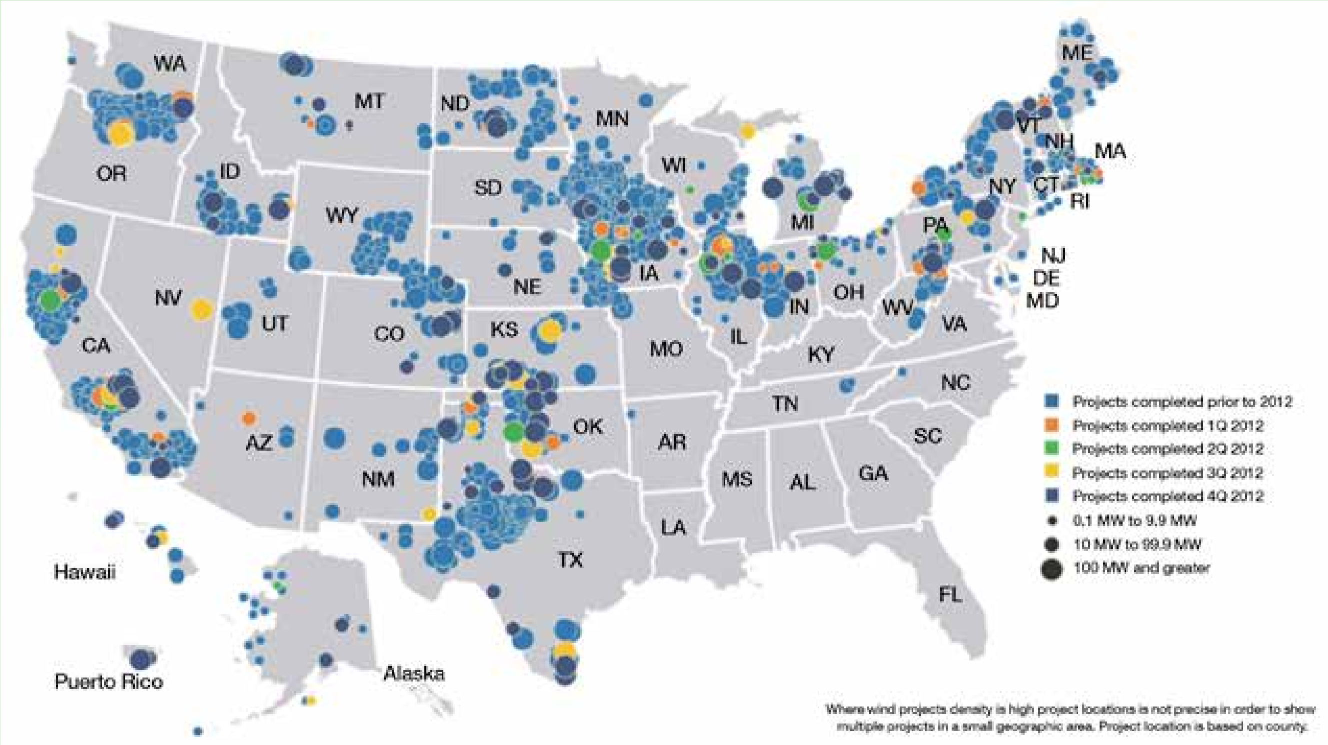

Figure 1. Geographic spread of wind power projects (Source: AWEA)

then select up to three of these projects for follow-on phases that focus on siting, construction, and installation and aim to achieve commercial operation by 2017.

Technology research is also underway to provide the emerging U.S. offshore wind industry with tools to move their projects forward.

4.1.2 Wind plant performance

Some wind facilities are underperforming by as much as 20–30%, according to recent assessments and simulations (15). Bringing wind plants up to the predicted performance level would reduce the cost of wind power. One way to improve performance is to better understand the multi-scale aerodynamics impacting wind plants in modern land-based and offshore wind facilities. This complex flow research focuses on integrated, interconnected, multi-turbine wind plants rather than on single turbines. It spans several spatial scales, from global and regional wind flows to flows into individual wind turbines and rotor blades, and it involves collecting experimental data to validate models.

A workshop held by the Wind Program in early 2012 identified research needs and challenges relating to the complex flow of wind into and out of the wind turbine environment, as well as the resulting impacts on the mechanical workings of individual wind turbines (15).

4.1.3 Wind plant reliability

Increasing wind plant and wind turbine reliability will reduce the cost of energy from wind generation. Research into the root causes of component, turbine, and wind plant failures will direct work to improve the reliability of and reduce the failure rates for large components, such as blades, gearboxes, and generators, resulting in reduced operation and maintenance costs.

To guide future research efforts, the performance of wind facilities in the United States is being tracked in a reliability database funded by the Wind Program through Sandia National Laboratories. The Continuous Reliability Enhancement for Wind database issued its second benchmark report in 2012, which covers three turbine manufacturers, six turbine models (at least 1-MW capacity), and more than 180,000 days of turbine operation (16).

4.1.4 Emerging technologies

Drivetrains are a significant cost driver for both land-based and offshore wind turbines. As a result, next-generation drivetrains need to be lighter, cheaper, and more reliable. Six innovative drivetrain projects received funds in 2011 to prepare engineering assessments and propose further development. In 2012, two of these projects won awards for further development: 1) a direct-drive superconducting generator with an advanced, single-stage gearbox; and 2) a medium-speed, permanent-magnet generator that reduces the need for rare earth materials.

4.1.5 Supply chain

To improve the position of U.S. manufacturers of small wind turbines in the global market, the Wind Program awarded two small wind turbine competitiveness improvement project grants: one company will identify component improvements that will increase performance and reduce costs, and another company will develop an advanced blade manufacturing process.

4.1.6 Environmental studies

In 2012, DOE funded a study by West Virginia University that used a global positioning system to track the movements of golden eagles and gain a deeper understanding of their movements and hence, the risks they face from wind energy development. DOE also continued to work with the National Wind Coordinating Collaborative (NWCC) to study the impacts of wind development on prairie chickens and sage grouse and with the Bats and Wind Energy Cooperative to investigate bat–wind turbine interactions. In November 2012, scientists from around the world convened at a meeting co-hosted by

Table 2. Offshore Demonstration Project Awards

Lead Organization	Key Partners	Region	State *(planned)*	Federal or State Waters *(planned)*	Fix or Float *(planned)*	Foundation Configuration *(planned)*	*Turbines (planned)*	Deployment Goal
In Federal waters								
Dominion	Alstom, KRB, NREL, VA Tech, VA DDME, NNS, UK Carbon Trust, Newport News Shipbuilding	Mid-Atlantic	Virginia	Federal	Fixed	Jacket	2 x 6.0 MW DD	2017
Principle Power	ABS, Macartney Underwater, Siemens Windpower, NREL, PNNL, Port of Coos Bay, Houston Offshore Eng	Pacific	Oregon	Federal	Floating	Semi-sub	5 x 6.0 MW DD	2017
Statoil	U Maine, NREL, Tetra Tech, RLC Engineering-Grid	North Atlantic	Maine	Federal	Floating	Spar	4 x 3.0 MW DD	2016
In State Waters								
LEEDCO	DNV KEMA, Offshore Design Eng, Global Marine, Great Lakes Construction, Siemens, Cleveland Public Power, COWI, NREL, PNNL	Great Lakes (Erie)	Ohio	State	Fixed	3 options	9 x 3.0 MW	2015
U. Maine	Iberdrola, Technip, ABS, NREL, AWS Truepower, Cianbro, Bath Iron Works, Goldwind	North Atlantic	Maine	State	Floating	Semi-sub	2 x 6.0 MW DD	2017
Baryonyx	Keppel AmFels, Siemans AG, Offshore Design Engineering Ltd., Texas A&M, UT Austin, Texas Tech	Gulf of Mexico	Texas	State	Fixed	Jacket	3 x 6.0 MW DD	2017
Fishermen's	NREL, Mott McDonald, Darwind, Siemens, Keystone Eng	Mid-Atlantic	New Jersey	State	Fixed	3 options	5 x 5.0 MW XEMC DD	2015

the NWCC and the American Wind Wildlife Institute in Colorado to share their latest findings and evaluate the progress in understanding and addressing wind energy's potential impacts on wildlife and wildlife habitat. The Wind Program has also supported work with the U.S. Fish and Wildlife Service to develop guidelines for wind developers on avoiding, minimizing, and/or compensating for the impacts on wildlife from wind energy development.

4.1.7 Workforce/Education

Spreading the word to educate, engage, and enable critical stakeholders to make informed decisions about how wind energy contributes to the U.S. electricity supply is important work for the Wind Program. The Wind for Schools project raises awareness in rural America about the benefits of wind energy and strives to develop a wind energy workforce. The project is active in 11 states and has installed 124 wind systems in host primary and secondary schools.

4.1.8 Wind test facilities news

The DOE Wind Program, through its national laboratories, university consortia, and research institutes, supports test centers to serve the wind energy R&D community. In 2012, the recently constructed Massachusetts Wind Technology Testing Center gained accreditation and began testing wind turbine blades up to 90 m in length to IEC standards. By the end of 2012, the center had completed certification testing on several multi-megawatt wind turbine blades for industry partners.

Full-scale tests under cooperative research agreements with industry partners continue employing the four large wind turbines (1.5-MW, 2-MW, 2.3-MW, and 3-MW) installed at the National Wind Technology Center at NREL, the 2.5-MW turbine at the University of Minnesota, and the 1.5-MW turbine at the Illinois Institute of Technology.

The University of Maine and NREL are now analyzing results from scaled testing to validate NREL's coupled numerical tools for accurate modeling of future offshore designs. These designs include the semisubmersible pilot-scale turbine that the university plans to deploy in 2013 at its deepwater offshore wind test site near Monhegan Island, Maine.

Construction began in 2012 on a new research and testing site, the Scaled Wind Farm Technology facility, to be operated by Texas Tech University, Sandia National Laboratories, and Group NIRE. Three research-scale wind turbines will be spaced and oriented to study turbine-to-turbine interactions and to validate aerodynamic, aero-elastic, and aero-acoustic simulations used to develop new technologies.

Two test facilities for large (5–15-MW) drivetrains designed for land-based and offshore applications are under development. When completed, the Clemson University drivetrain test facility will be capable of conducting full-scale, highly accelerated testing of advanced drivetrain systems for wind turbines in the 5 to 15-MW range. The new test stand at NREL will accommodate drivetrains of up to 5 MW. Both facilities will be able to expose the test articles to grid faults through a controllable grid interface.

4.2 International collaborative research

International collaboration, through bilateral agreements and participation in international organizations, ensures the application of worldwide experiences with wind energy to U.S. efforts. International collaborations in 2012 supported by DOE's Wind Program included work with IEC, the Institute of Electrical and Electronics Engineers, Underwriters Laboratory, the International Measuring Network of Wind Energy Institutes, and the IEA Wind Implementing Agreement.

IEA Wind is an important international research collaboration in which U.S. researchers and organizations participate in most of the active research tasks. In addition, U.S. representatives at NREL served as operating agents to several research tasks that had major achievements in 2012. IEA Wind Task 26, Cost of Wind Energy, published a final technical report on its first three-year term of activity (8) that incorporates the experience of experts from eight countries with U.S. efforts to identify cost drivers for land-based and offshore wind technologies. IEA Wind Task 30, Offshore Code Comparison Collaboration Continuation (OC4), is coordinating the work of 12 countries and 47 organizations to improve the design of offshore wind turbines using verified and improved codes. Jacket structure results were published in 2012 and provide enhanced tools for designers of offshore wind turbines. Work on semisubmersible substructures contributes to U.S. work with DeepCwind model test data to advance the offshore floating wind turbine industry. IEA Wind Task 31, Wakebench, manages the work of 14 countries to improve atmospheric boundary layer and wind turbine wake models by benchmarking wind and wake modeling techniques.

In 2012, U.S. experts also coordinated efforts to develop the important IEA Wind Recommended Practice 15: Ground-Based, Vertically-Profiling Remote Sensing for Wind Resource Assessment (17). The new IEA Wind Task 34 was approved with NREL as the operating agent. Participants will begin work in 2013 to share techniques and approaches to environmental assessment and monitoring of wind energy projects on land and offshore. In 2013, the U.S. representative to IEA Wind from DOE will serve as chair of the executive committee.

5.0 The Next Term

In 2013, DOE will renew its efforts to advance clean energy manufacturing by making 150 million USD (114 million EUR) in tax credits available for clean energy manufacturers. The Advanced Energy Manufacturing Tax Credit was established by the American Recovery and Reinvestment Act to support investment in domestic clean energy and energy efficiency manufacturing facilities through a competitively-awarded 30% investment tax credit. Over the past four years, the United States has more than doubled clean, renewable energy generation from wind, solar, and geothermal sources. At the same time, the American manufacturing sector has begun to rebound, with 500,000 manufacturing jobs added since the beginning of 2010. These tax credits will help continue this growth while enhancing the country's energy security and boosting local economic development.

DOE will also make 10.5 million USD (8 million EUR) available for small business research and development in clean energy technologies in 2013. The awards include three projects that will explore concepts for improving the performance and reducing the costs of land-based and offshore wind technologies.

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Opening Photo: Campo Band of Mission Indians of the Kumeyaay Nation Wind Farm

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Appendix A

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Appendix B

IEA WIND EXECUTIVE COMMITTEE 2012

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Appendix C

Currency Conversion Rates IEA Wind Annual Report 2012			
Country	Currency	1 EUR	1 USD
Australia	AUD	0.788	1.039
Austria	EUR	1.000	1.318
Canada	CAD	0.760	1.003
China	Yuan	0.122	0.160
Denmark	DKK	0.134	0.177
Finland	EUR	1.000	1.318
Germany	EUR	1.000	1.318
Greece	EUR	1.000	1.318
Ireland	EUR	1.000	1.318
Italy	EUR	1.000	1.318
Japan	JPY	0.0087	0.0116
Korea	KRW	0.00071	0.00094
Mexico	MXP	0.059	0.077
Netherlands	EUR	1.000	1.318
Norway	NOK	0.136	0.180
Portugal	EUR	1.000	1.318
Spain	EUR	1.000	1.318
Sweden	SEK	0.116	0.154
Switzerland	CHF	0.828	1.092
United Kingdom	GBP	1.123	1.626
United States	USD	0.758	1.000
Source: Federal Reserve Bank of New York (www.x-rates.com) 31 December 2012			

Appendix D

Availability: the percentage of time that a wind plant is ready to generate (that is, not out of service for maintenance or repairs).
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.
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

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
LVRT: low-voltage ride-through

m: meter
m a.g.: meters above ground
m.a.s.l.: meters above sea level
MOU: memorandum of understanding
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 organisations.

OA: Operating agent that manages the work of a research task
O&M: operations and maintenance

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
RPS: renewables portfolio standard

S.A.: Sociedad Anonyma

tCO_2-e per capita: tonne of carbon dioxide emissions per person
TNO: transmission network operator
Toe: 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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Produced for IEA Wind by

PWT Communications, LLC
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July 2013

ISBN 0-9786383-7-9

Front cover photo: Wind turbines on the coast of Norway near Rørvik. **Credit:** Rick Hinrichs, PWT Communications, LLC.

Back cover photo: Wind Power Kamisu Semi-Offshore Wind Farm that survived the great earthquake and tsunami of 2011. The SUBARU 80/2.0 wind turbines with rated power of 2.0 MW resumed operation when the utility grid was activated**. Credit:** Rick Hinrichs, PWT Communications, LLC.