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IEA WIND

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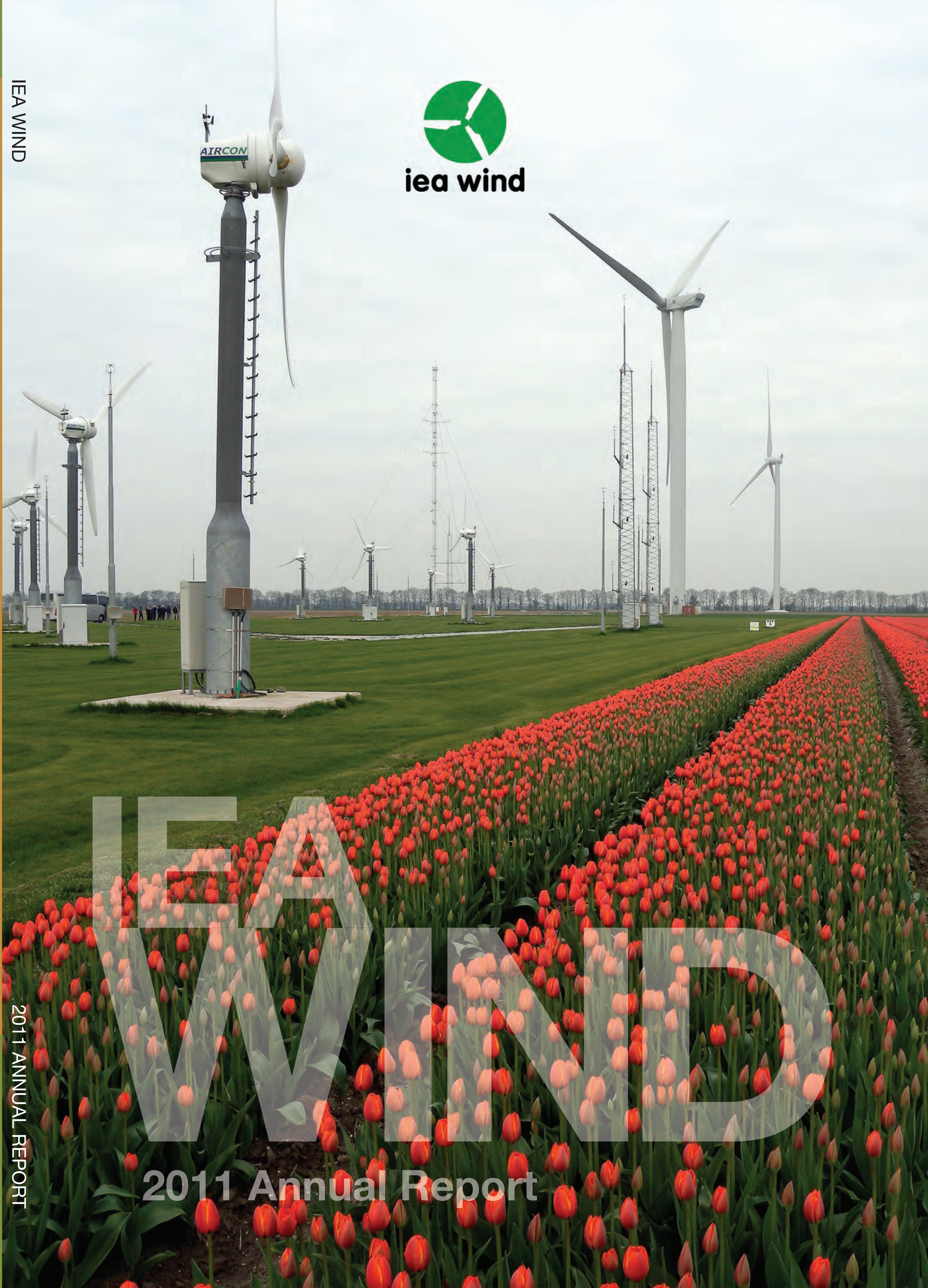
2011 Annual Report

2011 ANNUAL REPORT



IEA WIND
2011 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 2012

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Message from the Chair

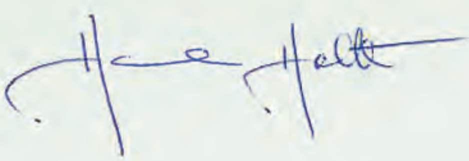
Welcome to the IEA Wind 2011 Annual Report of the cooperative research, development, and deployment (R,D&D) efforts of our member governments and organizations. IEA Wind helps advance wind energy in countries representing 85% of the world's wind generating capacity.

The year 2011 was a challenging year for wind energy, but resulted in impressive additions of wind power capacity as well as research efforts by the member countries. We published a revised strategic plan, a report on activities in the small wind sector, and final reporting of several tasks were ongoing to be published in early 2012. The first new IEA Wind Recommended Practice in a decade was published: *Recommended Practices for Wind Turbine Testing and Evaluation 12. Consumer Label for Small Wind Turbines*. Three new Topical Experts Meetings were held on statistical analysis on wind turbine failures, offshore foundation technology and long-term R&D needs for wind power. We published full proceedings of Topical Expert Meetings on wind conditions for wind turbine design; solutions and concepts for offshore wind turbines; micrometeorology inside wind farms and wakes between wind farms; and wind farms in complex terrain.

In 2012, we expect to approve new IEA Wind Recommended Practices for wind energy projects in cold climates, for remote wind speed sensing using SODAR and LIDAR, and for public acceptance of wind energy projects and wind integration. These official documents developed within our research tasks provide pre-normative guidelines for the wind community while formal standards efforts are under way.

Moving forward, we approved two new research tasks to start work in 2012, one to advance the use of Lidar remote sensing for wind plant development, and one to improve the use of reliability data to develop operation and maintenance strategies. In 2012, the eleven active research tasks of IEA wind will offer members many options to multiply their national research programs. Six of these tasks will generate technical reports based on their terms extending into 2012. And ideas for additional cooperative research are moving toward task proposals for 2012 and beyond.

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.



Hannele Holttinen
Chair of the Executive Committee, 2011 to 2012

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Executive Summary

Credit: Patricia Weis-Taylor

Wind energy production monitoring and control room, Dublin, Ireland

1.0 Introduction

Wind generation now meets a significant percentage of electrical demand worldwide. In 2011, the world added about 40 GW of wind generation, a 24% increase, to total more than 238 GW (GWEC 2012). This is enough capacity to cover about 3% of the world's electricity demand (WWEC 2012).

More than 85% of the world's wind generating capacity resides in 21 countries participating in the IEA Wind implementing agreement—an international cooperation to share information and research activities that advance wind energy deployment. These IEA Wind member countries added more than 33 GW of capacity in 2011. With a full 200 GW of wind generating capacity, electrical production from wind met 2.8% of the total electrical demand in the IEA Wind countries (Tables 1–3).

This *IEA Wind 2011 Annual Report* contains chapters from each member country, the Chinese Wind Energy Association, and the European Wind Energy Association. The countries report how much wind energy they have deployed, how they benefit from wind energy, and how their strategies and research will increase wind's contribution to the world energy supply. This Executive Summary presents highlights from the country chapters and compiled statistics for all countries. Data from the past 15 years as reported in previous IEA Wind documents (IEA Wind 1995–2010) are included as background for 2011.

Table 1. Key Statistics of IEA Wind Member Countries 2011	
Total installed capacity	203 GW
Total offshore wind capacity	3.3 GW
Total new wind capacity installed	33.6 GW
Total annual output from wind	365.2 TWh
Wind generation as % of national electric demand	2.8%

2.0 National Objectives and Progress

Governments and industry in IEA Wind member countries have set national targets for renewable energy and wind energy (Table 4) and designed incentive programs to help reach these targets (Table 9). Their reasons for supporting wind energy include increasing domestic energy supply, reducing greenhouse gas emissions, building domestic industry, and replacing nuclear energy.

2.1 National targets

The member countries of IEA Wind have targets for increasing the amount of renewable energy, or low-carbon energy, in the electrical generation mix (Table 4). These targets, whether embedded in legislation or appearing in roadmap documents, help drive policy measures to encourage deployment of renewables in general and wind energy in particular.

All EU member states have submitted National Renewable Energy Action Plans (NREAPs) detailing sectoral and technology-specific targets and policy measures to reach the legally binding 2020 renewable energy systems target. It is expected that more than 34% of EU electricity demand will be covered by renewable energy sources (RES), almost half of that (14%) by wind energy. According to the NREAPs, installed wind capacity in the EU will increase to 213.4 GW in 2020 (170.1 GW onshore and 43.3 GW offshore).

ExCo Meeting 68 Dublin, Ireland

Some countries have chosen goals that exceed the EU targets. Austria's new Green Electricity Act 2012 has a new long-term target of adding 2 GW of wind power to the existing capacity (1 GW) by 2020, which means a target of 3 GW by 2020. This target is higher than Austria's target for wind energy in its NREAP. Denmark became the first country to declare the intention to use 100% renewable energy for their energy and transport system by 2050. In Denmark, wind power covered 28% of electric demand in 2011 and is planned to cover 50% of electricity consumption by 2020. The German government plans to supply 50% of electricity consumption from wind by 2050. The German government also decided to move completely away from nuclear energy production by 2022. Ireland's target of 40% contribution from RES by 2020 will be largely met by wind energy.

Outside of Europe, planning is underway to increase wind power development. The Chinese organizations and the IEA Secretariat published the *China Wind Energy Development Roadmap 2050*.

Table 2. National Statistics of the IEA Wind Member Countries 2011

Country	Total installed wind capacity (MW)	Total offshore installed wind capacity (MW)	Annual net increase in capacity (MW)	Total no. of turbines	Average capacity of new turbines (kW)	Wind-generated electricity (TWh/yr)	National electricity demand (TWh/yr)	National electricity demand from wind* (%)
Australia	2,224	0	234	1,211	2,000	6.4	261	2.4%
Austria	1,084	0	73	656	2,220	2.2	68.7	3.6%
Canada	***5,265***	0	***1,298***	***3,094***	***1,930***	***14.3***	***555.0***	***2.5%***
China	62,364	108	17,631	45,898	1,545	73.2	4,692.8	1.6%
Denmark	3,952	871	206	4,972	2,155	9.8	34.9	28.0%
Finland	199	26	2	131	1,000	0.5	***84.4***	0.6%
Germany	29,075	200	2,007	22,297	2,243	46.5	608.0	7.6%
Greece	1,640	0	343	1,357	1,145	3.3	57.0	5.8%
Ireland	1,633	25	239	***1,200***	***2,000***	4.4	28.0	15.6%
Italy	6,878	0	1,080	5,446	1,831	***10.1***	332.3	***3.0%***
Japan	2,501	25	167	1,832	1,991	4.2	859.7	0.5%
Korea	406	0	27	234	1,381	0.8	451.1	0.2%
Mexico	570	0	50	450	1,250	1.3	219.0	***0.6%***
Netherlands	2,368	228	123	2,009	2,118	5.1	121.8	4.2%
Norway	511	2	76	242	2,300	1.3	131.2	1.0%
Portugal	4,302	2	315	2,349	2,000	9.0	50.5	18.0%
Spain	21,673	0	1,050	19,606	1,807	41.8	254.8	16.4%
Sweden	2,899	0	755	2,039	2,133	6.2	139.2	4.4%
Switzerland	46	0	3	30	1,625	***0.1***	***59.8***	***0.1%***
UK	6,470	1,838	1,092	***3,600***	***1,900***	15.5	365.3	4.24%
United States	46,916	0	6,816	39,292	2,000	119.7	3,769.3	***2.9%***
Totals	**202,976**	**3,325**	**33,587**	**157,945**		**375.7**	**13,143.4**	**2.8%**

*% of national electricity demand from wind = (wind generated electricity/national electricity demand) × 100
Bold italic = estimated

Table 3. Worldwide Installed Wind Capacity for 2011			
IEA Wind Members*		Rest of World**	
Country	MW	Country	MW
China	62,364	India	16,084
United States	46,916	France	6,800
Germany	29,075	Other Countries***	3,296
Spain	21,673	Turkey	1,799
Italy	6,878	Poland	1,616
United Kingdom	6,470	Brazil	1,509
Canada	5,265	Belgium	1,078
Portugal	4,302	New Zealand	622
Denmark	3,952	Taiwan	564
Sweden	2,899	Egypt	550
Japan	2,501	Morocco	291
Netherlands	2,368	Chile	205
Australia	2,224	Costa Rica	132
Greece	1,640	Argentina	130
Ireland	1,633	Honduras	102
Austria	1,084	Caribbean	91
Mexico	570	Iran	91
Norway	511	Dominican Republic	33
Korea	406	Vietnam	30
Finland	199	Cape Verde	24
Switzerland	46	Pacific Islands	12
Total IEA Wind Members	**202,976**	**Total Rest of World**	**35,059**
		Grand Total	**238,038**

* Numbers reported by IEA Wind member countries
**Numbers reported by GWEC (2012)
*** Those not in this list or in IEA Wind

In Canada, although there are no national wind energy deployment targets, the federal government has committed to have 90% of Canada's electricity produced by hydro, nuclear, clean coal, and wind power by 2020. Japan is reevaluating its dependence on nuclear power in 2011 after the tragic tsunami and its aftermath. 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. By the close of the year, an expert committee was reviewing the basic energy plan and goals for wind energy.

2.2 Progress

2.2.1 Capacity increases

Capacity increased in the IEA Wind member countries as a whole from less than 5 GW in 1995 to more than 200 GW in 2011 (Figure 1). In 2011, wind generation capacity increased in every IEA Wind member country, and they added more than 33 GW in all. Seven countries added more than 1 GW of new capacity: China (17.6 GW), the United States (6.8 GW), Germany (2.0 GW), Canada (1.3 GW), the United Kingdom (1.1 GW), Italy (1.0 GW), and Spain (1.0 GW) (Tables 2 and 5). Greece, Portugal, and Sweden also added more than 300 MW each. In all, fifteen countries added more than 100 MW of new capacity.

More wind capacity was added in 2011 than in 2010 in Australia, Austria, Canada, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Sweden, the United Kingdom, and the United States. Record increases in capacity were reported in Canada thanks to incentive schemes at the national and provincial level. Sweden also added a record amount of wind capacity in response to a renewable electricity certificate system with quotas.

China had the highest growth—a 39% increase—although this was less than that country's 73% growth in 2010. Overall rates of increase are slowing or leveling out (Table 5). In some countries, increases in capacity were less than hoped for because of uncertainty about government programs, very low prices for competing energy, or the general economic slowdown.

A notable shift toward renewable energy sources was reported. In the EU, during 2011, 6.3 GW of nuclear capacity was decommissioned and over 1 GW of fuel oil capacity was taken offline. Wind power accounted for 21.4% of new installations, the third biggest share after solar PV (46.7%) and natural gas (21.6%).

Among the IEA Wind member countries, offshore wind systems totaling about 3.3 GW were operating at the close of 2011 (Table 6). In the EU, by early 2012, almost 5.3 GW of offshore wind capacity was under construction. Once completed, installed offshore capacity in Europe will reach 9 GW. Furthermore, EWEA identified 18 GW of fully consented offshore projects in 12 European countries at the close of 2011. Korea began construction of a 100-MW offshore wind farm in 2011.

Intertidal wind installations are also taking place. By the end of 2011, 262 MW of offshore wind capacity were installed in shallow water and intertidal areas in three provinces of China.

In addition to bottom-fixed offshore turbines, a full-scale 2-MW floating prototype was installed in Portugal. Two other floating prototypes were tested in Norway and Sweden. Japan is also planning for floating offshore turbines.

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

Country	Official Target RES	Official Target Wind
Australia	45 TWh by 2020	----
Austria	plus 2,000 MW from 2010-2020	----
Canada	----	----
China	----	90 GW (5 offshore) by 2015; 150-200 GW (30 offshore) by 2020
Denmark	100% renewable energy and transport system by 2050	50% by 2020
European Commission	20% renewable generation by 2020	----
Finland	38% of gross electricity consumption by 2020	6 TWh/yr (2.5 GW) in 2020
Germany	35% of electrical energy consumption by 2020	10 GW offshore by 2020
Greece	40% of electricity by 2020	----
Ireland	40% by 2020	----
Italy	17% by 2020	----
Japan	----	----
Korea, Republic of	----	7.3 GW by 2030
Mexico	----	1.2 GW by end of 2012; 2% of 2013 national electric demand
The Netherlands	20% reduction CO_2 in 2020 as compared to 1990 level	----
Norway	----	----
Portugal	31% of gross energy consumption by 2020	6.8 GW onshore, 75 MW offshore by 2020
Spain	Official network planning of 29 GW by 2016; 38 GW by 2020	----
Sweden	Increase RES generation by 25 TWh over 2002 level	30 TWh by 2020
Switzerland	----	0.6 to 1.2 TWh/yr in 2030
United Kingdom	15% by 2020	----
United States	80% of electricity from clean sources by 2035	----

---- = No official target available

2.2.2 Electrical production

Total national electrical demand for 2011 increased in eight IEA Wind member countries (Canada, China, Ireland, Italy, the Netherlands, Norway, Sweden, and Switzerland), decreased in eight others (Austria, Denmark, Finland, Japan, Portugal, Spain, the United Kingdom, and the United States), and stayed the same in Australia, Germany, Greece, Korea, and Mexico. Electrical output from wind energy increased in all countries except Portugal and Spain in 2011. Output remained the same as in 2010 in Portugal and Spain largely because of an extremely poor wind year in that region.

Wind energy production is higher in good wind years and lower in poor years. For example, there was a greater than expected increase in electricity generation from wind in 2011 in the United Kingdom. Onshore wind production rose 30% from 7.1 TWh in 2010 to 10.4 TWh in 2011, partly due to increased capacity, but mainly due to much higher wind speeds (1.4 knots [1 m/s] higher than in 2010). Offshore, due to increased capacity and high wind speeds, production increased by 68%, from 3.0 TWh in 2010 to 5.1 TWh in 2011.

Calculating a wind index to correct the annual wind power production is becoming more common. These indexes are based on a five-year or ten-year average wind resource. For example, in the Netherlands, the wind index (*windex*) for 2011 was 0.96, meaning the wind was slightly less than the average of 1996-2005. In Norway, the wind index for 2011 was 113% resulting in an average capacity factor of 31.3% for wind plants operating normally. Table 7 reports the wind resource in 2011 compared to average as reported by the member countries.

New records for wind penetration (contribution to electric demand) were set in some countries (Table 8). In Ireland, wind energy penetration exceeded 40% in every month of the year reaching 53.5% on a day in December. The Irish system operator has a 50% rule-of-thumb limit for wind penetration. In Italy, temporary penetrations in Cicily up to 62% of hourly average power have been reported. Improved forecasting methods have been reducing errors in forecasting wind, thus helping handle larger wind penetrations. In Portugal a record penetration of 93% instantaneous power and 70% of energy consumption was set on 13 November 2011. Spain reported 59.6% of national power demand was covered by wind energy early one November morning.

2.3 National incentive programs

All member countries have government structures designed to encourage development of renewable energy. Most also apply to wind energy (Table 9). Feed-in tariffs (FIT) were used by 16 of the 21 IEA Wind member countries to encourage wind development and are reported as very effective tools for encouraging development. Also popular with the IEA Wind member countries are programs that mandate utilities to supply a portion of electricity from renewables. Ten countries use these utility obligations,

Table 5. Wind Energy Capacity Increases in IEA Wind Member Countries			
Country	2010 capacity (MW)	2011 added (MW)	Increase (%)
China	44,773	17,631	39
Sweden	2,163	755	35
Canada	***4,124***	***1,298***	***31***
Greece	1,210	343	28
United Kingdom	5,270	1,092	21
Italy	5,797	1,080	19
Ireland	1,415	239	17
Norway	435	76	17
United States	40,267	6,816	17
Australia	1,880	234	12
Mexico	520	50	9
Portugal	3,987	315	8
Austria	1,011	73	7
Germany	27,204	2,007	7
Japan	2,304	167	7
Korea	381	27	7
Switzerland	42	3	7
Denmark	3,802	206	5
Netherlands	2,245	123	5
Spain	20,676	1,050	5
Finland	197	2	0.3
Total	**169,703**	**33,587**	**20**
Bold Italic = estimated			

or in some cases resulting from the financial crisis.

Carbon taxes are being discussed in several countries. In Australia, a price on carbon will begin in mid-2012. The carbon price will provide 10 billion AUD (7.8 billion EUR) to the Clean Energy Finance Corporation, which will provide loans for clean energy initiatives aimed at early stage technologies such as geothermal, wave, and large-scale solar through the revenue it collects.

In Germany, offshore expansion is supported by a 5 billion EUR (6.5 billion USD) credit program of the government-owned KfW bank. A special FIT for offshore wind also applies from the time a turbine is connected to the grid and for 20 years after.

2.4 Issues affecting growth

By the end of 2011, about 14 GW of projects were reported as under construction, about the same amount that was under construction at the close of 2010. Germany and Greece did not report this number, so it is conservative. Planning approval had been granted to 41 GW. Another 68 GW had applied for planning approval and 41 GW had received planning approval (Table 10). The issues reported as limiting growth are being addressed through national research projects, incentive programs, and co-operative research projects of IEA Wind and other groups.

Most countries listed the economic climate as having a slowing effect in 2011 and likely to reduce growth in 2012. Government programs to increase access to financing, provide larger subsidies, and issue targeted grants are mentioned as ways to reduce the effects of this problem. In several countries, government cost-cutting measures

Table 6 Offshore Wind Energy Capacity in IEA Wind Member Countries	
Country	Capacity (MW)
United Kingdom	1,838
Denmark	871
Netherlands	228
Germany	200
China	108
Finland	26
Ireland	25
Japan	25
Norway	2
Portugal	2
Total	**3,325**

renewable obligations, or renewable portfolio standards (RPS). Markets in green electricity, often represented by certificates is used in eight IEA Wind member countries to encourage renewable generation, including wind.

Some existing incentive programs are at risk of expiring (e.g., the United States) or being rescinded (e.g., Portugal) due to changes in the political climate

Table 7. Reported Wind Resource Compared to Average		
High wind index*	Average wind index	Low wind index
Norway, and the United Kingdom	Australia, Austria, Canada, China, Denmark, Finland, Germany, Greece, Ireland, Italy, Japan, Korea, Mexico, Sweden, and the United States	The Netherlands, Portugal, and Spain
* check country chapters for more detail on the wind resources		

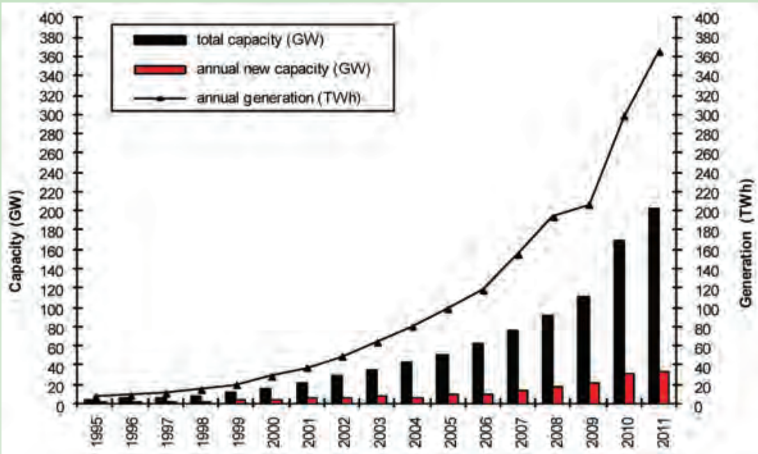

Figure 1. Annual installed capacity, cumulative installed capacity, and annual generation as reported by IEA Wind member countries, 1995–2011 (Note: China is first represented in 2010.)

have targeted funds allocated for incentive programs. Uncertainty about future support schemes has slowed markets in several countries (Greece, Italy, Portugal, Spain, and the United States).

Table 8. Contribution of Wind to National Electricity Demand 2011		
Country	2010 demand met from wind (%)	2011 demand met from wind (%)
Denmark	21.9	28.0
Portugal	17.0	18.0
Spain	16.4	16.3
Ireland	10.5	15.6
Germany	6.0	7.6
Greece	4.0	5.8
Sweden	2.6	4.4
Netherlands	4.0	4.2
United Kingdom	2.6	4.2
Austria	3.0	3.6
Italy	***2.6***	***3.0***
United States	***2.3***	***2.9***
Australia	2.0	2.4
Canada	***1.8***	***2.3***
China	1.2	1.6
Norway	0.7	1.0
Mexico	***0.6***	***0.6***
Finland	0.3	0.6
Japan	0.4	0.5
Korea	0.2	0.2
Switzerland	0.05	0.1
Bold Italic = estimate		

A trend away from nuclear power was reported as a result of the Fukushima Daiichi disaster early in the year. Governments of Germany, Japan, and Switzerland developed or planned to develop new energy strategies in 2011, reducing dependence on nuclear power and increasing efforts to promote wind energy.

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

In many countries, the electrical grids are adapted to the needs of centralized, large-scale power plants, and their capacity is limited to existing generation and demand. Some of these systems must absorb large amounts of wind power. Curtailment results when the grid operators shut down wind plants due to bottlenecks in transmission – and sometimes also due to stability concerns of the grid. Improved forecasting as well as grid upgrades are being explored to address this problem.

Delays due to permitting requirements have limited wind developments in several countries. In Finland, the effect of wind turbines on radar became an issue, so an impartial and transparent procedure and scientific tool were developed to help the Ministry of Defence estimate the radar impacts.

Concern about environmental impacts and social acceptance were also mentioned as issues affecting the permitting of new wind projects. IEA Wind Task 28 Social Acceptance of Wind Energy Projects is addressing the process of wind project development. Research projects on environmental impacts are underway in most countries.

3.0 Implementation

3.1 Economic impact

Wind energy development provides significant positive economic impacts. Table 11 shows reported effects for 2011 in the IEA Wind member countries. A key impact of wind energy development is creating employment and economic activity.

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 make concerted efforts to attract wind turbine manufacture to their domestic economies.

3.3 Operational details

The most dramatic demonstration of wind plant operation took place in Japan. On 11 March 2011, a devastating earthquake and tsunami struck the northeastern region of Japan where 190 wind turbines with a total capacity of 270 MW were installed. Almost all wind turbines survived the earthquake. And, most of them restarted soon afterward and contributed to Japan's power supply during the continuing crisis. The Wind Power Kamisu Wind Farm was struck by a 5-m-high tsunami. The SUBARU/Hitachi 80/2.0 wind turbines with rated power of 2.0 MW survived and resumed operation on 14 March, when the utility grid was activated. Due to severe liquefaction of the soil near the Kamisu wind farm, the foundation of one turbine shifted and the turbine became tilted. This was the only damage to a wind turbine caused by the earthquake, and it has been repaired. These results suggest that Japan's earthquake-proof wind turbine construction design is very reliable.

Table 9. Incentive Programs in IEA Wind Member Countries for 2011 into 2012		
Type of program	Description	Countries implementing
Feed-in tariff (FIT)	An explicit monetary reward for wind-generated electricity, 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, Finland (special definition), Germany, Ireland, Italy, Japan (from July 2012), Korea, the Netherlands (special definition), Portugal, Spain, Switzerland, United Kingdom (16 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, Korea (2012), Portugal, Sweden, United Kingdom, United States (10 countries)
Green electricity schemes and certificates	Customers may purchase green electricity based on renewable energy from the electric utility, usually at a premium price.	Australia, Austria, Canada, Finland, Netherlands, Sweden, Switzerland, United States (8 countries)
Capital subsidies	Direct financial subsidies aimed at the up-front cost barrier, either for specific equipment or total installed wind system cost.	Canada, Italy, Japan, Korea, Norway, United States (expired end of 2011) (6 countries)
Special planning activities	Areas of national interest are officially considered for wind energy development.	China, Korea, Mexico, the Netherlands, Sweden, Switzerland (6 countries)
Special incentives for small wind	Can include microFIT. Ireland: Reduced connection costs, conditional planning consent exemptions. VAT rebate for small farmers. Accelerated capital allowances for corporations.	Australia, Canada, Ireland (see left), Italy, Japan, United States (6 countries)
Income tax credits	Some or all expenses associated with wind installation may be deducted from taxable income streams.	Canada, Ireland, Mexico, Netherlands, United States (5 countries)
Net metering	In effect, the system owner receives retail value for any excess electricity fed into the grid, as recorded by a bidirectional 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, Sweden, Switzerland, United States (4 countries)
Wind-specific green electricity schemes	Customers may purchase green electricity produced by wind plants from the utility, usually at a premium price.	Finland, Sweden, Switzerland, United States (4 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, and United Kingdom (4 countries)
Net billing	The electricity taken from the grid and the 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 (microgeneration only), United States (3 countries)

Sustainable building requirements	New building developments (residential and commercial) are required 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.	Ireland, Portugal
Payroll tax credit	Developers of renewable energy projects with capacities greater than 30 MW may receive a rebate for payroll tax (4.95% of wages) incurred during project construction.	Australia
Carbon tax	Tax on carbon encourages move to renewables and provides investment dollars for renewable projects.	Australia
Relief from import tax	Large wind turbine technology and related components are included on lists of imports exempt from customs and import VAT charges.	China
Commercial bank activities	Includes activities such as preferential home mortgage terms for houses including wind systems and preferential green loans for the installation of wind systems.	Switzerland
Special licensing to reduce administrative burden	RES plants are exempt from the obligation to attain certain licenses; on islands, RES plants that are combined with water desalination plants get priority.	Greece

Germany's first offshore wind farm alpha ventus fed 267 GWh of energy into the German electricity grid in 2011. This result is 15% greater than the amount of energy anticipated for the year. It is the result of very good wind conditions and turbine availabilities up to 97%.

The world's first full-scale floating wind turbine (Hywind concept developed by Statoil) is operational in Norway. Statoil tested the wind turbine over a two-year period and has attained a high availability. Hywind has survived the heavy storm Berit followed by other storms with winds over 40 m/s and maximum waves over 18 m.

Annual capacity factor, a measure of wind plant productivity, is being reported by several countries. It is 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. 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, and the accuracy of nameplate rating versus rotor size. Capacity factor will be reduced if the utility curtails production. Most wind power plants operate at a capacity factor of 25% to 40%. Table 12 shows average capacity factors reported from the IEA Wind member countries. For reference, world average capacity factor for wind has been estimated at 21% (IEEE 2012); highest capacity factor reported offshore: Horns Rev Denmark 46.7% (http://www.4coffshore.com/windfarms/horns-rev-2-denmark-dk10.html); highest capacity factor reported onshore: Burradale, Shetland Islands 57.9% (http://www.reuk.co.uk/Burradale-Wind-Farm-Shetland-Islands.htm).

3.4 Wind energy costs

Costs have remained fairly stable in 2010 and 2011. Table 13 shows reported turbine costs in 2011, and Figure 2 shows trends of reported installed costs for wind projects by country.

4.0 R, D&D Activities

In 2010, IEA published the *Technology Roadmap for Wind Energy* (IEA 2010). That roadmap targets 12% of global electricity from wind power by 2050 and finds no fundamental barrier to achieving that goal. Significant investments will be required to reach that goal. For its part, the Executive Committee of IEA Wind updated its strategic plan in conjunction with the Technology Roadmap (IEA Wind 2011). In 2012, IEA Wind will publish an updated plan for long-term R&D needs to guide its work.

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 reported 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). Table 15 lists government budgets reported by some countries.

In the EU, around 20 wind R&D projects were running in 2011 with the support of the Sixth (FP6) and Seventh (FP7) Framework Programmes of the EU (the Framework Programmes are the main EU-wide tool to support strategic research areas).

Table 10. Potential Increases to Capacity IEA Wind Member Countries

Country	Planning application* (MW)	Planning approval** (MW)	Under construction*** (MW)	Total planned and/or under construction (MW)
Australia	8,745	5,269	1,270	15,284
Austria	300	400	327	1,100
Canada (by 2015)	---	---	---	5,000
China	42,000	18,000	---	60,000
Denmark	---	---	400	400
Finland	514	80	21	615
Germany	---	---	---	---
Greece	---	---	---	---
Ireland	1,500	500	200	2,200
Italy	2,300	---	500	2,800
Japan	---	500	221	721
Korea	---	---	420	420
Mexico	---	1,900	538	2,438
Netherlands	---	---	---	1,703
Norway	4,366	2,060	258	6,684
Portugal	---	11.6	240	252
Spain	---	911	993	1,904
Sweden	---	2,762	499	3,261
Switzerland	600	2	2	604
United Kingdom	8,079	9,141	---	17,220
United States	---	---	8,300	8,300
Totals	**68,404**	**41,536.6**	**14,189**	**130,906**

--- = No data available
* All papers have been submitted to official planning bodies
** Projects have been approved by all planning bodies..
*** Physical work has begun on the projects.

4.1.1 New test and research facilities

Several important new research centers were opened, under construction, or being planned in 2011. For more information on test centers, please refer to the country chapters and to the chapter from the European Commission/European Wind Energy Association.

Denmark is planning a national onshore test facility for wind turbines up to 250 m and an offshore center for testing wind turbine nacelles of 10 MW.

In Germany, research at the alpha ventus test site continued with 45 organizations including universities, institutes, and companies from around the world. The rotor blade test center at Bremerhaven now has a test stand for 90-m as well as a 70-m blades. Also in Bremerhaven, a drive train test center for research on gearless turbines is under construction. A test center for research on offshore support structures is in the planning stages at the University of Hannover.

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 offshore wind test facility at the New and Renewable Energy Centre (NAREC) will open in 2013 an open access, wind turbine drive train test rig that can test complete drive trains and nacelles up to 15 MW. There are also plans to open another offshore wind turbine centre, in Scotland, near Aberdeen (European Offshore Wind Deployment Centre).

The U.S. government opened a new large blade test facility equipped to test two blades up to 90 m long. It also installed four megawatt-scale turbines for testing at the National Wind Technology Center. Construction began on a 5-MW dynamometer test facility that can simulate wind loads in six degrees of freedom and can simulate grid connection for tests of low-voltage ride-through, response to faults, and reaction to other abnormal grid conditions. Another large drive train test facility is being built that will have 7.5-MW and 15-MW dynamometers. A new turbine test site will be built in Texas to improve turbine reliability and train engineers.

4.1.2 Highlights of research

For more information on research underway or completed in 2011, please refer to the country chapters and to the chapter from the European Commission and European Wind Energy Association.

To maintain acceptable sound levels, a research consortium in Germany tested sound absorber systems to formulate recommendations for sound mitigation strategies. Australia is reviewing the literature on the health effects of wind projects and is updating the Wind Industry Best Practice Technical Guidelines developed for Australia.

To meet the increasing global demand for ice-free turbines, a next-generation blade heating system has been developed in Finland, and further development is ongoing.

Floating wind turbines suitable for use in deep waters are being explored in several countries. The United States is working on models and prototypes of floating wind turbines. Norway and the United States are working with SWAY AS to collect and analyze data for a 1/5-scale prototype floating wind turbine deployed in Norway. Portugal and the United States are working to assess the WindFloat, 2-MW demonstration project

Table 11. Capacity in Relation to Estimated Jobs and Economic Impact			
Country	Capacity (MW)	Estimated number of jobs	Economic impact (million EUR; million USD)
China	62,364	260,000	---
United States	46,919	75,000	14,450; 18,698
Germany (a)	29,075	101,100	8,910; 11,530
Spain	21,673	16,970	2,894; 3,744
Italy	6,878	30,000	1,800; 2,329
United Kingdom	6,470	---	---
Canada	5,265	20,000	2,271; 2,938
Portugal	4,302	3,200	1,283; 1,660
Denmark	3,952	25,000	7,400; 9,575
Japan	2,501	2,500	1,800; 2,329
Netherlands	2,368	2,100	740; 957
Australia	2,224	2,000	912; 1,180
Sweden	2,899	---	---
Ireland	1,633	1,500	500; 647
Greece	1,640	1,800	---
Austria	1,084	3,300	500; 647
Mexico	570	1,500	208; 269
Norway	511	---	---
Korea	406	1,103	1,092; 1,413
Finland	199	2,000	780; 1,009
Switzerland	46	12,600	1,400; 1,811
Total	**202,979**	**561,673**	

--- = No data available
(a) Turnover of all wind turbine producers and component suppliers in 2011 (BMU http://www.erneuerbare-energien.de/erneuerbare_energien/downloads/doc/48501.php)

that supports a Vestas V80 turbine with a semisubmersible support structure.

Reducing the cost of offshore wind has been advanced by results in the United Kingdom. The UK Carbon Trust Offshore Wind Accelerator collaborative achieved some milestones in 2011. Thirteen leading designs were selected for funding from 450 entries in a competition for improved crew transfer vessels. These should allow maintenance to take place in much harsher sea states than is possible today, increasing availability. Another engineering design study confirmed the potential for higher voltage (66 kV) intra-array cables to reduce the cost of energy. The first of four foundation design finalists was demonstrated when the Keystone 'twisted jacket' was installed in the Hornsea zone, 100 km offshore in 30 m water to support a met mast. Two new wake effects models that forecast wind farm yields are also being developed to reduce financing costs and allow for more efficient wind farm layouts.

Improving the ability to integrate large amounts of wind power, Ireland's program for Delivering a Secure Sustainable Power System concluded that instantaneous wind penetration between 60 to 80% could be accommodated on the system if the correct measures are implemented. The program is developing tools to make such penetration levels sustainable.

In China, the State Grid Energy Research Institute and Vestas Wind Technology (China) Co., Ltd. responded to power production incidents, by conducting research and issuing a comprehensive strategy for wind power and grid coordinate development in China.

To improve wind turbine technology, the Chinese research program used a multi-objective optimum design method applied during R&D and the resulting prototype turbines of 3.6 MW, 5.0 MW, and 6.0 MW began tests in 2011. These wind turbines are direct-drive, permanent-magnet, or double-fed. These turbines have compact type drive train systems and advanced control technology to reduce loads, improve reliability, and increase performance.

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 continued field trials of small wind turbines and will make the data available to researchers in 2012. Italy completed a state-of-the-art report on small wind turbines based on monitoring data at different sites in Italy. Japan built a new field test site for small wind turbines in Rokkasho, Aomori. The Japan Small

Table 12. Reported Average Capacity Factors (%)	
Country	Average capacity factor
Australia	---
Austria	---
Canada	31.0%
China	---
Denmark	28.4%
Finland	28.0%
Germany	19.0%
Greece	---
Ireland	31.6%
Italy	18.0%
Japan	19.0%
Korea	---
Mexico	30.0%
Netherlands	---
Norway	31.3%
Portugal	26.0%
Spain	---
Sweden	---
Switzerland	20.0%
United Kingdom	onshore 27.4% offshore 36.7%
United States	33%

--- = No data available

Table 13. Estimated Average Turbine Cost and Total Project Cost for 2011		
Country	Turbine cost (EUR/kW*)	Total installed cost (EUR/kW*)
Australia	870 to 1,570	1,300 to 2,670
Austria	1,400 to 1,800	1,600 to 1,900
Canada	---	1,892
China	468	861 to 984
Denmark	---	onshore 1,030; offshore 2,680
Finland	---	---
Germany	---	onshore 1,336 to 1,756; offshore 3,323 to 3,561
Greece	1,050	---
Ireland	1,000	1,600 to 2,100
Italy	1,200	1,750
Japan	1,980	2,970
Korea	---	---
Mexico	1,100 to 1,200	1,500
Netherlands	---	onshore 1,325; offshore 3,200
Norway	---	---
Portugal	900 to 1,000	1,400
Spain	820	1,000 to 1,400
Sweden	1,400	1,600
Switzerland	1,450	2,100
United Kingdom	---	---
United States	818 to 1,004	1,562

*Applicable conversion rate to USD: 1.294
--- = No data available

Wind Turbine Association issued a small wind turbine performance standard in 2011, and type certification of small wind turbines began in Japan.

4.2 Collaborative research

The collaborative research conducted by organizations in the IEA Wind member countries made significant progress in 2011. Final reports and recommendations were issued on wind energy in cold climates, cost of wind energy, labeling small wind turbines, social acceptance of wind energy projects, and analysis of wind tunnel measurements and improvement of aerodynamic models. These and other reports are available on the IEA Wind public website: www.ieawind.org.

Task 11 Base Technology Information Exchange held three Topical Expert Meetings on the following topics: International statistical analysis on wind turbine failures; Offshore foundation technology and knowledge (shallow, middle, and deep waters); and Long-term R&D needs on wind power. In 2011, the proceedings were released to the public from 2010 meetings on Wind Conditions for Wind Turbine Design; High Reliability Solutions & Innovative Concepts for Offshore Wind Turbines; Micrometeorology inside Wind Farms and Wakes between Wind Farms; and Wind Farms in Complex Terrain. In 2011 a new Recommended Practices on "Consumer Label for Small Wind Turbines" was edited and approved by the Executive Committee. A new procedure for developing and issuing IEA Wind Recommended Practices in cooperation with the ongoing Task, was elaborated and approved at the executive committee meeting #67 in Amsterdam.

Task 19 Wind Energy in Cold Climates continued its work sharing information among its eight country participants on wind turbine solutions for cold-climate applications, including blade heating technologies, ice detection, and anti-icing strategies. Participants are preparing a public recommended practices document, Wind Performance and Load Conditions of Wind Turbines in Cold Climates, to summarize the best available practices for the development and construction of wind farms at cold-climate sites. The work of this task will likely be extended for another term. In 2011 a new Recommended Practices on "Consumer Label for Small Wind Turbines" was edited and approved by the Executive Committee. A new procedure for developing and issuing IEA Wind Recommended Practices in cooperation with the ongoing Task, was elaborated and approved at the executive committee meeting #67 in Amsterdam.

Task 25 Power Systems with Large Amounts of Wind Power now has 16 country participants and serves as an international forum on the topic. Collaboration with system operators in task meetings and through the International Council on Large Electric Systems (CIGRE) is important for the task. Task 25 participants have published several collaborative articles for journals and conferences, regarding reserve requirements due to wind power, modeling wind power in the unit commitment and dispatch, transmission planning with wind, experience in frequency control, and analyses of variability of large scale wind power production. Task 25 has collaboration with the IEA Secretariat's analysis project GIVAR (Grid integration of variable renewables) to develop a simplified assessment of wind integration efforts and power system flexibility. Participants have also started work on a recommendation report to compile the best practices and instructions on how to perform an integration study. The work of this task was approved for its third phase to begin in 2012.

Task 26 Cost of Wind Energy began work in 2009 to develop an internationally accepted, transparent method

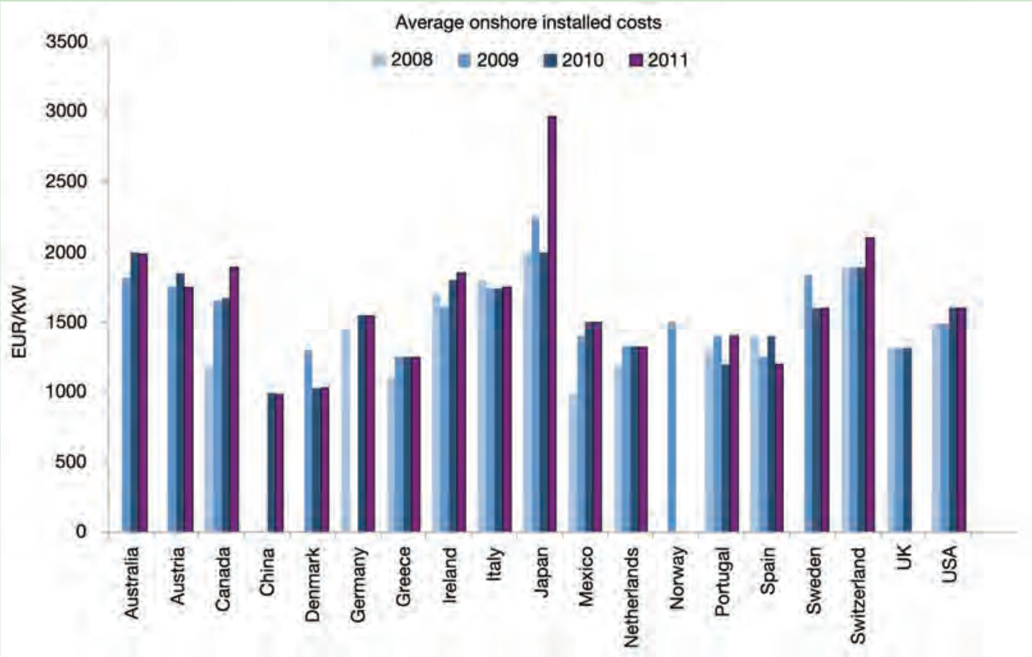

Figure 2. Average installed costs of wind turbines 2007–2011 as reported by IEA Wind member countries. Costs are not adjusted.

for calculating the cost of wind energy. Its first report was released in 2010. In 2011, the eight participating countries issued the second report, which highlighted the importance of considering levelized cost of energy 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. This task is expected to continue work for another term.

Task 27 Development and Deployment of Small Wind Turbine Labels for Consumers is 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. In 2011, an international sector guide, Recommended Practice for Consumer Labeling of Small Wind Turbines was issued as an IEA Wind document. In addition, Task 27 is assembling a small wind tester association that will work to increase the number of accredited test facilities of small wind turbines. The work of this task is expected to continue for another term.

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. Ten countries now participate in this task. A library of resource documents has been assembled and participants contributed to *The State of the Art on Social Acceptance of Wind Energy Projects*, published in 2010. The second report, on Good Practice Recommendations was written in 2011 and will be issued along with a final report in 2012. It is likely the work of this task will be continued for another term.

Task 29 Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models is working with existing wind tunnel data sets from the EU MEXICO project, the NASA-Ames experiment, and others to improve aerodynamic models used to design wind turbines. Improving these models should result in more durable, productive wind turbines. Ten countries have representative researchers participating in this task. Analyses of the databases were published in journals and presented at conferences and in a final report available at www.ieawind.org. Additional work will be proposed for a continued project in 2012.

Task 30 Offshore Code Comparison Collaboration Continuation (OC4) is working to improve the accuracy of existing computer codes and models for estimation of structural loads for offshore wind turbine foundations. Using a baseline jacket design, sixteen organizations ran the planned simulations. Simulation results were presented in the Internet meetings, and the reasons for discrepancies between the results have been discussed. Comparison of the results has been made through component masses, system eigenfrequencies, static loads, time histories, spectra, statistics, and damage equivalent loads. Several rounds of revisions to codes have been made by the participants in an attempt to converge to similar values. Simulations will be run and compared for the DeepCwind semi-submersible design in 2012.

Task 31 WAKEBENCH: Benchmarking of wind farm flow models was approved as a task in 2010. The Task provides a forum for industrial, governmental, and academic partners to develop and define quality-check procedures, as well as to improve atmospheric boundary layer and wind turbine wake models for use in wind energy. The work will identify and quantify best practices for using these models under a range of conditions,

Table 14. Reported Research Activities in IEA Wind Member Countries		
Type of program	Country activities reported	IEA Wind co-operative activities in 2011
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
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 11 Base Technology Information Exchange: Topical Expert Meetings "Remote Wind Speed Sensing Techniques using SODAR and LIDAR" 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, impacts on radar systems.	Task 11 Base Technology Information Exchange: Topical Expert Meeting "Radar Radio and Links with Wind Turbines" and "Sound Propagation Models and Validation"
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 and 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 develop 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; and Task 31 WAKEBENCH; Task 33: Reliability Data: Standardization of 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 Power Systems with Large Amounts of Wind Power
Innovative concepts	Vertical axis, hydraulic drive, kites, airships, etc.	

Table 15. National R&D Budgets for Wind Energy 2010 and 2011 for Reporting Countries		
Country	R&D Budget 2010 (in million EUR; million USD)	R&D Budget 2011 (in million EUR; million USD)
Canada	---	6.00; 7.76
Denmark*	134.00; 173.00	134.00; 173.00
Finland	4.00; 5.20	10.00; 12.90
Germany	53.00; 71.40	77.00; 99.60
Ireland	0.30; 0.40	0.30; 0.40
Italy	3.00; 4.03	3.00; 4.03
Japan	44.72; 58.72	56.60; 74.32
Netherlands	38.00; 51.07	7.08; 9.15
Norway	54.00; 72.58	54.00; 72.58
Spain	150.00; 115.91	150.00; 115.91
Sweden**	10.80; 14.51	10.80; 14.51
Switzerland	0.41; 0.53	0.41; 0.53
United States	59.52; 80.00	59.52; 80.00

*For energy technologies
**Swedish Energy Agency part of National R&D budget

both onshore and offshore, from flat to very complex terrain. In 2012, 30 organizations from 16 IEA Wind member countries have attended planning meetings and will join the task.

Task 32 LIDAR: Wind Lidar Systems for Wind Energy Deployment was approved in late 2011. Remote sensing has the potential to increase the accuracy and reduce the cost of wind resource assessment and wind farm operation. This task is designed to provide an international information exchange on lidar technology, so researchers can follow the new commercial lidar systems. Their potential will be assessed through work between the research community and the industry. At the close of 2011, 17 institutions from 8 countries have expressed interest in joining the task.

Task 33 Reliability Data: Standardizing Data Collection for Wind Turbine Reliability, Operation and 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.

5.0 The Next Term

Wind power is firmly established as a viable option for increasing green electricity production, and continued increases in capacity are expected in 2012. The co-operative research efforts of IEA Wind will publish significant reports on integration of large amounts of wind power, cost of wind energy, labeling of small wind systems, social acceptance of wind energy projects, and aerodynamic models and wind tunnel data.

China, Denmark, Finland, Germany, Japan, the Netherlands, Norway, Portugal, the United Kingdom, and the United States will expand their efforts to develop offshore wind technology through research, demonstrations, and financial incentives.

IEA Wind Recommended Practices will be published on good practices for gaining social acceptance of wind energy projects and remote sensing techniques for wind power development. The work of the IEA Wind research tasks should support efforts worldwide to increase the contribution of wind energy.

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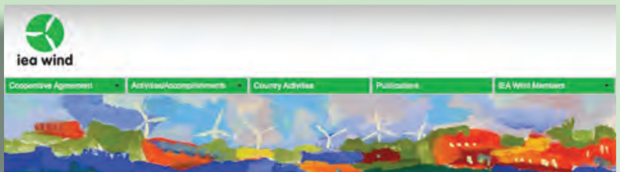
Statistics for IEA Wind member countries have been provided by the authors of the country chapters and represent the best estimates of their sources in February 2012. For the latest information, visit www.ieawind.org.

Author: Patricia Weis-Taylor, Secretary, IEA Wind.

Implementing Agreement 1



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. 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-fourth *IEA Wind Annual Report*, lists accomplishments in 2011. The Executive Summary compiles information from all countries and tasks to highlight important statistics and trends. Activities completed in 2011 and planned for 2012 are reported for the overall agreement (Chapter 1) and for the research tasks (Chapters 2 through 12). Member country chapters (Chapters 14 through 34) describe activities in the research, development, and deployment of wind energy in their countries during the year just ended. The *IEA Wind 2011 Annual Report* is published by PWT Communications, LLC in Boulder, Colorado, United States, on behalf of the IEA Wind Executive Committee (ExCo).

In 2011, IEA Wind published two final technical reports, issued a new recommended practice, approved the *Update 2011 of the Strategic Plan for 2009–2013*, extended four research

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* 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.

Table 1. Participants in IEA Wind in 2011	
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 National Technology Agency of Finland, 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 (AIST)
Korea	Government of Korea
Mexico	Instituto de Investigaciones Electricas (IIE)
Netherlands	The Netherlands Agency
Norway	Norwegian Water Resources and Energy Directorate (NVE) and Enova SF
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	Department of Energy and Climate Change (DECC)
United States	U.S. Department of Energy
Sponsor Participants	
CWEA	Chinese Wind Energy Association
EWEA	European Wind Energy Association

tasks, and approved two new research tasks to support the economic deployment of wind energy systems.

In conjunction with Executive Committee meetings, experts from the IEA Wind research tasks and from some member countries, conduct workshops for local industry and research actors. In 2011, local industry encounters were held in Amsterdam, the Netherlands and Dublin, Ireland.

2.0 Collaborative Research

Participation in research tasks (Table 2) is open to any organization located in member countries of IEA Wind (Table 1). Member countries choose to participate in tasks that are most relevant to their current national research and development programs. A lead organization in each country must agree to the obligations of task participation (pay a common fee and agree to perform specified parts of the work plan). In 2011, member countries continued work on nine tasks and approved the start of two new research tasks. Research tasks are approved by the ExCo as numbered annexes to the Implementing Agreement text. Additional tasks are planned when new areas for co-operative research are identified by members.

Progress of the co-operative research tasks is reported in Chapters 2 through 12 of this Annual Report. 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. Task 31 WAKEBENCH: Benchmarking of Wind Farm Flow Models was approved late in 2010 to begin work in 2011. Task 32 LIDAR: Wind Lidar Systems for Wind Energy Deployment was approved to begin work in 2011. Task 33 Reliability Data: Standardizing Data Collection for Wind Turbine Reliability and Operation and Maintenance Analyses was approved to begin work in 2012.

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 benefit of co-operative research.

- Task 24 Integration of wind and hydropower systems (completed in 2010) Contribution per participant: 16,430 USD (11,797 euro [EUR]) plus in-kind effort. Total value of shared labor received: 6.24 million USD (4.48 million EUR)
- Task 25 Power systems with large amounts of wind energy Contribution per participant: 7,002 euro (9,747 U.S. dollars [USD]) plus in-kind effort over 3 years. Total value of shared labor received: 9.53 million euro (13.26 million USD)

By the close of 2011, 20 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 2011.

To obtain more information about the co-operative research activities, contact the OA representative for each task

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 (2009-2012)
Task 19	Wind Energy in Cold Climates OA: Technical Research Centre of Finland - VTT (2001 to 2011)
Task 25	Power Systems with Large Amounts of Wind Power OA: Technical Research Centre of Finland – VTT, Finland (2005 to 2011)
Task 26	Cost of Wind Energy OA: NREL, United States (2008 to 2011)
Task 27	Consumer Labeling of Small Wind Turbines OA: CIEMAT, Spain (2008 to 2011)
Task 28	Social Acceptance of Wind Energy Projects OA: ENCO Energie-Consulting AG, Switzerland (2007 to 2011)
Task 29	Mexnex(T): Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models OA: ECN, the Netherlands (2008 to 2011)
Task 30	Offshore Code Comparison Collaborative Continuation (OC4) OA: NREL, the United States and Fraunhofer IWES, Germany (2010 to 2013)
Task 31	WAKEBENCH: Benchmarking of Wind Farm Flow Models OA: CENER, Spain and NREL, United States (2011 to 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)

listed in Appendix B, or visit www.ieawind.org (follow the links to individual Task Web sites or check the IEA Wind Members tab).

3.0 National Programs

The national wind energy programs of the participating countries are directed toward the evaluation, development, and promotion of wind energy technology. Overall statistics and highlights of national program activities are presented in the Executive Summary of this Annual Report. Individual country activities are presented in Chapters 13 through 34.

4.0 Executive Committee (ExCo)

Overall control of information exchange and of the R&D tasks is vested in the 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 various tasks, and to plan future activities. Decisions are reached by majority vote or, when financial matters are decided, by unanimity. Members share the cost of administration for the ExCo through annual contributions to the Common Fund. The Common Fund supports the efforts of the Secretariat and other expenditures approved by the ExCo in the annual budget, such as preparation of this Annual Report and maintenance of the ieawind.org website.

Officers

In 2011, Hannele Holttinen (Finland) served as chair. Joachim Kutscher (Germany) and Jim Ahlgrimm (United States) served as Vice Chairs.

Participants

In 2011, there were several personnel changes among the members and alternate members representing their organizations. (See Appendix B IEA Wind Executive Committee for members, alternate members, and OA representatives who served in 2011.) 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 2011 to review ongoing tasks, 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 R&D activities in the member countries and in the research tasks. The second meeting was devoted to reports from member countries and tasks about deployment activities.

The 67th ExCo meeting was hosted by the Netherlands in Amsterdam 12–14 April 2011. Representative from 16 of the contracting parties attended, along with nine operating agent representatives

Table 3. Member Participation in Research Tasks During 2011

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	X		X		
CWEA, China	X		X		X			X	X		X
Denmark	X		X	X	X	X	X	X	X	X	
European Commission	X										
EWEA			X	X							
Finland	X	OA**	OA			X		X			
Germany	X	X	X	X		X	X	X		OA	OA
Greece								X	X		
Ireland	X		X		X	X					
Italy	X		X		X				X		
Japan	X		X		X	X	X	X	X	X	
Korea, Republic of	X				X		X				
Mexico	X										
Netherlands	X		X	X		X	OA	X			
Norway	X	X	X			X	X	X	X		X
Portugal			X								
Spain	OA		X	X	OA		X	X	OA		
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	
Totals	18	8	16	8	12	10	10	10	12	4	3

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

of the tasks, and observers from the IEA RETD implementing agreement, Germany, and the Netherlands. The ExCo approved the *Update 2011 of the Strategic Plan for 2009–2013* and the *2009 Small Wind Annual Report*. The new Task 32 LIDAR: Wind Lidar Systems for Wind Energy Deployment was approved, as was the IEA Wind audit report of the Common Fund for 2010. On 14 April, the meeting participants visited the ECN wind energy facilities and the Ecofys wind turbine test site.

The 68th ExCo meeting was hosted by Ireland in Dublin 18–20 October 2011. Participants from 14 contracting parties were present, and OA representatives from all of the active tasks gave reports. The ExCo approved the extension proposals (2012 to 2014) of Task 19 Wind Energy in Cold Climates, Task 25 Power Systems with Large Amounts of Wind Power, Task 27 Development and Deployment of a Small Wind Turbine Consumer Label, and Task 29 MexNex(T) Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models. These tasks were approved in principle, with final approval pending development of detailed work plans to be presented at ExCo 69. The ExCo approved in principle the new Task 33 Reliability Data: Standardizing Data Collection for Wind Turbine Reliability and Maintenance Analyses. Budgets for the ongoing tasks and for the Common Fund for 2012 were approved. The ExCo re-elected officers through 2012: Hannele Holttinen (Finland) as

Chair; Joachim Kutscher (Germany) as Vice Chair; and Jim Ahlgrimm (United States) as Vice Chair. On 20 October, meeting participants visited the Eirgrid control room (Irish TSO), listened to presentations by the University College Dublin Electricity Research Centre, and visited the Lisheen Wind Farm.

5.0 Outreach activities

The *IEA Wind 2010 Annual Report* was published in July 2011, and the website, www.ieawind.org, continued to expand coverage of IEA Wind activities. Four Task 11 Proceedings of Experts Meetings from 2010 were posted on the public website. Two technical reports of IEA Wind were approved for release by IEA Wind in 2011. Countless journal articles, conference presentations, and poster presentations drew upon the work of the IEA Wind research tasks. In addition, *Recommended Practices for Wind Turbine Testing and Evaluation* 12. *Consumer Label for Small Wind Turbines* was approved and published as work of Task 27 Consumer Labeling of Small Wind Turbines. Task 19 Wind Energy in Cold Climates prepared the *Expert Group Study on Recommended Practices 13. Wind Energy Projects in Cold Climates* for review and approval in 2012. Recommended Practices are under development in Task 28 on social acceptance of wind energy projects and in Task 32 Lidar.

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 co-operation activities between ExCo meetings. Support for IEA Paris initiatives has been provided by the Planning Committee. A representative from IEA Wind attended an IEA Experts Group on R&D Priority Setting and Evaluation: The Transition to a Low-Carbon Society, a meeting of the Electricity Coordination Group (ECG), the Second IEA Energy Technology Network Communication Workshop meeting, and the REWP spring meeting.

Invitations to attend ExCo meetings were extended to several countries that are not yet participants. 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.

2 Task 11

Base Technology Information Exchange

1.0 Overview

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 cooperative activities have been part of the Wind Implementing Agreement since 1978.

Table 1 lists the countries participating in this Task in 2011. These countries pay a fee to support the work of the 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 immediately following the meetings to organizations in countries that participate in the Task. After one year, documents can be accessed on the IEA Wind public Web pages (www.ieawind.org).


Source: Rick Hinrichs

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 to enable the exchange of information between the participant countries is to arrange Topical Expert Meetings (TEM) focused on priority issues. 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 TEM arranged in the last five years (2006-2011).

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

3.0 Progress in 2011

3.1 Topical Expert Meetings

Four TEMs were organized in 2011 but one was cancelled due to the low number of experts registered. Proceedings were published on the ftp-server for country members. Proceedings are available to the public after one year on www.ieawind.org. Meeting topics for 2012 have been selected by the IEA Wind ExCo.

TEM 65: International statistical analysis on wind turbine failures

TEM 65 was hosted by Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) in Kassel, Germany, 30-31 March 2011. A total of 22 persons attended the meeting from Denmark, Finland, Germany, The Netherlands, Norway, Sweden, and the United States. Sixteen presentations were given.

After the discussion, it was decided to launch a new Task under the umbrella of IEA Wind on databases for wind turbine failures. IWES led a working group that prepared the proposal for the new task, in collaboration with SINTEF and NREL. At ExCo 68, a proposal for Task 33: Reliability Data: Standardization of Data Collection for Wind Turbine Reliability and Maintenance Analyses was approved in principal and the participants began organising their work. Final approval will be discussed at ExCo 69 in May 2012.

Table 1. Task 11 participants		
	Country	Institution
1	Canada	National Resources Canada (NRCan)
2	Chinese Wind Energy Association	Chinese Wind Energy Association (CWEA)
3	Denmark	Risø National Laboratory/Danish Technical University (DTU)
4	European Commission	European Commission
5	Finland	Technical Research Centre of Finland (VTT)
6	Germany	Bundesministerium für Unwelt, Naturschutz und Reaktorsicherheit (BMU)
7	Ireland	Sustainable Energy Authority Ireland (SEAI)
8	Italy	Ricerca sul Sistema Energetico (RSE S.p.A.)
9	Japan	National Institute of Advanced Industrial Science and Technology (AIST)
10	Republic of Korea	POHANG University of Science and Technology (POSTECH)
11	Mexico	Instituto de Investigaciones Electricas (IEE)
12	Netherlands	Agentschap, NL
13	Norway	The 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 Kingdom	UK Dept for Business, Enterprises & Regulatory Reform (BERR)
18	United States	The U.S Department of Energy (DOE)

TEM : Control strategies for integration of wind farms on weak grids

The host was Instituto de Investigaciones Eléctricas (IIE) in Cuernavaca, Mexico. Initially the meeting was organized for 25-26 January 2011, but due to the low number of experts registered, it was postponed to 17-18 May 2011. However, the meeting was cancelled due to the low number of experts registered to attend the meeting.

TEM 66: Offshore foundation technology and knowledge (shallow, middle, and deep waters)

Vattenfall Wind Turbine Control Centre, in Esbjerg, Denmark was the host of the meeting that took place 20-21 September 2011. A total of 20 persons attended the meeting from Denmark, Finland, Germany, Ireland, Norway, Spain, Sweden, the United Kingdom, and the United States. A participant from the EWEA also attended. Thirteen presentations were given.

One priority identified was the need to have measured data from experimental offshore installations to validate existing models. The main action identified for future interchange of information about this topic is the workshop that NREL (U.S.) will organize in 2012 under the umbrella of Task 30 Offshore Code Comparison Collaboration Continuation (OC4) on test methods, data availability, and code validation. The majority of the participants decided that more development is required before a specific task covering the priorities selected could be launched.

TEM 67: Long-term R&D needs on wind power

At the ExCo 67 meeting in Amsterdam, it was decided to arrange a TEM on "Long Term R&D Needs" at the European Wind Energy Association (EWEA) in Brussels, Belgium (5 October 2011). The aim of this TEM was to discuss long-term research needs for the timeframe 2011-2030, to give recommendations to the IEA Wind ExCo and to the governments involved, which are based at the latest international wind technological stage.

The meeting was attended by 21 participants from 8 countries (Denmark, Finland, Greece, The Netherlands, Norway, Spain, Sweden, and the United States). Representatives from the EWEA and EC, and the IEA Secretariat also attended the meeting. Fifteen presentations were given. The outcome of the meeting will be used to develop a new strategic R&D plan for IEA Wind.

3.2 Development of Recommended Practices

The IEA Wind RP 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 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 RPs can be prepared in a shorter period of time and will be an important input for the future elaboration of IEC standards.

Table 2. Topical Expert Meetings (2006-2011)			
TEM No.	Title	Year	Location
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
55	Long-Term Research Needs in the Frame of the IEA Wind Co-operative Agreement	2007	Berlin, Germany
54	Social Acceptance of Wind Energy Projects	2007	Luzerne, Switzerland
53	Radar, Radio, and Wind Turbines	2007	Oxford, United Kingdom
52	Wind and Wave Measurements at Offshore Locations	2007	Berlin, Germany
51	State of the Art of Remote Wind Speed Sensing Techniques Using SODAR, LIDAR, and Satellites	2007	Roskilde, Denmark
50	The Application of SMART Structures for Large Wind Turbine Rotor Blades	2006	Delft, the Netherlands
49	Challenges of Introducing Reliable Small Wind Turbines	2006	Stockholm, Sweden
48	Operation and Maintenance of Wind Power Stations	2006	Madrid, Spain

A new procedure for developing and issuing IEA Wind Recommended Practices in cooperation with the ongoing Tasks was elaborated and approved at the ExCo 67 meeting in Amsterdam.

In 2011, a new Recommended Practices for Wind Turbine Testing and Evaluation 12, Consumer Label for Small Wind Turbines was approved by the Executive Committee.

Two RPs are being developed dealing with measuring wind speed using SODAR and LIDAR type instruments.

Two additional actions have been identified for preparation of new IEA Wind RP:

Performance and Load Conditions of Wind Turbines in Cold Climates

Cost of Wind Energy (Update the existing IEA Wind RP)

These RPs will be prepared in cooperation with Task 19 Wind Energy in Cold Climates, and Task 26 Cost of Wind Energy.

4.0 Plans for 2012 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 2011-2012.

New TEM topics were selected in 2011 and the planned TEM for 2012 are:

TEM 68: Advances in Wind Turbine and Components Testing. Technical University of Aachen, Germany, 21-21 February 2012.

TEM 69: Operation and Maintenance Challenges. CWEA, Republic of China, 20-21 March 2012.

TEM 70: Social Acceptance of Wind Energy. Swiss Federal Office of Energy, 14-15 June 2012.

TEM 71: Wind Farm Control Methods (Host and date TBD).

The OA of Task 11 will collaborate with the OAs of Tasks 19 and 26, to begin development of new IEA Wind RPs: Performance and Load Conditions of Wind Turbines in Cold Climates and Cost of Wind Energy.

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

3 Task 19

Wind Energy in Cold Climates

1.0 Overview

Wind turbines are increasingly being deployed to sites where climate conditions are out- side the standard operational limits of wind turbines. Such sites also require more prudent measures during the project development phase due to demanding climate conditions. During the last ten years, technology has been developed to meet those challenges. As specific icing and low temperature new technology is being demonstrated, the need grows to collect experiences in a form that can be used by developers, manufacturers, consultants, and financiers.

Starting in 2002, IEA Wind set up an international co-operation, Task 19, that collects and evaluates information that covers all aspects of turbine operation in cold climate and icing conditions, e.g. site assessment, economic and safety issues, and mitigation strategies. Participants in Task 19 have gathered information about wind turbine operation in icy and low temperature environments, published several reports and papers and have drafted Recommended Practices. Table 1 lists the participating countries in 2011.

The expression "cold climate" was defined to apply to sites where turbines are exposed to low temperatures outside the standard operational limit, and to sites where turbines face icing. These kind of cold climate conditions retard energy production during the winter. Such sites are also often elevated on hills above the surrounding landscape or located in high northern latitudes.

2.0 Objectives and Strategy

The objectives of Task 19 for 2009 to 2012 are as follows:

- Determine the current state of cold climate solutions for wind turbines, especially anti-icing and de-icing solutions that are available or are entering the market
- Review current standards and recommendations from the cold climate point of view and identify possible needs for updates
- Find and recommend a method for estimating the effects of atmospheric icing on energy production because the commonly used standard tools do not address 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 stand-alone systems
- Define recommended limits for the use of standard technology (site classification)
- Create and update the Task 19 state-of-the-art report and expert group study on guidelines for applying wind energy in cold climates.

The items above have been identified as those key topics that are slowing

Table 1. Task 19 participants				
	Country	Contracting party	Company	Representative
1	Austria	Austrian Federal Ministry for Transport, Innovation, and Technology	Energiewerkstatt	Andreas Krenn
2	Canada	Natural Resources Canada	Natural Resources Canada	Antoine Lacroix
3	Finland	TEKES	Technical Research Centre of Finland	Esa Peltola, Tomas Wallenius
4	Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety	Fraunhofer IWES	Michael Durstewitz
5	Norway	Kjeller Vindteknik	Kjeller Vindteknik	Lars Tallhaug
6	Sweden	Energimyndigheten	WindREN AB	Göran Ronsten
7	Switzerland	Swiss Federal Office of Energy	Meteotest	René Cattin
8	United States	NREL	National Renewable Energy Laboratory	Ian Baring-Gould

cold climate wind power development. The ongoing national R&D activities in task participant countries will tackle these challenges and provide new information on the subject.

The results of the ongoing national activities will improve the overall economy of wind energy projects, especially in cold climates and thus significantly lower the risks of developing in areas where low temperatures and atmospheric icing are frequent.

The collaboration actively disseminates results through the Task 19 web site (linked at www.ieawind.org), and through conferences and seminars. At the end of the current Task 19 period, a final report will be published that describes updated state of the art of cold climate technology. It will issue a report on recommended practices that focuses on how to minimize and mitigate the additional risks of a cold climate wind energy project. One important dimension of this work will be the initiation of conversation about whether cold climate issues should be recognized in future standards that set the limits for turbine design.

3.0 Progress in 2011

The ongoing third term for Task 19 will come to an end in the first quarter of 2012. The main activity for 2011 and early 2012 will be the finalization of the recommended practices document. This document will summarize the best available practices for the development and construction of wind farms for a cold climate sites. The Recommended Practices for Wind Energy Projects in Cold Climates is based on a major revision of Recommendations for Wind Energy Projects in Cold Climates, published in 2009 (1). The report includes the classification of wind farm sites with respect to icing conditions.

The IEA Wind Task 19 recommended practices report was taken in 2011 as one basis for the fourth revision of IEC 61400-1 Design requirements – standard to include the effect of ice loads and low temperatures in design load cases.

Additionally, state-of-the-art of wind energy in cold climates, which was published in 2009, was updated in 2011 for publication in 2012 (2).

Two meetings were organized in 2011. The first took place in February in Umeå hosted Swedish Energy Agency with participation from all member countries and observers from China and Denmark. The meeting was in connection to Winterwind 2011, which is the largest cold climate wind energy specific conference. Task 19 participated actively in the arrangements of the conference. The second meeting in Kjeller, Norway in September was hosted by Kjeller Vindteknikk. Several web-meetings were organized to agree and organize preparation of the work.

4.0 Plans for 2011 and beyond

Cold climate deployment is expected to continue and increase in countries in the northern hemisphere between 2012 -2016. It has been estimated that generation capacity of 4,000 to 5,000 MW (Figure 1) annually will be installed at cold climate sites in the present Task 19 member countries. Thus, discussion of a possible fourth term for Task 19 will be initialized in 2012.

Table 2. IEA Wind ice classification with corresponding recommendations			
IEA Wind ice class	Meteorological icing	Instrumental icing	Production loss
	% of year	% of year	% 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

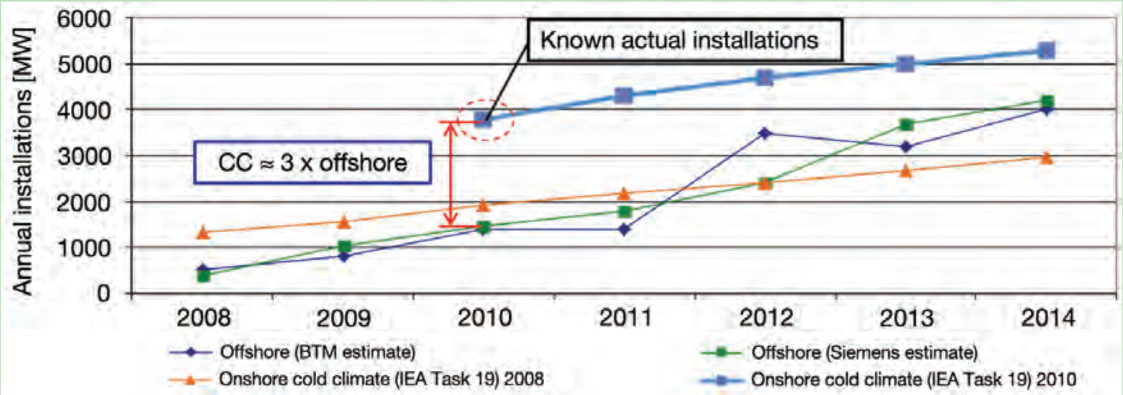

Figure 1. Estimated size of cold climate wind power market

The results and activities of Task 19 have been disseminated in the following conferences in 2011.

- WINTERWIND 2011, Umeå, 9-10 February, Sweden
- EWEA 2011, 16-18 March, Brussels, Belgium
- Optimising Wind Energy Operations and Maintenance Forum, 7-8 April, Barcelona, Spain
- Nordic Wind Power Conference Operations & Maintenance, 12-13 April, Copenhagen, Denmark
- IWAIS 2011, 8-13 May Chongqing, China
- CWEC 2011 Beijing International Wind Energy Conference and Exhibition, 13-15 October, China
- NordVind seminar Vindkraft i kaldt klima, 1 December, Copenhagen Denmark

References:

(1) Wind Energy Projects in Cold Climates (pdf) available at http://www.vtt.fi/inf/pdf/workingpapers/2010/W151.pdf

(2) State-of-the-art of wind energy in cold climates (pdf) available at http://www.vtt.fi/inf/pdf/workingpapers/2010/W152.pdf

Authors: Esa Peltola, Tomas Wallenius, VTT Technical Research Centre of Finland; Timo Laakso, Pöyry Finland Oy, Finland.

4 Task 25

Power Systems with Large Amounts of Wind Power

1.0 Introduction

Wind power will introduce more uncertainty into operating a power system because it is variable and partly unpredictable. To meet this challenge, there 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. So far, the integration of wind power into regional power systems has mainly been studied on a theoretical basis, because wind power penetration is still rather limited in most countries and power systems. The small power system of the island of Ireland already has about 10% of yearly electricity consumption from wind, and countries like Denmark and the Iberian Peninsula (Spain and Portugal) show a high penetration of closer to 20%. Also regions like Northern Germany, Southern Italy, and Mid-Western United States experience high penetration levels. All these countries 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. An in-depth review of the studies has been started in Task 25 to draw conclusions on the range of integration costs for wind power. 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. The challenge is both to create coherence between parallel activities with transmission system operators (TSOs) and other R&D task work and to remain as an internationally accepted forum for wind integration.

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 farm 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 2006-08 work. The task will end with developed guidelines on the recommended methodologies to use when estimating the system impacts and the costs of wind power integration. Also, best practice recommendations will be formulated on system operation

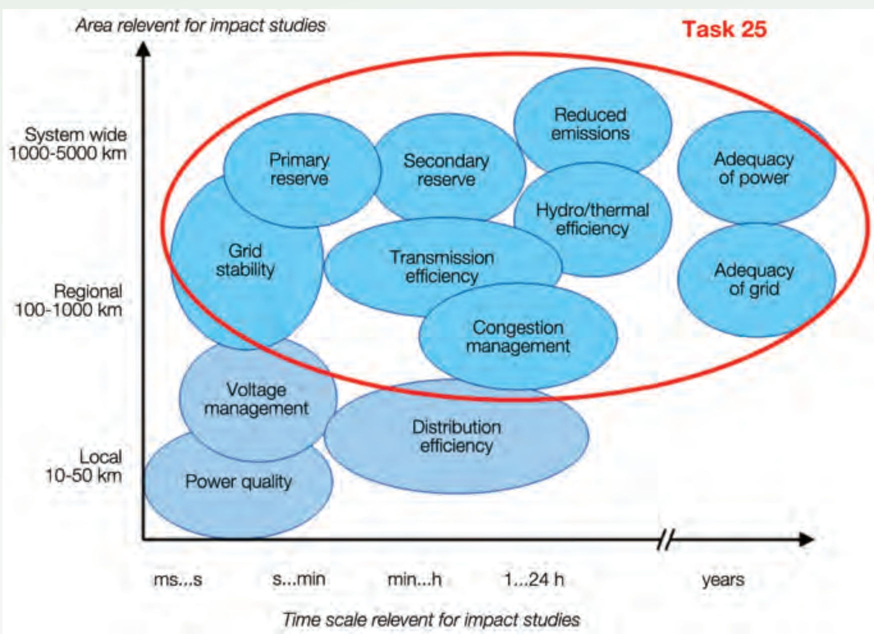

Figure 1. Impacts of wind power on power systems, divided into different time scales and size of area relevant for the studies. Primary reserve is denoted for reserves activated in seconds (frequency activated reserve; regulation) and secondary reserve for reserves activated in 5–15 minutes (minute reserve; load-following reserve).

Table 1. Countries Participating in IEA Wind Task 25, third term 2012-2014		
	Country	Institutions coordinating work in countries (TSO participating in some meetings in parenthesis)*
1	Canada	Hydro Quebec
2	China, 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; (Statnett)
12	Portugal	LNEG, (REN Rede Electrica Nacional)
13	Spain	Universidad de Castilla-La Mancha; (REE)
14	Sweden	KTH Kungliga Tekniska Högskolan
15	United Kingdom	DG & SEE Centre for Distributed Generation & Sustainable Electrical Energy; (National Grid)
16	United States	NREL National Renewable Energy Laboratory; UWIG Utility Wind Integration Group

*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.

practices and planning methodologies for high wind penetration.

Annex 25 to the IEA Wind Implementing Agreement was approved at ExCo 56 in September 2005 for three years, 2006–2008. The work was granted a second term 2009-2011 at ExCo 62 in 2008, and a third term 2012-14 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 in the Task. For the second term Canada, Japan, and Italy have also joined Task 25. For the third term, the Chinese State Grid Research Company has joined.

3.0 Progress in 2011

The meetings organized by Task 25 have established an international forum for exchange of knowledge and experiences. The spring task meeting in 2011 was organized in Stockholm hosted by KTH in Sweden. In the autumn meeting, hosted by LNEG in Portugal, participating countries began work on final reporting of the 2009-11 phase.

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; 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, Spain, and the UK have joined the meetings through 2011. The IEA Secretariat work on integrating renewable energies (GIVAR project) has been followed.

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, Bremen and Quebec International Workshops on Large-Scale Integration of Wind Power into Power Systems, as well as on Transmission Networks for Offshore Wind Farms in 2009 and 2010. Task 25 work and results were presented at several meetings in 2011: IEA Paris Electricity Grid Coordination meeting April (H. Holttinen); AnemosPlus (EU project) workshop, Paris 29th June (H. Holttinen). Collaborative papers were presented in IEEE Power and Energy Society General Meeting 24 – 28 July 2011, Detroit, USA. ("Impact of Wind Power on the Unit Commitment, Operating Reserves and Market Design" presented by P. Meibom, DTU Wind) and Variability of Large-Scale Wind Power (H. Holttinen at the wind integration workshop in October 2011). In addition, the national participants presented Task 25 in their national workshops (J. Kondoh in Japan and P. Meibom in Denmark). Collaborative journal articles have been submitted regarding reserve requirements, transmission planning, and experience in frequency control.

Work has begun on a simplified assessment of wind integration effort and

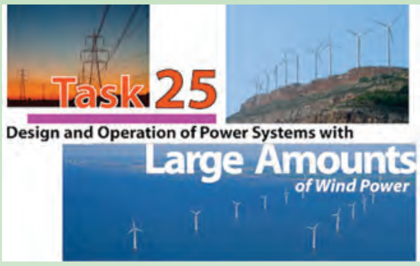

Figure 2. The Task 25 website is accessed from www.ieawind.org under Task Web Sites.

power system flexibility, in collaboration with the IEA secretariat study on integrating renewable energy sources (GIVAR project). The Task 25 website has been established at http://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 early 2012. The members-only section details the meeting presentations and information relevant to task participants.

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

Changes in system management may need to be made from the start to

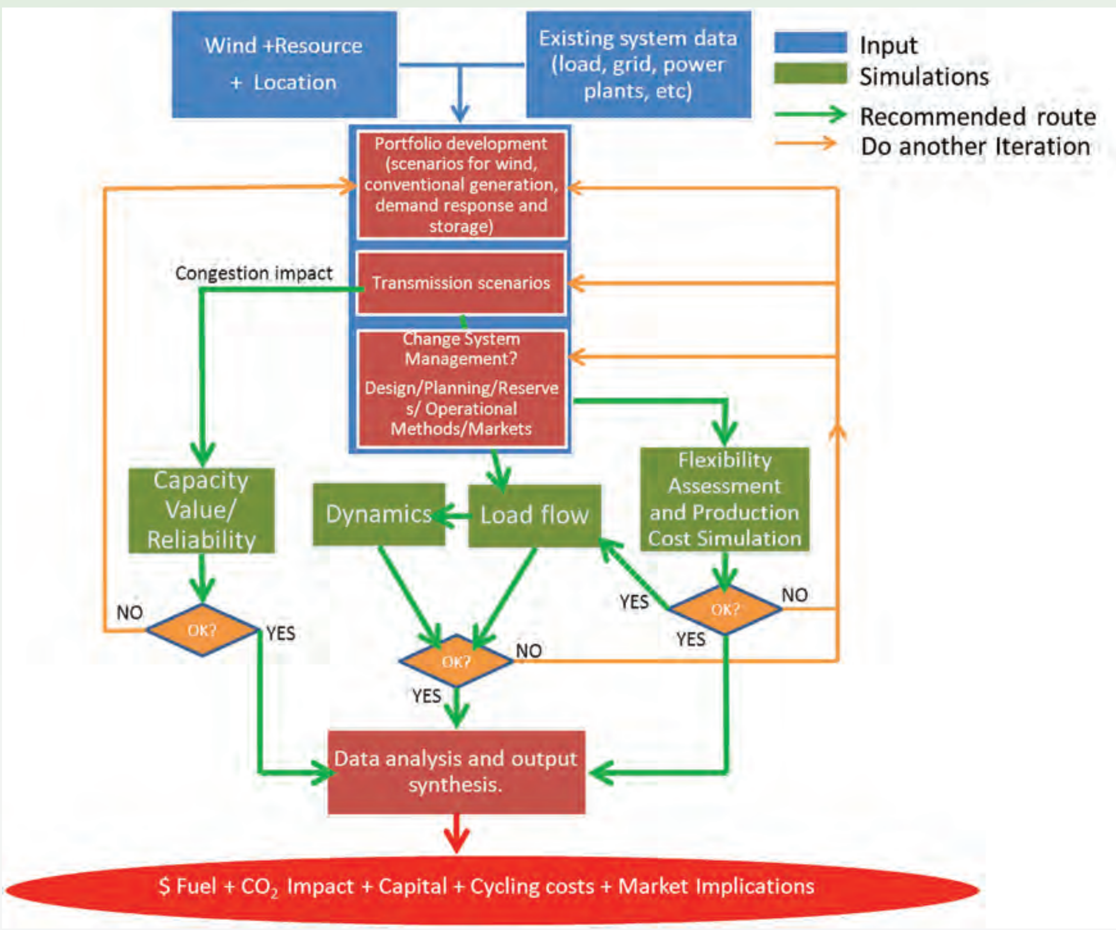

Figure 3. Flow chart of a complete wind integration study, showing relevant iteration loops from simulations to set-up and portfolio development

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. Transmission planning involves contingency analysis and stability studies as well as profitability analysis of the investment options. 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 will 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. There is an allocation challenge especially for grid reinforcement costs as most grid upgrades also benefit other users.

Another issue is operational costs. The operating costs of power systems will actually be reduced due to wind power. This is because the bulk of operating costs come from fuel costs and wind power will replace fossil fuel use (operational costs exclude the investment costs for power plants). The integration cost is then actually the difference of full credit for operating cost reduction compared with cost for system operation with increasing variability introduced by wind power. Gas or coal power plants will perform more balancing to follow the combination of load and wind, rather than just following the load. Any penalties due to decreased efficiency and more wear and tear on these balancing units are quite modest compared to the total operating costs.

When estimating increases in operating costs, it is important to note whether a market cost has been estimated or whether the results refer to technical costs for the power system. A "market cost" includes transfer of money from one actor to another actor, while "technical costs" implies a cost for the whole system. 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 2012

The meetings in 2012 will take place in Rome, hosted by the Italian System Operator Terna, and Tokyo, hosted by AIST. Task 25 work and results will be presented also at several meetings in 2012: a session in EWEA 2012 in Copenhagen, the wind integration symposium in June, the IEEE PES meeting in July, and in the wind integration workshop in November. The important conclusions from the 2009-11 phase will be published as recommendations and a summary report. Journal articles will be written about critical modeling issues in wind integration studies.

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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5 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. Signals in the U.S. market indicate an increase exceeding 60% from average investment costs for projects installed from 2001 through 2004, up to approximately 2,100 USD/kW; 1,562 EUR/kW (1). Other important markets for wind energy are also experiencing rising costs, although noticeable differences still exist among countries.

This is precisely the background that justifies the initiation 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 transparent 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 objectives of this task are:

- To establish an international forum for exchange of knowledge and information related to the cost of wind energy
- To identify the major drivers of wind energy costs, e.g., capital investment, installation, operation and maintenance, replacement, insurance, finance, and development costs, and to quantify the differences of these cost elements among participating countries
- To develop an internationally accepted, transparent method for calculating the cost of wind energy that can be used by IEA and other organizations
- To derive wind energy cost and performance projections, or learning curves, which allow governments and the research community to anticipate the future trends of wind generation costs
- To compare the cost of wind energy with those of other electricity generation technologies, making sure that the underlying assumptions used are compatible and transparent
- To survey various approaches to estimating the value of wind energy, e.g., carbon emission avoidance, fuel price stability.

Three activities are proposed to achieve these objectives: development of a transparent method for estimating cost of wind energy and identification of major cost drivers; estimation of future cost and performance of land-based and offshore wind projects; and assessment of methodologies and results for estimating the value of wind energy.

Providing transparency in the cost elements of wind projects among all

Table 1. Task 26 Participants

	Country	Institution(s)
1	Denmark	Risoe/DTU, EA Energy Analyses
2	EWEA	European Wind Energy Association
3	Germany	WindGuard
4	Netherlands	ECN
5	Spain	AEE
6	Sweden	Swedish Energy Agency, Vattenfall
7	Switzerland	Swiss Federal Office of Energy
8	United States	NREL, LBNL

participating countries will result in better understanding of the cost drivers of wind technology and the reasons for differences among participating countries. Development of a simple spreadsheet model that represents the major elements of wind project costs will result in a tool that could be used by IEA or others in estimating wind project costs. A report summarizing these results provides insight into the different cost drivers for each participating country.

Estimates of future cost and performance for wind technology are important for analyses of the potential for wind energy to meet national targets for carbon emission reductions or renewable electricity generation. Learning curves are one method for assessing the effect of technology development, manufacturing efficiency improvement, and economy of scale. Component level cost and scaling relationships can also be used to estimate future technology development pathways. While costs have decreased since the early 1980s, recent trends indicate rising costs that have been attributed to tight supply, commodity price increases, and other influences. These effects may continue in the future, and it's important to identify the contribution of such market influences to wind technology costs. These effects, and their relation to technology advances, should be incorporated into methods to project future costs and performance for wind technology. A thorough assessment of the effect of wind technology changes such as increased generator size, larger rotors, and taller towers over the past decade will help inform the use of learning curves and engineering models to develop future cost and performance trajectories.

Wind energy technology ultimately operates in an electric system that includes conventional and other alternative electricity generation technologies. Wind energy technology adds value to a system in a number of ways including reducing carbon emission, diversifying fuel supply and providing stable energy production prices. Various methods and approaches are used to quantify these impacts of wind energy deployment. This work package will provide a summary of these concepts and approaches.

3.0 Progress in 2011

In March of 2011 an in-person meeting was organized by NREL and hosted in Golden, Colorado. This meeting supported the development and scoping of the second report of Task 26. A series of web-meetings and conference calls were held throughout the second and third quarters of 2011 to provide additional input into the 2011 activities and to provide updates on the work achieved.

Activities completed in 2011 emphasized 1) the collection of historical cost and performance data from multiple participating countries; 2) analysis of the expected near-term LCOE from projects in late-stage development in the U.S. and Denmark, using the same transparent cash flow model referenced above; 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 (2). 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, In fact, 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

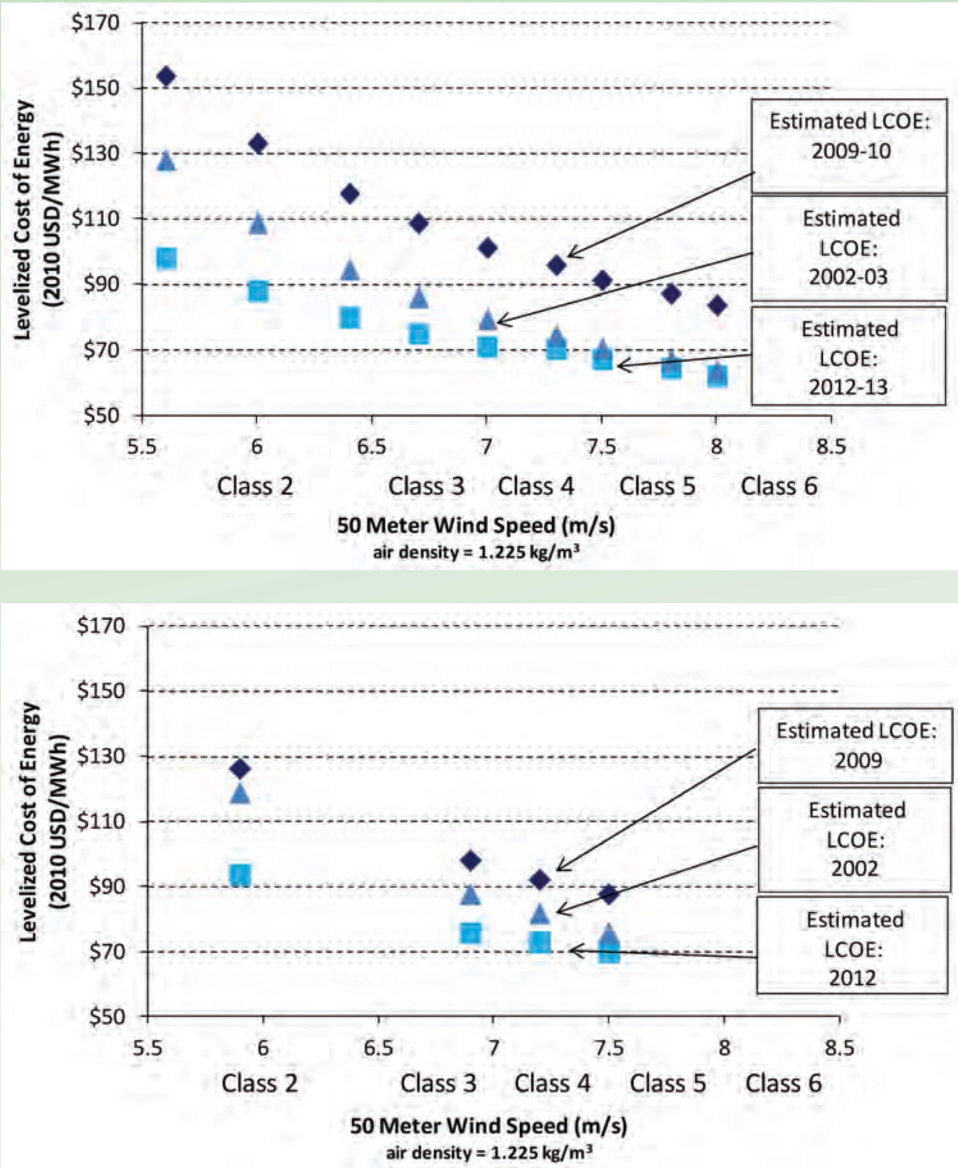


Figure 2. LCOE for wind energy over time in the United States (top) and Denmark (bottom)

forecast data shown in Figure 3 whereby LCOE reductions, across virtually all studies and scenarios in the literature today, fall to less than 1% per year 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.

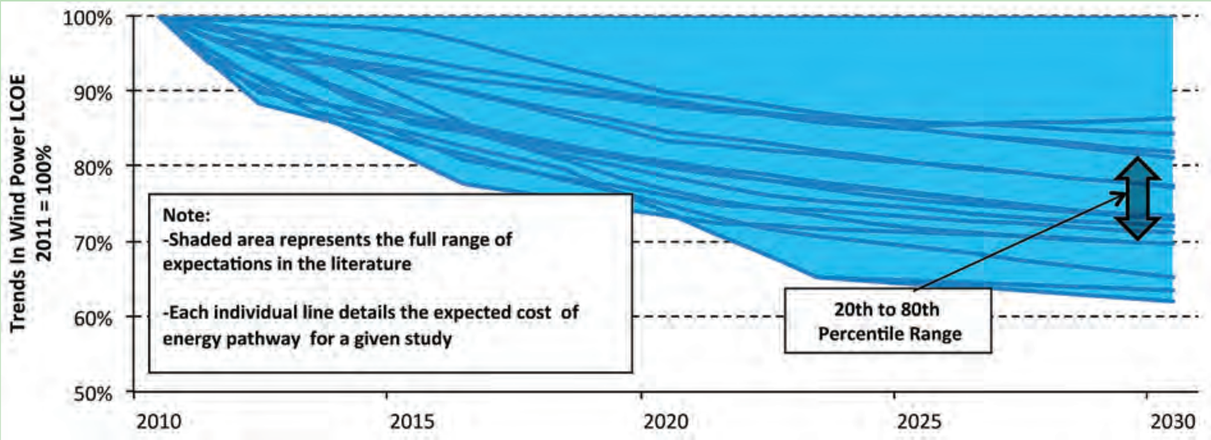


Figure 3. Estimated range of wind LCOE projections across 18 scenarios

4.0 Plans for 2012 and Beyond

The second report of Task 26 has completed an in-depth review process and will be published in 2012. An abbreviated version of the report was accepted as part of the World Renewable Energy Forum, where the work will be presented to a diverse international audience. Portions of the work have also been presented in various other conferences and contexts. We anticipate the submission of an edited version of the second report will also be submitted to a peer-reviewed journal.

During 2012 a proposal extension for Task 26 has also been drafted. Future work is anticipated to emphasize: updates to the LCOE analysis of onshore wind completed in 2010; cross country analysis of the cost of offshore wind energy, including an analysis of primary cost drivers; and continued exploration of new methods for understanding future costs of wind power as well as the value of wind in the electric system.

References

(1) Wiser, R. and M. Bolinger (2010), 2009 Wind Technologies Market Report, DOE/GO 102010-3107.

(2) 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: M. Maureen Hand and Eric Lantz, National Renewable Energy Laboratory, United States.

6 Task 27

Consumer Labeling of Small Wind Turbines

Development and Deployment of Small Wind Turbine Labels for Consumers

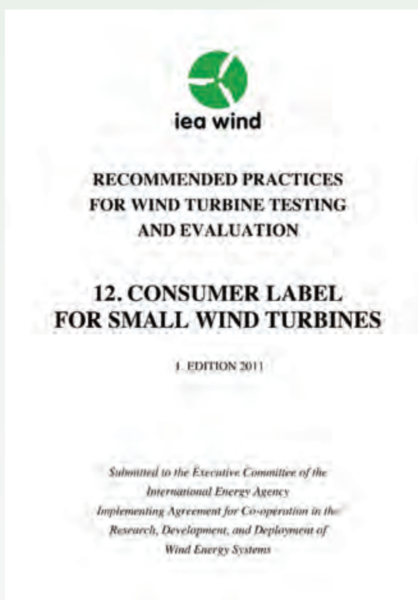
1.0 Introduction

The objective of this task is to develop a system of consumer labeling for small wind turbines (SWT). The SWT sector is defined as wind turbines with a swept area not exceeding 200 m^2 according to IEC 61400-2 2nd Ed:2006, which is the only standard developed so far for this sector. Having in mind the rapid growth of the SWT sector, it is also the objective of this task to provide valuable, publicly available information for anyone interested in buying a small wind turbine. This information could include recommended methodologies and independent test reports on: power performance curves and/or energy production, acoustic noise emissions, duration test results, and safety and function test results.

A key goal of this task is therefore to increase the use of common methodologies for testing SWTs. These methodologies could in the near future provide feedback and know-how to develop international standards in the area of quality and performance of these SWTs.

In 2011, the participants completed development, gained approval, and published the *IEA Wind Recommended Practices for Wind Turbine Testing and Evaluation: 12. Consumer Label for Small Wind Turbines* (Figure 1).

During the activity to develop the recommended practice on labeling, some new issues were identified related to SWTs for urban integration. The special wind conditions found in the built environment and its effect on wind resource assessment methodology need to be explored. Now that the goal of publishing *IEA Wind Recommended Practices for Consumer Label for Small Wind Turbines* has been achieved, the participants developed a proposal to extend Task 27 and explore issues of the built environment.


iea wind

RECOMMENDED PRACTICES FOR WIND TURBINE TESTING AND EVALUATION

12. CONSUMER LABEL FOR SMALL WIND TURBINES

1. EDITION 2011

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

Figure 1. Approved IEA Wind Recommended Practice

From the beginning of this task in December 2009 through December 2011, eleven IEA Wind Task 27-IEC MT2 liaison meetings have been conducted. These meetings were held in Madrid (Spain), London (United Kingdom), Wausau (United States), Toronto (Canada), Tokyo (Japan), Kaiser-Wilhelm-Koog (Germany), Glasgow (United Kingdom), Boulder (United States), Perth (Australia), Madrid (Spain), and Xianshan (People's Republic of China) (Figure 1).

2.0 Objectives and Strategy

The primary goal of this task is to give incentives to the SWT industrial sector to improve the technical reliability

Table 1. Task 27 Participants		
#	Country	Institution(s)
1	Australia	Australian National Small Wind Turbine Centre (RISE) Murdoch University
2	Canada	Wind Energy Institute of Canada (WEICan)
3	China CWEA	Chinese Wind Energy Association (CWEA)
4	Denmark	Risø National Laboratory (Risø-DTU)
5	Ireland	Dundalk Institute of Technology
6	Italy	University of Napoli
7	Japan	National Institute of Advanced Industrial Science and Technology (AIST)
8	Korea, Republic of	Korean institute for Energy Research (KIER)
9	Spain	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)
10	Sweden	TEROC AB /INTERTEK AB
11	United Kingdom	National Engineering Laboratory (TUV-NEL)
12	United States	National Renewable Energy Laboratory (NREL)
	Observers	CSTB Centre Scientifique et Technique du Bâtiment; TERTEC (Taiwan Electric Research and Testing Center)

and performance of small wind turbines. This task will enable the use of common methodologies to test the equipment and to display the results of those tests in a form recognized by potential residential consumers. It will contribute to identifying the good SWT manufacturers that are struggling to compete with outdated (or undemonstrated) technologies also available in the market. But mostly, the outcomes of this task will benefit potential buyers, installers, and official energy entities that are giving permits to connect SWTs to the electric grid.

Specific outcomes include:

- Review of the state of the art regarding SWT testing and reporting
- Identification of the tests required for labeling
- Recommendations for labeling reporting
- Identification of the label display parameters
- Publication requirement of summary test results
- Peer reviewed testing and development at Small Wind Association of Testers (SWAT).

To accomplish this, partial goals are to:

- Build up a critical mass of involvement in the development of methodologies for testing and presenting the results as well as labeling classification, by including government agencies, wind turbine manufacturers, and third party testers (such as primarily universities, national laboratories and institutes, and companies with large experience in the testing of wind power devices). This critical mass should provide the necessary basis for the wide use in the SWT sector of the IEA Wind Recommended Practices that have been developed.
- Test the labeling and testing methods in practice on a number of small wind turbines to provide feedback to the continued updating of methodologies in this area.
- Increase awareness among consumers and official entities.

An important reason for the entire wind energy sector to support the labeling initiative is to reduce the risk of accidents with SWTs as well as minimize poor investments in substandard equipment.

Expected results include:

- Report about state of the art regarding SWT testing and reporting
- Recommendations for labeling reporting

Figure 2. IEA Wind Task 27 meeting in Xianshan, People's Republic of China

- Internationally accepted SWT customer label
- Development of SWAT

3.0 Progress in 2011

3.1 Meetings of participants

Two meetings were held during 2011. Experts from certification bodies, research institutes and universities, and the SWT industry were invited to exchange knowledge and gain a common understanding of the developments, conflicts, and their solutions.

The first IEA Wind Task 27-IEC MT2 Liaison meeting was hosted by CIEMAT on 3-4 March 2011, in Madrid, Spain. Experts (20) represented Australia, Denmark, Ireland, Japan, Spain, Sweden, UK, and the United States. An observer from France also participated.

The activities performed during the meeting are shown below:

- IEA Wind 2009 country reports
- The Subtask A deliverable Development of Recommended Practices for consumer labeling for small wind turbines was finalized.
- The Subtask B: deliverable Development and Deployment of the Small wind association of testers was discussed. SWAT governance, membership, and round robin activities issues are still under debate. An international SWAT conference was proposed.
- A task extension proposal related to built-environment Recommended Practice was proposed.
- New SWT R&D activities (urban integration, non standard wind conditions, water pumping systems test recommended practices proposal, research and validation on simplified design equations for VAWT, turbine & inverter modeling) were identified.
- A round robin test in several sites with different conditions (in special TI conditions) is on going.

The second IEA Wind Task 27-IEC MT2 Liaison meeting was hosted by the company Ginlong on 10-11 November 2011in Xiangshan (People's Republic of China). Experts (14) represented Australia, China, Denmark, Ireland, Korea, Japan, Spain, UK, and the United States. Several observers also attended.

The activities performed during the meeting are shown below:

- Discussion of the IEA Wind label use
- Progress on Subtask A: Country SWAT
- Review SWAT scope and governance
- Plans for SWAT round robin activities
- Presentations on draft UK Renewable "Proposal for Development of a Medium Wind Standard, Draft Version 2" April 2011 – A. Mackinnon
- Discussion about the possibility to develop a Recommended Practice for Medium Wind Turbines within the IEA Wind Task 27 extension
- Presentation of Annex 27 – Task Extension Proposal Draft and discussion
- Built-Environment Recommended Practice.

3.2 Reports, conferences and decisions

The *Recommended Practices for Wind Turbine Testing and Evaluation: 12 Consumer Labels for Small Wind Turbines* was approved by the task participants and approved by the ExCo in July 2011 (electronic ballot). The first label will appear on the Task 27 Web page of IEA Wind in 2012.

Other dissemination activities include:

- A presentation titled *International Standardisation and Labelling* was given by the OA at the Second World Summit on Small Wind Turbines New Energy held in Husum, (Germany) on March 2011.
- A presentation was titled *IEA Wind Task 27- Overview of the 2009 Small Wind Report Annual Report* was given the OA at the International Small Wind Conference 2011 held in the UK on 5-6 April 2011.
- A presentation titled *Development and Deployment of Consumer Label for Small Wind Turbines* was given by the OA at the Irish Wind Industry Encounter with IEA Wind held in Dublin (Ireland) on 17 October 2011.

A decision was taken to begin SWAT deployment in individual countries because it will be difficult to establish an international association without formal funding. In the member countries of IEA Wind Task 27, deployment will be based in the participation of the existing local SWT test centers: RISE (Australia), WEICAN (Canada), RISØ-DTU (Denmark), KIER (Korea), CIEMAT (Spain), etc. The participants agreed to convene the first International SWAT conference in early 2012 in conjunction with the IEA Wind Task 27 meeting.

A SWAT governance decision was taken to guaranty the quality of the test when performed by unaccredited test organizations. In this case before the label is published, a round robin test with the raw data must be done by at least one SWAT member that is an accredited laboratory in order to validate the test.

Table 2 lists the data available today from SWT test facilities covered by the IEA Wind Task 27 participants. Test sites include accredited, unaccredited, industry testing.

A proposal to extend IEA Wind Task 27 beyond 2011 was developed. The main objective of the extension is to develop a new Recommended Practice for Design of Small Wind Turbines in the Built Environment. Built-environment wind turbines (BWT) can be defined as those turbines installed on the roofs of buildings, side mounted to a building, integrated into the building design, or in the urban setting near buildings. The wind resource in built environment has to be better understood and testing and design standards for BWTs have to be developed. Another aim of the extension is to reinforce the IEA Wind Recommended Practice 12 for consumer labeling through the formation of SWAT and setting up peer-reviewed wind turbine testing and evaluation.

The expected results are the development of an IEC design class for BWT, which includes not only wind speed requirements but increased level of

Table 2. Data available from SWT test facilities		
Country	SWAT test sites available	Data availability
Australia	RISE Facilities	Low turbulence data available
Canada	WEICan / DEWI	Low turbulence and very cold weather data available
Denmark	RISOE-DTU	Low turbulence data available
Germany		
Greece	TEI	
Ireland	DIT	Low turbulence data available
Japan	No available yet	High turbulence data available
Spain	CIEMAT-CEDER	Mid/High turbulence data available. IEC Class I/II sites
Sweden	No available yet	
United Kingdom	TUV-NEL	Mid turbulence data available
United States	NREL	High turbulence data available
United States	SWCC	
United States	Regional Test Centers	
France (observer)	SEPEN /Narbone	High turbulence data unavailable

turbulence intensity. Research and measurements from existing 3-D data sources will be gathered and analyzed to better understand the inflow in the urban and built-environment. Participation in this data collection and analysis task will be undertaken in Australia (Murdoch University), Denmark (RISØ-DTU), Italy (University of Napoli), Japan (Nasu-Denki), Spain (CIEMAT-CEDER), Sweden (University of Uppsala), and the United States (NREL).

4.0 Plans for 2012 and beyond

The primary activity will be the deployment of the IEA Wind Task 27 label and SWAT. The idea is to have some labels ready to be shown in early 2012 to test the labeling procedure. Some activities are scheduled dealing with the dissemination of the IEA Wind Task 27 activities in magazines, conferences, and workshops. The intention is to develop an annual International SWAT Conference to exchange SWT test experiences, harmonize test criteria, exchange information about the situation of the small wind sector in the different countries, information about the requirements for certification and accreditation in the different countries, information about new standards, new test facilities, etc.

The second activity is to complete and gain approval from the ExCo for extension of IEA Wind Task 27. The draft extension proposal which came out of the Xiangshan meeting will be reviewed and accepted in a virtual meeting and in the face-to-face meeting to be held in New York, United States in April 2012.

In addition, some ongoing R&D activity about turbulence intensity values at potential SWT sites in non-open terrain will provide results during 2012.

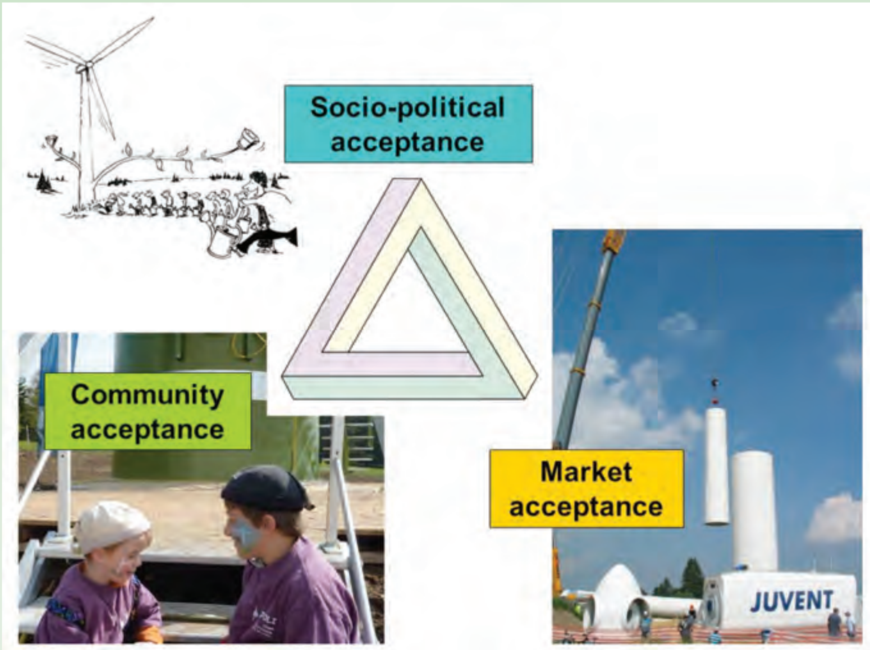
Table 3 shows the scheduled meetings for 2012 and 2013. The IEA Wind Task 27 extension should last four years (2012-2015).

Author: Ignacio Cruz, CIEMAT, Spain.

Table 3. Task 27 Past Meetings			
M#	Date	Location	Topic
M1	April 2012	Ithaca NY (United States)	International SWAT, IEA Wind Task 27
M2	July 2012	Virtual meeting (Webinar or teleconference)	IEA Wind Task 27 Progress
M3	25-27 September 2012	Dundalk (Ireland)	IEA Wind Task 27 Progress
M4	January 2013	Virtual meeting	IEA Wind Task 27
M5	April 2013	Soria (Spain)	International SWAT, IEA Wind Task 27
M6	July 2013	Virtual meeting	IEA Wind Task 27 Progress
M7	Sep 2013	Jeju Island (Korea)	IEA Wind Task 27

7 Task 28

Social Acceptance of Wind Energy Projects



1.0 Introduction

Renewable energies have many technical aspects that offer a variety of possibilities for optimization and improvement, for example efficiency or materials. Far off-shore wind and marine energy technologies are still at the beginning of large-scale development.

"Social" or "public acceptance" topics, on the other hand, are non-technical issues and therefore much harder to grasp than technical issues. This means that it is important to understand the real concerns behind the opposition to renewable energy technologies or to transmission infrastructure, and also to address the issues and find viable solutions. Rational arguments may not reach the counterpart, emotions are felt subjectively, and there are many different stakeholders involved. Wüstenhagen et al. in 2007 (1) tried to capture those actor groups in three dimensions as shown in the opening photo: Socio-political acceptance is about the decision and opinion makers, regional or national institutions, organizations and general opinion; market acceptance comprises the wind industry, project developers, operators, but also the grid companies, investors and the power consumer; and community acceptance includes the host communities with their manifold interests and population groups. Hansen(2) proposed the endless triangle(3) in between the groups to symbolize the interactions and interdependencies between them. The endless triangle also highlights the need to take all three stakeholder groups into account as acceptance on a public, market and community level is necessary to establish projects.

IEA Wind Task 28 was set up three years ago as an interdisciplinary and trans-national working group to consolidate and review the current research and to exchange regional experience with experts from many countries. The diverse background of disciplines, experience, and regional framework from Europe, Northern America, and Japan (Table 1) enabled a broad view on the issues of wind energy acceptance. It is intended to help practitioners, politicians, and communities alike to improve the projects and to make them acceptable to a broad majority.

2.0 Objectives and Strategy

IEA Wind Task 28 aims to assist participating countries in reaching their ambitious renewable energy goals. The exchange should result in the translation of current research knowledge into the language of developers, planners, administrative bodies, and communities to bring forward wind energy projects. The current activities, based on the three work packages proposed (Figure 1), are concentrating on:

- International forum for exchange of knowledge and experiences related to social acceptance and other societal issues of wind energy development: working group meeting regularly and national experts gathering in connection with the working group meetings
- Based on the knowledge of the State-of-the-Art Report, Good Practice Recommendations have been developed and will be published in 2012 as an excerpt of the three year exchange
- Dissemination activities have been developed successively in the last three years including working group members promoting the knowledge gained in their work and within the international forum in presentations and papers. The Operating Agent explicitly passed the results of the Task`s work on by presentations, workshops and publications.

Table 1. Task 28 participants		
	Country	Institution(s)
1	Canada	Natural Resources Canada, CANMET Energy Technology Centre; University of Québec at Montréal
2	Denmark	Danish Energy Authority; Ministry of Climate and Energy
3	Finland	Finnish Funding Agency for Technology and Innovation, Energy and Environment Industries (TEKES); wpd Finland oy
4	Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety; Martin Luther University; Otto von-Guericke University
5	Ireland	Sustainable Energy Ireland
6	Japan	National Institute of Advanced Industrial Science and Technology; University of Tokyo
7	The Netherlands	Agentschap NL, NL Energy and Climate
8	Norway	Norwegian Water Resources and Energy Directorate; Enova SF; Norwegian University of Science and Technology, Centre for Energy and Society
9	Switzerland	Federal Department of the Environment, Transport, Energy and Communications, Swiss Federal Office of Energy; ENCO Energie Consulting AG, Wind department
10	United States	U.S. Department of Energy, National Renewable Energy Laboratory Wind Technology Center

The structure of social acceptance issues developed at the beginning of the Task 28 work has been retained for all following discussions, but has been refined and elaborated (Figure 2):

3.0 Progress in 2011

Discussions on Good Practice Recommendations and dissemination by working group members and the Operating Agent were the focus of 2011as a further result of the Task`s work.

The Good Practice Recommendations were already broached in 2010, but the two meetings in 2011 centered on the elaboration of this report and gave the working group time to work on them in detail: Fifth working group meeting in Utrecht, the Netherlands (spring 2011); Sixth working group meeting in Trondheim, Norway (autumn 2011). Both meetings were connected with half-day meetings of national practitioners and researchers.

A web meeting was held in September to prepare the autumn meeting and to keep the working group members up-to-date in a more interactive form than the regular mailings by the Operating Agent could offer.

The Operating Agent and working group members also maintained contacts with experts from countries that are not participating in the task. Some of these experts live in member countries of IEA Wind and therefore may be able to participate in a possible second phase of IEA Wind Task 28. The Operating Agent also answered several queries on the issue of social acceptance from around the world or placed social acceptance experts as speakers for conferences.

The dissemination activities of working group members and the Operating Agent included in 2011:

- Participation at the IEA Wind side event at EWEA 2011, by Eric Lantz, NREL (http://www.ewec2011.info/conference/side-events/ieawind-summary-of-international-collaboration-on-wind-energy-r-d-tasks/)
- Input to an IEA experts group on R&D priority setting and evaluation, by Stefanie Huber, ENCO AG
- Publication for *Wiley Interdisciplinary Reviews: Energy and Environment,* "Large-scale wind deployment," social acceptance, by Robert Horbaty, Stefanie Huber, ENCO AG, and Geraint Ellis, Queens University Belfast (in review)
- Publication of a book chapter in *Learning from Wind Power: Governance, Societal and Policy Perspectives on Sustainable Energy*, "Social Acceptance of Wind Energy Projects: Learning from Trans-national experience," by Stefanie Huber, Robert Horbaty, ENCO AG, Geraint Ellis, Queens University Belfast (in review)
- Presentation at the 10th wind energy symposium in St. Pölten, Austria, by Jan Hildebrand Zoellner, Otto-von-Guericke-University Magdeburg (http://www.awes.at/?mdoc_id=1000826)
- Presentation at a bilateral South Africa training event in Johannesburg, by Gundula Hübner, Martin-Luther-University Halle-Wittenberg
- Interview for the *Wind Directions* magazine of EWEA, by Stefanie Huber, ENCO AG

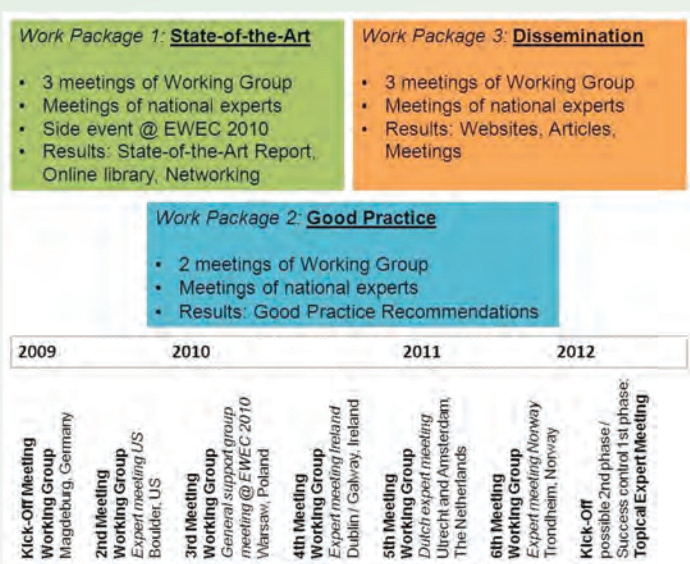


Figure 1. Schedule, work packages, and anticipated results of Task 28

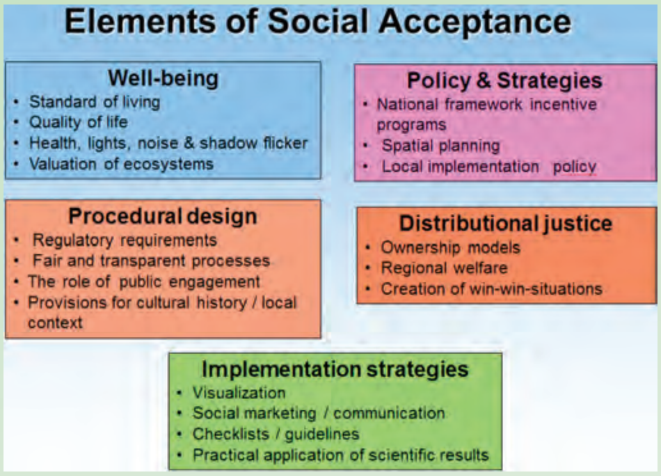


Figure 2. Elements of social acceptance (of wind energy) as collected by IEA Wind Task 28

• Interview for the *Les affaires* journal on social acceptance issues, by Maya Jegen, University of Québec (http://www.lesaffaires.com/archives/generale/privatiser-un-mot-a-utiliser-avec-prudence-au-quebec/525100)
• Publication in the *Bulletin* magazine of the Swiss electricity branch, by Stefanie Huber, ENCO AG, Markus Geissman, Swiss Federal Office of Energy (http://www.bulletin-online.ch/de/themen/artikel-detailansicht/news/4071-soziale-akzeptanz-von-windenergie.html)
• Results from IEA Wind Task 28 work were also integrated in publications by Gundula Hübner in German publications on acceptance of renewable energies.

The website and the web database were regularly updated and include all available public publications and presentations of IEA Wind Task 28. Amongst others, the dissemination and link page were elaborated. The working group also discussed a presence on social media, but decided on rather focusing on the production of relevant knowledge and passing this knowledge onto practitioners and institutions.

The visits on the website, www.socialacceptance.ch, developed as shown in Figure 3. The visitors continuously increased during the first three-year period. It is very interesting to see the peak in spring/summer 2011, which coincides with the events in Fukushima and the redefinition of energy policy in several countries.

3.0 Plans for 2012 and beyond

In 2012, the final report of IEA Wind Task 28 will be finished and presented to IEA Wind ExCo together with the final proposal on the possible continuation of IEA Wind Task 28 with a second three-year period. Discussion of a possible continuation of the task began in 2011 and a short proposal on a possible second phase was discussed at IEA Wind ExCo 68.

Interesting topics for the next three-year period include: Measurement and monitoring with respect to quantification and valuation, assessment of the magnitude of the issue, and tracking of developments; support for the establishment of policies and standards; successful supporting structures; discussion of current and new issues influencing social acceptance that are being debated in the participating countries and stressing of research gaps; deduction and dissemination of the lessons learned, good practices, successful strategies, etc.

The working group would also like to include new participating countries from IEA Wind. It would be especially useful to have more countries from Asia and other continents to broaden the experience also to developing countries. The core element of Task 28 with a working group meeting regularly and connected national expert meetings should be continued. A meeting in summer 2012 is planned where a "success control" of the first phase and the kick-off for the next phase should be combined around a Topical Expert Meeting (IEA Wind Task 11) in Switzerland.

Further, the publications in review and in press will be moved through to publication.

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(3) http://measureofdoubt.files.wordpress.com/2011/11/imp-triangle-drawing.png.

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

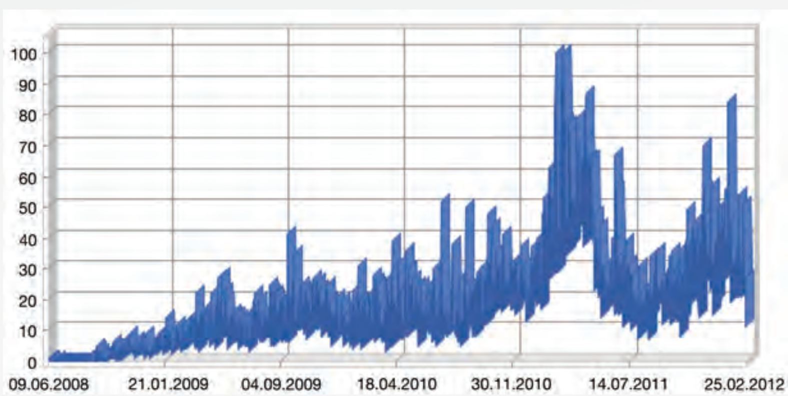

Figure 3. Development of daily visitors on www.socialacceptance.ch between summer 2008 and February 2012, the running time of IEA Wind Task 28

8 Task 29

MexNex(T) Analysis of Wind Tunnel Measurements

1.0 Introduction

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

The availability of high quality measurements is the most important prerequisite to gain insight into these uncertainties and to validate and improve aerodynamic wind turbine models. For this reason, the European Union project MEXICO: Measurements and EXperiments In COntrolled conditions has been carried out (2). In this project, 10 institutes from six countries cooperated in doing experiments on an instrumented, 3-bladed, 4.5-m diameter wind turbine placed in the 9.5 m^2 open section of the Large Low-speed Facility (LLF) of German Dutch Wind Tunnel (DNW) in the Netherlands. The opening photo shows the set-up of the MEXICO model in the LLF tunnel of DNW. The collector is shown in the background and the nozzle in the foreground. The measurements were performed in December 2006 and resulted in a database of combined blade pressure distributions, loads, and flow field measurements that can be used for aerodynamic model validation and improvement.

Previous measurements (on a 10-m diameter turbine) were performed by the National Renewable Energy Laboratory (NREL) in the National Aeronautics and Space Administration (NASA) Ames wind tunnel (8). An obvious difference between the two types of experiments lies in the larger size of turbine diameter for the latter experiment. On the other hand, the NASA-Ames experiment only concerned rotor measurements, whereas the MEXICO experiment also included flow field measurements of inflow and wake. These are important features in understanding discrepancies between calculated and measured blade loads because the load calculations take place in two steps. First, the flow field around the blade (i.e. the induction) is calculated, and second from that the loads are derived. Each of these steps has its own uncertainty (e.g. the second step may contain the uncertainty in airfoil characteristics). In conventional experimental programs, only blade loads are measured, therefore, it is not possible to distinguish between these two sources of discrepancies. The addition of flow field measurements should open up this possibility.

The MEXICO project database was still in a rather rudimentary form and only limited analyses were carried out. This is the case because the amount of data is vast and the time needed to analyze all data is extremely long for a single party. As such, it was beneficial to organize the analysis of the MEXICO data in a joint project under IEA Wind, since this made it possible to share tasks. Added value also lied in the fact that the task served as a forum for discussion and interpretation of the results. The outcome of the data analysis was better than the summed result from the individual projects.

In the IEA Wind Task 29, MEXNEX(T), the accessibility of data is facilitated and a thorough analysis of the data takes place. This includes an assessment of the measurement uncertainties and a validation of different categories of aerodynamic models. The insights have been compared with the insights that were gained within IEA Wind Task 20 (8) on the NASA-Ames experiment and other wind tunnel experiments. The Operating Agent is the Energy Research Center of the Netherlands where the following institutes participate.

In principal MEXNEX(T) ended in 2011. In October 2011 a second phase of MEXNEX(T) was approved at the 68th Executive Committee meeting of the IEA Executive Committee which was kicked-off in December 2011. The present report mainly describes the progress on the first phase. More information is given on the second phase of MEXNEX(T) in section 4.0.

2.0 Objectives and Strategy

The objective of the IEA Wind Task 29 MEXNEX(T) was to improve aerodynamic models used for wind turbine design. Therefore the participants conducted a thorough investigation of the measurements that were carried out in the EU sponsored MEXICO project. Special attention was paid to yawed flow, instationary aerodynamics, 3-D effects, tip effects, non-uniformity of flow between the blades, near wake aerodynamics, turbulent wake, standstill, tunnel effects, etc. These effects were analyzed by means of different categories of models (CFD, free wake methods, engineering methods, etc.). A comparison of the MEXICO findings with the findings of the NASA-Ames and other experiments was also carried out. As such, the Task has provided insight on the accuracy of different types of models and (descriptions for) improved wind turbine models. In order to reach the objective, the workplan was divided into five work packages:

- WP1: Processing/presentation of data, uncertainties. The aim of this work package was to provide high quality measurement data to facilitate and compare calculations. To that end, the quality of the data is assessed and the data was reprocessed.
- WP2: Analysis of tunnel effects. The 4.5-m diameter wind turbine model was placed in the open jet section of the LLF facility (9.5 m x 9.5 m). This ratio of turbine diameter over tunnel size may make the wind tunnel situation not fully representative of the free stream situation. Therefore, tunnel effects were studied with advanced CFD models.
- WP3: Comparison of calculational results from different types of codes with MEXICO measurement data. In this work package, the calculational results from the codes that are used by the participants were compared with the data from the MEXICO experiment.
- WP4: Deeper investigation into phenomena. In this work package, a deeper investigation of different phenomena took place. The phenomena were investigated with isolated sub-models, simple analytical tools, or by physical rules. The phenomena which were investigated included 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 and rotational effects.
- WP5: Comparison with results from other (mainly NASA-Ames) measurements. The results from WP3 and WP4 provided many insights on the accuracy of different codes and their underlying sub-models. Within WP5 it was investigated whether these findings are consistent with results from other aerodynamic experiments, particularly the data provided within IEA Wind Task 20 by NREL (i.e. the NASA-Ames experiment).

Table 1. Task 29 participants

	Country	Institution(s)*
1	Canada	École de technologie supérieur, Montreal (ETS), University of Victoria (Uvic)
2	Denmark	Risø National Laboratory (Risø-DTU) and DTU (MEK)
3	Germany	University of Stuttgart (IAG), University of Applied Sciences at Kiel, ForWind, Windguard
4	Japan	Mie University/National Institute of Advanced Industrial Science (Mie/AIST)
5	Korea	Korea Institute of Energy Research (KIER) and Korea Aerospace Research Institute (KARI)
6	the Netherlands	Energy Research Center of the Netherlands (ECN), Technical University of Delft (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) and National Institute for Aerospace Technology, INTA
9	Sweden	Royal Institute of Technology/University of Gotland (KTH/HGO)
10	the United States	National Renewable Energy Laboratory (NREL)

* Technion in Israel is a subcontractor to Task 29.

3.0 Progress in 2011

In 2011, the project was completed and a final report prepared. This report will be published at www.ieawind.org in 2012 after it has been approved by the IEA Wind Executive Committee.

Instead of making various task reports for the different Work Packages it was decided to make one coherent final report in which all Work Packages reports are included. Apart from the Work Package descriptions it includes all comparisons between calculations and measurements together with an analysis of these comparisons. The calculational models are also described and where possible the explanation between calculations and measurements is related to model differences.

The main conclusions and results from the project as described in the final report are:

- Aerodynamics is very important for the successful employment of wind energy
- It is the combination of measurements of detailed aerodynamic loads and detailed flow field which makes the MEXICO experiment unique and an assessment could be made of several codes on basis of loads and velocity measurements
- At first sight the agreement between calculated and measured loads is less than expected from other projects (e.g. the blind comparison from IEA Wind Task 20). Further analysis shows that the calculational results from IEA Wind Task 20 were generally more randomly distributed in a wide spread around the measured results. In MEXNEX(T) the level of disagreement is of the same magnitude but it is striking to see that all loads along the blade are consistently over predicted. The availability of velocity measurements made it possible to find a 'direction' for the explanation: The relation between loads and velocities does not seem to obey the momentum relation and a vortex shedding is found at the inner part of the blade,

possibly due to a change in airfoils. Although some codes do predict some vortex shedding, they do not predict the impact on the velocity field in agreement with the measurements.

• Despite the fact that some results are not understood it is extremely important to note that generally speaking the understanding of the 3-D flow field around a wind turbine and the near wake has increased enormously. Furthermore it was, for the first time, possible to validate the flow details around a wind turbine with design codes. These details were predicted extremely well, even in yawed conditions.

• All engineering codes under-predict the loads at stalled conditions. The same was found in the comparisons made with measurements from IEA Task 14/18 and NREL Phase VI (NASA-Ames). It was found that CFD predicts these loads better. CFD also predicts the loads under yawed conditions better than most engineering models.

• Directions have been given for engineering model improvement: stall delay effects should be enhanced and the tip speed ratio dependency in the Prandtl tip loss factor should be adjusted. Furthermore, in case of asymmetric flow, the velocities at a particular blade should include the velocities induced by the bound vortex of the other blades.

• The Mexico data analyzed in MEXNEX(T) are stored in a reported database, which, after signing an NDA is made accessible to outside parties;

• The MEXICO experiment was repeated on two smaller scales which led to insights in scaling effects

• Results have been published and presented in at least 27 papers and articles, see (10), (11), and (15) to (39).

The main recommendations as described in the final report are that aerodynamic validation material is far too limited. Much more detailed aerodynamic measurements are needed, both in the field (full scale) as well as in the wind tunnel. Details should be measured of the flow field, pressure distributions and loads, boundary layer, and noise sources.

With regard to noise sources, it should be realized that the acoustics of a wind turbine are 'driven' by the aerodynamics. As such a good understanding of the acoustics requires detailed acoustic measurements in combination with detailed aerodynamic data. New measurements under a 'New Mexico' activity are needed including flow field measurements of the inner part in order to solve the problem of the non-understood relation between loads and velocities.

4.0 Plans for 2012 and beyond

MEXNEX(T) Phase 1 is finished. However, all participants expressed their wish for a follow-up IEA Wind Task on aerodynamics. This resulted in a proposal for a second phase of the task, MEXNEX(T)-II, which was approved at the 68th IEA Wind Executive Committee meeting. In addition to the MEXNEX(T) Phase I participants, China has also expressed interest in joining MEXNEX(T)-II.

Generally speaking MEXNEX(T)-II consists of two elements:

1. An inventory and further analysis of ALL historical aerodynamic wind turbine measurements (where history ranges from very past to very recent, and includes the MEXICO experiment). This is believed to lead to the maximum possible understanding of wind turbine aerodynamics. In principle, no new measurements are foreseen apart from PIV measurements on the scaled down MEXICO rotor from INTA. Furthermore, under the condition that funding can be secured, the scaled down MEXICO rotor from Kier will be placed in the TUDelft Open Jet Facility where PIV measurements will be performed. These measurement will confirm or contradict the findings on the MEXICO rotor and they will anyhow lead to additional insights on the non-understood phenomena.

2. Brainstorming workshops on aerodynamics. These workshops will be organized in conjunction with EERA (a European program which aims to align the programs of various research institutes).

Some of the questions from the MEXNEX(T) project can only be answered with additional dedicated measurements. Therefore, a proposal has been made by all MEXNEX(T) participants for the European Union aerospace project ESWIRP, see http://www.eswirp.eu/.

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9 Task 30

Offshore Code Comparison Collaboration Continuation (OC4)

Photo by Amber Taylor

1.0 Introduction

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

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

The Offshore Code Comparison Collaboration (OC3), which operated under Subtask 2 of the IEA Wind Task 23, was established to meet this need. Task 23 was completed in 2009; in 2010, a new task - Task 30 OC3 continuation (OC4) project was established to continue the work. Task 30 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, 84 individuals from 35 organizations in 14 countries have contributed to 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

Table 1. Task 30 Participants		
	Country	Institution(s)
1	China, CWEA	China General Certification Center
2	Denmark	DTU Wind Energy, campus Risø, DHI
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
7	The Netherlands	Energy Research Centre of the Netherlands (ECN), The Knowledge Centre WMC, GustoMSC, TU Delft
8	Norway	Center for Ships and Ocean Structures at Norwegian University of Science and Technology (NTNU), FEDEM Technology, Institute for Energy Technology, Marintek
9	Spain	Acciona Energia, ALSTOM Wind, CENER, SAMTECH
10	United States	ABS, National Renewable Energy Laboratory, Principle Power, MSC Software, Texas A&M University, Clear Path Energy
	Observers	SAMTECH, Belgium; Pohang University of Science and Technology, University of Ulsan, Korea; GE Wind, Teknikgruppen, Sweden; GL Garrad Hassan, UK

- Identifying further research and development (R&D) needs.

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 Task 23 OC3, and now again in Task 30 OC4, the "NREL 5-MW offshore baseline turbine" (1) is used as the turbine model. Emphasis is given to the verification of the offshore support-structure dynamics as part of the dynamics of the complete offshore wind turbine system. This emphasis distinguishes OC3 and OC4 from previous wind turbine code-to-code verification activities. To encompass the variety of support structures required for cost effectiveness at varying offshore sites, different support structures (for the same wind turbine) are investigated in separate phases of the projects. In OC3, four phases were used to consider (I) a fixed-bottom monopile with rigid foundation, (II) a fixed-bottom monopile with flexible foundation, (III) a fixed-bottom tripod, and (IV) floating spar buoy. The results of the OC3 project are summarized in its final report (2). OC4 consists of two phases that were not considered in OC3: (I) analysis of a wind turbine on an offshore fixed-bottom jacket and (II) analysis of a wind turbine on an offshore floating semisubmersible (see Figure 1). Additionally, 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 2011

The project had two physical meetings in 2011; the first was in conjunction with the ISOPE conference in Maui, Hawaii, United States, in June. The second meeting was held in conjunction with the European Wind Energy Association (EWEA) offshore conference in Amsterdam, the Netherlands, in December. In between physical meetings, progress was made through e-mail communication and Internet-meetings scheduled every one to two months. Since the project's initiation, many new countries joined IEA Wind Task 30, for a total of 10 committed countries. A few countries are still considering joining as of February 2012.

Significant progress was made on Phase I of the project, the analysis of a wind turbine on an offshore fixed-bottom jacket. The fixed-bottom jacket system design analyzed in Phase I of OC4 was finalized and disseminated to the project participants. The specification consists of the geometry, mechanical properties, hydrodynamic coefficients, and marine growth of the jacket. The OC4 jacket was based on the jacket designed by Rambøll for the UpWind project (3). The jacket was designed to support the NREL 5-MW offshore baseline wind turbine (1). The load cases

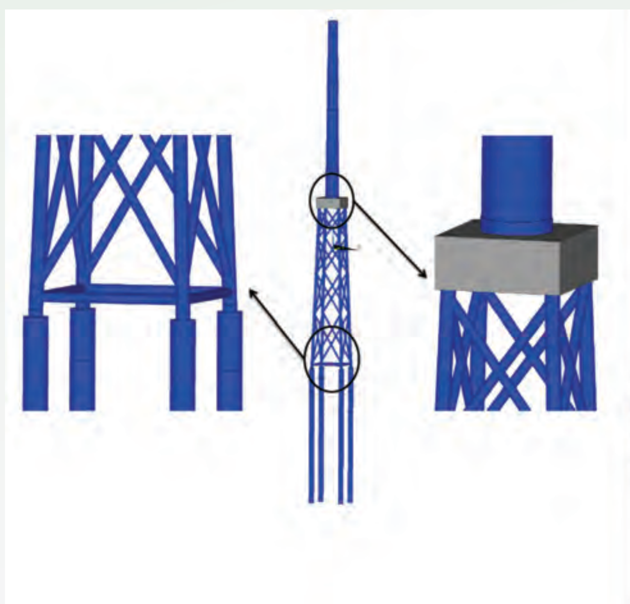

Figure 1. Offshore wind system designs analyzed in Task 30, OC4

(b) Floating Semisubmersible to be Analyzed in OC4 Phase II analyzed in Phase I were finalized 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. Stochastic wind files were generated and disseminated to participants for use in the simulations.

Using the Phase I jacket system design, sixteen different organizations have now run some to all of the cases described for this phase. Simulation results have been presented in the Internet-meetings, and the reasons for discrepancies between the results have been discussed. Comparison of the results has been made through component masses, system eigenfrequencies, static loads, time histories, spectra, statistics, and damage equivalent loads. Several rounds of revisions have been made by the participants 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 analysis has been submitted by the OC4 committee for presentation at the ISOPE conference in June, 2012 (4).

The configuration of the semi-submersible design to be used for Phase II was decided at the June physical meeting by a vote. The choices were between designs developed for the DeepCwind project in the U.S. and the design to be used in the HiPRwind project in Europe. The decision was made to use the DeepCwind design, primarily because of the open availability of the design. A presentation on the specifications of the design was given at the December physical meeting. Suggestions were made on how to refine the design further and these design refinements are ongoing.

Planning has begun for the experts meeting on validation. The meeting will take place 15-16 May 2012 in Boulder, Colorado, United States near NREL. Invitations were sent to potential participants and speakers.

A SharePoint website (oc4.collaborationhost.net) was established for the exchange of data related to this project. The website contains all material related to the project (meeting presentations/minutes, model and load case descriptions, and simulation results). The majority of the website is open to anyone who requests a password, with the exception of the simulation results, which are restricted to only participants from those countries who have formally committed to joining this project. All information from the Task 23 OC3 project was also uploaded to the OC4 SharePoint site, including: meeting presentations/minutes, model descriptions, simulation results, and publications from all of the phases. Public information from Task 23, OC3 activities remains on the www.ieawind.org web.

Many participants of OC4 who were also actively involved in the OC3 project under IEA Wind Task 23 Subtask 2 have worked on a journal article summarizing the OC3 project's process and important results. This article is being considered for publication in *Wind Energy.*

4.0 Plans for 2012 and Beyond

IEA Wind Task 30 will last for three years. Each phase will last for about two years, with one year of overlap in the middle. Phase I of the project is scheduled to be completed in the spring of 2012, with a conference paper to be presented at the ISOPE conference in June 2012 in Rhodes, Greece. Additional papers will be created on the results of the experts meeting and 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. The DeepCwind semi-submersible design to be used in this phase will be described in a specification report, to be released to members in the spring of 2012. The details of this design will be discussed and refined at the next physical meeting in June 2012. Analysis of this design will then begin in the months following this meeting after a final design is decided and the load cases to be run are defined. A second physical meeting will be held in the fall/winter time-frame of 2012.

The topical experts meeting will take place on 15-16 May 2012 in Boulder, Colorado near NREL's National Wind Technology Center. The purpose of the meeting will be to bring experts together to discuss the issues associated with validating a model of an offshore wind system, and decide a path forward to collaborate on these issues, potentially through a new IEA Wind task.

The verification activities that were performed in OC3 and are continuing in OC4 are important because the advancement of the offshore wind industry is closely tied to the development and accuracy of dynamics models. Not only are vital experiences and knowledge exchanged among the project participants, but the lessons learned have and will continue to help identify deficiencies in existing codes and needed improvements, which will be used to increase the accuracy of future predictions.

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

10 Task 31

WAKEBENCH: Benchmarking Wind Farm Flow Models

1.0 Introduction

Since the late 1980s with the appearance of the European Wind Atlas (1), the standard model for wind resource assessment has been the Wind Atlas Analysis and Application Program (WAsP) with its Wind Atlas Methodology. The model, based on a linearization of the Navier Stokes equations originally introduced by Jackson and Hunt (1975), is meant to be used reliably in neutral atmospheric conditions over mild terrain, with sufficiently gentle slopes in order to ensure fully attached flows. Nevertheless, due to its simple usage and the increasing experience of the users with the model, WAsP has also been used in situations out of its range of applicability.

The alternative to linear models, such as 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. The application of CFD in wind resource assessment is still largely based on Reynolds average Navier Stokes (RANS) (2) turbulence models because large-eddy simulation (LES) (3) still remains far more costly and few academic simulations have been made in small sites. CFD models based on steady RANS simulations are being developed for wind resource assessment in order to complement linear models in complex terrain and other complex flow situations (wakes, forests, obstacles, etc.).

Using CFD in operational wind resource assessment is less than 10 years old and a large variety of commercial and research models are in the market. Yet, the transition from traditional linear models requires significant training and experience from the user. This is 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 1980's with work by Ainslie (1988) (4). 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. This 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. The simplest is a drag element that extracts momentum and injects turbulence over a few simulation grid points. These models often use mesoscale models with larger domains to determine macro influences of large wind farms. The next level of complexity is blade element momentum-based models that calculate blade forces and the wake influence using a global momentum balance. The forces in these models are then distributed around a disk and the influence of axial and rotational momentum is then propagated into the wake. Such a model can also be coupled to a wake meandering model that predicts the unsteady oscillation of the wake as it moves downstream. As turbine models get more complicated, the details of the blade aerodynamics become more prevalent. Recent calculations of multiple turbine interactions have used actuator line methods, where the blades are treated as airfoils distributed along rotating lines. Various other inviscid calculations of blade aerodynamics can also be used, including panel methods and boundary element methods that directly calculate the blade forces instead of using airfoil lookup tables.

With the need to calculate viscous aerodynamics of the blades, researchers have moved into CFD modeling. As with wind models, researchers have used RANS, unsteady RANS, detached eddy simulation (which is a hybrid between RANS and LES), and even full LES of rotating blades. Researchers have also created computational domains where the rotor plane is treated as a viscous area and the downstream region treated as inviscid, which can lead to significant savings of computational time. Although, typically the more detail contained in the turbine model, the smaller the simulation due to constraints of computing resources.

In both wind and wake modeling, the model developer has to design a model evaluation strategy to prove that the model is correctly formulated (verification) and to provide 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 (5). The adoption of VV&UQ procedures is an unresolved issue in wind resource assessment due to the inherent complexity of the system to model. The main difficulties are threefold: first, the domain size requires large wind tunnels and computer clusters, second, the wind conditions are the result of the interaction of a wide range of spatial and temporal scales, and third, the simulation of open flow fields produces ill-defined boundary conditions.

As stated in the COST 732 Action (2009) report on micro-scale model evaluation (6), there is neither a distinct definition of the requirements of a validation test case dataset nor 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 because most of the microscale wind assessment models are based on steady-state simulations. 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 of the partners of the project. These inter-comparison case studies will produce enough background information for the discussion of the VV&UQ strategies.

2.0 Objectives and Strategy

The Task 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 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 types 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 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 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 2011

Task 31 was approved by the IEA Wind ExCo in October 2010. Since then, the

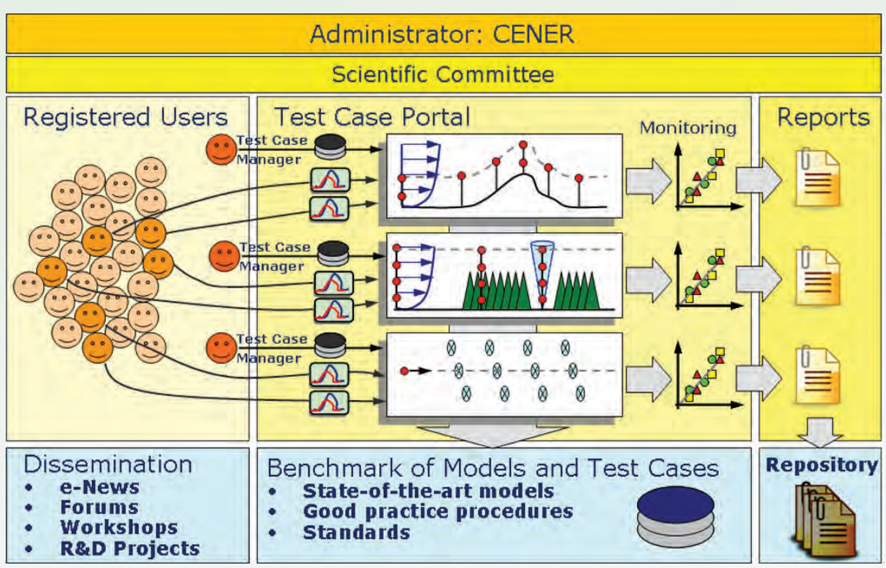

Figure 1. Sketch of the "WINDBENCH" webportal for management of test cases

OAs have been collecting expressions of interest from potential participants in the Task. In the first year of operation, the task has collected expressions of interest from more then 80 organizations. Canada, Denmark, China, Greece, Italy, Japan, Norway, Spain, Sweden, Switzerland, U.K., and the U.S. have joined the task. The Netherlands and Germany have agreed to send letters of participation, and Ireland, Finland, and the Republic of Korea are considering joining.

4.0 Plans for 2012 and Beyond

Besides the consolidation of the participants in the Task, 2012 will be devoted to the design of a detailed work plan. To this end an inventory of test cases will be elaborated and a schedule of basic simulations will be designed in order to get acquainted with the models and the evaluation protocol.

The first deliverable of the Task will be the Evaluation Protocol for Wind Farm Models. The first draft will be discussed at the NREL workshop with the goal of releasing the first edition by the end of 2012. This document will be used in the remaining years of the Task to guide participants during the model inter-comparison benchmarks.

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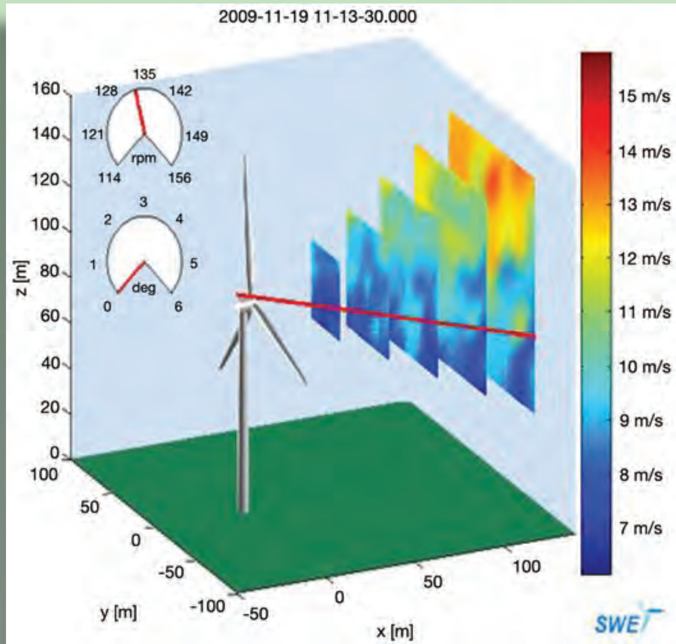
11 Task 32

LIDAR: Wind Lidar Systems for Wind Energy Deployment



1.0 Introduction

The aim of IEA Wind Task 32 is to address the very fast development of wind lidar technologies and their applicability for more accurate measurement of wind characteristics relevant to reliable deployment of wind energy power systems. The purpose is to bring together actors in the research community and 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 until today despite several research projects during the last years. Secondly, the spread of several new commercial lidar systems with different specifications makes it very difficult for the community to keep up with the advances of this specific technology. Finally, a large number of new applications only possible with wind lidar systems are being developed. However, their real potential cannot be assessed nor exploited without strong work between the research community and the industry.The present state of the lidar technology (Figure 1) can be summarized as: follows.

Several commercial and research systems are available. At the moment, all but one of these are based on the coherent detection principle. The majority of the commercial systems available today are built on a pulsed (range-gated) measurement technology. There already exists quite a fair amount of verification data, which have been, or are being, measured by high-quality calibrated standard meteorological masts, of heights up to 100+ m. This serves as a basis for comparison of wind lidar system performance.

Ground-based lidar systems using the Velocity Azimuth Display (VAD) mode offer high correlation of the measured mean wind speed with conventional cup anemometry in flat terrain. This has been supported by extensive comparison studies (1).

Today, there is high confidence in wind lidar measurements performed over flat terrain and fair atmospheric conditions. In complex conditions, however, there are needs for better site characterizations and corresponding mitigation of errors due to non-homogeneities in the flow fields.

An outstanding issue is also that lidar and conventional wind anemometry (e.g., cups) measure turbulence differently. This becomes evident when vertical profiles of turbulence measured by lidars are compared with turbulence measured by conventional instrumentation (2, 3). Accurate turbulence measurements are important for assessment of site-specific design conditions and wind turbine loads.

Most of the lidar systems at present have been developed for ground operation as replacement for conventional anemometry. However, new applications such as power curve measurement, load estimation, and wind turbine control make use of less standard approaches from the nacelle (4), spinner hub (5), or even blade-integrated. Likewise, floating lidars are under development to replace extremely expensive bottom-mounted offshore met towers.

New developments are being tested:

- Nacelle-based systems for control of wind turbines (6) and power curve measurements
- Systems based on multiple synchronized lidar devices for 'true' three dimensional measurement
- Lidar measurements inside and in the wakes of wind farms

2.0 Objectives and Strategy

The proposed activities build upon the discussions and work already performed in regards to lidar technology during the 51st (2007) and 59th (2009) IEA Wind Topical Expert Meetings on remote wind speed sensing techniques using sodar and lidar. Task 32 will only consider lidar systems even though sodar is also a remote sensing technique that was considered as an alternative to lidar systems in the IEA

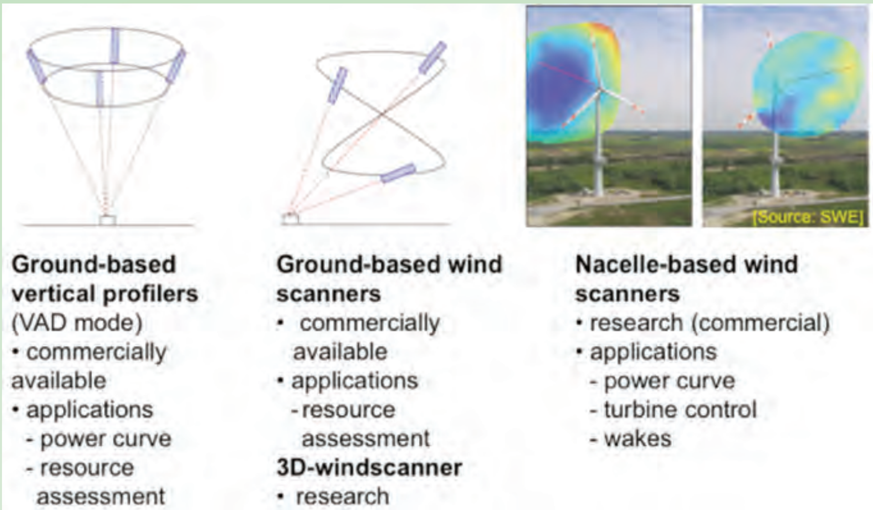


Figure 1. State of the art lidar technology

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 suitable for power curve assessment, are not useful for nacelle-mounted approaches, and do not include a scanner system. Task 32 will consequently address wind lidar technology only, with efforts and resources focused on a few detailed topics.

The understanding gained in IEA Wind Task 32 will be collected and summarized in an IEA Wind Recommended Practices for Lidar Measurements that will be published in two editions. The first edition, expected by the end of 2012 or the beginning of 2013, will deal with standard procedures for the assessment of wind conditions in flat terrain. The second edition 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 (to be published in 2014).

Task 32 is will have four subtasks, which have been selected as the most relevant at present (Figure 2).

2.1 Subtask I: Lidar measurements

Comprehensive efforts have recently been undertaken to quantify the accuracy of lidar measurements and their comparability with standard anemometry. This has revealed a high complexity, which reflects different sources of error, compared to standard anemometry. The sources for uncertainty have to be properly assessed in order to provide reliable measurements. Guidelines are needed to perform such assessments because the different technologies applied and the fast development of new methodologies and systems make comparability difficult to the end-user.

Subtask I will request all participating institutes to re-run their calibration processes adopting other procedures already developed for lidar systems by other member organizations. This will reveal the benefits and issues of performing cross-calibrations. This will lead to refined procedures and to new and commonly approved wind lidar calibration procedures. This task can benefit from the results of several national and European projects.

2.2 Subtask II: Wind conditions

Comparisons between lidar systems and standard anemometry have shown good correlations concerning the average wind speed time averaged over a ten-minute period over flat terrain. This high degree of correlation between the mean quantities is however not possible to attain with the stochastic turbulent quantities, such as turbulence intensity.

Subtask II will bridge the gap of understanding, by studying new ways to make a more comprehensive description of turbulence, which will be directly usable at the industrial level. In addition, the subtask will evaluate 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. 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.

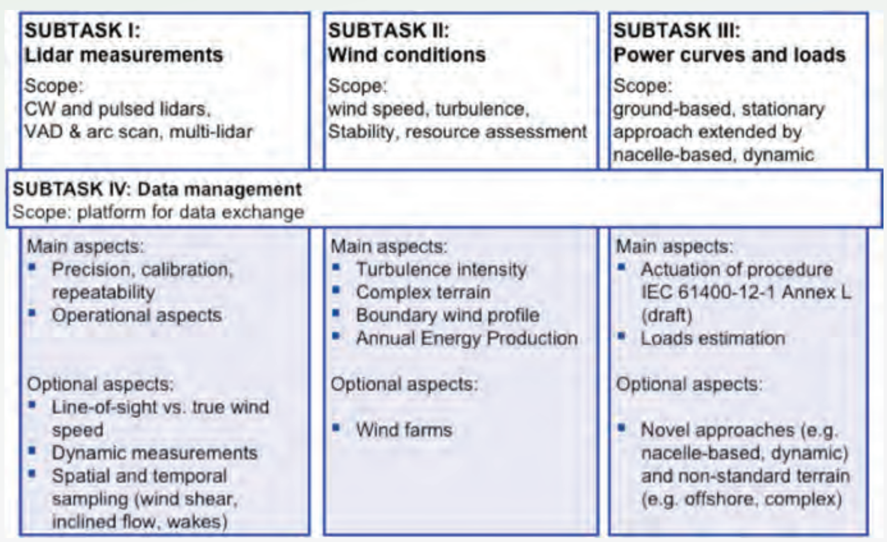


Figure 2. Scope and contents of the four subtasks

2.3 Subtask III: Power curves and loads

Recent research results have demonstrated the need for more comprehensive measurements of the power curve of wind turbines. It has been shown that the wind shear has an important effect on the uncertainty of power curves. The shear can be estimated with ground-based or nacelle-based lidar systems. The first makes part of the recommendations for remote sensing measurements of the IEC-61400-12-1 Annex L.

Subtask III aims at evaluating the present state of the art recommendations to include wind shear effects in the assessment of power curves. Moreover, it will look at the different new nacelle-based approaches and assess their accuracy and scope of applicability. The aim is to use a properly normalized set of data, which will be exchanged and could be used to estimate a wind power curve at a particular, hopefully standard, site with an application of different recommended methods. The advantages and disadvantages of the methods could be then seen. Furthermore, efforts will be spent in the study of possible lidar-based methods to estimate the mechanical loads acting on a wind turbine.

2.4 Subtask IV: Data management

This subtask is proposed as a cross-cutting activity to establish and coordinate 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. First, pure vertical wind speed profile measurements, and second, 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 2011

IEA Wind Task 32 was approved by the IEA Wind ExCo in October 2011. Since then, the operating agent (manager) has been collecting expressions of interest from potential participants. By the end of December 2011, 17 institutions from eight countries have indicated their interest and three participants – Denmark, Japan, and the United States – have submitted their formal Notice of Participation to the IEA Executive Director.

4.0 Plans for 2012 and beyond

The kick-off workshop of IEA Wind Task 32, where the final work program will be agreed upon, has been scheduled for early spring 2012. Besides the consolidation of the participants in the Task, the coming year will be devoted to establishing the exchange procedure of lidar measurement data and to starting the cross-calibration among the participants. Therefore the focus of the work will be on the subtasks on lidar measurements and data management. The activities in the two other subtasks will begin in the second half of 2012. In addition, the preparation of the first edition of the IEA Wind Recommended Practices for Lidar Measurements has been scheduled for 2012.

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12 Task 33

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

1.0 Introduction

The formation of Task 33 Reliability Data was approved by the IEA Wind Executive Committee in October 2011. It will continue for a period of three years beginning in 2012.

Experience has shown that reliability and operation and maintenance (O&M) procedures can be improved (and costs reduced) when maintenance strategies are based on sound statistical approaches. Task 33 deals with standardized, well-structured databases for optimizing reliability and O&M procedures. It addresses the different developments of data collection and failure statistics to agree on standards and overall structures. The purpose is to bring together the present actors in the industry and research community to create synergies and agreements in the many R&D activities already on-going in the field of statistical failure analysis.

Task 33 aims to:

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

2.0 Objectives and Strategy

High reliability of wind plants guarantees a high degree of operating and personal safety, high system availability, and low necessary maintenance. These characteristics are important to reducing the cost of energy from wind plants. Modern onshore wind turbines attain high technical availability of up to 98% (Figure 1). Evaluation of maintenance activities in operating wind projects shows, however, that high availability requires additional maintenance work, which can be costly. Moreover, offshore wind farms with their increased difficulty of access for maintenance, stimulate the demand for improved reliability while keeping maintenance requirements low.

Maintenance of wind turbines is currently planned and carried out according to statutory requirements and rough guidelines from manufacturers. Unplanned maintenance measures due to sudden malfunction of components can cause serious economic losses, especially offshore. Experience, however, has shown that reliability and O&M procedures can be improved when maintenance strategies are based on sound statistical approaches.

Statistical analyses of O&M data of wind turbines and their components can be used to identify weak points and to define maintenance services at an early stage. Maintenance strategies should be shifted from unplanned and corrective measures to more preventive measures based on experience acquired at many locations.

To take full advantage of historical data on reliability, a semi-automated and highly-simplified data management approach is needed. Effective analysis to improve reliability and maintenance requires more parameters, data, and additional information than we see collected today. Electronically supported reporting by service teams will be necessary to supply this increased detail.

2.1 The Data

A renowned wind turbine failure statistic database has been established in the scientific measurement and evaluation program Wissenschaftliches Mess- und Evaluierungsprogramm (WMEP), included in the German subsidy measure 250 MW Wind (2). The WMEP database contains a large quantity of O&M data and detailed information about both the reliability and availability of wind turbines. It provides the most comprehensive study of the long-term reliability behavior of wind turbines. It records the most trustworthy characteristic reliability parameters published to date: mean time between failure (MTBF) and mean time to repair (MTTR).

Besides the WMEP database there exist more publicly available sources of

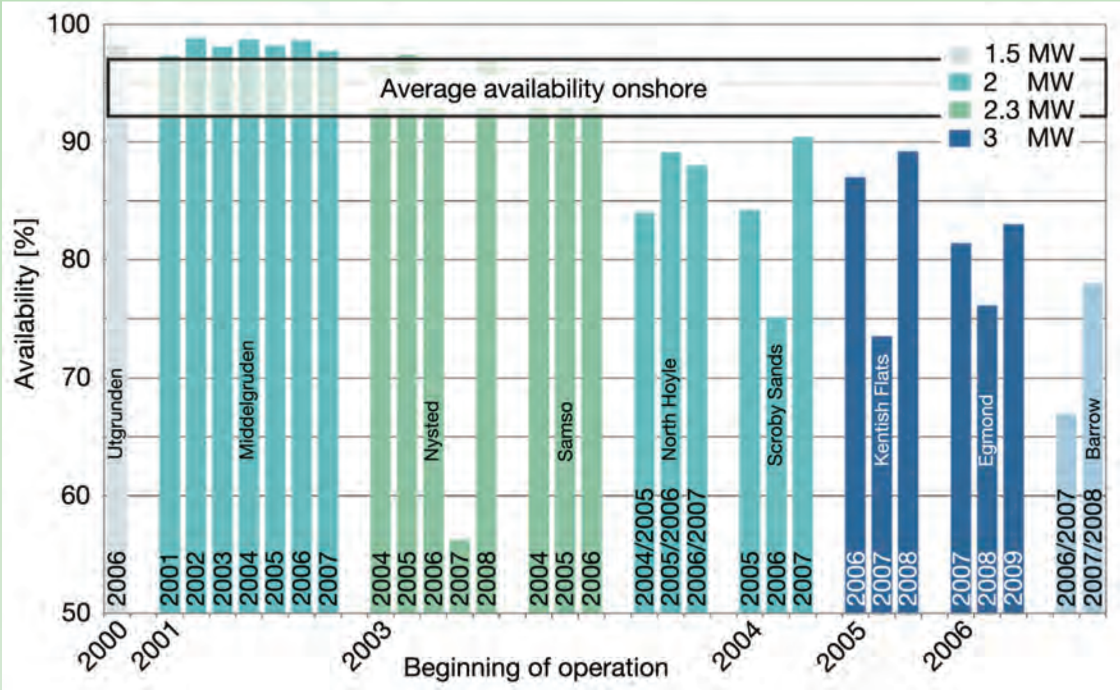

Figure 1. Availability of onshore and offshore wind turbines (1)

experience. However, these databases differ from each other in monitoring period, number, size, and type of wind turbines. They differ in the definition of subassemblies and failures, in the level of detail, and in the overall structure. Nevertheless, surveys have been compared with one another, including WMEP, Windstats Germany and Denmark, Landwirtschaftskammer Schleswig-Holstein (LWK) Germany, Elforsk Sweden, and VTT Finland. It has been found that, despite their differences, there is agreement to a certain degree. However, the loads on wind turbine components differ due to the technical concepts and site conditions, which lead to a dispersion of results.

None of the publicly available failure databases are detailed and large enough for appropriate reliability analyses. Even with a broad database, like WMEP, the breakdown in concept groups, power classes, site conditions, etc. lead to a point where the statistical basis is insufficient. Different lifetime expectations of the components and a spread of results are due to different strains on the wind turbine components, (e.g., because of the technical concepts in use or different site characteristics), but also due to the use of identical and similar components from different manufacturers. This shows the need for broader databases and for appropriate standard data structures.

2.2 Cooperation

Today, there is insufficient co-operation among wind industry stakeholders: operators, manufacturers, component suppliers, designers, service providers, and researchers. Such co-operation brings great benefits and is common in other industries such as aerospace. To use experience on wind turbine O&M to improve the result, steps must be taken to gather the available knowledge. Although wind energy has been used widely in recent years, common standards for the documentation of O&M measures as well as for a uniform structure of databases are still missing.

So far, data collection for operators is quite limited. It exists mostly as written reports from manufacturers or service companies with brief descriptions or with encoded descriptions. The reports are usually not detailed enough for analysis and have no failure analysis. This lack of structure in reporting makes it difficult to carry out an effective and optimized maintenance based on analysis of the past. It is therefore essential to pursue a standardized form of data. The biggest challenges are to implement systematic collection of data, uniform description of sub-assemblies, and description of operating conditions, malfunctions, and failures equally.

Several national initiatives now aim to collect failure information for reliability analyses, e.g., Offshore~WMEP (3), Reliawind (4), EVW (5), Sandia CREW database (6), and OREDA database (7). They all (except (7)) intend to establish a database for wind turbine failure statistics. Task 33 will endeavor to coordinate these effort to ensure that the results may be combined to increase the statistical basis available for analysis. All initiatives share the following crucial issues:

1. Which data are to be collected?
2. What data are needed for the different analyses?
3. How to implement a system to collect information in an appropriate, structured, detailed, and strongly automated way?

2.3 Uniform reporting

Uniform labeling of components and operating systems and the systematic storage of errors and data will allow the management of standardized, electronic logging of events. This will simplify the monitoring process, improve financial and technical reporting, and increase cooperation with similarly oriented businesses. Detailed documentation of maintenance measures for many plants and a purposeful structured database are necessary to draw sound conclusions from the operational experience. This standard way of documenting and collecting data provides experience to apply when optimizing availability of wind turbines through design and construction and through effective O&M.

Validity of reliability data can be achieved, by using detailed, systematically recorded operation and maintenance data that has been processed with standardized and electronically aided protocols. However, only large amounts of information will allow identification of weak points and development of meaningful statements on the failure probability of certain components. Only such a large database allows improving and optimizing maintenance strategies. For this reason, defined and standardized structures are indispensable for comparing or merging different databases. Analyses of captured information from collaborative databases provide resilient figures for detecting weak points and cost drivers as a basis for decision-making processes. As a result, components can be qualified in cooperation with manufactures and suppliers and statements about the probability of failure behavior can be made.

3.0 Progress in 2011

The task was approved in late 2011 and interested parties began sending letters of participation.

4.0 Plans for 2012 and beyond

The new Task 33 Reliability Data will begin its work in 2012 and continue for a period of three years. To optimize reliability and availability of wind power plants, this task will work to standardize data collection and will compare different data sources. To do this collaborations will be established among the different initiatives to share or group some of the data. The three subtasks 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.

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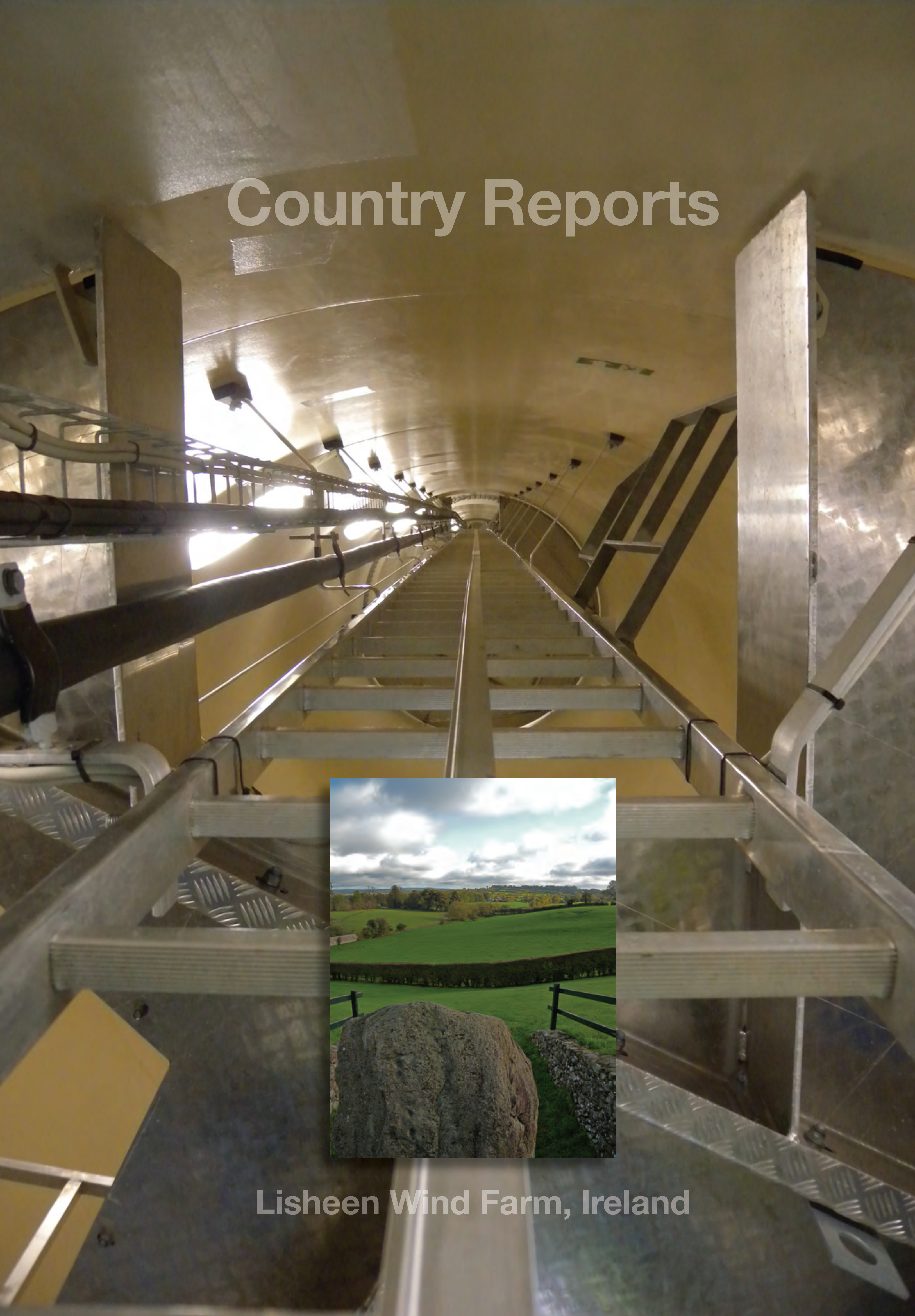
Country Reports



Lisheen Wind Farm, Ireland

13 Australia


Source: REpower

1.0 Overview

The Australian continent boasts some of the best wind resources in the world, courtesy of the Roaring Forties winds blowing hard onto the country's southern coastline. Wind energy continues to make a significant contribution to Australia's clean energy mix and now supplies over 6,400 GWh annually – more than 2% of the nation's overall electricity needs and the equivalent of more than 900,000 average Australian households.

Although the cost of wind energy continues to fall, government support is crucial in supporting investment in the industry and enabling wind to play a major role in helping Australia transition to a low carbon economy. The country's Renewable Energy Target (RET) is designed to deliver 20% of Australia's electricity by 2020 and a price on carbon will begin in mid-2012. The RET is expected to unlock more than 20 billion AUD (15.7 billion EUR; 19.7 billion USD) in investment over this decade. As the lowest cost form of large-scale renewable energy, much of this target is expected to be met with investment in wind energy.

At the close of 2011 Australia had 58 wind farms with a total operating wind capacity of 2,224 MW. Five new projects were commissioned in 2011, adding another 234 MW of capacity to the Australian electricity grid. Seven projects were under construction as at the end of 2011 and are expected to contribute an additional 1,060 MW within the next three years. Another 18,000 MW of projects are currently

Table 1. Key Statistics 2011: Australia	
Total installed wind generation	2,224 MW
New wind generation installed	234 MW
Total electrical output from wind	***6.4*** TWh
Wind generation as % of national electricity demand	2.4%
Average capacity factor	
Target:	The expanded Renewable Energy Target, (45,000 GWh from renewables by 2020) commenced in 2010.
Bold italic indicates estimates.	

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 expanded RET replaced the previous Mandatory Renewable Energy Target (MRET) on 1 January 2010. Its target was four times that of the original scheme which was introduced in 2001. The aim of the RET is to set aside a share of the electricity market to be filled by clean energy technologies. Its aim is to bridge the gap between the costs of renewable energy and the price of black electricity. Renewable energy generation under the RET scheme creates Renewable Energy Certificates (RECs) which must be surrendered each year by electricity retailers as prescribed by the RET legislation.

In June 2010, the Australian Parliament passed legislation to separate the enhanced RET into two parts – the Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES). These schemes commenced operating on 1 January 2011. The LRET and SRES together are expected to deliver more than 45,000 GWh of renewable energy in 2020.

In 2011, the Australian government legislated a price on carbon that will be the foundation of a national strategy to limit carbon pollution. From 1 July 2012, a fixed carbon price will start at 23 AUD (18 EUR; 17.7 USD) per ton (indexed annually at 2.5%) for three years then transition to an emissions trading scheme from July 2015. Around 500 companies - those that emit more than 25,000 tons of CO_2-e emissions each year - will be liable under the carbon pricing mechanism. Sectors covered by the carbon price include stationary energy, waste, industrial processes, and fugitive emissions.

Half of the income raised from the carbon pricing mechanism will be spent on assisting households to adjust to the impacts of the carbon price and the other half will be spent on supporting jobs and investing in clean energy programs. The carbon price mechanism will provide support to the wind industry via increases in wholesale electricity prices. The federal government will create an independent body, the Climate Change Authority, which will track Australia's pollution levels and provide independent advice on the performance of the carbon price and other initiatives.

2.2 Progress

The cumulative installed wind capacity in Australia has increased markedly since 2000. The amount of installed capacity of wind power has experienced an average growth of around 35% per annum over the past five years.

At the close of 2011, there were 58 wind farms (with two or more turbines) in Australia, with a total of 1,211 operating turbines. The estimated annual wind generation output in Australia from the 2,224 MW of installed wind power capacity was 6,400 GWh or 2.4% of national electrical demand.

Five new projects became fully operational throughout the year, adding capacity to the Australian electricity grid. These were spread throughout Australia - Hallett 4 (AGL, 132.3 MW) in South Australia, Woodlawn (Infigen Energy, 48.3 MW) and Gunning (Acciona Energy, 46.5 MW) in New South Wales and two community wind farms - Hepburn (Hepburn Wind, 4.1 MW) in Victoria and Mt Barker (Mt Barker Power Company, 2.4 MW) located in Western Australia. An additional seven projects (Table 2) with a total of 1,060 MW are under construction and expected to be fully commissioned within the next three years.

2.3 National incentive programs

The main incentive program for wind farms is through the national RET, but South Australia has set its own renewable energy target of 33% by 2020 which provides an additional incentive for investment in the state.

As part of the Australian government's Clean Energy Future carbon price package, 10 billion AUD (7.9 billion EUR; 9.8 billion USD) of the revenue collected from liable parties will go towards the Clean Energy Finance Corporation (CEFC). The CEFC is intended to operate independent of government and provide loans for promising clean energy initiatives, helping to unlock sources of private capital. It is aimed particularly at early stage clean energy technologies such as geothermal, wave, and large scale solar.

In 2011 the federal government announced its intention to establish the Australian Renewable Energy Agency (ARENA) as an independent statutory body. ARENA will incorporate the existing Australian Centre for Renewable Energy (ACRE) and the Australian Solar Institute. ARENA will provide 3.2 billion AUD (2.5 billion EUR; 3 billion USD) of financial assistance to promote research and development, demonstration, commercialization, and deployment of renewable energy projects and will consolidate existing programs such as the Connecting Renewables Initiative, Solar Flagships Program, Emerging Renewables Program and the Renewable Energy Venture Capital Fund.

The 200 million AUD (157 million EUR; 196 million USD) Clean Energy Innovation Program will provide grants to support research and development, proof of concept, and early stage commercialization in clean energy technologies.

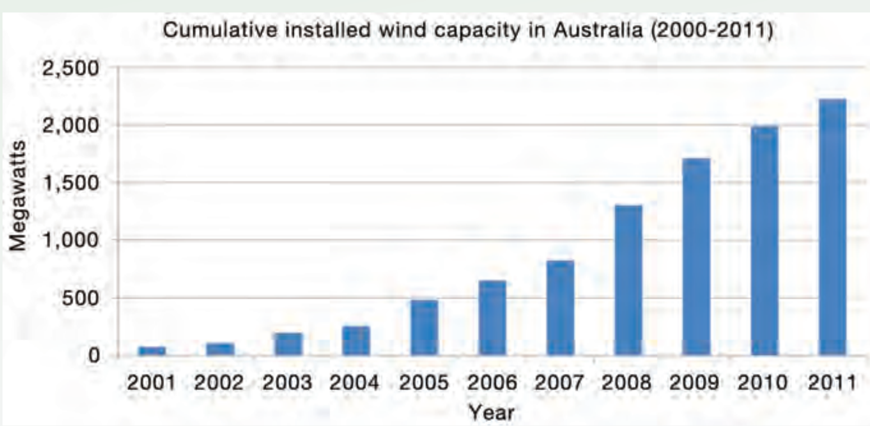


Figure 1. Cumulative installed wind capacity in Australia 2000-2011

Table 2. Wind farms under construction				
Owner	Location/Name	State	Expected commission year	Installed capacity
AGL / Meridian Energy	Macarthur	Victoria	2013	420 MW
UBS ITT/ REST	Collgar	Western Australia	2012	205 MW
Hydro Tasmania	Musselroe	Tasmania	2013	168 MW
Union Fenosa	Crookwell 2	New South Wales	2014	92 MW
AGL	Oaklands Hill	Victoria	2012	67 MW
Verve Energy & Macquarie Capital	Mumbida	Western Australia	2012	55 MW
AGL	Hallett Stage 5 (Bluff Wind Farm)	South Australia	2012	53 MW

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 (786,000 EUR; 983,000 USD) for wind farms. The scheme commenced in July 2010 and is valid for a period of four years.

2.4 Issues affecting growth

Wind energy is the fastest growing large-scale renewable energy source for electricity generation in Australia, and many wind farm projects are currently proposed across Australia. The size of projects are also increasing with some very large projects proposed. A report prepared by Garrad Hassan for the Clean Energy Council predicts that an additional 6.9 GW of wind power would be constructed under the enhanced RET. However, the low prices for the RECs, policy uncertainty around the introduction of a carbon price, and the financial crisis have made it challenging for many developers to secure financing for new projects in the past few years.

Changes and proposed changes to planning laws at state level have also introduced significant uncertainty into the industry. Changes of government in some states have resulted in proposed or implemented amendments to planning laws. Victoria has adopted a policy that requires a setback of wind farms of 2 km from residences. Other state political parties currently in opposition have also flagged their intention to introduce similar setbacks. Restrictive planning laws such as these have caused wind farm developers to reassess their planned projects in the affected areas.

Australia's electricity transmission system can present a challenge to connecting wind farms to the grid, especially in areas where there are high rates of wind penetration. Upgrades and extensions to parts of the grid are required to support the continuing expansion of the wind sector.

Table 3. Australian wind energy industry 2011 – environmental benefits	
Installed megawatts	2,224
Number of wind turbines	1,211
Average number of Australian households powered by wind energy	901,408
Number of wind energy projects (two or more turbines)	58
Annual greenhouse gas emissions displaced (tons CO_2/yr)	6,400,000
Equivalent number of cars taken off the road/yr	1,422,000
Note: All figures are estimates only, based on current available information obtained by the Clean Energy Council.	

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 new financial investment in wind power in the 2010-11 Australian financial year was almost 1.16 billion AUD (0.912 billion EUR; 1.1 billion USD). Nationally, wind power is spread over most states with South Australia having the highest capacity (Figure 2).

Wind farm project development generates employment nationally and within the local regional area. Around 2,000 people are employed in the wind sector 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.

Some wind farm developers also make contributions to local communities through sponsorship of sporting clubs or community festivals. Wind turbines provide an alternative income stream for farmers, who enter into leasing agreements to host them on their properties.

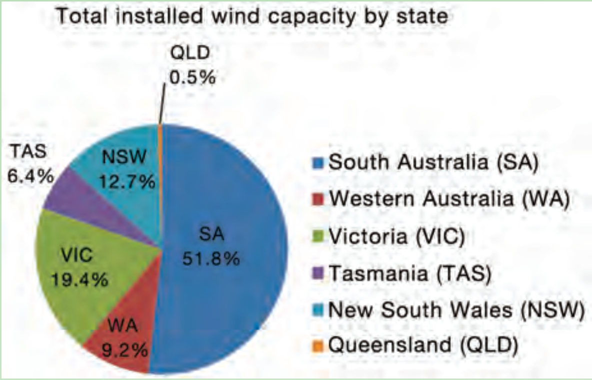


Figure 2. Installed wind capacity in Australia by state

3.2 Industry status

A wide variety of developers participate in the Australian market, including large energy utility companies, investment banks, and specialist wind development companies. Companies include Acciona Energy, AGL, Hydro Tasmania, Infigen Energy, Origin Energy, Pacific Hydro, TRUenergy, and Verve Energy. Investment and infrastructure funds such as Macquarie Capital and Transfield Services Infrastructure Fund are also involved in this space. ANZ Infrastructure Services Limited is a division of ANZ Banking Group Limited, representing private equity in the sector. 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.

Wind turbines are manufactured outside of Australia and imported as required. A number of new turbine suppliers have entered the Australian market recently, but the market remains dominated by two main suppliers – Vestas/NEG Micon and REpower, which merged with Suzlon's Australian operation in 2011 (Figure 3).

3.3 Operational details

The size of Australian projects has been progressively increasing. Acciona's 128-turbine Waubra Wind Farm is currently the largest in Australia at 192 MW. AGL's Macarthur Wind Farm is under construction and will be significantly larger at 420 MW. There are also proposals under evaluation for larger wind farms such as Epuron's 1,000 MW wind farm at Silverton and its proposal for a 1,100 MW wind farm at Liverpool Range, both of which are in New South Wales.

Every Australian state generates wind power to a greater or lesser degree. South Australia accounts for 52% of the total national installed capacity. Currently there are 13,749 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 2). Another 5,604 MW of projects are undergoing feasibility studies. All these proposed projects are onshore wind farms.

3.4 Wind energy costs

The contribution of capital costs to total wind farm production costs can vary significantly from site to site. Table 4 shows a typical breakdown of the major development costs associated with wind farm projects.

4.0 R, D&D Activities

ARENA will provide 3.2 billion AUD (2.5 billion EUR; 3 billion USD) of financial assistance to promote research and development, demonstration, commercialization, and deployment of renewable energy projects. The 200 million AUD (157 million EUR; 196 million USD) Clean Energy Innovation Program will provide grants and to support research and development, proof of concept, and early stage commercialization in clean energy technologies.

5.0 The Next Term

With the right policy mix and an increasing demand for low emission energy, the wind industry can remain a major contributor to the multi-billion dollar challenge of de-carbonizing Australia's energy supply. It is expected that the Australian wind industry will experience a period of significant growth over this next decade provided a stable investment and planning environment exists.

A Senate Inquiry into the Social and Economic Impact of Rural Wind Farms held in 2011 recommended the federal government conduct studies into noise and health. The National Health and Medical Research Council is undertaking a review of scientific literature on the possible health impacts of wind

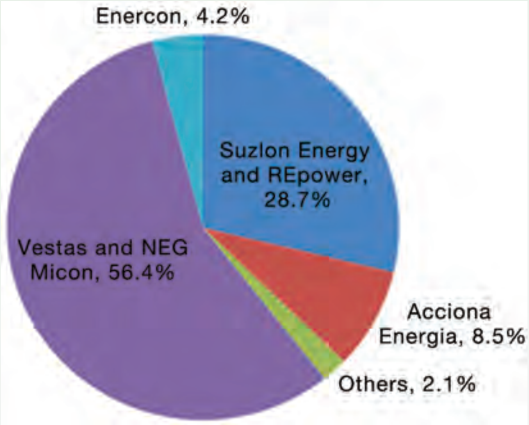


Figure 3. Installed wind capacity in Australia by turbine supplier

Source: Review of the Australian Wind Industry for the Clean Energy Council, Garrad Hassan, 2011

Table 4. Indicative development costs for Australian wind farms		
Cost item	Million AUD/MW (EUR;USD)	Contribution to capital costs
Turbine works	1.10-2.00 (0.86-1.5; 1.08-1.9)	60-75 %
Civil and electrical work up to the point of connection	0.35-0.6 (0.28-0.5; 0.34-0.58)	10-25 %
Grid Connection	0.05-0.35 (0.04-0.28; 0.04-0.58)	5-15 %
Development and consultancy work, wind speed monitoring	0.15-0.42 (0.11-0.33; 0.14-0.42)	5-15 %
Total	1.7-3.4 (1.3-2.6; 1.6-3.3)	100 %
Source: Review of the Australian Wind Industry for the Clean Energy Council, Garrad Hassan, 2011		

farms. A reference group which will include a member of the Clean Energy Council is being established to guide this work.

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. The Clean Energy Council is reviewing and updating the *Wind Industry Best Practice Technical Guidelines* for the implementation of wind energy projects in Australia. It is also developing a range of community engagement tools including best practice guidelines for Community Engagement and a community expectations handbook.

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14 Austria

1.0 Overview

In Austria, 2011 was a successful year for wind power. In July, the Austrian parliament adopted new legislation for electricity from renewable energy sources, the Ökostromgesetz 2012 (Green Electricity Act 2012, GEA 2012). This law maintains the existing feed-in-system but establishes for the first time a stable legal framework by 2020. It has a target of adding 2,000 MW of wind power to the existing capacity (1,011 MW) by 2020. As before, the feed-in tariff is 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 feed-in-tariff for 2012 was fixed at 0.095 EUR/kWh (0.123 USD/kWh), a small decrease to 2011's tariff of 0.097 EUR/kWh (0.126 USD/kWh).

In 2011, 31 wind turbines were built with a total capacity of 73 MW. At the beginning of 2012, 656 wind turbines were operating with a total capacity of 1,084 MW. These turbines are producing 2.2 TWh of electricity each year, which is a share of 3.4% of Austrian electricity demand or energy for approximately 600,000 households. In 2012, added installation of 327 MW are expected.

Table 1. Key Statistics 2011: Austria

Total installed wind generation	1,084 MW
New wind generation installed	73 MW
Turbines dismantled	3.3 MW
Total electrical output from wind	2.2 TWh
Wind generation as % of national electric demand	3.6%
Average capacity factor	
Target:	plus 2,000 MW from 2010-2020

2.0 National Objectives and Progress

2.1 National targets

The new GEA 2012 sets a specific target of adding 700 MW of wind power capacity by 2015 (a rise to 1,700 MW). For the first time the GEA 2012 establishes a stable legal framework by 2020, with 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 (NREAP). In this NREAP (according to European Union directive 2009/28/EC), Austria set a target of 1,951 MW by 2015 and 2,578 MW by 2020. In a 2007 study, the Austrian Wind Energy Association 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

At the end of 2011, 1,084 MW of wind capacity were installed in Austria (Figure 2), producing 2.2 TWh/yr. This is equivalent to 3.4 % of the Austrian electricity demand. This way wind electricity avoids 1.4 million tons of CO_2 emissions every year. With the estimated increase in installations of about 327 MW in 2012 all Austrian wind turbines will produce an equivalent of 4.9 % of the Austrian electricity demand and avoid approximately 2 million tons of CO_2.

Most wind turbines (606.1 MW) are located in Lower Austria, followed by Burgenland (390.5 MW), Styria (52.7 MW), Upper Austria (26.4 MW), Vienna (7.4 MW) and Carinthia (0.5 MW), see Figure 3.

2.3 National incentive programs GEA (Ökostromgesetz) 2012

The GEA (Ökostromgesetz), adopted in 2002, triggered investments in wind energy in the years 2003 to 2006 (Figure 2). 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 feed-in tariff 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. Many projects that had obtained all planning permits had applied for a contract (granting the feed-in-tariff) 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, the GEA 2012 (Ökostromgesetz). This law preserves the existing feed-in-system but for the first time establishes a stable legal framework by 2020, with a target of adding 2,000 MW wind power to the existing capacity (1,011 MW) by 2020. Furthermore, all 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 feed-in-tariff of 0.097 EUR/kWh (0.0126 USD/kWh); those with a queue position in 2014 and 2015 got a feed-in-tariff of 0.095 EUR (0.123 USD/kWh).

However, there are still restrictions for new projects. Those projects only get a purchase obligation and a feed-in tariff if they get a contract with the Ökostromabwicklungsstelle OeMAG. The Ökostromabwicklungsstelle is the institution in charge of buying green electricity at the feed-in tariff 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. There are 50 million EUR/yr (65 million USD/yr) for new projects, enough for approximately 120 to 350 MW of new wind capacity per year, depending on the market price for electricity and the applications from PV and small hydro power plants. 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 will enter into force on 1 July 2012. Up to this date the Green Electricity Act 2002 (as amended in BGBl Nr. 1 104/2009) is in force.

Green Electricity Regulation – Ökostromverordnung 2012

As before, the feed-in tariff is set by an ordinance and is not fixed in the GEA 2012 itself. The feed-in tariffs 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 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 feed-in-tariff for 2012 was fixed at 0.095 EUR/kWh (0.123 USD/kWh), a small decrease to 2011's tariff of 0.097 EUR/kWh (0.126 USD/kWh).

2.4 Issues affecting growth

Crucial for the growth of wind power capacity are the amount of the feed-in tariff, the stability of the incentive

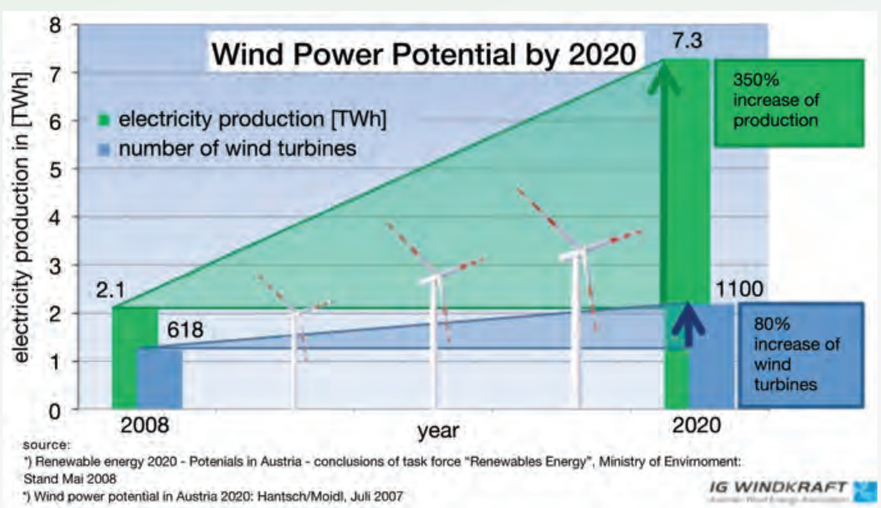

Figure 1. Wind power potential in Austria by 2020

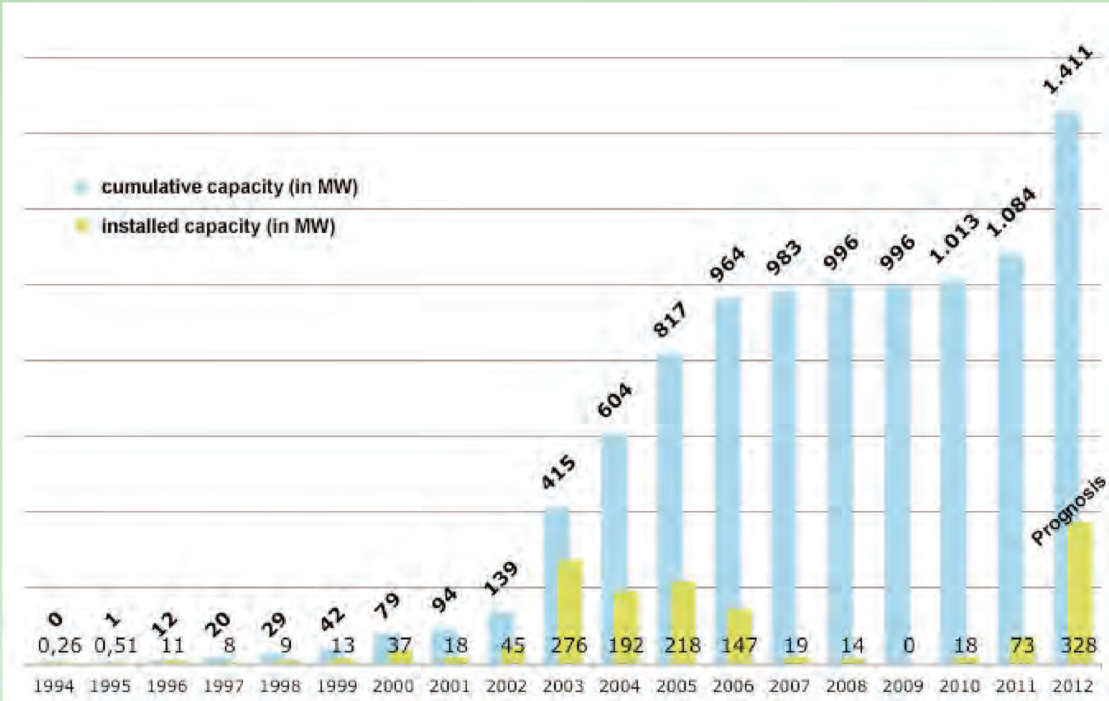

Figure 2. Total wind power capacity in Austria

program, and the annual amount of money for new projects (annual funds). Due to the adoption of the new Green Electricity Act 2012, which establishes a long term framework up to 2020, the determining factor for wind power growth will be the height of the feed-in-tariff, which basically will be fixed year by year, but – for technologies like wind power - can also be fixed for a longer period.

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. The annual turnover of operators of existing wind parks is about 150 million EUR (194 million USD).

Austrian companies supply components including wind turbine control systems, blade materials, generators, and wind turbine designs. There is also one turbine manufacturer. The turnover of these companies amounts to 500 million EUR (647 million USD). So far, 3,300 jobs have been created in the wind energy sector.

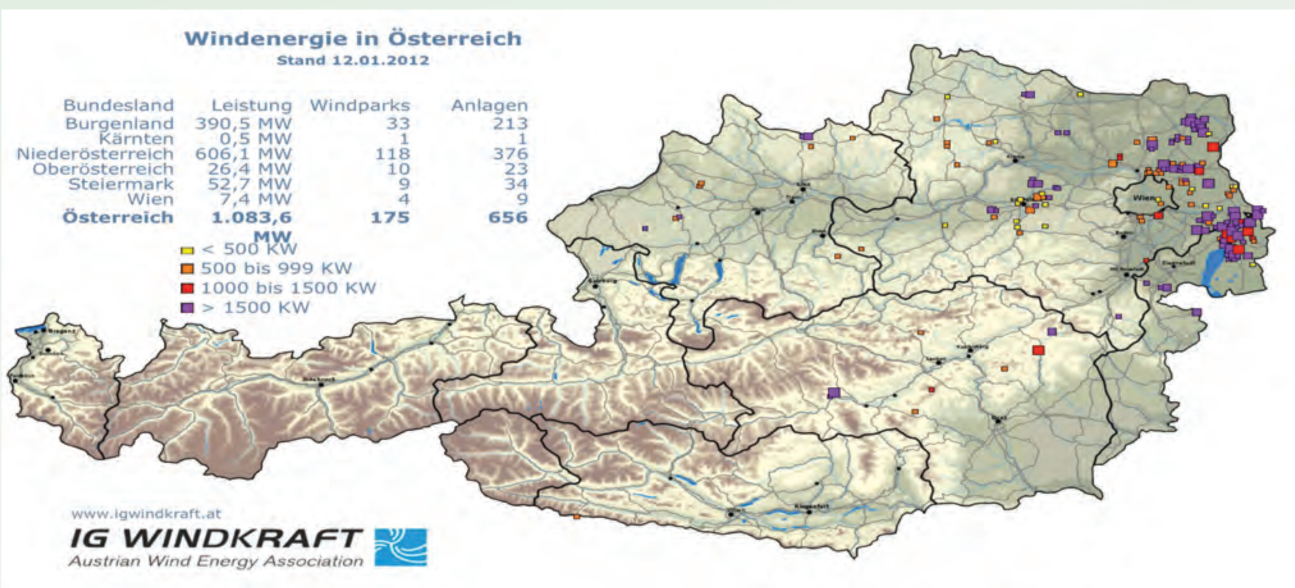

Figure 3. Wind power in Austria

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 co-operatives 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 Austrian manufacturers of wind turbines. However there are manufacturers of micro wind turbines in Austria.

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. AMSC Windtec GmbH is an engineering company that develops complete electrical and mechanical systems for wind turbine applications. For its customers it develops customized wind turbine concepts and works as an advisor for technology transfer. Prangl, Palfinger, and Felbermayr Austria has companies in the logistic sector that provide services onshore and offshore throughout Europe.

Table 2. Market shares of wind turbine manufacturers in Austria

Supplier	Installed Turbines	% of turbines	Installed MW	% of capacity
Bonus	16	2.44	22.30	2.06
DeWind	48	7.32	74.25	6.85
Enercon	288	43.90	495.50	45.73
Fuhrländer	1	0.15	0.03	0.00
GE	11	1.68	13.80	1.27
Lagerwey	4	0.61	1.50	0.14
Leitwind	2	0.30	2.85	0.26
NEG-Micon	13	1.98	12.90	1.19
Nordex	9	1.37	5.30	0.49
Repower	7	1.07	14.00	1.29
Seewind	5	0.76	0.57	0.05
Siemens	14	2.13	17.00	1.57
Vestas	237	36.13	422.06	38.95
Windtec	1	0.15	1.50	0.14
total	**656**		**1083.56**	

Table 3. Cost of new wind energy projects

Total investment costs	1,762 EUR/kW	2,368 USD/kW
Turbine costs	1,434 EUR/kW	1,927 USD/kW
Connection to grid and grid reinforcement	140 EUR/kW	188 USD/kW
Development costs	50 EUR/kW	67 USD/kW
O&M costs years 1 to 12	0.0236 EUR/kWh	0.0317 USD/kW
O&M costs years 13 to 20	0.0356 EUR/kWh	0.0478 USD/kW

3.3 Operational details

Most of the turbines in Austria are 1.8 MW to 2.3 MW in capacity. Enercon and Vestas are the most important suppliers of turbines (Table 2).

3.4 Wind energy costs

Table 3 shows estimated costs for wind energy project elements (price basis 2009).

4. R, D&D Activities

4.1 National R, D&D efforts

Due to the Austrian orography with its high elevations, completed and on-going research projects mainly have been focusing on issues regarding complex terrain and cold climate solutions.

Addressing the complex wind conditions in Austria, a two-year national research project (Project AuWiPot) has produced a high-resolution wind map of Austria. The new wind map combines numerical flow models with a geo-statistical approach. Based on those calculation results a WebGIS application has been set up, which allows the users to estimate the theoretical maximum achievable wind potential on the district level. This estimation takes into consideration manifold technical economic and spatial criteria, which can be altered by the user. Both results, the wind map and the WebGIS application were published in 2011. Starting from the results of the WebGIS Application the practically achievable wind potential is currently being assessed. The results take into consideration political aspects in the different cantons, land availability and aspects of acceptance. For more information see www.windatlas.at.

Due to the importance of better knowledge as to the risk of ice fall from wind turbines, the Austrian Climate and Energy Fund is supporting 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 the 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. The following four Small Wind Power (SWP) projects are funded by the Austrian Research and Development Programme "Neue Energien 2020" of the Austrian Climate and Energy Fund.

The project SMARTWIND will create a database for the development of a simple and economical small wind plant for decentralized applications like private households or small companies. This approach will use new wind wheel geometry and composite materials. The goal is to produce electricity efficiently even in low wind speeds. The project will create the necessary technical, legal, and economical data for successful development of these systems.

The second SWP assesses the technical and economic potential of small wind power. To increase sustainable energy production from renewable sources and improve the energy efficiency in buildings, this project will investigate the legal, technical, and economical framework conditions, which have hindered SWP in urban areas. Solving these problems and integrating SWP in the urban environment can have a major impact on decentralized sustainable energy production.

In the third project called IPPONG the exact positioning of small wind turbines is analyzed. This question is particularly important in the urban environment where flow characteristics are highly unstable and influenced by numerous parameters, such as geometry and the orientation of the buildings, as well as their disposition. This project will create a numerical simulation of 3-D flow fields around buildings to improve energy efficiency, operational reliability, and acceptance of small wind turbines in the urban area.

The fourth 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 in the course of permission. 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 planning, permitting, constructing, grid-connecting, and operating small wind power stations.

4.2 Collaborative research

In 2009, Austria joined IEA Wind Task 19, Wind Energy in Cold Climates. The Ministry for Transport, Innovation and Technology has assigned Energiewerkstatt as the Austrian representative in this Task due to long-time experience with projects in the Austrian Alps. The research activities will continue for two and a half years and focus on operational experiences at Wind Farm Moschkogel. Preliminary results have been published at the Swedish conference 'Winterwind 2011' (windren.se/WW2011/62a_Energiewerkstatt_Krenn_Deicing_Enercon.pdf).

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) to 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, as the three SEEWIND project sites have challenges similar to many locations in Austria.

5.0 The Next Term

The Green Electricity Act 2012 is a solid basis for the further development of wind power in Austria. In 2012, we expect the installation of 327 MW. Crucial for the growth of wind power capacity will be the amount of the feed-in tariffs of the following years and measures of grid reinforcement and enlargement in the eastern part of Austria.

Authors: Ursula Nährer, Austrian Wind Energy Association; Andreas Krenn, Energiewerkstatt Friedburg; and Susanne Glanzegg, Federal Ministry of Transport, Innovation and Technology, Austria.

15 Canada

1.0 Overview

Canada is the ninth largest producer of wind energy in the world. It has over 5,200 MW of installed wind energy capacity, which produces enough energy to meet about 2.5% of the country's total electricity demand.

The wind energy industry in Canada enjoyed a record year in 2011, with the addition of nearly 1,300 MW of new wind energy capacity to provincial grids. This represented more than 3 billion CAD (2.3 billion EUR; 2.9 billion USD) in new investments and created over 13,000 person years of employment (PYE). For 2011, Canada ranks sixth globally in terms of new installed wind energy capacity.

Canada has more than 140 wind farms, spread across 10 provinces and the Yukon. Ontario currently leads in installed wind capacity, with over one-third of the country's total capacity. The government of Canada continues to fund the growth of Canada's wind power sector through the 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 changes. Ontario, for example, is moving forward with a review of its Feed-in Tariff (FIT) program. The province of Saskatchewan's Go Green Fund committed an additional 2.9 million CAD (2.2 million EUR; 2.8 million USD) to its existing net metering rebate program. New manufacturing facilities opened in Ontario, Quebec, and Nova Scotia.

The provinces of Ontario, Quebec, and Nova Scotia are spurring community power in Canada. Ontario Power Authority (OPA) has already signed FIT contracts with several First Nations for wind projects across the province. Subject to approvals, the province of Quebec will have an installed capacity of 291 MW of community wind by 2015.

Table 1. Key Statistics 2011: Canada	
Total installed wind capacity	5,265 MW
New wind capacity installed	1,298 MW
Total electrical output from wind	14.3 TWh
Wind generation as % of national electric demand	2.5%
Average capacity factor	31%
Target:	N/A

Nova Scotia is reviewing project applications for new Community Feed-in Tariff (COMFIT) projects.

Canada's federal departments and research organizations are working together in R, D&D areas that are particularly relevant to Canada, including: improving the performance and reliability of small wind turbines, reducing the cost and increasing the penetration of large wind turbines, and addressing the issues of variable energy supplied to the electrical grid. The federal government supports R, D&D in wind through programs such as the Clean Energy Fund and the new EcoENERGY Innovation Initiative (ecoEII).

2.0 National Objectives and Progress

By the end of 2011, Canada had more than 5,200 MW of total installed wind energy capacity – producing enough energy to meet about 2.5% of the country's total electricity demand. Nearly 1,300 MW of new wind capacity was installed in the provinces of Alberta, British Columbia, Manitoba, New Brunswick, Nova Scotia, Ontario, Quebec, and Saskatchewan. Ontario led the way, with more than 500 MW of new wind installations in 2011.

2.1 National targets

Although there are no national wind energy deployment targets, Canada's federal government has made a commitment to have 90% of Canada's electricity produced by non-emitting sources such as hydro, nuclear, clean coal, and wind power by 2020.

Some provinces, however, have set renewable production targets, and others are improving on their targets (2.2 Progress 2). For example, the Nova Scotia government enacted a new Renewable Electricity Regulations under the Electricity Act in October 2010. Since then, the Electricity Act has been amended to confirm in regulation a renewable electricity target of 40% by 2020.

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, wind energy is playing an increasingly important role in meeting Ontario's demand for electricity, according to the province's Independent Electricity System Operator (IESO). Ontario has more than 1,700 MW of installed wind capacity. Wind energy production added up to 3.9 TWh in 2011 – 2.6% of output from all fuel types.

Ontario's new Bruce to Milton Transmission Reinforcement Project has allowed the OPA to offer new contracts for renewable energy projects under the province's FIT. In July 2011, the OPA awarded contracts to 19 wind projects on the FIT priority ranking list. The projects had previously not been awarded contracts and had been added to the priority list because transmission capacity was not available at the time. The projects selected range from 2 MW to 150 MW, and they will have a combined capacity of over 1 GW. They will be brought online through the largest transmission project in Ontario in 20 years.

In British Columbia, the Dokie wind farm (opening photo) was commissioned in February 2011. The 43-turbine, 144-MW wind farm is the second wind farm operating in the province. Under the province's last Clean Power Call, BC Hydro (the province's electric utility) has awarded Power Purchase Agreements (PPAs) to six additional wind projects.

In Saskatchewan, the province's electric utility SaskPower has selected 20 new environmentally preferred power projects through its second annual Green Options Partners Program lottery. The projects selected will add about 50 MW of green electricity to the electricity grid, half of which will come from three wind projects. Selection in the lottery commits the applicant to proceeding with a feasibility study, but does not commit either the applicant or SaskPower to proceeding with a PPA.

In southern Manitoba, the province's second wind farm is fully operational. Following the successful negotiation of a 27-year PPA between Manitoba Hydro (the province's utility) and Pattern Energy, the first group of turbines at the St. Joseph wind farm began producing electricity in January 2011. St. Joseph is a 138-MW wind farm with 60 wind turbines located within 125 square kilometers.

In Quebec, proponents of wind projects selected by Hydro-Québec following a call for tenders issued in 2009 have signed Electricity Supply Contracts with the utility. The Hydro-Québec call was for the purchase of two separate blocks of 250 MW of wind power generated in Quebec - one block from Aboriginal projects and one block from community projects. Hydro-Québec awarded twelve PPAs totaling 291 MW – one for the Aboriginal block and eleven for the community block. The

Table 2. Provinces with renewable energy targets

Province	Target
British Columbia	2010 Clean Energy Act – 93% of electricity from "clean or renewable" objective
Manitoba	Goal – 1,000 MW of wind by 2016
Ontario	Long Term Energy Plan – 10,700 MW of renewable energy by 2018 (excluding hydroelectric)
Quebec	Quebec Energy Strategy – 4,000 MW of wind by 2015; 100 MW of wind for every 1,000 MW of new hydro
New Brunswick	10 year energy plan – increase electricity from new renewable sources to an additional 10% of total use by 2016
Nova Scotia	Renewable Energy Standard – 25% of electricity by renewable sources by 2015, 40% by 2020
Prince Edward Island	10 Point Plan – 500 MW of wind by 2013

Kahnawà:ke Sustainable Energies' 24 MW wind project was the only project selected for the Aboriginal block.

In Nova Scotia, power production operators reported that wind energy generation reached a record high of 250 MW on 24 April 2011, representing 20% of the province's electricity generation. The province's Department of Energy began accepting applications for a new COMFIT in September 2011. COMFIT is designed for locally-based renewable electricity projects. To be eligible, projects must be community-owned and connected at the distribution level (i.e., typically under 6 MW). As of December 2011, 88 project applications (90% for wind projects) have been submitted, and five have been approved by the Province. All successful applicants will be notified before early spring 2012.

In Prince Edward Island, four community ice rinks have begun reaping the benefits of wind generation (Figure 1). With the installation of a 50 kW turbine at each rink, electricity generated can contribute up to 190 MWh/yr, equivalent to nearly 85% of the annual electricity consumption of each rink. Moreover, Saskatchewan's power utility (SaskPower) is also exploring the potential economic and environmental benefits of using the wind to partially power ice rinks. Through the "SaskPower Self-Generated Electricity Demonstration Project for Rinks," wind turbines have been installed in four locations to determine the benefit of self-generating electricity.

In the Northwest Territories, Diavik Diamond Mine has started construction of a wind farm at its mine site. Diavik currently relies on diesel fuel for all its energy needs, but the construction of four 2.3 MW turbines will reduce the mine's diesel use by approximately four million liters, or about 10% of total diesel consumption. Construction of the wind farm is expected to be completed next year. Once operational, it will be the first large-scale wind farm in Canada's Northwest Territories and the first large-scale wind farm at an operating mine.

2.3 National incentive programs

The government of Canada launched the 1.48 billion CAD (1.12 billion EUR; 1.45 billion USD) ecoENERGY for Renewable Power (ecoERP) program in 2007. Through this program, the government has committed close to 980 million CAD (741 million EUR; 960 million USD) for 65 qualifying wind energy projects, representing 3,400 MW. These projects will receive funding of 0.01 CAD/kWh (0.007 EUR; 0.009 USD) 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 federal government announced the renewal of its ecoENERGY for Aboriginal and Northern Communities Program. The program will receive an injection of 20 million CAD (15 million EUR; 19 million USD) over the next 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. Proposals submitted are being assessed, and applicants will be informed once a final funding decision has been made.

Provinces across Canada continue to offer a range of incentives for renewable power, including wind. In Ontario for example, the Ministry of Energy released a Long-Term Energy Plan (LTEP) for the province in November 2010. Included in the plan was a commitment to review the province's FIT program and to will consider issues such as: FIT price reduction, long-term sustainability of clean energy procurement, job creation, consideration of new technologies and fuel sources, local consultations, and the renewable energy approval process.

In August 2011, the province of Saskatchewan's Go Green Fund committed an additional 2.9 million CAD (2.2 million EUR; 2.8 million USD) to its existing net metering rebate program. The program provides rebates of up to 35,000 CAD (26,500 EUR; 34,300 USD) to people who wish to install small (less than 100 KW) wind, solar or other green power generation equipment and connect to the province's electricity grid. Additional funds will extend the program by one year – to 30 March 2012. As of 31 March 2011, 265 small-scale renewable power systems have been installed and over 1.7 million CAD (1.3 million EUR; 1.6 million USD) provided in refunds.

In July 2011, the Nova Scotia Utility and Review Board (UARB) announced their decision to set a price of 0.452 CAD/kWh (0.342 EUR/kWh; 0.443 USD/kWh) for small wind turbines of 50 kW and under. For larger community wind projects above 50 kW

Figure 1. Wind turbine powering Jacques Cartier Arena in PEI Source: WEICan

the price is 0.139 CAD/kWh (0.105 EUR/kWh; 0.135 USD/kWh). These new community COMFIT rates position the province of Nova Scotia at the forefront of North America in small and community wind energy projects.

3.0 Implementation

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 MW of new installed wind generation capacity represents approximately 2.5 million CAD (1.9 million EUR; 2.4 million USD) in private sector investment – a cumulative total of over 13 billion CAD (9.8 billion EUR; 12.7 billion USD) for Canada.

3.1 Economic impact

Nearly 1,300 MW of new wind energy capacity was added in 2011, representing more than 3 billion CAD (2.3 billion EUR; 2.9 billion USD) in investments, and creating over 13,000 PYE – a record year for Canada. To date, the industry has also created a cumulative total of 55,000 PYE in construction and nearly 20,000 PYE in operations and maintenance.

The growth of Canada's wind energy industry is contributing to an increase in high quality jobs and injecting millions of dollars into communities hosting wind energy developments. A recent study commissioned by CanWEA indicates that the wind energy industry in Ontario is forecasted to create more than 80,000 PYE, and attract more than 16 billion CAD (12 billion EUR; 15 billion USD) in private sector investments in the next eight years. The report 'The Economic Impacts of the Wind Energy Sector in Ontario 2011–2018' by ClearSky Advisors is the most comprehensive study ever undertaken on the economic impacts of the wind energy industry in the province of Ontario.

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 new manufacturing facilities opening in Ontario, Quebec, and Nova Scotia.

3.2.1 Ownership

In Canada, wind farms are typically owned by independent power producers (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.

OPA has already signed FIT contracts with several First Nations. For example, the M'Chigeeng First Nation has been guaranteed 0.15 CAD/ kWh (0.114 EUR/kWh; 0.148 USD/kWh) (0.135 CAD plus a 0.015 CAD Aboriginal adder) over the course of a 20-year contract. The Band is in the final stages of securing funding for a 4-MW wind farm. The federal government has committed to investing 980,000 CAD (742,000 EUR; 960,000 USD) to enable the M'Chigeeng to implement its wind project. It will make history in Ontario as the first commercial scale wind farm completely owned and developed by an Aboriginal community.

In Quebec, the Viger-Denonville Community Wind Farm Project received approval from the Quebec Energy Board for the 20-year PPA awarded in the previous year by Hydro-Québec. Developed through a partnership between the company Innergex and the host community Rivière-du-Loup, the wind farm will have an installed capacity of 24.6 MW. Hydro-Québec also selected eleven other projects, under the 2009 call for tenders for 500 MW from community and Aboriginal projects. Subject to approvals, Quebec will have an installed capacity of 291 MW of community wind by 2015.

3.2.2 Manufacturing

In November 2011, CS Wind officially opened its wind turbine tower plant in Windsor, Ontario. The plant will employ 300 workers when it is fully operational, and is expected to build 300 towers a year. CS Wind has invested 7.4 million CAD (5.6 million EUR; 7.3 million USD) into its new 360,000 square foot plant.

Daewoo Shipbuilding & Marine Engineering (DSME) celebrated the grand opening of DSME Trenton Ltd. (DSTN) in June 2011. The company's new facility in Trenton, Nova Scotia already employs more than 100 workers who are fulfilling orders for 30 towers. The province of Nova Scotia secured a 49% stake in the operation through investments made in 2010 to establish DSTN as a joint venture between the province and DSME. An additional 10 million CAD (7.6 million EUR; 9.8 million USD) was invested by the government of Canada.

In July 2011, ENERCON Canada, Inc. officially inaugurated the WEC Tours Québec, Inc. concrete tower and power converter factory in Matane, Quebec. The factory is the first ENERCON production facility to operate in Canada, and it is the first facility to provide serial production of concrete towers to the North American market. The new 15,000m² manufacturing facility will provide local employment to 130 people and is expected to produce 150 concrete towers per year. In a new deal with Niagara Region Wind Corporation, ENERCON has also committed to opening a converter and control panel factory, and a concrete tower manufacturing facility, both in the Niagara Region of Ontario.

3.2.3 Applications - Offshore

In March 2011, British Columbia's NaiKun Wind Project was granted a federal screening decision. The decision states that NaiKun meets the requirements of the Canadian Environmental Assessment Act (CEAA), successfully concluding the environmental assessment review process. Federal environmental approval for the Naikun project positions northern British Columbia to become Canada's first offshore wind producing region. The 396-MW project off the northwest coast of British Columbia 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.

In February 2011, the government of Ontario announced that the province will not proceed with proposed offshore wind projects. Applications for offshore projects will no longer be accepted, and current applications for offshore projects will be suspended. Despite this, a consortium of Lake Ontario based companies have come together to encourage and facilitate the development of offshore wind power in the province. The Lake Ontario Offshore Network (LOON) is comprised of manufacturers and suppliers with skills and interest in developing offshore wind projects in Lake Ontario. LOON is preparing for anticipated growth in the offshore wind industry, and encouraging the Ontario government to move forward to attract industry-related jobs and investments to the province.

3.3 Operational details

Twenty wind farms were commissioned across ten provinces in 2011. (Table 3)

4.0 R, D&D Activities

The focus of Canada's wind energy R&D activities is the integration of wind energy technologies into the electrical grid and into remote community applications, and 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: improving the performance and reliability of small wind turbines, reducing the cost and increasing the penetration of large wind turbines, and improving the performance and reliability of turbines in Canada's north.

Environment Canada monitors environmental impacts of wind development, including potential impacts on migratory birds and bats and other wildlife. The department also maintains the Canadian Wind Energy Atlas and it conducts research on wind resource assessment and on wind and ice forecasting.

Health Canada is coordinating federal, provincial, and territorial efforts in the development of National Guidelines on Noise from Wind Turbines. The department examines possible health impacts, and collaborates in both domestic and international settings in efforts related to health impacts of wind turbines.

National Research Council conducts research on the aerodynamics of wind turbines and siting of wind farms in complex terrain.

A number of 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. In the fourth year of its five year mandate, ongoing network activities are focused on technical research, development of highly trained personnel to meet the growing demand within the industry, and interaction with existing industry partners. The Outreach Committee and Scientific Committee of WESNet continues to promote network activities and identify new opportunities and partnerships with the Canadian wind industry (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 (http://www.eolien.qc.ca) owns an experimental cold climate wind energy site and two REpower MM92 CCV wind turbines with a capacity of 2.05 MW each. A number of projects involving eleven Quebec and foreign enterprises are either underway, or have already been completed since the wind turbines were commissioned. Moreover TCE is working with REpower on five research projects designed to improve the performance of CCV turbines in northern climates. Eleven million CAD (8.3 million EUR; 10.7 million USD) of new funds will help to finance research, development and technology transfer projects conducted in partnership with the wind energy industry and the scientific community at universities and colleges.

Wind Energy Institute of Canada (WEICan) is a not-for-profit wind energy research, testing and training facility located in PEI. WEICan's (www.weican.ca/) activities fall under four strategic areas: testing leading to certification; research, development and demonstration; training, outreach and public education; and technical consultation and assistance. WEICan has a collaborative agreement with the German Wind Energy Institute, for prototype testing of large wind turbines and WEICan is recognized as a non-accredited test site by the Small Wind Certification Council (SWCC) for testing small wind turbines. WEICan has also partnered with TUV NEL to validate its testing procedures and protocols to enable the Institute to test small wind turbines for the UK Microgeneration Certification Scheme (MCS). Construction of WEICan's 10-MW Wind Energy R&D Park is well underway, with installation of five DeWind D 9.2 wind turbines completed in December 2011 (Figure 2). A request for expression of interest for energy storage technology to be coupled with the wind park for research purposes has been issued.

4.1 National R, D&D efforts

Research efforts conducted by federal government researchers include the development of weather prediction models combined with icing prediction models in order to generate a predictive tool for icing incidents. The work involves simulations of icing events (and comparisons with observations) on Mount Washington in New Hampshire in collaboration with the U.S. Cold Region Research and Engineering Laboratory, and more

Table 3. Statistics for new wind farms commissioned in 2011: Canada

Smallest wind farm	0.8 MW - Spiddle Hill Phase I, Nova Scotia
Largest wind farm	165.6 MW - Comber Wind Farm, Ontario
Wind farm locations (provinces)	Alberta, British Columbia, Manitoba, New Brunswick, Nova Scotia, Ontario, Quebec, Saskatchewan
Turbine manufacturers	Enercon, GE, Acciona, Siemens, Vensys, Vestas
Turbine sizes (range)	0.8-3 MW
Average turbine size	1.93 MW

Figure 2. Five DeWind D9.2 wind turbines at WEICan in PEI (Source: WEICan)

recently for the Gaspé area in conjunction with Hydro-Québec.

EcoENERGY Innovation Initiative (ecoEII) is a new federal program that received 97 million CAD (73 million EUR; 95 million USD) in Budget 2011, for a comprehensive suite of R, D&D projects. The initiative's objective is to support energy technology innovation to produce and use energy more cleanly and efficiently.

EcoEII supports activities in five strategic priority areas: energy efficiency, clean electricity and renewables, bioenergy, 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). The LOIs were reviewed, and applicants of LOIs that were accepted for consideration were asked to submit a full project proposal. As of the beginning of 2012, the proposals are under review, and successful applicants will be notified in the spring of 2012.

In 2009, the Government of Canada announced a five-year, 795 million CAD (601 million EUR; 778 million USD), Clean Energy Fund (CEF). The CEF aims to advance Canadian leadership in both carbon capture and storage, and renewable and clean energy systems. Up to 146 million CAD (110 million EUR; 142 million USD) will be invested in small-scale renewable and clean energy demonstration projects. Two of which are wind demonstration projects. The CEF is also investing in renewable and clean energy R&D projects within the federal government. Over the next two years, up to 918,000 CAD (695,000 EUR; 899,000 USD) will be invested in three wind projects. Descriptions of the 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 11 – Base Technology Information Exchange, Task 19 – Wind Energy in Cold Climates, Task 25 – Power Systems With Large Amounts of Wind Power, and Task 28 – Social Acceptance of Wind Energy Projects, as well as in Technical Committee-88 (TC-88) of the International Electrotechnical Commission.

5.0 The Next Term

With approximately 1,500 MW of new developments expected to come online in Alberta, British Columbia, Prince Edward Island, Nova Scotia, Ontario, and Quebec, 2012 is expected to be another record year for wind development in Canada. More than 5,000 MW of wind energy projects are already contracted to be built in Canada within the next five years.

According to a new report from the National Energy Board (NEB) – "Canada's Energy Future" (www.neb-one.gc.ca), the share of wind power generation in Canada's electricity supply mix will triple from approximately 2% of total generation currently to 6% in 2035. The NEB sees growth in wind energy and expects total installed wind power capacity to reach 23 GW over the next two decades, with the largest capacity additions in Alberta, Ontario, and Quebec. In Ontario alone, over 2 GW of wind energy projects have already been signed and are to be constructed before 2018.

Author: Melinda Tan, Natural Resources Canada, Canada.

16 CWEA

Chinese Wind Energy Association

1.0 Overview

China is a country striving for sustainable economic development, speedy industrialization, and urbanization. As a result, energy demand is rising, and China is facing the challenge of how to guarantee a sustainable energy supply for economic development, while building a stable, clean, and safe energy supply system. In March 2011, the Chinese government promulgated the outline of the 12th Five-Year Plan for Economic and Social Development, which included measures such as "conservation priority, domestic-based, development diversification, environment protection, strengthen mutually beneficial international cooperation, adjust and optimize structure, build a safe, stable economical and clean modern energy industrial system." These measures will be adopted to push forward the transformation of energy production and utilization.

The Renewable Energy Law of the People's Republic of China (Amendment) was implemented in 2010. This law established a system to guarantee the purchase of electricity generated by renewable energy and established a renewable energy development fund. The law listed the renewable energy industry as one of the seven key new strategic industries to be developed during 12th Five-year Plan. This has further promoted the development of wind energy in China.

In 2011, ***17.6*** GW of new wind power capacity was installed in China and total installed capacity reached ***62.4*** GW. Although this capacity is the largest of any country in the world, compared

Table 1. Key Statistics 2011: China	
Total installed wind generation	***62,364*** MW
New wind generation installed	***17,631*** MW
Total electrical output from wind	73.2 TWh
Wind generation as % of national electric demand	1.6%
Average capacity factor	
Target:	90 GW (including 5 GW offshore) in 2015, 150–200 GW (including 30 GW offshore) by 2020.
Bold italic indicates estimates	

with conventional energy in China, wind power is a very small portion of China's energy mix. In the future, wind power could play a more important role in Chinese clean and sustainable energy and electricity supply.

In 2011, the Chinese Energy Research Institute of the National Development and Reform Commission worked with IEA and other Chinese organizations to create the *China Wind Energy Development Roadmap 2050.* This roadmap put forward the strategic development target and scenarios of Chinese wind power in 2030 and 2050. For the near term, wind energy development in China will focus on onshore, and offshore wind energy will be developed as appropriate. The mix of distributed off-grid and grid-connected generating systems to be developed will depend on the regional needs within China.

2.0 National Objectives and Progress

2.1 National targets

In the outline of the 12th Five-Year Plan for Economic and Social Development, three restraining factors are mentioned: (1) non-fossil energy will contribute 11.4% to energy consumption in 2015, compared with 8.3% in 2010, (2) energy consumption per GDP will be reduced by 16%, and (3) CO_2 emission per GDP will be reduced by 17%. In this way, China is initiating a low-carbon energy strategy, and wind power is one of the key technologies to realize the strategy.

The outline of the 12th Five-Year Plan for Economic and Social Development proposes the construction of enhanced grid-connected supporting projects to develop wind power effectively. In 2011, the National Energy Administration made the Renewable Energy Development 12th Five-Year Plan (draft), which mentioned that by the end of 2015, the total grid-connected capacity of wind power will reach 100 GW. Large land-based wind power facilities will represent 70 GW, distributed wind power will represent 30 GW, and offshore facilities will represent 5 GW. The implementing plan of the national grid to accommodate 100 GW wind power is established.

In July 2011, the Ministry of Science and Technology made the National 12th Five-Year Science and Technology Development Plan. It focused on developing key technologies for large wind turbines and key components for design. It will support design and operation of onshore large-scale wind farms and offshore wind farms. It will address manufacture of key components, wind power grid connection, dispatch, and O&M. At the end of 2011, the first group of projects was launched, including wind turbine blade advanced airfoil series design and application, 7-MW wind turbines, key components design and manufacture, and key technology for offshore wind power engineering construction.

2.2 Progress

According to the statistics of CWEA, during 2011 17.6 GW and 11,409 new wind turbines were installed in China (Taiwan excluded). This new capacity represents 43% of all new wind power installed worldwide. The total wind capacity in China reached 62.4 GW at the end of 2011 (Figure 1). This represents an increase of 39.4% over 2010. In 2011, the output of wind power was 73.2 TWh, covering 1.6% of total power consumption.

At the end of 2011, over 1,000 wind projects had been built in 31 provinces and municipalities (Taiwan excluded). The Inner Mongolian Autonomous Region has over 10 GW of wind power capacity, followed by Hebei (6.9 GW), Gansu (5.4 GW) (opening photo), Liaoning (5.2 GW), and Shandong (4.6 GW) as the top five provinces.

Offshore wind power development in China began with the Shanghai Donghai Bridge 100-MW offshore wind farm demonstration project. So far, the project has produced 200 billion kWh. In mid-2011, bidding was completed for the second phase of Shanghai Donghai Bridge offshore wind farm. The project will include 27 turbines

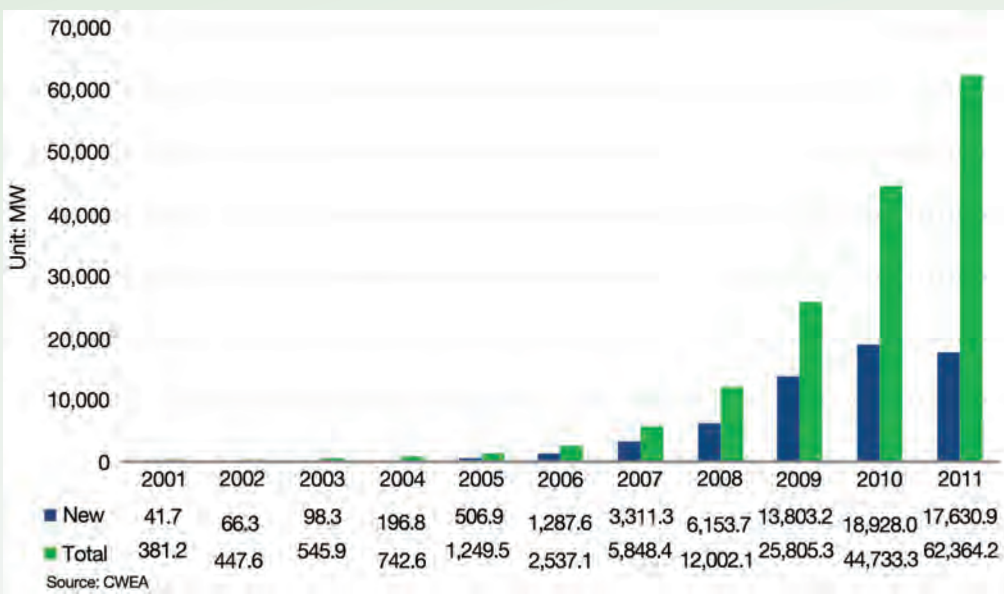

Figure 1. New and accumulated wind power capacity from 2001 to 2011

rated at 3.6 MW and 1 turbine rated at 5 MW.

Longyuan has developed its first intertidal offshore wind pilot project with 99 MW of installed capacity. By the end of 2011, 262 MW of offshore wind capacity were installed in shallow water and intertidal areas in three provinces.

2.3 National incentive programs

During 2011, in response to problems and trends of the wind power industry in China, a series of management methods and guidelines were developed. To standardize and promote the sound and stable development of the wind power industry, these methods included: normalize wind power projects development and construction, the principal of "overall planning, orderly development, distributed implementation, coordinated development," and post evaluation is to be made after the project completion.

In order to promote the development and utilization of decentralized wind resources, guidance for decentralized wind power development was made. It was decreed that decentralized wind power projects should not use plowed land, not affect existing facilities, not construct new transmission and distribution facilities, and not affect grid safety.

To regulate the management of offshore wind project development and construction the State Oceanic Administration and the National Energy Administration jointly issued the *Offshore Wind Power Development and Construction Interim Method* in January of 2010. This method regulates the use of marine areas, the protection of the ocean environment, and the management of offshore wind power development and construction. In 2011, to further guide offshore wind power development, these administrations clarified the offshore wind power plan and concrete procedures. Based on the *Offshore Wind Power Development and Construction Interim Method,* they have clarified management responsibilities, requirements, and working procedures of relevant authorities and enterprises to promote sound and orderly development of the offshore wind power industry.

2.4 Issues affecting growth

Because of the booming wind power industry in China and the continuous increase of installed capacity, wind power development faces some restrictions. In the first half of 2011, there were four incidents of grid dropout at the wind farm in Jiuquan City of Gansu Province. In some areas, wind curtailment happens because of lag of the transmission grid.

Aiming at these problems, the Chinese government and relevant departments adopted corresponding measures, making regulations, standards and specifications to enhance wind farm supervision, management, and grid-connection dispatchability. To enhance wind farm safety management, the developers must take responsibility for construction quality and operation safety. Wind farm operation information should be reported regularly and accidents due to poor quality should also be reported in a timely manner. Manufactures should enhance process control and quality management. CWEA is authorized to carry out quality surveys regularly. The results will be published and anti-accident measures as well as warning signs will be proposed. CWEA issued the *Notification of Strengthening Wind Farm Grid-connection Operation and Management*, which promulgated 17 industrial technology standards.

In 2011, the National Energy Administration released relevant documents regarding management of wind farm power prediction and forecasting as well as wind turbine low voltage ride through ability. In addition, the National Energy Laboratory of Wind and Solar Simulation, Testing, and Certification was established to perfect wind power standards, testing, and certification systems in China and to guarantee wind turbine reliability and promote wind power technology.

3.0 Implementation

3.1 Economics

In 2011, China added 14 billion Yuan (1.7 billion EUR; 2.2 billion USD) in investments in wind farm development, which led to 17.6 GW of new capacity and 62.4 GW of total installed capacity. Of these turbines, 47 GW of capacity are gird connected. Wind power generated 73.2 TWh, which could satisfy the electrical needs of 47 million households in China.

3.2 Industry status

3.2.1 Developers

In 2011, the top five wind power developers (Guodian Group, Huaneng Group, Datang Group, Huadian Group, and Guohua) held 59% of the annual newly developed wind farms (Table 2). In 2011, big utilities increased their activities in wind resources reservation and wind project development, which caused a drop in market share for local

Table 2. Top 10 wind developers in China in 2011

Rank No.	Developer	Capacity (MW)	Share
1	Guodian Group	12,861.3	20.6%
2	Huaneng Group	8,578.0	13.8%
3	Datang Group	8,007.1	12.8%
4	Huadian Group	3,829.9	6.1%
5	Guohua	3,440.1	5.5%
6	China Power Investment Group	2,944.9	4.7%
7	CGN Wind	2,891.5	4.6%
8	China Resource Power	1,773.4	2.8%
9	Jingneng	1,686.3	2.7%
10	Suntien Green Power	1,278.6	2.1%
	Other	15,073.4	24.2%
	Total	62,364.2	100.0%

energy investment enterprises in 2011.

3.2.2 Manufacture industry

In 2011, more than 121 wind turbine manufacturing facilities, 54 blade facilities, 36 generator facilities, 33 gearbox facilities, 25 bearing facilities, and 43 converter facilities were located in 25 provinces (including municipalities).

The top five manufacturers in wind power installations for 2011 were: Goldwind (3,600 MW), Sinovel (2,939 MW), United Power (2,847 MW), Mingyang (1,177.5 MW), and Dongfang Electric Corporation (946 MW) (Table 3). In China, there are nine domestic manufacturers, which could supply more than 500 MW in wind turbines annually. The top 15 suppliers all installed more than 300 MW in 2011. Comparatively, the number of suppliers with capacity above 300 MW annually was twelve in 2010 and only one at the beginning of China's 11th Five-Year Plan.

The supply chain was vastly improved in 2011. Key components like megawatt-class blades, gearboxes, generators, yaw mechanisms, and pitch bearings now have enough domestic supply capacity. Some components like gearbox bearings, main shaft bearings for multi-megawatt turbines, and converters still depend on import products. Although some multi-megawatt components have not achieved industrialization, progress such as technology breakthroughs and creation of prototypes could be seen. A small group of manufacturers have already started small-scale production as well.

3.3 Wind farm operation

By the end of 2011, China had more than 1,000 wind farms with total capacity over 62 GW. The top three provinces installed the following amounts: Inner Mongolian Autonomous Region (17,594 MW), Hebei (6,970 MW), and Liaoning (5,249 MW). The equivalent annual full load hours were 1,903 in 2011, 100 hours less than the 2010 level. Low wind speed wind farm construction was the main reseaon for the decrease in full load hours.

3.4 Capital expenditures

In 2011, wind farm capital expenditures continued decreasing from 8,600 Yuan/kW (1,057 EUR/kW; 1,368 USD/kW) average in 2010 to around 7,000 to 8,000 Yuan/kW (861 to 984 EUR/kW; 1,114 to 1,273 USD/kW). This decrease was because the biggest part of capital expenditures, wind turbine costs, declined from 4,200 Yuan/kW in 2010 to 3,600 to 3,800 Yuan/kW (516 EUR/kW in 2010 to 442 to 467 EUR/kW; 668 USD/kW in 2010 to 572 to 604 USD/kW). The logistics and installation costs were increasing due to the development of low wind speed and high-altitude areas. This is especially true in Yunnan and Guizhou provinces, where such costs could reach 600 to 1000 Yuan/kW (73 to 123 EUR/kW; 95 to 159 USD/kW).

Table 3. Top 10 wind turbine manufacturers in 2011

Rank No.	Name	Capacity (MW)	Share
1	Goldwind	3,600.0	20.4%
2	Sinovel	2,939.0	16.7%
3	United Power	2,847.0	16.1%
4	Mingyang	1,177.5	6.7%
5	Dongfang Electric Corporation	946.0	5.4%
6	XEMC-Wind	712.5	4.0%
7	SEWIND	708.1	4.0%
8	Vestas	661.9	3.8%
9	CCWE	625.5	3.5%
10	CSR	451.2	2.6%
11	GE	408.5	2.3%
12	CSIC-Haizhuang	396.0	2.2%
13	Windey	375.0	2.1%
14	Gamesa	361.6	2.1%
15	Envsision	348.0	2.0%
16	Yinxing	221.0	1.3%
17	SANY	179.5	1.0%
18	Xuji	166.0	0.9%
19	HEAG	151.0	0.9%
20	Suzlon	96.2	0.5%
	Other	259.4	1.5%
Total		17,630.9	100%

4.0 R,D&D Activities

4.1 National R, D&D efforts

4.1.1 Fundamental research

In 2011, the *National Key Basic Research and Development Program—973 Program, the Fundamental Research on the Aerodynamics of Large-scale Wind Turbines* was accepted. In the last five years, a series of system research projects have been carried out under this project, such as wind turbine complex flow structures, unsteady aerodynamics, aero-elastics, and aero-acoustics of wind turbines. The projects applied theoretical analysis, numerical simulation, wind tunnel experiments, and wind power blade R&D platforms. The research results have broadened Chinese wind turbine aerodynamics development and improved wind turbine blade optimization design methods.

In 2011, *the National High Technology Development Program—863 Program, the Design and Utility of Advanced Airfoil Families of Wind Turbine Blades* was accepted. In the past five years, research on airfoil design and analysis methods for performance was conducted applying theoretical analysis, numerical computation, and wind tunnel experiments (Figure 2 and Figure 3). Two groups of wind turbine airfoils were developed with established databases. In 2012, China will continue to support this project and use the developed wind turbine airfoil for the research and development of megawatt-class blades.

In addition to the National 973 Program and 863 Program, the National Natural Science Foundation of China supports fundamental research projects in the wind energy field every year. In 2011, eight wind energy fundamental research projects obtained support from them.

4.1.2 Wind power integration technology

In the first half of 2011, four incidents of large-scale wind farms dropping off line occurred in Gansu Jiuquan of China causing lost output of 4,195 MW. These events highlighted the need to (1) ensure operational security of the whole power system after wind power is connected to power grid and (2) ensure normal wind power generation. To address these needs, the State Grid Energy Research Institute and Vestas Wind Technology (China) Co., Ltd. conducted research and issued a report on a comprehensive strategy for wind power and grid coordinate development. They put forward a new concept of building a grid-friendly wind farm and wind power friendly power system in the report.

In October of 2009, the National Wind Power Integration Research and

Figure 2. Airfoil test in the China Aerodynamics Research and Development Center, 4-m by 3-m wind tunnel

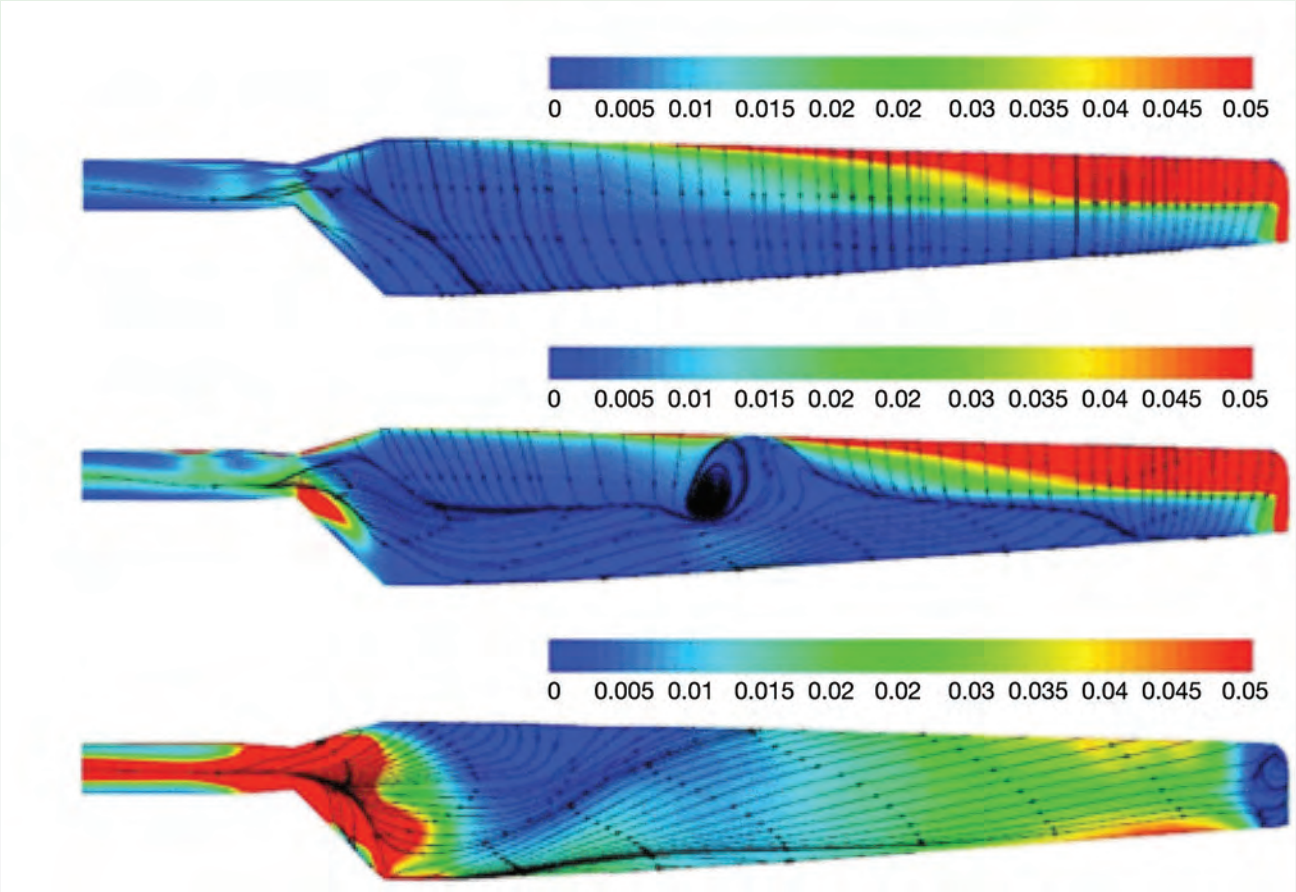

Figure 3. Wind turbine performance calculations by computational fluid dynamics

Test Center (laboratory) of the China Electric Power Research Institute was formally established. Then the 25 km^2 wind power test base was established in Zhangbei County of Hebei province (Figure 4). This base can accommodate 30 large wind turbines for testing grid adaptability and low voltage ride-through tests. In 2011, the development focus of wind power integration technology was put on wind power detection technology research and application. By the end of 2011, low voltage ride-through tests for 45 types of WTGS have been completed.

In 2011, the precision of wind power prediction systems were greatly improved. By the end of 2011, short-term wind power prediction systems covered more than 90% of wind power capacity connected to the grid, and the prediction accuracy is basically the same as at the international level.

4.1.3 China Wind Energy Development Roadmap

In 2011, the *China Wind Energy Development Roadmap 2050* was completed, based on research of the China Academy of Engineering, the Energy Research Institute of National Development and Reform Commission, and of the International Energy Agency. The report lists the installed capacity goals of China wind energy development for 2020 as 200 GW, for 2030 as 400 GW, and for 2050 as 1,000 GW. This capacity would meet 17% of the electricity demand in China by 2050. The report also gives the application path of wind power technology R, D&D.

4.1.4 Large wind turbine R&D

While the scale-up of onshore wind farms was taking place, offshore wind farm engineering models were developed, and R&D was begun for megawatt-class offshore wind turbines above 3.0 MW. In 2011, prototype turbines of 3.6 MW, 5.0 MW, and 6.0 MW were put into trial operation. These wind turbines are mainly direct-drive, permanent-magnet, and double-fed. Compared with previous megawatt-class wind turbines, the multi-objective optimum design method applied during R&D has resulted in compact type drive train systems and advanced control technology to reduce loads, improve reliability, and increase performance.

4.1.5 Engineering offshore wind farms

A good portion of offshore wind farms in China are being constructed on tidal land in the coastal area. To support these efforts, wind turbine transport equipment and installation equipment suitable to intertidal wind farm engineering were specially researched and developed. In 2011, 142 MW of wind turbines were installed in the tidal area at the offshore wind power demonstration project in Jiangsu province.

4.1.6 Typhoons

A typhoon is extreme weather that will affect wind energy developments in the southeast coastal areas of China. Therefore, anti-typhoon designs must be considered when designing and manufacturing wind turbines for these areas. The China Meteorological Administration used data from 88 anemometer towers in the coastal areas to analyze the extreme wind characteristics and turbulence intensity around typhoon centers and nearby. The results showed that wind model application in typhoon regions still needs to be improved.

4.2 Collaborative research

In 2011, CWEA organized manufacturing enterprises, research institutions, and universities to participate in the following activities under IEA Wind research Tasks: Task 11 Base Technology Information Exchange, Task 19 Wind Energy in Cold Climates, Task 27 Consumer Labeling of Small Wind Turbines, and Task 30 OC4 for Offshore Foundation Analysis. The activities played an important role in advancing wind power technical progress and industry development in China. In addition, CWEA plans to apply to participate in Task 26 Cost of

Figure 4. National Wind Power Integration Research and Test Center

Figure 5. Wind Farm in Gansu Province, China

Wind Energy and Task 29 MexNext Aerodynamics Analysis.

Furthermore, in 2011, China and the Danish government began to implement the Sino-Denmark Renewable Energy Development Programme and established the China National Renewable Energy Center. The Center is a business-supporting organization that assists the national energy management department with carrying out research on renewable energy policy and with organizing, implementing, and coordinating industry management.

The Chinese and German government technical cooperation project—part II of the project on wind power research and training— began to apply research and training on the technology of wind farm grid connection and maintenance.

In addition, China continues to lead the editing work begun in 2011 on the IEC standard *Part 5: Wind Turbine Blades IEC 61400-5: Wind Turbine Generator Systems.*

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(2) *Integrated Solution Strategies for Coordinated Wind Power and Grid Development—International Experience and China Practices*, Wind Energy (ISSN 1674-9219), Issue 8, Chinese Wind Energy Association, State Grid Energy Research Institute, Vestas Wind Technology (China) Co., Ltd.

Authors: He Dexin, Zhao Jinzhuo, and Wang Yongli, Chinese Wind Energy Association.

17 Denmark


Credit: Anders Ramsing, Vestergaard

1.0 Overview

Approximately 22.5% of Denmark's energy consumption came from renewable sources in 2011, 38.9% from oil, 18.9% from natural gas, and 17% from coal. The production from wind turbines alone corresponded to 28% of the domestic electricity supply, compared to 21.9% in 2010. This is due to a 9% reduction in overall electricity production in the last year alone, along with a 25% increase in wind energy production. The opening photo is from the DTU Høvsøre test station.

Wind power capacity in Denmark has increased by 206 MW in 2011, bringing the total to 3,952 MW (Table 1). All the installed wind turbines were onshore in 2011, except for one 3.6-MW (Siemens) turbine at Hvidovre, just south of Copenhagen. This is the last of the three planned turbines acting as an offshore demonstration turbine, placed in shallow waters and close to shore. This was also the largest rated turbine to be installed in 2011.

In November 2011, the Danish government published its Our Energy Future (2), an ambitious future energy plan to convert its energy and transport system to a 100% renewable one by 2050. Wind, especially offshore, is to contribute significantly to this, with a strategic milestone of 50% of electricity consumption to be covered by wind power by 2020 alone. Furthermore, as the technology is already cost effective, it is included in the short to medium term implementations to replace existing capacity in the next 10 to 20 years. Subsequently The Danish Energy Agreement of March 2012 has been reached by a large and broad majority in the Danish Parliament. The agreement maintains the long-term goal for Danish energy policy: that the entire energy supply is to be covered by renewable energy by 2050.

Table 1. Key Statistics 2011: Denmark	
Total installed wind capacity	3,952 MW
New wind capacity installed	206 MW
Total electrical output from wind	9.8 TWh
Wind generation as % of national electric demand*	28%
Average capacity factor	28.4%
Target:	50% by 2020
* In 2011 the wind index was 100.1%	

2.0 National Objectives and Progress

On 22 March 2012, a new Energy Agreement was reached in Denmark; an ambitious and internationally minded future energy plan to convert into a 100% renewable energy and transport system by 2050 with 50% of electricity consumption to be covered by wind power by 2020 (15).

2.1 National targets

The national targets can be summarized in the milestones presented in the report "Our Future Energy," published in November 2011 and outlining the initiatives for the Energy Strategy 2050. With the proposed initiatives, it is estimated that the share of renewable energy will reach 36% in 2020 (2), up from around 20% in 2009, and exceeding the EU target of a 30% RE share by 2020. The wind penetration is to be 52% by 2020 (2), as opposed to 50% in the previous government's proposal (1). The proposed initiatives are expected to be finalized in parliament the first quarter of 2012.

2.2 Progress

As shown in Table 1 and Figure 1, the contribution from wind alone to the domestic electricity production was 28% compared to 21.9% in 2010. This is due

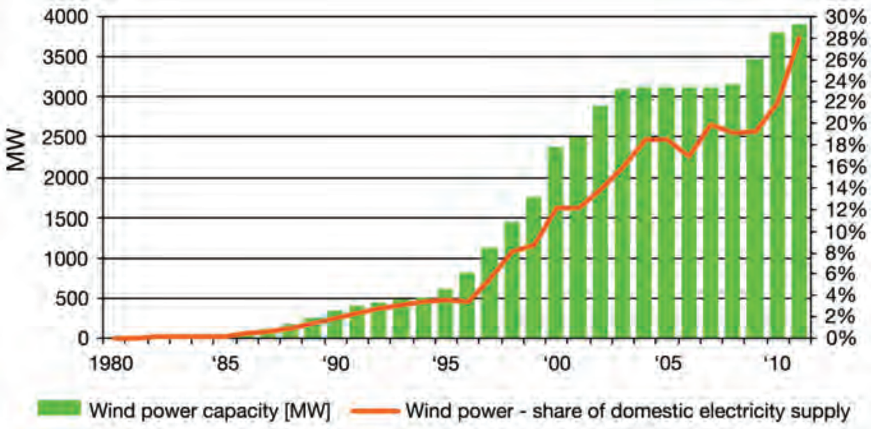

Figure 1. Danish wind power capacity and its share of domestic electricity supply

to a 9% reduction in overall electricity production in the last year alone, along with a 25% increase in wind energy production. The total electricity production from wind energy in 2011 was 9,844 GWh compared to 7,818 GWh in 2010.

The newly commissioned wind capacity in Denmark was 206 MW in 2011, with a total of 94 turbines, and with 160 turbines decommissioned with a total capacity of 56 MW, bringing the total capacity up to 3,952 MW from 3,802 MW in 2010. Although the total capacity increased, the number of turbines decreased in 2011 to 4,972 from 5,033 in 2010. The average capacity of installed turbines in 2010 was thus 2.2 MW. All the installed wind turbines were onshore in 2011, except for one 3.6-MW (Siemens) turbine at Hvidovre, just south of Copenhagen. This is the last of the three planned turbines acting as an offshore demonstration turbine, placed in shallow waters and close to shore. This was also the largest rated turbine to be installed in 2011. A detailed history of installed capacity and production in Denmark can be downloaded from the Danish Energy Agency Web site (3).

The environmental benefits due to the 2011 wind energy production, assuming coal is being substituted, results in 70% of Denmark's yearly CO_2 reduction obligation (1990-2010). More specifically (2): Saved coal: 3,296,154 tons (338 g/kWh); CO_2: 1,024,551 tons (784 g/kWh); SO_2: 1,073 tons (0.11 g/kWh); NO_X 2,243 tons (0.23 g/kWh); Particles 293 (0.03 g/kWh); Cinder/Ash 497,349 tons (51 g/kWh) (4).

2.3 National incentive programs

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 were introduced. A brief summary of proposed measures for wind are reported in Section 2.4.

2.4 Issues affecing growth

The initiatives in the new Energy Agreement are expected to boost wind energy deployment in Denmark in the coming years, in order to meet a 50% wind penetration by 2020 and a fossil-free Denmark by 2050. Specific initiatives being discussed in (2) and agreed on in parliament in March 2012 include the following.

- Call for tenders for 1,500 MW of offshore wind up to 2020 including 400 MW at Horns Rev II and 600 MW (Danish part) offshore at Kriegers Flat (expected operation 2018-2020): see Section 3.3 for more details.
- In the first half of 2012, screening of offshore areas as well as setting the framework for 500MW of offshore wind turbines closer to shore, up to 2020.
- Measures for more efficient tendering procedures and therefore cheaper expansion of offshore turbines.
- Support municipal planning for new onshore wind turbines, for 1800 MW capacity in total up to 2020. Of this, 1300 MW is expected to be replacement of older turbines.
- Gradual phase-out of premium for onshore wind, for wind turbines connected to the grid after 1 January 2014. Introduction of new cap of 0.58 DKK/kWh (0.07 EUR/kWh; 0.10 USD/kWh) for the electricity market price.
- Focus of strategic energy research in areas which reflect Danish strongholds.

3.0 Implementation

The Danish wind turbine industry publishes an annual report on the industry status and economic impact. The information in the latest annual report Branchestatistik 2011 (6) is for 2010.

3.1 Economic impact

The turnover of the industry located in Denmark in 2010 was 55.3 billion DKK (7.4 billion EUR; 9.9 billion USD), which is an increase of 8.3% compared to 2009. The turnover of the Danish wind industry worldwide was 98.8 billion DKK (13.2 billion EUR; 17.8 billion USD) in 2010, an increase of 8.1% compared to 2009.

The industry has continued its globalization during the financial crisis with foreign production facilities increasingly supplying the markets in primarily Asia and North America. This is mainly the large producers. The Danish wind industry's total export amounted 46.2 billion DKK (6.2 billion EUR, 8.3 billion USD) in 2010, an increase of 11% from 2009. Danish suppliers to the wind energy industry increased their global activity by more than 20% in 2010. This accounts for 8.5% of total Danish

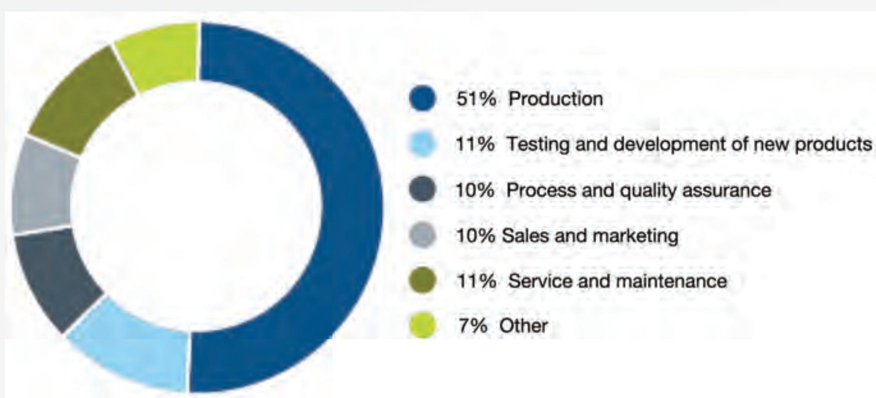

Figure 2. Employees classified by job type (7)

exports and 70% of energy technology exports.

The number of people employed within the wind energy sector in Denmark was about 25,000 employees at the end of 2010, an increase of 1.2% compared to 2009. This figure conceals high variation of employment changes between different companies, with major rounds of layoffs especially in production staff, but new jobs were created within e.g. suppliers, project developers, consultants, marketing, research and development. In Figure 2. Employees classified by job type (7), the employees in the Danish wind industry are classified by job type (7).

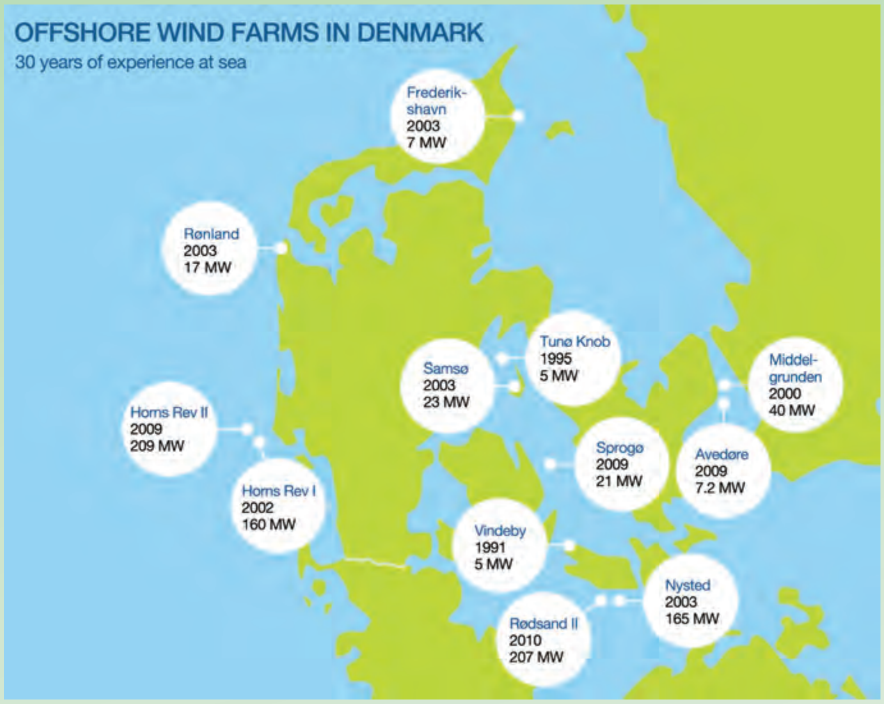

Figure 3. Existing offshore wind farms in Denmark (7)

3.2 Industry status

The Danish Wind Industry Association has published an updated membership directory, "Wind Power Hub – The Green Pages" in November 2011, which lists Denmark-based companies alphabetically and by type e.g., wind turbine, tower, blades, control systems manufacturer, consultancies, project development, etc. The major Denmark-based manufacturers of large commercial wind turbines of one megawatt or larger are Siemens Wind Power (formerly Bonus Energy A/S) and Vestas Wind Systems A/S.

3.3 Operational details

Existing offshore wind farm locations in Denmark can be seen in Figure 3 (7). In 2013, Anholt (400 MW) comes online, and the next large offshore wind farm planned is Horns Rev III and Krieger's Flak, with a combined capacity of 1,000 MW. The latter will be the first offshore wind farm with the grid connection replaced by a transmission line between two countries (Denmark and Germany).

The Anholt project (400 MW) was awarded to DONG energy in June 2010. The wind farm will begin production in 2012. When fully operational, it will provide 4% of Denmark's power consumption. Siemens Wind Power will supply 111 wind turbines with a capacity of 3.6 MW and a rotor diameter of 120 m for the project. Energinet.dk will be responsible for financing and constructing the substation at sea and connecting the farm to the electrical grid on land. The wind farm will cost an estimated 10 billion DKK (1.34 billion EUR; 1.8 billion USD). DONG Energy will get a feed-in tariff of 1.051 DKK/kWh (0.141 EUR/kWh; 0.189 USD/kWh) for the first 20 TWh. On 31 October 2011, the Danish Energy Agency granted DONG Energy the permit to commence the construction of Anholt Offshore Wind Farm and this was commenced at the turn of the year 2011/2012, as can be seen on the dedicated website launched by Dong Energy (8).

The Krieger's Flak (Baltic Sea) is located at the borders between Denmark, Germany and Sweden. The area was chosen as the first place in the world to have a joint offshore electricity grid. A joint feasibility study has been published in February 2010 (5). Germany is currently constructing Krieger's Flak 1(400MW), while Sweden has withdrawn from the project. In the Energy Agreement it was agreed, that Denmark will call for a tender of 600 MW in the period 2013-2015. Energinet.dk will be responsible for the environmental impact assessment as well as the preliminary investigations. The European Commission supports the project in the frame of the EU Recovery Plan with financial support of up to 150 million EUR (194 million USD) for a combined offshore grid connection. The Horns Rev 3 is a part of the Danish Energy Agreement of March 2012. Between 2013 and 2015 the Danish Energy Agency will call for a tender of 400 MW. Grid connection will be possible from 2017. As is the case for Krieger's Flak, Energinet.dk will be responsible for the environmental impact assessment as well as the preliminary investigations.

3.4 Wind energy costs

No new information is available since 2010 in which a report on wind energy

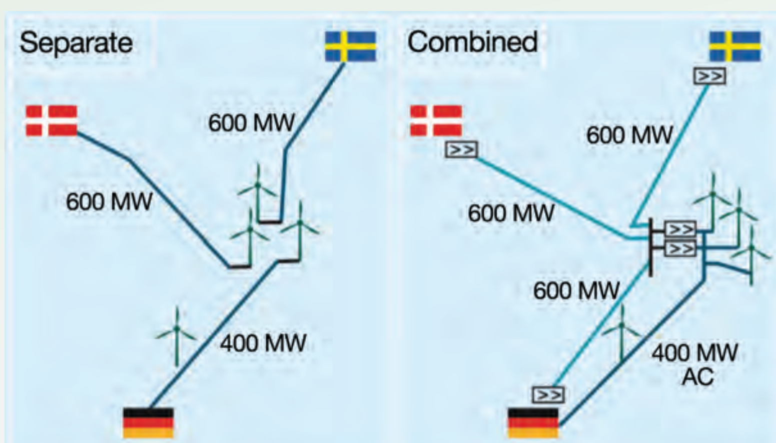

Figure 4. Variant of the combined solution referred to as the Combined Grid Solution (CGS)

costs in Denmark as of end of 2009 has been published under the EUDP 33033-0196 project (10), and summarized in the *IEA Wind 2010 Annual Report*.

4.0 R, D&D Activities

An annual report on the energy research program's budget, strategy, and projects by technology is published in cooperation between Energinet.dk, the EDDP, the DCSR, the EC representation in Denmark, and the Danish Advanced Technology Foundation (9). An updated list of Danish funded energy technology research projects is also available online (14).

In 2011, the available funding for R, D&D within energy technologies was 1 billion DKK (134 million EUR, 174 million USD). Figures from Eurostat and IEA show that Denmark is the fourth largest investor in energy-technology R, D&D, after Finland, Japan, and Norway (the latter two spend a high proportion of this on nuclear power). The different program through which funding can be granted and their position in the R, D&D development are the same as mentioned in the IEA Wind 2010 Annual Report. (9). Grants to wind energy projects supported in 2011 totaled 103 million DKK (approximately 770,000 euro; approximately 1 million USD). The projects that received funding in 2011 are presented in Table 2. For a list of currently running projects please refer to (10).

4.1 National R, D&D efforts

The main priorities defined for R, D&D in wind can be summarized as follows.

- Reduce the cost of energy for offshore wind: a target has been set to reduce cost of offshore wind energy by 50% by 2020 (11).
- In order to keep Denmark a center of competence it is deemed important to develop test and demonstration facilities of components, wind turbines and wind farms, and wind power plants in the energy system (12).
- Development, test and demonstration of grid integration solutions and smart grid solutions considering the target of integration of 50% wind to the grid by 2020 (13).

The thematic priorities for offshore R, D&D, in order to attain the envisioned cost reductions in offshore wind energy are presented in (11) and summarized in Table 2.

The planned onshore and offshore test and demonstration facilities were described in more detail in the IEA Wind 2010 Annual Report. Status of further development is given here.

The onshore national test center at Østerild is currently being established. Calls for tenders for rental of two of the seven stands were issued in November 2011, with rental periods commencing from August 2012. The first two test stands allow erection of wind turbines up to 210 m and 250 m respectively.

The Lindoe Offshore Renewables Center for testing wind turbine nacelles of 10 MW is being endorsed. As of 1 January 2012, the DTU Wind Energy Institute has been established. The institute is composed of the former Wind Energy Division at Risø DTU, two groups from DTU Mechanical Engineering that focus on fluid dynamics and composite mechanics, and two groups from the Materials Research Division at Risø DTU that focus on composite and metallic materials.

5.0 The Next Term

The proposed initiatives for reaching a fossil-free Denmark by 2050 and 50% wind penetration by 2020 have now been agreed on in parliament as of end March 2012. These are expected to boost wind energy deployment in Denmark in the coming years.

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Authors: Jørgen Lemming and Helen Markou, Risø DTU, Denmark.

Table 2. Danish R, D&D programs: Funded projects in 2011 and projects funded end 2010 (marked start January 2011) and not listed in the IEA Wind 2010 Annual Report

Project Title; Project Manager	Period; Budget	Purpose/Project description
EUDP (call Sep 2011)		
Demonstration of a method for design of tall wind turbines; DTU Institute for Wind Energy	Period: 201201-201412 EUDP funding: 5,312,000 DKK (711,808 EUR; 924,288 USD) Total funding: 10,403,000 DKK (1,394,002 EUR; 1,810,122 USD)	For operational reliability, international standards for turbine design must be updated. This private-public co-operation will provide the scientific basis for the industry's recommendations by documenting increased loads related to atmospheric flow effects

Project Title; Project Manager	Period; Budget	Purpose/Project description
Global wind atlas; DTU Institute for Wind Energy	Period: 201202-201501 EUDP funding: 6,949,000 DKK (931,166 EUR; 1,209,126 USD) Total funding: 8,175,000 DKK (1,095,450 EUR; 1,422,450 USD)	A large public database containing global wind resources. Access through web-based application programs will make the Atlas indispensable for all energy planners
Investigation of critical aeroelastic design challenges for wind turbines; DTU Institute for Wind Energy	Period: 201201-201312 EUDP funding: 4,327,000 DKK (579,818 EUR; 752,898 USD) Total funding: 7,609,000 DKK (1,019,606 EUR; 1,323,966 USD)	Identifies four critical aero-elastic design challenges for the wind through the development, demonstration, and deployment of new tools and models. Close co-operation between research partners and industry
Concrete element windmill tower; Conelto Ltd.	Period: 201201-201307 EUDP funding: 18,000,000 DKK (2,412,000 EUR; 3,132,000 USD) Total funding: 39,937,000 DKK (5,351,558 EUR; 6,949,038 USD)	Develops concept and a prototype tower with a hub height of 140 m. Will lead to further optimization of the concept
Demonstration of partial pitch 2-bladed (PP-2B) wind turbine concept; Envision Energy (Denmark) ApS.	Period: 201201-201307 EUDP funding: 8,259,000 DKK (1,106,706 EUR; 1,437,066 USD) Total funding: 16,849,000 DKK (2,257,766 EUR; 2,931,726 USD)	Demonstrates the PP-2B concept and its potential of tower and foundation load reductions
Recommendations for wind park modeling IEA Task 31 (WakeBench); DTU Institute for Wind Energy	Period: 201201-201307 EUDP funding: 873,000 DKK (116,982 EUR; 151,902 USD) Total funding: 1,027,000 DKK (137,618 EUR; 178,698 USD)	Achieve international consensus on the use of flow models in and around wind farms by participating in collaborative research in IEA Task 31
PSO		
Poseidon 2; DTU Institute for Wind Energy	Period: 201101-201206 PSO funding: 1,376,000 DKK (184,384 EUR; 239,424 USD) Total funding: 1,860,000 DKK (249,240 EUR; 323,640 USD)	Uses combined wave and wind energy conversion platform Poseidon37 to model and understand combined wave and wind energy platforms. Creates a database of measurements, an aero-elastic-hydrodynamic simulation tool, and a map of up-scaling problems
EASE WIND; Vestas Wind Systems A/S	Period: 201101-201403 PSO funding: 6,000,000 DKK (804,000 EUR; 1,044,000 USD) Total funding: 22,546,000 DKK (3,021,164 EUR; 3,923,004 USD)	Provides wind generation and conventional power generation plant properties regarding their interaction with the grid to enable higher percentage of wind energy integration into high voltage networks
Thermal modeling and analysis of a wind turbine generator; DTU Elektro	Period: 201101-201106 PSO funding: 697,000 DKK (93,398 EUR; 121,278 USD) Total funding: 918,000 DKK (123,012 EUR; 159,732 USD)	Validated thermal models will be developed and used in a proposed state monitoring method for wind turbine generators using thermal imaging
EUDP (call March 2011)		
System Services from small decentralized energy units; PowerLabDK Consortium	Period: 201107-201409 EUDP funding: 31,708,000 DKK (4,248,872 EUR; 5,517,192 USD) Total funding: 47,771,000 DKK (6,401,314 EUR; 8,312,154 USD)	Supports the standardization process, including development of distribution companies' grid codes in relation to the connection of decentralized units
NextRotor; DTU Mechanical Engineering	Period: 201107-201406 EUDP funding: 10,030,000 DKK (1,344,020 EUR; 1,745,220 USD) Total funding: 16,717,000 DKK (2,240,078 EUR; 2,908,758 USD)	Develops high efficiency, low cost, and low-noise wind turbine blades
Predictive Health Monitoring of Wind Turbines based on dynamic characterization; Brüel & Kjær Sound and Vibration Measurement A/S	Period: 201109-201408 EUDP funding: 7,006,000 DKK 938,804 (EUR; 1,219,044 USD) Total funding: 12,699,000 DKK (1,701,666 EUR; 2,209,626 USD)	Develops a system for predictive structural health monitoring for early discovery and prediction of damage to structural components of a wind turbine such as the blades

Project Title; Project Manager	Period; Budget	Purpose/Project description
Innovative blade root element; Fiberline Composites A/S	Period: 201108-201307 EDDP funding: 4,392,000 DKK (588,528 EUR; 764,208 USD) Total funding: 8,785,000 DKK (1,177,190 EUR; 1,528,590 USD)	Develops and demonstrates a prototype device for mounting a wind turbine blade. Experimentally characterize the strength and the process for a pilot plant designed
Use of vibration monitoring for troubleshooting on turbine mechanical parts; OrtoSense Wind Power ApS	Period: 201106-201212 EUDP funding: 1,303,000 DKK (174,602 EUR; 226,722 USD) Total funding: 2,606,000 DKK (349,204 EUR; 453,444 USD)	A solution will be developed to allow the wind turbine owner or O&M company to have early warnings of possible serious faults on the mechanical parts of the wind turbine. This will allow optimization of service planning
The towers for the next generation of wind turbines; FORIDA Development A/S	Period: 201107-201312 EUDP funding: 11,937,000 DKK (1,599,558 EUR; 2,077,038 USD) Total funding: 21,737,000 DKK (2,912,758 EUR; 3,782,238 USD)	Construct a hybrid tower: lower part is UHPC-elements, and upper part is steel. Will result in higher towers than are currently economically advantageous
Mobile mounting device for wind turbine tower; Ib Andresen Industri A/S	Period: 201101-201112 EUDP funding: 2,501,000 DKK (335,134 EUR; 435,174 USD) Total funding: 5,745,000 DKK (769,830 EUR; 999,630 USD)	Develop and demonstrate a Mobile Assembly Unit (MAU) to assemble a new innovative form of wind turbine towers
Experimental research wing - Phase 2; DTU Institute for Wind Energy	Period: 201101-201312 EUDP funding: 10,000,000 DKK (1,340,000 EUR; 1,740,000USD) Total funding: 17,194,000 DKK (2,303,996 EUR; 2,991,756 USD)	Develop an experimental platform to design stronger and more reliable wind turbine blades; new test and measurement methods; a design framework providing guidance on how appropriate numerical analysis and structural tests achieve the optimum design for a particular level of reliability
DCSR Funding		
Research on DC Network: connecting a new wind generator system; AAU Institute for Energy Technology	Period: 201101-201406 DCSR funding: 5,000,000 DKK (670,000 EUR; 870,000 USD) Total funding: 6,500,000 DKK (871,000 EUR; 1,131,000 USD)	Explore a new wind propulsion system, including a direct, low-speed drive system with a Switched Reluctance Generator (SRG DL) and a DC network that connects DL SRGs to the network
Aerodynamics and optimization of wind turbine systems in complex terrain; DTU Mechanical Engineering	Period: 201101-201403 DCSR funding: 4,928,000 DKK (660,352 EUR; 857,472 USD) Total funding: 8,508,000 DKK (1,140,072 EUR; 1,480,392 USD)	In cooperation between Danish and Chinese experts on wind turbine aerodynamics, optimization and atmospheric turbulence, the project will develop an integrated model, which is able to handle the multi-scale phenomena in complex terrain for the calculation of energy generation and loads on wind turbines
High reliability of large wind turbines due to improvements in wind turbine blade materials' performance based on micromechanics; DTU Institute for Wind Energy	Period: 201101-201406 DCSR funding: 4,998,000 DKK (669,732 EUR; 869,652 USD) Total funding: 5,500,000 DKK (737,000 EUR; 957,000 USD)	Provide a scientific basis for the development of advanced, strong material for wind turbine blades by optimizing their structures at the microscopic level
REWIND - Knowledge based engineering for Improved reliability of critical wind turbine components; DTU Mechanical Engineering	Period: 201101-201612 DCSR funding: 30,109,000 DKK (4,034,606 EUR; 5,238,966 USD) Total funding: 45,644,000 DKK (6,116,296 EUR; 7,942,056 USD)	Wind components such as gears and hubs are exposed to large and highly dynamic loads, which conventional manufacturing methods have difficulty to handle. Focuses on materials, processes, components, operation and loads to get a more holistic understanding of the components

18 EU, EWEA

European Union, European Wind Energy Association

1.0 Introduction

Europe maintains the largest amount of cumulative installed wind capacity in the world and remains the second biggest annual market. During 2011, according to European Wind Energy Association (EWEA) statistics, the European Union's (EU) wind energy market remained stable compared to the previous year as 9,616 MW of new capacity were commissioned compared to 9,648 MW in 2010.

Of the 9,648 MW of new turbines, 866 MW were installed offshore. However, the amount of new offshore installations decreased slightly (-1.9%) compared to the previous year due to harsh weather conditions in the last weeks of the year delaying work to make connections. However, considerable preparatory work was carried out on new offshore projects and numerous financing deals were concluded, suggesting solid future growth in this sector.

1.1 Overall capacity increases

Wind power capacity increases were led by Germany where 2,086 MW of new capacity were installed during 2011. The United Kingdom (UK) came in second with 1,293 MW, 752 MW (58%) of which were offshore, followed by Spain with 1,050 MW. Italy (950 MW), France (830 MW), and Sweden (763 MW) were followed by Romania (520 MW).

Among the emerging Central and Eastern European markets, after Romania, Poland installed the second most capacity in 2011 (436 MW). Both remain among the ten biggest European markets for the second year running.

Annual installations in the three pioneering wind power Member States has been decreasing. In 2000, 85% of all new installations in the EU were in Germany, Spain or Denmark, whereas in 2011 this share decreased to 34%. Wind power is increasingly being installed across Europe.

At the end of 2011, there were 93,957 MW of total installed wind capacity in the EU, an 11% increase compared to the previous year. This amount of capacity will, in a normal wind year, produce 204 TWh of electricity, enough to meet 6.3% of overall EU electricity consumption (up from 5.3% in 2010).

Over 29 GW (31% of the EU total) is installed in Germany. Spain has the second biggest wind power capacity, almost 22 GW (23% of the EU total). France (6.8 GW) has the third biggest installed capacity, taking the position that was formerly Italy's (6.7 GW). The fifth largest installed wind power base is in the UK (6.5 GW).

In terms of new power generating installations as a whole, 2011 was a record year in the EU, with 44.9 GW of new capacity connected to the grid, a 3.9% increase compared to 2010. Wind power accounted for 21.4% of new installations, the third biggest share after solar PV (46.7%) and natural gas (21.6%).

No other technologies compare to wind, PV, and natural gas in terms of new installations. New coal installations represented 4.8% of capacity additions, fuel oil 1.6%, large hydro 1.3% and CSP 1.1%. Nuclear, biomass, waste, geothermal, and ocean technologies each represented less than 1% of new capacity installations.

In 2000, new renewable power installations totaled 3.5 GW. Since then, renewable capacity installations grew almost tenfold, to reach 32 GW in 2011. Moreover, the share of new RES installations has also increased steadily, from 13% to 71% in 2011.

During 2011, 6.3 GW of nuclear capacity was decommissioned and over 1 GW of fuel oil capacity was taken offline. More renewable generating capacity was installed in the EU than ever before representing 71.3% of all new installations. Since 2008, renewable capacity installations have represented more than half of all new installed capacity.

In total, 302.6 GW of new power capacity has been installed in the EU since 2000. Of this, 28.2% was wind power, 47.8% renewables, and 90.8% renewables and gas combined.

The net growth since 2000 of gas power (116 GW), wind power (84.2 GW) and PV (47.4 MW) was at the expense of fuel oil (down 14.2 GW), nuclear (down 13.5 GW) and coal (down 10.3 GW). A sharp decrease was seen in 2011 in nuclear capacity due to the early decommissioning of a number of reactors in Germany. The other renewable technologies (hydro, biomass, waste, CSP, geothermal and ocean energies) have also been increasing installed capacity over the past decade, albeit more slowly than wind and PV.

The 21st century sees the EU power sector moving away from fuel oil, coal, and nuclear while continuing to increase its total installed capacity with gas, wind, and PV to meet increasing demand.

1.2 Offshore wind

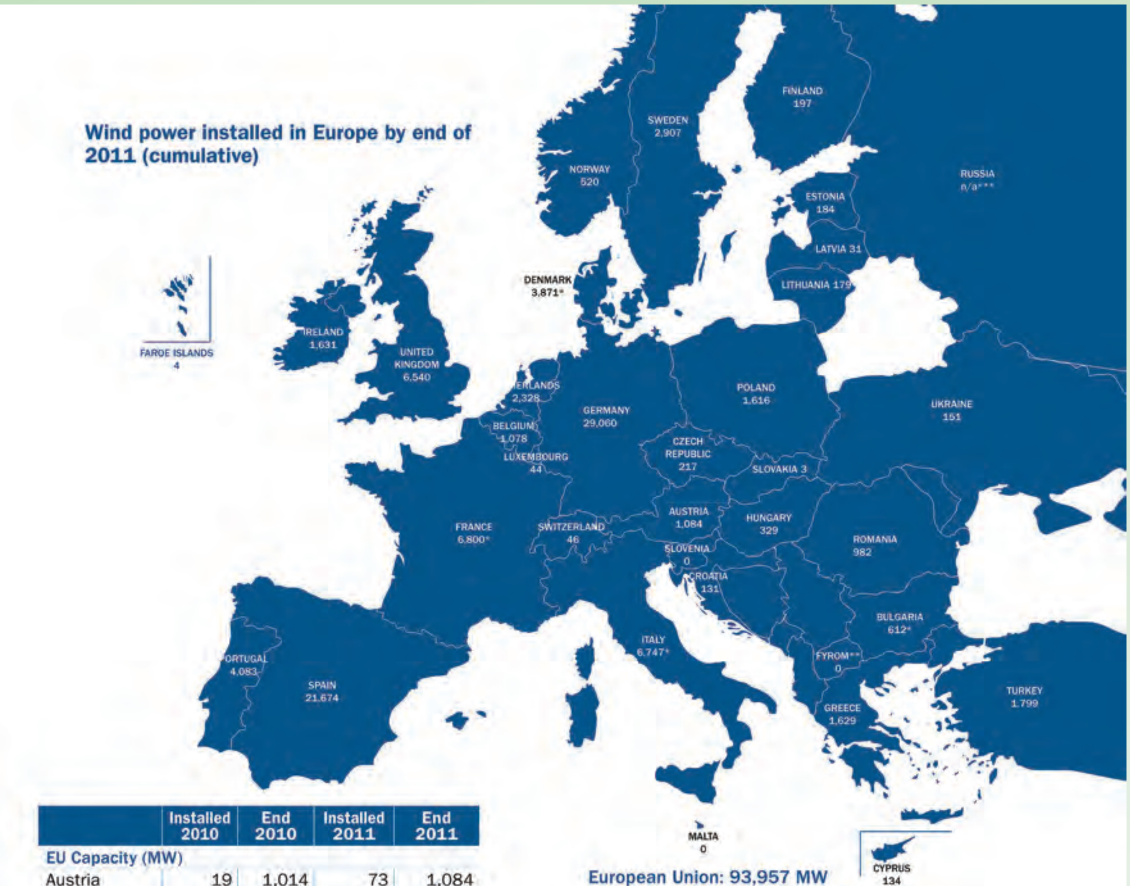
In European waters, 235 new offshore wind turbines, in nine wind farms, were fully grid connected during 2011. By the end 2011, 1,371 turbines were fully grid connected, totaling 3,813 MW in 53 wind farms in ten European countries. During the year, work was carried out on 15 offshore wind farms. Additionally, preparatory onshore work began in eight additional projects and prepiling in a ninth.

With 752 MW grid-connected in British waters during 2011, 87% of new capacity was added in the United Kingdom. In Germany, 108 MW were added, a 3.6-MW turbine was grid connected in Denmark, and a full scale 2-MW floating prototype was installed in Portugal. Two other down-scaled floating prototypes were tested in Norway and Sweden.

The UK is by far the largest market for offshore wind power with 2,094 MW installed, representing over half of all installed offshore wind capacity in Europe. Denmark follows with 857 MW, then the Netherlands (247 MW), Germany (200 MW), Belgium (195 MW), Sweden (164 MW), Finland (26 MW), and Ireland (25 MW). Norway and Portugal both have a full-scale floating turbine.

By early 2012, almost 5.3 GW of offshore wind capacity was under construction. Once completed, installed

Wind power installed in Europe by end of 2011 (cumulative)



European Union: 93,957 MW
Candidate Countries: 1,930 MW
EFTA: 565 MW
Total Europe: 96,607 MW

	Installed 2010	End 2010	Installed 2011	End 2011
EU Capacity (MW)				
Austria	19	1,014	73	1,084
Belgium	325	886	192	1,078
Bulgaria	322	500	112*	612*
Cyprus	82	82	52	134
Czech Republic	23	215	2	217
Denmark	315	3,749	178	3,871
Estonia	7	149	35	184
Finland	52	197	0	197
France	1,396	5,970	830*	6,800*
Germany	1,493	27,191	2,086	29,060
Greece	238	1,323	311	1,629
Hungary	94	295	34	329
Ireland	82	1,392	239	1,631
Italy	948	5,797	950*	6,747*
Latvia	2	30	1	31
Lithuania	72	163	16	179
Luxembourg	1	44	0	44
Malta	0	0	0	0
Netherlands	56	2,269	68	2,328
Poland	456	1,180	436	1,616
Portugal	171	3,706	377	4,083
Romania	448	462	520	982
Slovakia	0	3	0	3
Slovenia	0	0	0	0
Spain	1,463	20,623	1,050	21,674
Sweden	604	2,163	763	2,907
United Kingdom	1,005	5,204	1,293	6,540
Total EU-27	**9,648**	**84,650**	**9,616**	**93,957**
Total EU-15	**8,144**	**81,571**	**8,409**	**89,670**
Total EU-12	**1,504**	**3,079**	**1,208**	**4,287**

	Installed 2010	End 2010	Installed 2011	End 2011
Candidate Countries (MW)				
Croatia	61	89	42	131
FYROM**	0	0	0	0
Serbia	0	0	0	0
Turkey	528	1,329	470	1,799
Total	**589**	**1,418**	**512**	**1,930**
EFTA (MW)				
Iceland	0	0	0	0
Liechtenstein	0	0	0	0
Norway	18	436	84	520
Switzerland	25	42	3	46
Total	**43**	**478**	**87**	**565**
Of which offshore and near shore	0	2	0	2
Other (MW)				
Faroe Islands	0	4	0	4
Ukraine	1	87	66	151
Russia	0	9	n/a***	n/a***
Total	**1**	**101**	**66**	**164**
Total Europe	**10,280**	**86,647**	**10,281**	**96,607**

* Provisional
** Former Yugoslav Republic of Macedonia
*** Figure not communicated
Note: Due to previous year adjustments, 216.03 MW of project de-commissioning, re-powering and rounding of figures, the total 2011 end-of-year cumulative capacity is not exactly equivalent to the sum of the 2010 end-of-year total plus the 2011 additions.

offshore capacity in Europe will reach 9 GW. Furthermore, EWEA has identified 18 GW of fully consented offshore projects in 12 European countries.

2.0 R, D&D Wind Energy Projects

In 2011, around 20 R&D projects were running with the support of the Sixth (FP6) and Seventh (FP7) Framework Programmes of the EU (the Framework Programmes are the main EU-wide tool to support strategic research areas). The management and monitoring of these projects is divided between two Directorate-Generals (DGs) of the EC: the Directorate-General for Research and Innovation (DG Research) for projects with medium- to long-term impact and the Directorate-General for Transport and Energy (DG ENER) for demonstration projects with short- to medium-term impact on the market. The following paragraphs summarize both the nature and the main data of EU R&D initiatives funded projects during 2011 managed by DG Research.

2.1 DG Research activities

The last FP6 project UPWIND and two FP7 projects, RELIAWIND and ORECCA finished in 2011. The other FP7 projects SAFEWIND, Marina

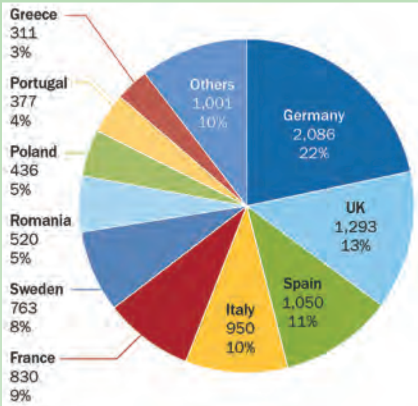


Figure 1. EU Member State shares for new wind power capacity installed during 2011 (Source: EWEA)

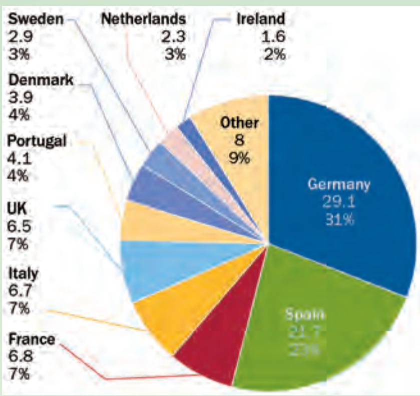


Figure 2. EU Member States shares for total wind power capacity installed at end 2011 (Source: EWEA)

Platform, HAWE, DeepWind and HiPRwind continued their activities while one new project, ClusterDesign, started at the end of the year. The following gives some details about those projects:

UPWIND: This Integrated Wind Turbine Design (www.upwind.eu) activity, started in March 2006 to tackle, over six years, the challenges of designing very large turbines (8 to 10 MW), both for onshore and offshore. UPWIND focuses on design tools for the complete range of turbine components. It addresses the aerodynamic, aeroelastic, structural, and material design of rotors. Critical analysis of drive train components is also being carried out in the search for breakthrough solutions. UPWIND is a large initiative composed of 40 partners and brings together the most advanced European specialists of the wind industry.

RELIAWIND: Offshore wind energy is called to play a key role in the achievement of the EU 2020 objectives. Currently, offshore maintenance costs are still too high and thus require higher feed-in tariffs for the private investor's business case to reach minimum profitability. The RELIAWIND project aims to offset this paradigm and allow offshore wind power to be deployed in the same way onshore wind power has been. Based on the success of collaborative experiences in sectors such as aeronautics, members of the European wind energy sector established the RELIAWIND consortium to jointly and scientifically study the impact of wind turbine reliability. The mission of the consortium was to change the paradigm of how wind turbines are designed, operated, and maintained. This will lead to a new generation of offshore (and onshore) wind energy systems that will hit the market in 2015. RELIAWIND started in March 2008 and continued for 36 months. This research project has achieved many results related to the following objectives:

- To identify critical failures and components (WP-1: Field Reliability Analysis)
- To understand failures and their mechanisms (WP-2: Design for Reliability)
- To define the logical architecture of an advanced wind turbine generator health monitoring system (WP-3: Algorithms)
- To demonstrate the principles of the project findings (WP-4: Applications)
- To train internal and external partners and other wind energy sector stakeholders (WP-5: Training)
- To disseminate the new knowledge through conferences, workshops, web site, and the media (WP-6: Dissemination).

SAFEWIND: The integration of wind generation into power systems is affected by uncertainties in the

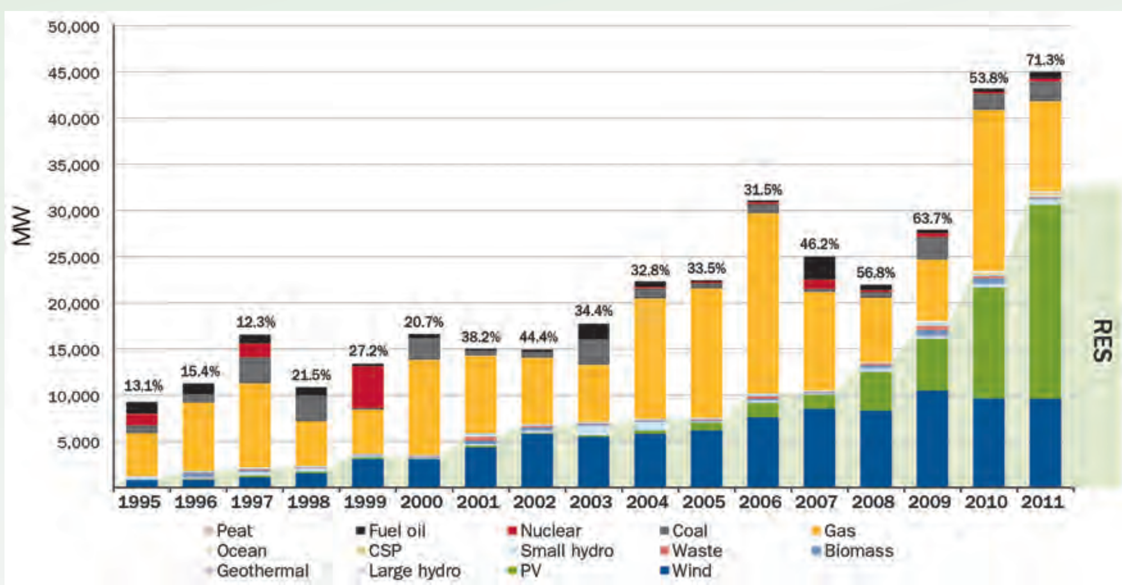


Figure 3. EU installed power generating capacity per year in MW and RES share (%) (Sources: Bentek Energy PowerVision, EWEA, Eurostat, EU-OEA, EPIA, Estela, EGEC)

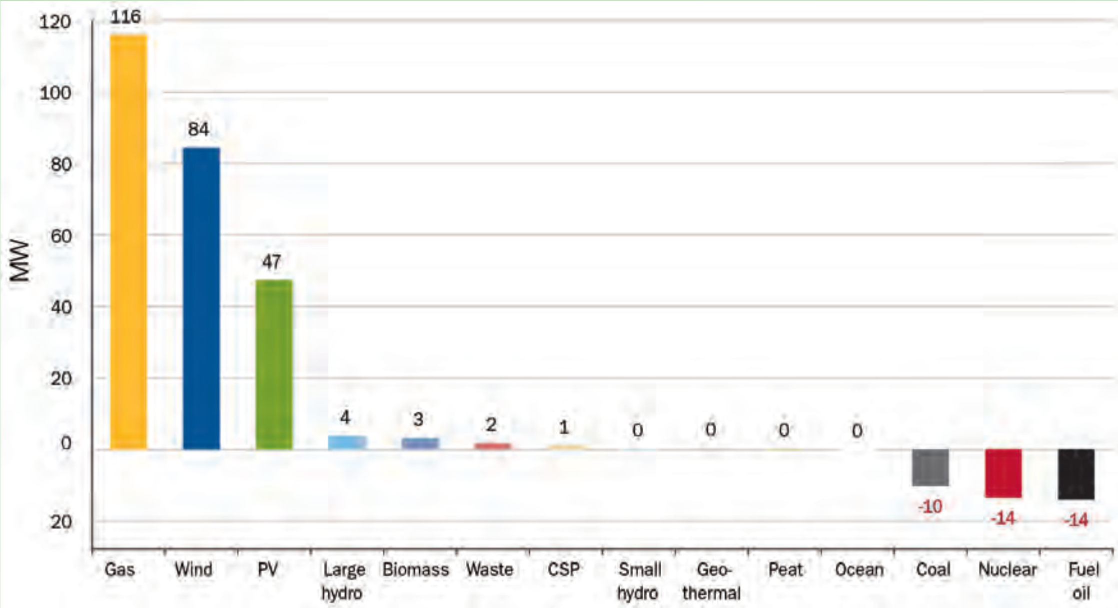


Figure 4. Net electricity generating installations in EU 2000 – 2011 (GW) (Sources: Bentek Energy PowerVision, EWEA, Eurostat, EU-OEA, EPIA, Estela, EGEC)

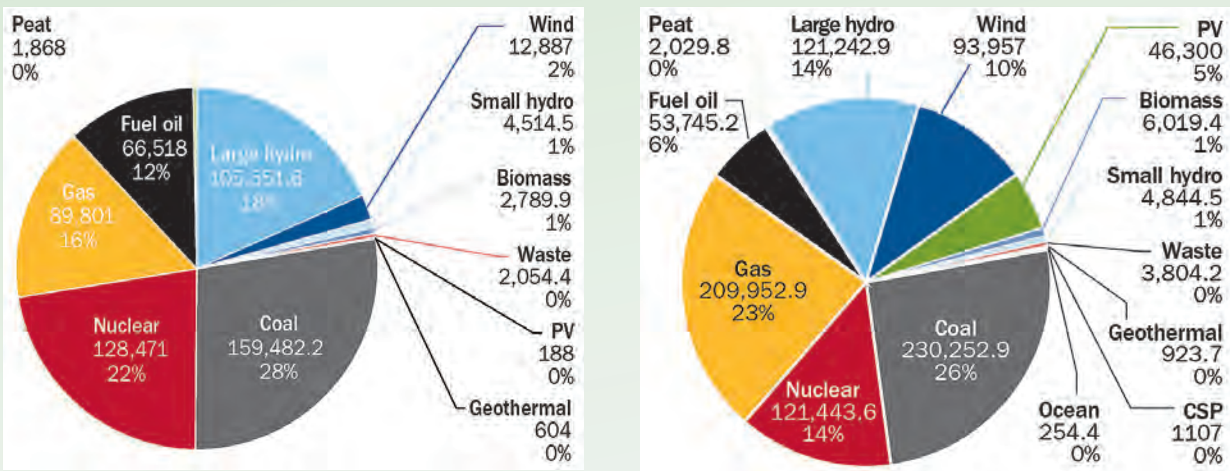


Figure 5. EU power capacity mix in 2000 and 2011 (Sources: Bentek Energy PowerVision, EWEA, Eurostat, EU-OEA, EPIA, Estela, EGEC)

forecasting of expected power output. Misestimating of meteorological conditions or large forecasting errors (phase errors, near cut-off speeds, etc), are very costly for infrastructures (such as unexpected loads on turbines) and reduce the value of wind energy for end-users. The state-of-the-art techniques in wind power forecasting have focused so far on the "usual" operating conditions rather than on extreme events. Thus, the current wind forecasting technology presents several strong bottlenecks. End-users argue for dedicated approaches to reduce large prediction errors and for scaling up local predictions of extreme weather (gusts, shears) to a European level because extremes and forecast errors may propagate. Similar concerns arise from the areas of external conditions and resource assessment where the aim is to minimize project failure. The aim of this project is to substantially improve wind power predictability in challenging or extreme situations and at different temporal and spatial scales. Going beyond this, wind predictability will be considered as a system parameter linked to the resource assessment phase, where the aim is to make optimal decisions for the installation of a new wind farm. Finally, the new models will be implemented into pilot operational tools for evaluation by the end-users in the project. SAFEWIND started in September 2008 and will last for 48 months. The project concentrates on:

• Using new measuring devices for a more detailed knowledge of the wind speed and energy available at local levels
• Developing strong synergy with research in meteorology
• Developing new operational methods for warning/alerting that use coherently collected meteorological and wind power data distributed over Europe for early detection and forecasting of extreme events
• Developing models to improve medium-term wind predictability
• Developing a European vision of wind forecasting that takes advantage of existing operational forecasting installations at various European end-users.

ORECCA: The objectives of the Offshore Renewable Energy

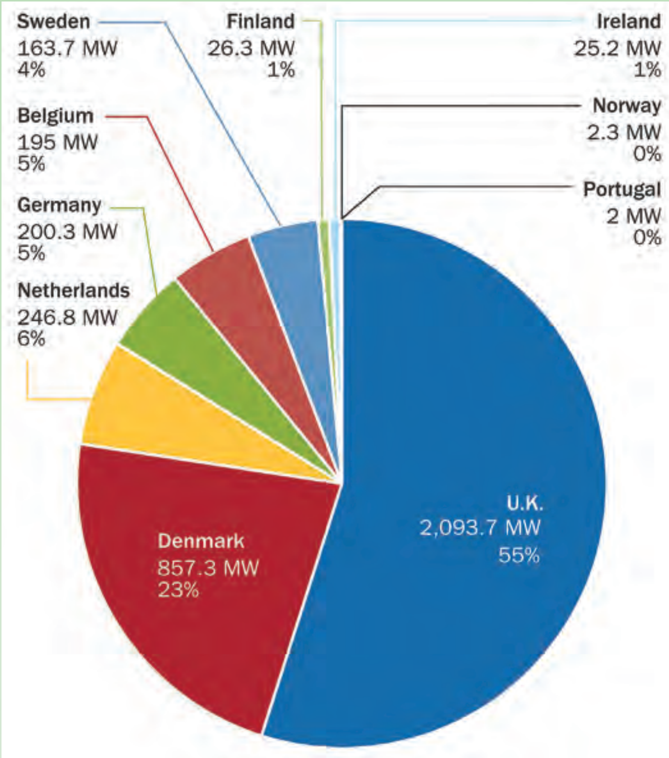


Figure 6. EU Member States shares of cumulative offshore wind power capacity at end 2011 (Source: EWEA)

Conversion Platforms – Coordination Action are to create a framework for knowledge sharing and to develop a research roadmap for activities in the context of offshore renewable energy (RE). In particular, the project has stimulated collaboration in research activities leading towards innovative, cost efficient, and environmentally benign offshore RE conversion platforms for wind, wave and other ocean energy resources, for their combined use as well as for the complementary use such as aquaculture and monitoring of the sea environment. The use of the offshore resources for RE generation is a relatively new field of interest. ORECCA has contributed to overcome the knowledge fragmentation existing in Europe and to stimulate the key experts to provide useful inputs to industries, research organizations and policy makers (stakeholders) on the necessary next steps to foster the development of the ocean energy sector in a sustainable and environmentally friendly way. A focus was given to respect the strategies developed towards an integrated European maritime policy. The project has defined the technological state of the art, described the existing economical and legislative framework and identified barriers, constraints and needs within.

ORECCA has enabled collaboration of the stakeholders and defined the framework for future exploitation of offshore RE sources by defining two approaches: pilot testing of technologies at an initial stage, and large scale deployment of offshore RE farms at a mature stage. ORECCA has finally developed a vision including different technical options for deployment of offshore energy conversion platforms for different target areas in the European seas and delivered integrated roadmaps for the stakeholders. These will help to define the strategic investment opportunities, the R&D priorities and the regulatory and socio-economic aspects that need to be addressed in the short to the medium term to achieve a vision and a strategy for a European policy towards the development of the offshore RE sector aims to overcome knowledge fragmentation in Europe, with a focus on platform designs and technologies including supply chain issues.

Marina Platform: Research in the MARINA Platform project will establish a set of equitable and transparent criteria for the evaluation of multipurpose platforms for marine renewable energy (MRE). Using these criteria, the project will produce a novel, whole-system set of design and optimization tools addressing: inter alia, new platform design, component engineering, risk assessment, spatial planning, and platform-related grid connection concepts, all focused on system integration and reducing costs. These tools will be used, incorporating into the evaluation all, presently known proposed designs including (but not limited to) concepts originated by the project partners, to produce two or three realizations of multi-purpose renewable energy platforms. These will be brought to the level of preliminary engineering designs with estimates for energy output, material sizes and weights, platform dimensions, component specifications and other relevant factors. This will allow the resultant new multi-purpose MRE platform designs, validated by advanced modeling and tank-testing at reduced scale, to be taken to the next stage of development, which is the construction of pilot scale platforms for testing at sea.

HAWE (High Altitude Wind Energy): The quest for clean and renewable energy sources found tremendous potential in wind power. So far, it has been harvested mostly by wind towers, which use only wind currents close to the ground (bellow 200 m). Since low altitude wind currents are slow and intermittent, most wind farms operate, on average, 25-35% of their capacity. This represents a severe limitation to current state-of-art wind power technology, as towers can hardly be taller than 130 m without prohibitive costs and insurmountable technical difficulties. To bypass these difficulties, it is proposed to perform R&D in a multitude of technology fields such as materials, aerodynamics, and control, further developing a wind power system capable of harnessing the energy potential of high altitude wind without the need for heavy towers or expensive elevated nacelles. HAWE consists of a buoyant air ship anchored to a ground station by a tether cable operating a two phase cycle. During the power production phase the airborne module generates lift, pulling up the tether cable which, at the ground station, is in a winch drum driving a flywheel connected to an alternator producing electricity. When the tether cable is fully unwound, the recovery phase starts – as the cylinder rotation ceases and the cable is reeled back to its initial position decoupled from the flywheel, completing a cycle. This is performed continuously. The successful implementation of this concept will increase the share of renewable energy in Europe since the achievement of the goal to produce renewable energy at competitive prices with coal derived energy should lower its cost. A high security of supply, a cleaner environment, and the possibility to keep Europe as a global leader in wind power, are other benefits of this technology.

DeepWind: The hypothesis of this project is that a new wind turbine concept developed specifically for offshore application has potentials for better cost efficiency than existing offshore technology. Based on this hypothesis the objectives are:

- to explore the technologies needed for development of a new and simple floating offshore concept with a vertical axis rotor and a floating and rotating foundation
- to develop calculation and design tools for development and evaluation of very large wind turbines based on this concept and
- evaluation of the overall concept with floating offshore horizontal axis wind turbines.

Upscaling of large rotors beyond 5 MW has been expressed to have more cost potentials for vertical axis wind turbines than for horizontal axis wind turbines due to less influence of cyclic gravity loads. However, the technology behind the proposed concept presents extensive challenges needing explicit research, especially: dynamics of the system, pultruded blades with better material properties, sub-sea generator, mooring and torque absorption system, and torque, lift, and drag on the rotating and floating shaft foundation.

In order to be able to evaluate in detail the technologies behind the concept the project comprises:

- numerical tools for prediction of energy production, dynamics, loads and fatigue,
- tools for design and production of blades
- tools for design of generator and controls,
- design of mooring and torque absorption systems, and
- knowledge of friction torque and lift and drag on rotating tube.
- The technologies need verification, and in the project verification is made by:
- proof-of concept testing of a small, kW sized technology demonstrator, partly under real conditions, partly under controlled laboratory conditions,
- integration of all technologies in demonstration of the possibility of building a 5 MW wind turbine based on the concept, and an evaluation of the perspectives for the concept.

HiPRwind: The aim of the HiPRwind project is to develop and test new solutions for very large offshore wind turbines at an industrial scale. The project addresses critical issues of offshore wind turbine technology such as extreme reliability, remote maintenance and grid integration with particular emphasis on floating wind turbines, where weight and size limitations of onshore designs can be overcome. HiPRWind will test a cost effective approach to floating offshore wind turbines at a 1:10 lower MW scale as a first of its kind worldwide. Innovative engineering methods, new rotor blade designs and built-in active control features will reduce the dynamic loads and thus weight and cost drastically compared to existing designs. It will overcome the gap in technology development between small scale tank testing and full scale offshore deployment. Thus HiPRwind will significantly reduce risk and cost of deep offshore technology commercialization.

The HiPRwind project can make use of two existing offshore test areas, with a favorable permitting situation and suitable infrastructure such as the grid connection and monitoring facilities. In WP 1, a floating support structure and the moorings system will be designed and manufactured. WP 2 covers the operation of the research projects of the platform. Within WP 3 to 6, critical aspects of the floating wind turbine are investigated, such as the structure and its system dynamics, the controller, high reliability power electronics to be tested in the lab at a multi-MM scale, the condition and structural health monitoring systems and the rotor based on innovative blade designs and features. The results feed into WP 7 to identify and refine new concepts for very large offshore wind turbines. The full impact of the project is ensured by a strong participation of leading industrial as well as R&D stakeholders from the offshore-maritime and the wind energy sector with a strong background in harsh environment industrial developments.

ClusterDesign: Today, an offshore wind farm is merely a collection of wind turbines where the components of an offshore wind farm cluster are optimized but not the overall cluster. In the future, the best-performing wind farms will be designed with an integrated approach. For this purpose, design tools for offshore wind farm clusters must then yield for the overall optimum. This means they must integrate the cluster and grid connection design with new intelligent mechanisms for wind turbine, farm, and cluster control already in the design phase.

The objective of the project is to develop toolbox for such an integrated offshore wind farm clusters design. In line with the call this is achieved by combination of the following different design optimization tools elements as advanced wake models, turbine load models, grid interconnection models, and by incorporating the operation of the offshore clusters as a virtual offshore power plant. The consortium will depart from existing state of the art models that are further developed within the project. In parallel, extensive measurements and data collection is carried out in order to validate the models, to calibrate and further improve them. Furthermore the developed control mechanisms for virtual offshore power plant operation will be tested in existing wind farms to verify that indeed an increase of the overall energy yield, a reduction of load on the single turbines, and a flexible operation of the wind farm clusters is achieved.

2.2 Future R&D projects

New FP7 projects to start in 2012 will address the topics of innovative wind conversion systems (10 to 20 MW) for offshore applications (EC Call FP7-ENERGY-2012-1) and demonstration of innovative designs to reduce fatigue loads and improve reliability of multi-MW turbines (FP7-ENERGY-2012-2). R&D for offshore wind energy is also included in the 2011 "Ocean of Tomorrow" topic "multi-use offshore platforms".

3.0 Plans and Initiatives

The Strategic Energy Technology Plan (3) is a pragmatic and pioneering tool for supporting the development of low carbon technologies to significantly contribute to the European energy and climate change objectives. As part of this plan, eight European Industrial Initiatives were set up to include the industrial sector in setting priorities, objectives, activities, and in identifying the financial and human needs to make a step change in the energy sector (including in wind power).

The European Wind Initiative, which was launched in June 2010, has the objective to make wind one of the cheapest sources of electricity and to enable a smooth and effective integration of massive amounts of wind electricity into the grid. To achieve this, special efforts will be dedicated to greatly increase the power generation capacity of the largest wind turbines (from 5 to 6 MW to 10 to 20 MW) and to tap into the vast potential of offshore wind. This will pave the way for achieving ambitious targets by 2020:

- Supplying up to 20% of the EU electricity consumption
- Making wind energy the most competitive energy source
- Enabling the development of new types of turbines reaching up to 20 MW.

The European Wind Initiative, which has a budget of 6 billion EUR (7.76 billion USD) (public and private resources) for the 2010 to 2020 period, will integrate the following elements:

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

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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, Garrad Hassan, and Risø DTU. Its objectives are to identify and prioritize areas for increased innovation, new and existing research, and development tasks and to formulate relevant funding recommendations to EU and national public authorities in order to support wind power R&D.

Historically, the main drivers for wind energy cost reductions have been R, D&D, for approximately 40% and economies of scale for around 60%. The scope of the TPWind mirrors this duality. 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 a one working group focusing on policy issues.

Further to that, TPWind also has a Member States Mirror Group gathering representatives from national governments. The Platform is led by a Steering Committee of 25 Members, representing a balance between the industry and the R&D community, and between European countries. Altogether, TPWind is composed by approximately 150 high-level experts representing the whole wind industry.

Since December 2010, TPWind selected 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. TPWind also provides an opportunity for informal collaboration and coordination between EU member states, including those less developed in wind energy terms.

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 European Commission in 2009 and is now being implemented by EU institutions, member states, and TPWind. The budget of the EWI for the 2010-2020 period is 6 billion EUR (7.76 billion USD), including public and private resources.

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19 Finland

1.0 Overview

In Finland, 27% of electricity consumption was provided by renewables in 2010. Finland's generating capacity is diverse. In 2011, 26% of gross demand was produced by nuclear, 15% by hydropower, 31% from combined heat and power (coal, gas, biomass, and peat), 11% from direct power production from mainly coal and gas, and 16% from imports. Biomass is used intensively by the pulp and paper industry, raising the share of biomass-produced electricity to 11% in Finland. The electricity demand, which is dominated by energy-intensive industry, was reduced by 4% in 2011, with a total of 84.4 TWh.

Finland aims to increase the share of renewables from 28.5% to 38% of gross energy consumption to fulfill the EU 20% target in 2020. The national energy strategy foresees biomass as providing most of the increase in renewables. The hydropower resource has the potential for only about 1 TWh/yr more. This makes wind power the second largest source of new renewables in Finland, with a target of 6 TWh/yr in 2020.

Wind energy potential is located mostly on coastal areas. There is a huge technical potential offshore, with ample shallow sites available. Wind energy deployment has been very slow, but setting the target of 6 TWh/yr for 2020 (2,500 MW) and a market based feed-in tariff system starting in 2011 has led to a rush for the best sites. At the end of 2011, a total of 199 MW were installed, producing about 0.5 TWh, or 0.6% of gross demand in Finland. At the beginning of 2012, there were 3,300 MW of wind power projects in various phases of planning onshore, and 3,000 MW of announced projects offshore.

A market based feed-in premium with a guaranteed price of 83.5 EUR/MWh (108 USD/MWh) entered into force on 25 March 2011. There will be an increased tariff of 105.3 EUR/MWh (136.3 USD/MWh) through the end of 2015 (maximum three years). The difference between the guaranteed price and

Table 1. Key Statistics 2011: Finland	
Total installed wind generation	199 MW
New wind generation installed	2 MW
Total electrical output from wind	0.48 TWh
Wind generation as a percentage of national electric demand	0.6%
Average capacity factor	28%
Target:	6 TWh/yr (2,500 MW) in 2020

spot price of electricity will be paid to the producers as a premium.

Wind power technology exports from Finland have been about 0.8 billion EUR (1.03 billion USD). The wind turbine manufacturer WinWinD developed further the ice prevention system for its 3-MW turbines. Mervento built its first 3.6-MW, direct-drive wind turbine in Vaasa. Moventas is developing its gearboxes for larger turbines, and ABB and The Switch are developing generator and frequency converter solutions for wind power. Ruukki Oy provides steel materials and structures and has launched a lattice tower up to 140 m in height.

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 RES (current RES share 28.5%).

2.2 Progress

The development in wind power capacity and production is presented in Figure 1. In 2011, there was one wind farm installed, but it was not yet producing power at the end of the year so the new installed capacity in the statistics is only one second-hand 750-kW turbine, and the total capacity was 198 MW at the end of 2011. There are several other wind farms in the building phase, so the new installed capacity during 2012 will be 70 MW to 100 MW.

The wind resource was close to average during 2011, after two low wind years. The 50 MW of new capacity installed in 2010 had their first full year of operation, therefore increasing wind energy production in 2011 by 65% compared to 2010. The production of 483 GWh 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 new wind farms produce considerably better than the old ones.

At the end of 2011, 131 wind turbines were in operation in Finland (Figure 2). The average wind turbine size is 1.5 MW. About 37% of the capacity is from turbines originating from Finland, 46% from Denmark, 14% from Germany, and 3% from the Netherlands. The size of the installed capacity ranges from 75 kW to 3.6 MW. In early 2012, there were 21 MW installed (six 3-MW turbines in Simo and one 3.6-MW pilot plant in Vaasa) and 50 MW to 150 MW worth of wind power projects were preparing for construction (in Simo, Hamina, Kotka, and Raahe).

The Åland islands between Finland and Sweden constitute an autonomous region with its own legislation, budget, and energy policy. Wind energy covered 23% of electricity consumption in 2011 with 22 MW of installed capacity. A transmission line to mainland Finland is planned and this will help further deployment of wind power in this wind rich region. However, the region has not been included in the guaranteed price mechanism thus making all development dependent on the regional, limited subsidies.

2.3 National incentive programs

A feed-in premium entered into force on 25 March 2011 in Finland, replacing the old investment subsidy scheme with limited amount of funds. Earlier, a tax refund of 6.9 EUR/MWh (8.9 USD/MWh) was awarded. This small subsidy for the older projects (not in the feed-in premium scheme) was stopped in 2011.

The feed-in premium scheme means that a guaranteed price of 83.5 EUR/MWh (108 USD/MWh) is set for wind power, where the difference between the guaranteed price and spot price of electricity will be paid to the producers as a premium. There is a higher guaranteed price level of 105.3 EUR/MWh (136.2 USD/MWh) until the end of 2015 (maximum three years) to encourage early projects. A three-month average spot price (day-ahead electricity market price at the Nordic market Elspot) will be the comparison price to determine the payments to the producers. The producers will be paid the guaranteed price minus the average spot price, after every three-month period. Should the average spot price rise to above the guaranteed price, the producers will get this higher price. However, wind power producers will also be responsible for paying the imbalance fees from their forecast errors. This has been estimated to add 2 to 3 EUR/MWh (2.6 to 3.9 USD/MWh) to the producers, if they use a weather forecast based prediction system for the day-ahead bids to the electricity market.

If the emission trading of fossil fuel prices raises electricity market prices, this will reduce the taxpater payments for this subsidy. The cost for the subsidy

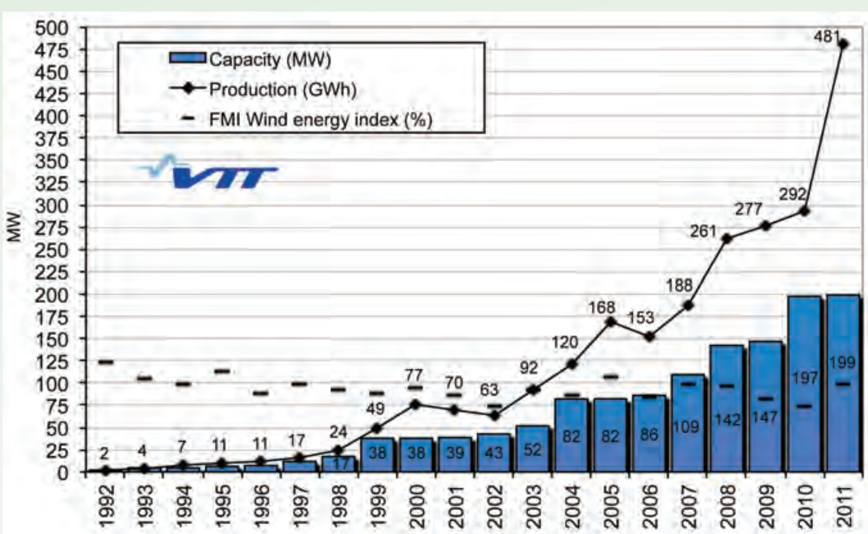

Figure 1. Wind power capacity and production: FMI Wind energy index is calculated from Finnish Meteorological Institute (FMI) wind-speed measurements and converted to wind power production; 100% is average production from 1987 to 2001.

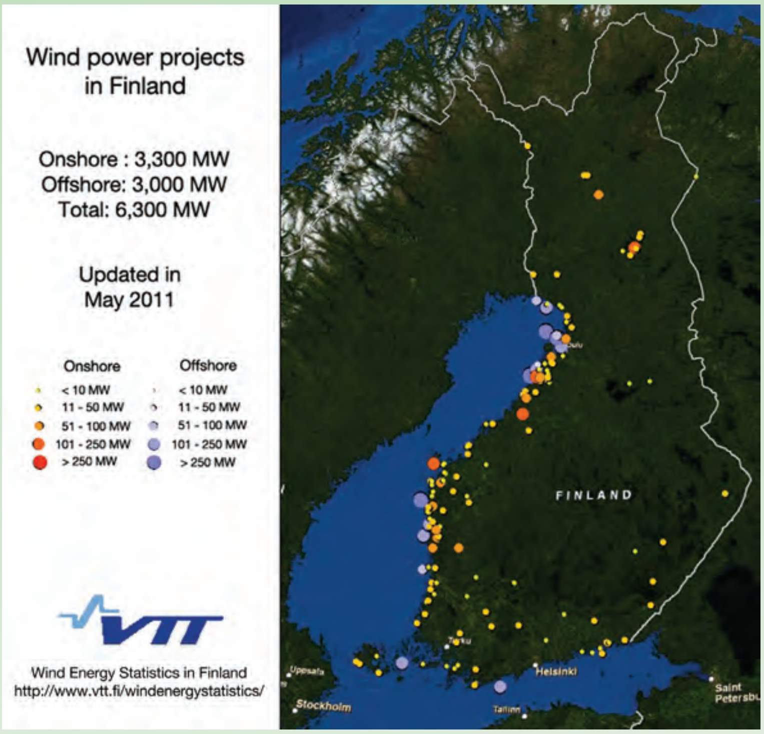

Figure 2. Wind turbines operating in Finland by the end of 2011 (right) and wind power projects published (left)

will be recovered by electricity taxes. The regulator Energy Market Authority is managing the system. A special subsidy for offshore wind power will still be considered. Negotiations for an investment subsidy for the first large offshore demonstration wind power plant are ongoing. There is a 20 million EUR (25.9 million USD) demonstration subsidy included for an offshore wind farm in the budget frame in 2013-2015.

The guidelines for planning and building permission procedures for wind power plants are currently being revised by Ministry of Environment.

2.4 Issues affecting growth

The progress in wind power capacity in Finland has been slow compared with other European countries. The funds available for investment subsidies were inadequate to achieve any large increases in wind-power capacity. From 2005 to 2008, no specific goal for wind power was set.

The target of 6 TWh/yr for 2020 (2,500 MW) and the preparation for feed-in premium system led to a rush for the best sites during the last couple of years. At the beginning of 2012, there were 165 wind power projects totaling 4,800 MW in various phases of planning onshore, and 16 announced projects offshore totaling 3,000 MW. The guaranteed price 83.5 EUR/MWh (108 USD/MWh) is not sufficient to start offshore projects.

Permitting has proved to be a challenge for many of the planned projects. Concerns have been raised on 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.

Radar influence became an issue in 2010 stopping all building permits for a while. A project to develop an impartial and transparent procedure and scientific tool to help Ministry of Defence to estimate the radar impacts was made in 2011. Based on the investigations since then, more than 40 sites were given permission from radar interference point of view. Currently about 40 sites are on the list for a more detailed assessment and less than ten projects have been declined based on radar issue.

Sites for wind power have been added to regional plans by the authorities. This is an on-going practice in all regional plan updates and will help in permitting future wind power projects. To overcome planning and permitting problems, investigation on administrative barriers for Finnish wind power was launched by the Ministry of Economy and Employment. Investigator Justice Lauri Tarasti was appointed to come up with proposals by April 2012.

3.0 Implementation

3.1 Economic impact

Direct and indirect employment in the energy sector of the wind power industry is still quite low (less than 100 people). However, the technology sector is strong. There are more than 20 technology and manufacturing companies involved in wind power in Finland, employing more than 3,000 people, with an economic turnover of about 0.8 billion EUR/yr (1.03 billion USD/yr). All in all, there are more 100 companies in the whole value chain from development and design of wind farms to O&M and other service providers.

Technology Industries has estimated that maintaining current market share in global wind power markets would mean increasing economic turnover to a level of 3 billion EUR/yr (3.8 billion USD/yr) in 2020. However, if global market share increased, there is the potential to raise technology exports to a level of 12 to 14 billion EUR/yr (15.5 to 18.1 billion USD/yr) in 2020. Employment in the wind power sector in Finland could increase to 14,000 to 36,000 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.

3.2 Industry status

3.2.1 Manufacturing

The Finnish manufacturer WinWinD presented its first 1-MW pilot plant in spring 2001 and erected the 3-MW pilot plant in 2004 in Oulu. Their turbines operate at variable speed with a slow speed planetary gearbox and a low-speed, permanent-magnet generator. By the end of 2011, WinWinD had installed 314 MW in seven countries including Estonia, Finland, France, Portugal, and Sweden. WinWinD has manufactured 37% (73 MW) of the installed wind power capacity in Finland (Figure 3). In 2011, the number of employees was about 800 (311 in Finland).

In 2009, a new turbine manufacturer, Mervento, started to develop its first prototype that is especially designed for offshore applications. The 3.6-MW pilot turbine was erected in the beginning of 2012. The turbine is direct-drive and the pilot 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.

Several industrial enterprises have developed important businesses as world suppliers of major 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 to meet the needs of 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.

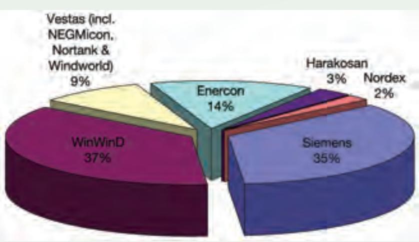

Figure 3. Market shares of turbine manufacturers in Finland as a percentage of total capacity at the end of 2011 (198 MW)

3.2.2 Ownership and applications

Most of the turbines in Finland are located along the coast and are owned by power companies and local energy works. Green electricity is offered by most electric utilities. In recent years, many new customers are purchasing renewable electricity products.

The supply of used turbines from the first demonstration projects in Finland and from the Netherlands has encouraged some farmers to acquire second-hand turbines. These turbines are located inland where the wind resource is limited at heights below 60 m due to forested landscape.

There is an ever-increasing interest in offshore projects, as good sites for larger wind farms on the coastal areas are scarce. The first semi-offshore projects were built in 2007. Six 2.3-MW turbines were installed on small islands in Åland Båtskär. In 2007 to 2008, ten 3-MW WinWinD turbines were erected in Kemi Ajos. Eight of these turbines (24 MW) are offshore. In 2010, a 2.3-MW turbine was erected offshore, 1.2 km from Meri-Pori harbor. This turbine is a pilot for a 90-MW offshore project. Environmental impact analyses have been started for several offshore wind farms and the first of them (Suurhiekka, 288 MW) received a building permit according to the water act early in 2011 (the building permit according to the building act is still to be applied for). Besides this project, six other offshore projects (almost 1,200 MW) have finished their environmental impact assessment. An offshore demonstration will need extra subsidies to be realized.

3.3 Operational details

The average capacity factor of wind turbines operating in Finland was 28% in 2011. This is a new record in Finland, the capacity factor has ranged from 17% to 24% in previous years. A good wind year, together with new larger, well-sited turbines with longer blades, explains the good average capacity factor for 2011. The wind power production index was 92% to 106% in different coastal areas in Finland. 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 (Figure 4). Higher turbines produce significantly more in the forested landscape of Finland. The average availability of wind turbines operating in Finland has been 89-96% in 2001-2010.

3.4 Wind energy costs

For the feed-in tariff working group in 2009 the cost of wind energy production was estimated for coastal sites in Finland to range between 60 to 80 EUR/MWh (77.6 to 103.5 USD/MWh) without subsidies. This calculation assumes 2,100 to 2,400 h/a full load hours for yearly average production; 1,300 to 1,400 EUR/kW (1682 to 1811 USD/kW) investment cost; 20 years, 7% internal rate of return; and 26 to 28 EUR/kW/yr (33 to 36 USD/kW/yr) O&M cost. Balancing cost of 2 EUR/MWh (2.6 USD/MWh) was assumed – this would apply for 2010 prices for distributed wind power production; for a single site, the cost would be 3 EUR/MWh (3.9 USD/MWh). The estimated cost of offshore production could exceed 100 EUR/MWh (129.4 USD/MWh).

The average spot price in the electricity market Nordpool was 49 EUR/MWh (63.4 USD/MWh) in 2011 (57 EUR/MWh; 73.7 USD in 2010). Wind power still needs subsidies to compete even on the best available sites. The guaranteed price of 83.5 EUR/MWh (108 USD/MWh) for 12 years (105.3 EUR/MWh; 136.3 USD/MWh for the first three years but only until the end of 2015) is expected to open the onshore market in 2012-13.

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 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.

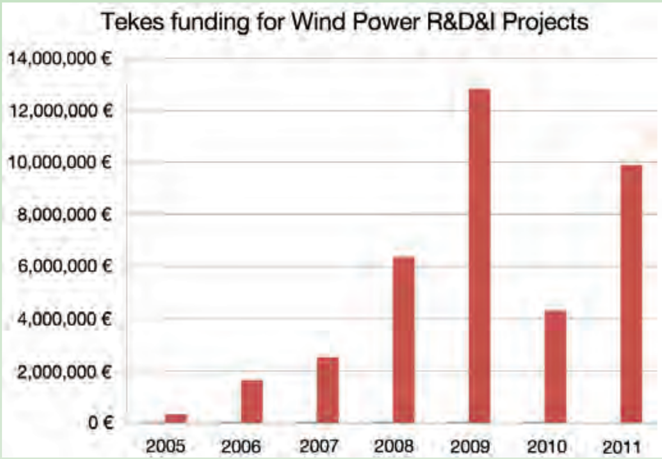

Figure 4. Tekes funding for wind power R&D projects in the last seven years

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 610 million EUR (789.3 million USD) in R&D projects in 2011. In 2011, 10 million EUR (12.9 million USD) was invested in wind projects (Figure 4). Tekes is the main source of funding for Finnish co-operation with IEA.

Since 1999, Finland has no national research program for wind energy. Individual projects can receive funding from Tekes. Some wind integrated projects are in the SGEM Smart Grids program and in GROOVE Growth from Renewables program. Most of the wind power R&D projects in 2011 were industrial development projects. The main developed technologies were power electronics, generators, permanent-magnet technologies, gearboxes, wind turbines (large and small ones), foundry technologies, manufacturing technologies, construction technologies, automation solutions, and services.

A Finnish consortium MegaCentre was formed by a group of industrial players, VTT, and academia to design, plan, and build a research facility for large wind turbines and their components. The planning phase started in late 2010 by financial support from TEKES and consortium members.

The wind atlas, launched by the Finnish Meteorological Institute 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 (Figure 5).

VTT is developing technologies, components, and solutions for large wind turbines. An icing wind tunnel for instrument and material research and testing in icing conditions began operation in 2009. Industrial collaboration in the development of reliable and cost-efficient solutions for drive trains for future wind turbines continued. Several technical universities also carry out R&D projects related especially to electrical components and networks (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 system services from wind power are studied to help wind integration.

VTT is participating in two Nordic Energy Research projects Offshore DC Grid and IceWind.

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

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

VTT is a founding member of the European Energy Research Alliance (EERA) and participating actively in the joint program in wind energy. The FMI has been active in EU collaboration for

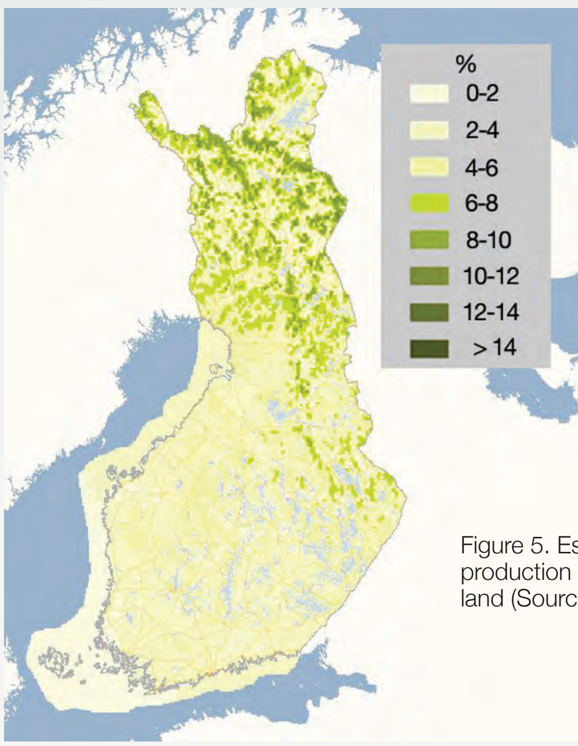

Figure 5. Estimate of average annual production losses due to icing in Finland (Source: Icing atlas, FMI and VTT)

wind and ice measurement technology. FMI has been coordinating the COST collaboration "Measuring and Forecasting Atmospheric Icing of Structures."

5.0 The Next Term

A record year of installations is expected in 2012 for Finland. The trend should continue in 2013 as all projects try their best to get as many years as possible for the higher guarantee price period expiring end of 2015. Approximately 70 to 100 MW of new capacity is anticipated for 2012. A huge number of projects are planned, under feasibility studies, or have just been proposed: 4,800 MW onshore and 3,000 MW offshore. A list of wind turbine projects in Finland can be found at http://www.vtt.fi/windenergystatistics.

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 MegaCentre facility is expected to enter construction phase in 2012.

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20 Germany

1.0 Overview

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

At the end of 2011, Germany had 22,297 wind turbines (2010: 21,572) installed, with a total capacity of 29,075 MW (2010: 27,191 MW). The new capacity installed in 2011 was 2,007 MW (2010: 1,551 MW) (1).

By the close of the German offshore market's third year, a total capacity of 215 MW (55 wind turbines) were installed in the Baltic 1 (Baltic Sea, opening photo), BARD Offshore 1 (North Sea), and alpha ventus (North Sea) offshore wind farms. Thirty three of these wind turbines have been connected to the grid in December 2011(108 MW). But only six wind turbines were newly installed in the sea in 2011. Even though this seems to be a reduction of the offshore growth, many projects are contracted or in preparation. Four offshore wind farms will start installation at sea in 2012. Thirty offshore wind farm projects have received permission by the federal authorities since 2000. Companies are expanding their production of offshore wind turbines, offshore foundations, and their capacity for offshore logistics and construction processes. The offshore expansion is supported by a 5 billion EUR (6.5 billion USD) credit program of the government-owned bank "KfW Bankengruppe" (Kfw). The working group

Table 1. Key Statistics 2011: Germany (1)	
Total installed generation	29,075 MW
New wind generation installed	2,007 MW
Total electrical output from wind	46.5 TWh
Wind generation as % of national electric demand	7.6%
Average capacity factor	19%*
Targets	35% of electrical energy consumption by renewables and 10 GW offshore wind by 2020. 80% electrical energy consumption by renewables in 2050.
Preliminary results of wind energy monitor 2011 by Fraunhofer IWES.	

"Acceleration of Grid connection of OffshoreWind Farms," initiated by the federal government, developed measures for the improvement of this process in 2012.

Onshore, there was a remarkable extension of the wind energy capacity also in some of the German states far from the coast such as Rheinland-Palatinate and Bavaria.

According to plans of the federal government, half of German electricity consumption shall be produced by wind in 2050. Repowering (exchange of older wind turbines by new turbines with higher capacity) shall extend the onshore capacity. In 2011, 270 wind turbines (123 MW) were removed and replaced by 96 new wind turbines (238 MW).

Construction of the first German offshore wind farm, the alpha ventus test site, began in 2009. It became operational in April 2010. In 2011, the wind farm consortium DOTI reported 4,450 full load hours and a technical availability of up to 97%. The accompanying research initiative at alpha ventus, RAVE, is funded by the BMU with about 52 million EUR (67 million USD). After completion of the installation of all measuring equipment and sensors at foundations and turbines, RAVE started its practical data acquisitions from the alpha ventus test site. Researchers used the data in 2011 to validate numerical models and study the performance of the wind farm in operation.

An important issue that will influence wind energy development and the entire grid technology during the next ten years is the federal government's decision to step away completely from 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 (plan). The scenarios informing the Energy Concept have shown that in 2050 wind energy will play a key role in electricity generation (2). The Energy Concept therefore emphasizes the extension of onshore and offshore wind energy. The Energy Concept explicitly formulates the target of 25 GW of offshore wind power installed by 2030. More general policy objectives are the extension of the share of renewables in electrical energy consumption to 50% by 2030, 65% by 2040, and up to 80% by 2050 (2).

2.2 Progress

In 2011, the share of renewable energy production in relation to the electrical energy consumption has grown rapidly from 17.1% (2010) to 20.0% (2011). Wind energy alone had a share of 7.6%. While 2010 was a year of below average wind conditions, 2011 had reasonably good wind conditions so that wind produced 46.5 TWh (+23%) of electrical energy (3). This is equivalent to 36.1 Mt of avoided CO_2 emissions (1).

The total electrical energy production from renewable energies was 122 TWh. Of the electrical energy production from renewable energies, 38.1% was generated by wind, followed by biomass (30.0%), hydropower (16.0%) and photovoltaics (15.6%) (3).

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 2011, the German Parliament voted for an amendment of the EEG, which became effective 1 January 2012. For onshore wind, the premium tariff remained the same (89.3 EUR/MWh; 115.55 USD/MWh). In order to further stimulate cost reductions, the digression will increase from 1% to 1.5% in 2012. Also the Repowering Bonus (4.8 EUR/MWh; 6.21 USD/MWh) as well as the Ordinance on System Services by Wind Energy Plants stayed the same (4.8 EUR/MWh; 6.21 USD/MWh). The latter one (Ordinance on System Services) will be prolonged by one year, meaning that any project connected to the grid before 2015 is eligible. The tariff for offshore wind energy for wind turbines installed in 2012 will be 150 EUR/MWh (194 USD/MWh) until 2017. Due to delays in project starts, the digression is postponed by three years and will only become active in 2018. In return, the digression will increase from 5% to 7%. To stimulate investments in offshore wind energy, an optional, no additional costs compression model has been introduced. Instead of 150 EUR/MWh (194 USD/MWh) for a period of 12 years, operators of offshore wind farms may chose 190 EUR/MWh (246 USD/MWh) for a period of just eight years. Depending on water depths and distance to shore, the allowance will then drop to the standard 150 EUR/MWh (194 USD/MWh) and eventually to the base allowance of 35 EUR/MWh (45 USD/MWh). The incentive regime will stay the same for 20 years, as it is valid in the year the turbine is connected to the grid (4).

2.4 Issues affecting growth

As in 2010, the worldwide financial crises hampered the acquisition of debt capital and by that the growth of the German wind energy market, especially offshore. New bank rules like Basel III increased the efforts needed to allocate the necessary investment money. To compensate for this, the business development bank of the Federal Republic and the federal states (kfw) has set up a 5 billion EUR (6.5 billion USD) cash program for up to ten offshore wind farms. By means of this program banks shall be able to gain experience in financing offshore wind projects so that future projects can get financing quicker and easier.

Delays in electricity grid expansions is another major issue affecting the growth. For offshore wind energy, the situation became critical in November 2011, when the transmission system operator (TSO) responsible for connecting the offshore wind farms in the North Sea announced serious problems in realizing the grid connections in due time. Task forces such as the working group "Acceleration" consisting of all relevant stakeholders have been implemented to work out possible solutions (5).

Despite different factors influencing the annual installation, overall growth in capacity has stayed roughly stable since 2004 (Figure 1).

3.0 Implementation

The entire wind energy industry with its turbine manufacturers, sub-suppliers, and service providers has become an important, innovative, and mature industry sector for the German national economy. This holds true for onshore as well as offshore wind energy. Important sub-suppliers are located in almost every German state, so not only coastal states like Lower Saxony or Bremen benefit from revenues and employment,

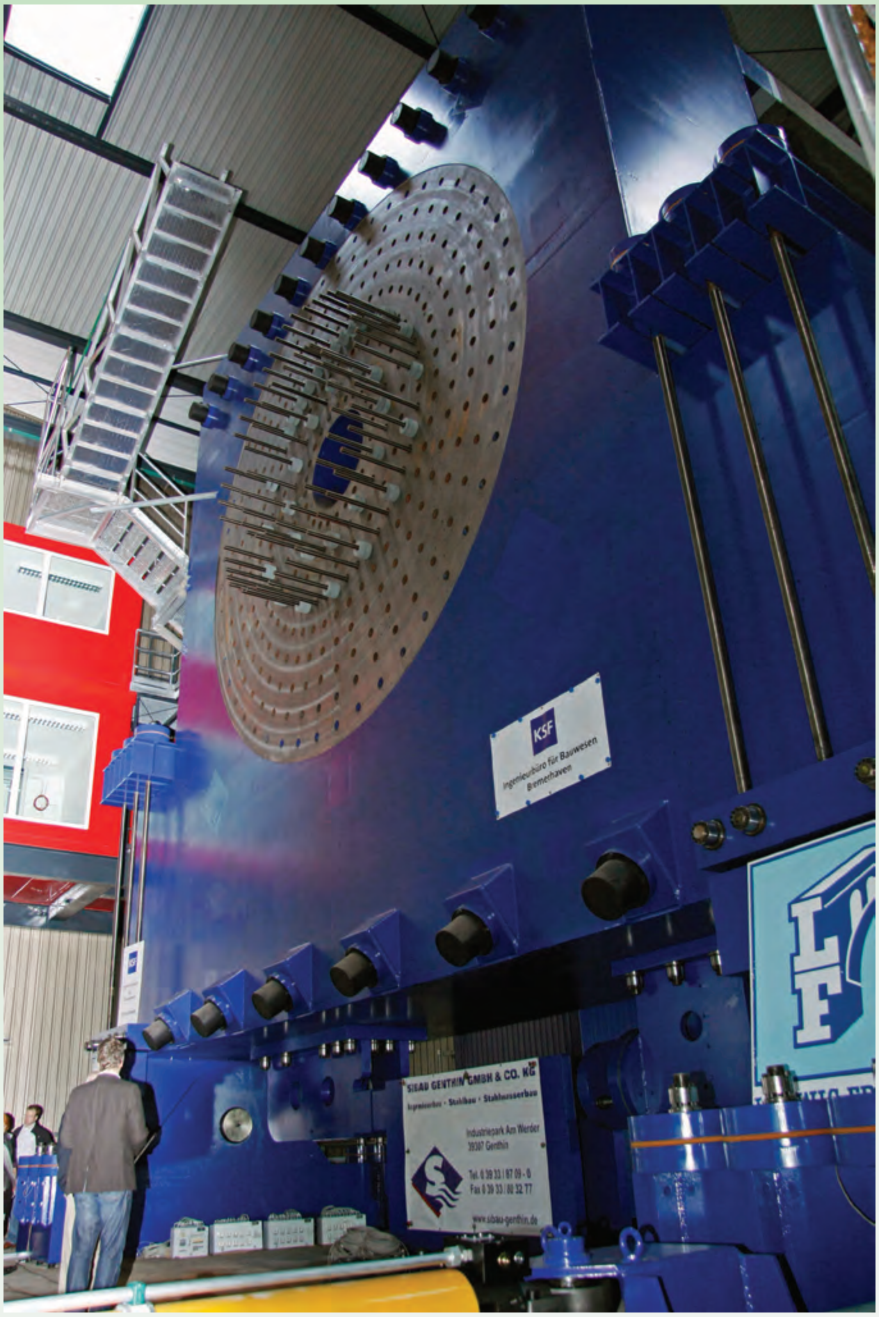

Figure 1. The new, 90-m test rig at the rotor blade test center at Fraunhofer IWES in Bremerhaven

but even southern states like Bavaria or Baden-Wurttemberg.

3.1 Economic impact

Investment in wind energy in Germany was 2.95 billion EUR (3.82 billion USD) in 2011. An additional turnover of 1.4 billion EUR (1.8 billion USD) resulted from wind turbine operations. The turnover of all turbine and component producers located in Germany was 8.91 billion EUR (11.5 billion USD) (German market including export). Employment increased slightly again, with approximately 101,100 people (Table 2) working in the business (2010: 96,100). Employment in R&D and public administration for all renewable energies rose to another 9,600 people. (6)

To cope with the resulting demand for highly educated people, new training centers and study programs have been set up. Those range from vessel and crane simulators to dedicated wind energy study courses at universities and universities of applied sciences. For the first time, universities from Denmark, Germany, the Netherlands, and Norway started a joint European Wind Energy Master program (www.windenergymaster.eu).

3.2 Industry status

By 2020, the world market for offshore wind energy will be dominated by the North Sea region. Therefore the offshore home market is of major importance for German-based manufacturers. Production lines and harbors have been further developed accordingly.

WeserWind, a support structure manufacturer located in Bremerhaven, officially launched its serial production line for offshore support structures in September 2011. Siemens opened its new world wide Wind Power Headquarters in Hamburg in October 2011. The company plans to increase staff from 170 in 2011 to 500 in 2013. AREVA Wind GmbH, based in Bremerhaven, put its 5-MW, full-load test bench in operation in October 2011. All AREVA turbines leaving the production line will be tested by this test bench. This is one of the lessons learned from the offshore test site alpha ventus. AREVA developed a new version of its M5000 5-MW turbine with a larger rotor diameter of 135 m. Experiences and results of the alpha ventus test site research were used to develop a new light nacelle conception adopted to the harsh offshore conditions (7).

The BARD Company installed the fiftieth foundation at the BARD Offshore 1 wind farm at the end of 2011. Not all installed turbines of this wind farm were connected to the grid in 2011, but those connected show a good performance. Negotiations for the sale of the BARD Company to a new investor continued at the end of the year (7).

With respect to newly installed capacity (2,007 MW, 895 wind turbines) the largest share of the German wind market are still held by Enercon (59.5%), Vestas (21%) and REpower Systems (9.7%). Vestas showed the largest growth in market share 2011 (+6.4%).

3.3 Operational details

Germany's first offshore wind farm alpha ventus fed 267 GWh of energy into the German electricity grid in 2011. This result is 15% greater than the amount of energy anticipated for the year. It is the result of very good wind conditions and turbine availabilities up to 97%.

Based on its experiences with Baltic 1, the utility EnBW began its second offshore wind farm. Baltic 2 will be four times larger than Baltic 1 and will provide six times as much energy, 1,200 GWh/yr. Due to varying water depths from 23 m to 44 m, a mixture of monopile and jacket foundations will be used.

In January and February BARD replaced the nacelles of its two 5-MW offshore prototype turbines near Emden with a new 6.5-MW version, while keeping the size of the nacelle the same. Also in January 2011, Enercon installed its 7.5-MW version of the E-126 wind turbine in Magdeburg – at that time the world's most powerful wind turbine. Eleven E-126 turbines (6 MW and 7.5 MW) have been used for an onshore wind park in Estinnes (Belgium), as the construction was completed in June 2011. The wind farm is expected to deliver 187 GWh annually.

Compared to recent years the mean turbine size increased significantly in Germany. In 2011 the average wind turbine had a capacity of 2.24 MW, an increase by 9% compared to the average turbine in 2010.

3.4 Wind energy costs

Exact figures for the cost of wind energy are very difficult to gain and depend very much on practical project conditions. While for good onshore locations electricity production costs are in parity with the average production costs, offshore wind energy is still at an early stage and not yet fully optimized. Nevertheless, with a steep learning curve, intense R&D, and better wind conditions offshore, wind energy is expected to become competitive

4.0 R, D&D Activities

4.1 National R, D&D efforts

An important step to implement the Energy Concept of the federal government was the adoption of the sixth Energy Research Program in August 2011 (8). The program describes the baselines for energy research in the years to come. For research on renewable energies, the government plans to spend 1.3 billion EUR (1.7 billion USD) until 2014, most of this amount is for funding projects. The call of BMU for research on renewable energies, published in December 2011, details the main topics of funding (9) including the following.

- further development of complete wind turbines
- concepts for drive trains and electrical components
- rotor blades
- foundations and concepts for towers and support structures
- wind physics, wind field investigation
- logistics, installation processes, operation and maintenance
- environmental aspects, accompanying ecological research, and acceptance of wind energy.

In 2011, 74 new projects (including thematic and financial extension of ongoing projects, 2010: 37) have been funded by 77 million EUR; 99 million USD (2010: 53 million EUR; 68 million USD). Most projects have a duration of three years. Figure 2 shows the development of R&D funds for new projects and the number of new projects each year since 2004. A little more than half of the new projects deal with specific offshore topics. Half of the new R&D projects are carried out by companies or in cooperation between research institutes and companies.

4.1.1 Highlights of Ongoing Research

The federal authorities require a sound level of 160 decibels or less at 750 m from the pile for offshore ramming activities. To be able to maintain this level in the future, a consortium under coordination of the RWE Offshore Logistics Company (OLC) tested a series of different sound absorber systems under comparable conditions (ESRa-project). The consortium aims to formulate recommendations for future sound mitigation technologies on the basis of a systematic analysis of the data obtained. ESRa is funded by BMU with 900,000 EUR (1.1 million USD).

Progress was made in 2011 in establishing test facilities for wind turbines and large wind turbine components. The rotor blade test center at Fraunhofer IWES in Bremerhaven for up to 70-m long blades (InnoBladeTeC-project) was supplemented by a second 90-m test rig in spring 2011 (Figure 1). The University of Hannover started the planning and construction of a test center for research on offshore foundation components and large scale models of complete foundations. The foundation test center is funded by BMU with 12 million EUR (15.5 million USD). The hall, laboratories, and infrastructure are financed by the state of Lower Saxony.

The Fraunhofer IWES in Bremerhaven started the development and construction of a drive train test center for research on gearless turbines (Dynamic Nacelle Laboratory – DyNaLab). It will be designed for full scale tests of turbines in the power range of 2 MW to 7.5 MW. The project is funded by BMU with 10 million EUR (12.9 million USD). Furthermore, infrastructure is financed by the state of Bremen and by the European Fund for Regional Development.

Another research center specialized in drive train investigation and development was founded at the Technical University Aachen. The Center for Wind Power Drives (CWD) developed a first 1-MW drive train test rig, which will be used for research purposes. On the basis of the experiences gained, CWD will develop a larger test rig for turbine drives with gears.

The research initiative at the test site alpha ventus, RAVE, continued its work in 2011 as a major activity in wind energy research. Through the end of 2011, 51.6 million EUR (66.7 million USD) have been funded for RAVE, which involves about 45 universities, institutes, and companies. The RAVE research data bank contains 10 TB of information from the test site after about 17 months of full

Table 2. Number of employees for different branches of wind energy

	By investment including export	By operation and maintenance	Total employment 2011 for wind
Onshore Wind	74,700	17,800	92,500
Offshore Wind	7,900	700	8,600
Total	82,600	18,500	101,100

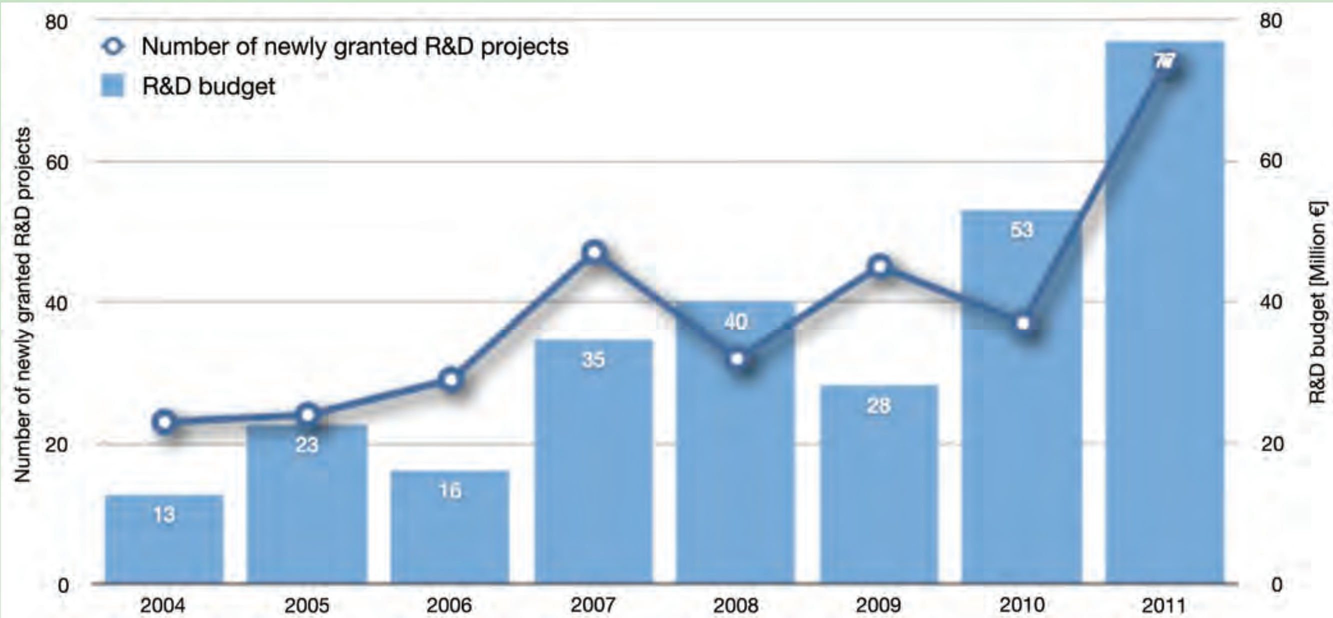

Figure 2. Development of R&D funds for new projects and the number of yearly new projects funded by BMU since 2004

operation. A more detailed description of RAVE was given in the *IEA Wind 2010 Annual Report*. A 50-page brochure describing all RAVE-projects can be ordered at Fraunhofer IWES (info@rave-offhore.de). The experiences gained by the operator of the wind farm and other involved parties during planning and construction of alpha ventus have been published in the book *ALPHA VENTUS – Operation offshore* containing a chapter on RAVE (10). A YouTube channel with information on RAVE was established in 2011 (11).

RAVE organized a networking workshop with other European wind energy research initiatives including we@sea (the Netherlands), FLOW (the Netherlands), Enova (Norway), and Vindforsk (Sweden) as a side event at the EWEA 2011 Offshore Wind Conference in Amsterdam. A Memorandum of Understanding with the Norwegian NORCOWE research center was concluded by IWES. New RAVE projects established in 2011 are investigating turbulence, corrosion and material degradation, and the use of Lidar for the characterization of wakes.

The three FINO offshore research platforms continued their measurements in 2011. A virtual visit of the FINO 3 platform can be found at www.fino3.de/joomla15/index.php?option=com_content&view=category&layout=blog&id=28&Itemid=367. A joint workshop organized by GL Garrad Hassan in May 2011 in Hamburg summarized the research activities at the FINO platforms and presented results and experiences achieved so far (12). As a result of the workshop, a project proposal was developed to undertake a detailed comparative analysis of the wind data of all three platforms. A further project will develop common information and publication activities of the three platform operators and research teams.

Investigation of onshore wind conditions in complex terrain and forests is done in a project, which installed a 200-m measuring mast at such a location. It will develop recommended practices for wind energy use in medium mountains and forests. The mast is used by Fraunhofer IWES as well for the calibration of Lidar instruments (13).

4.1.2 Wind Energy Research Networks

Wind energy research in Germany has experienced rapid development in recent years. In 2011, Fraunhofer IWES and ForWind (Center for Wind Energy Research of the Universities of Bremen, Hannover and Oldenburg) joined the forces of their approximately 450 staff members by collaborating in a Wind Energy Research Association, now covering a broad spectrum of technical wind energy research (Research Network North). Other research collaborations followed.

The research network WindForS, founded in 2011, consists of universities of the German southern states including University of Stuttgart, Karlsruhe Institute of Technology, Technical University Munich, and others. Research is focused on wind physics, turbulence, Lidar wind measuring technology, aerodynamics, and wind energy use in complex terrain.

The Competence Centre for Wind Energy Berlin was founded in 2010 by the Technical University Berlin, the Federal Institute for Materials Research and Testing (BAM), and the University for Economics and Technology. Research is focused on geo-mechanical aspects of offshore foundations, material testing, energy converters, as well as on ecological and planning aspects of wind energy.

The CWD center for drive train investigations described above is located in the state North-Rhine-Westphalia.

The fifth network founded in 2005 is the Centre of Excellence for Wind Energy Schleswig-Holstein (CEwind). Topics of research are small wind turbines, turbulence, marine ecology, lightning protection, and research at offshore measuring platforms (FINO 1 and FINO 3).

4.2 Collaborative research

A new IEA Wind Task was initiated by the University Oldenburg to develop recommended practices for the application of Lidar measuring techniques (Task 32 Wind Lidar Systems for Wind Energy Deployment). Fraunhofer-IWES presented a new task proposal on the development of recommended standards and structures of operation for reliability data bases. Such data bases exist in several countries. The proposed new task will develop common principles to make information of these data bases comparable.

There is progress to develop an offshore database (OWMEP, operational data and information on failure) in Germany comparable to the WMEP onshore database that has existed for many years. So far, eight offshore wind farm owners partly operating internationally have announced their participation in OWMEP.

5.0 The Next Term

Offshore generation will expand in response to a 5 billion EUR (6.5 million USD) credit program of the government-owned bank "KfW Bankengruppe" (Kfw). Four offshore wind farms will start construction in 2012 and companies are expanding their production of offshore wind turbines, offshore foundations, and their capacity for offshore logistics and construction processes. The working group "Acceleration of Grid connection of OffshoreWind Farms," initiated by the federal government, developed measures for improving connection approval in 2012. RAVE will hold an international conference in May 2012 in Bremerhaven to report research findings at alpha ventus.

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21 Greece

During 2011, total installed wind power increased from 1,210 MW in 2010 to 1,640 MW. The Greek government acknowledges the importance of renewable energy sources and sets new national policy for their development. In June 2010, a new law L3851/2010 entitled "Accelerating the Development of Renewable Energy Sources to deal with climate change and other regulations addressing issues under the authority of the Ministry of Environment, Energy and Climate Change" came into force. The main goal of the law was to simplify and accelerate licensing procedures. Regarding R&D, the Ministry of Environment, Energy and Climatic Change continues to support and promote all RE activities in the country.

Table 1. Key Statistics 2011: Greece	
Total installed wind generation	1,640 MW
New wind generation installed	343 MW
Total electrical output from wind	3.3 TWh/yr
Wind generation as % of national electric demand	5.8%
Average capacity factor	N/A
Target:	40% of electricity from renewables by 2020

22 Ireland

1.0 Overview

In 2011, wind generating capacity totaling 239 MW was installed in Ireland, a 17% increase by year's end. Annual capacity additions have averaged of 22% over of the past four years and installed capacity has doubled since the middle of 2008. The additional capacity regularly delivers new system records for wind power production. On 26 November 2011, instantaneous wind power output reached 1,474 MW. Instantaneous wind penetration levels peaked above 40% in every month of the year, reaching a maximum of 53.5% on 29 December 2011. This is remarkable given the relatively isolated nature of Ireland's electricity grid. After a wind lull in 2010, 2011 marked a return to wind conditions which are more in line with the recent trend. In 2011 ***18.7%*** of electricity supply was via renewable generation, ***15.6%*** of which was by wind.

Much innovative work is ongoing to facilitate the de-carbonizing of Ireland's electricity supply by variable resources. Falling or stagnant demand for electricity will, however, exacerbate the economic and technical challenges in the integration of large amounts of renewable generating capacity before the end of the decade. Maximum instantaneous wind output will, in the very near future, exceed minimum system demand. Significant developments in interconnection, power system operations, and demand side management are either under way or planned in order to maximize use of Ireland's wind resource. Ireland's overall dependence on imported fossil fuels remains high at 86% of total primary energy (3).

Table 1. Key Statistics 2011: Ireland	
Total installed wind capacity (1) (including 2 MW of micro-wind)	1,633 MW
New wind capacity installed	239 MW
Total electrical output from wind	***4.38 TWh***
Wind generation as % of national electric demand	***15.6%***
Average capacity factor (2)	***31.6%***
Target:	40% RES-E by 2020
*****Bold italic*** indicates an estimate	

2.0 National Objectives and Progress

2.1 National targets

Ireland's binding EU 2020 target is to supply 16% of gross energy consumption from renewable sources. The government has adopted sectoral targets devised to achieve this overall target, meaning 40% of electricity, 10% of transport energy and 12% of heat energy are to come from renewable sources.

Ireland's first progress report under the National Renewable Energy Action Plan (NREAP) framework was submitted in January 2012 (4). The impact of existing and planned strategies, measures, and interventions all feed in to the report's analysis and forecasting. To meet the 40% RES-E target, it is now forecast that 3,521 MW of wind need to be connected. The NREAP originally forecast (in July 2010) a requirement for 4,649 MW. With 1,631 MW already installed, 1,437 MW with connection contracts in place, and approximately 3,400 MW of connections with contract offers issued by the end of 2011, it is clear that there is sufficient potential to exceed the 2020 targets. The rapid expansion of the sector may, however, have a detrimental effect on the financing environment for wind projects. A particular issue is the financial impact of the curtailment and constraint of wind farm output for system operation and network reasons and the allocation mechanisms for these are currently a focus of attention.

2.2 Progress

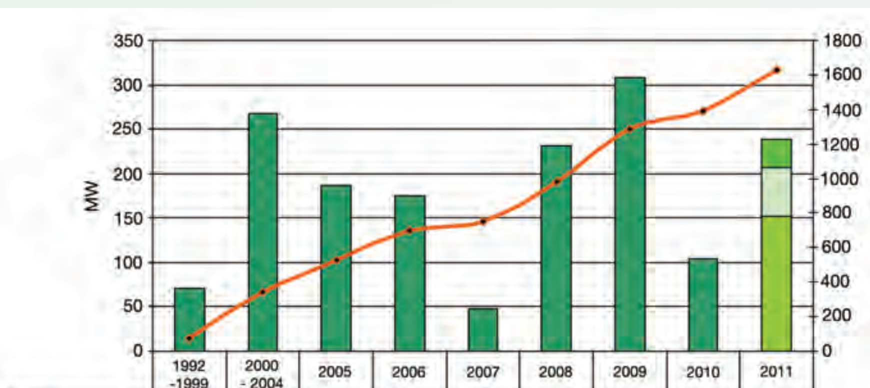
In 2011, 239 MW of new capacity was added, an increase (Figure 1) over the 103 MW added in 2010. Of this new capacity, 198 MW were connected at the distribution level and one 41-MW wind farm was connected at transmission level. Of the capacity added in 2011, 151.4 MW had formerly had a target connection date in 2010, while another 32.5 MW of the capacity added were brought forward from 2012 (5).

Wind contributed ***15.6***% of the electricity generated during 2011. To meet its 2020 EU renewable energy target, Ireland requires that 40% of electricity demand be met from renewable sources. In 2011, Ireland supplied a gross 18.7% of its electricity from renewable sources.

Figure 2 depicts the wind capacity by county (with each individual site marked in yellow). Also shown is the 2020 horizon pipeline of projects at various stages of development, the vast majority of which are in planning or pre-construction.

Significant progress was made in 2011on two important developments, which will facilitate variable power sources, smart metering, and the 500-MW interconnector to the United Kingdom (EWIC).The EWIC is on schedule to be energized in 2012 (6). Substantial smart metering technology and customer behavior trials were concluded, and January 2012 saw the beginning of a consultation on the proposed national rollout of the technology (7). The data from the trials is available online (8). Several key decisions relating to connection policy (CER/11/083) (9), guarantees of origin (CER/11/824) (9), and dispatch (SEM-11-062, SEM-11-105) (10) were published in 2011. See also reference 11.

Other evolutions of the sector include early moves towards wider market integration with Europe and renewable trading co-operation mechanisms with the UK through the British Irish Council.



	1992 -1999	2000 - 2004	2005	2006	2007	2008	2009	2010	2011
Fwd from 2012									32.5
Annual Inst.	70.81	267.8	186.6	175.4	48.3	231.0	308.6	103.42	55
Rolled 2010									151.4
Inst. Cap.	71	339	525	701	749	980	1288	1392	1631

Figure 1. Wind generation capacity added from 1992-2011 (including cumulative capacity trend line) Data source: EirGrid

2.3 National incentive programs

Ireland's Renewable Energy Feed in Tariff 1 (REFIT 1) support mechanism for wind is funded through an European Commission state-aid sanctioned, Public Service Obligation (PSO) on final customers. Please see the *IEA Wind 2010 Annual Report* for more information. The reference prices for large (>5 MW) and small (<5 MW) projects are currently 68.08 EUR (88 USD) per MWh and 70.47 EUR (91 USD) per MWh respectively.

The cost of the above PSO fund is allocated to all customer categories as a separate item on bills. The cost of the PSO to domestic customers during the 2011/12 tariff year is 1.61 EUR (2.08 USD) per account per month (12). Approximately 66% of the ex-ante fund from which the charge is calculated is created by subsidies to non-renewable generators such as natural gas and peat. It is not generally appreciated by consumers that the PSO levy primarily supports fossil-fired generation and that wind depresses wholesale electricity prices. Work carried out by SEAI and EirGrid shows that the latter effect is such that it cancels out the PSO costs for wind; see Section 3.4 and the *IEA Wind 2010 Annual Report* for more details.

On 12 January 2012, the European Commission signaled its intention to provide state aid clearance for REFIT 2. Once the decision is fully communicated, a government decision to launch the scheme will be sought. The REFIT 1 and REFIT 2 (and REFIT 3 for biomass) mechanism are separate schemes, new terms and conditions in respect of each new scheme will be published as they are launched.

On 18 January 2012 the Minister for Communications Energy and Natural Resources stated that the government did not intend to seek state aid approval for a REFIT for offshore wind at this time. This statement rescinded a proposed offshore wind REFIT of 140 EUR/MWh (181 USD/MWh) announced in February 2008. The government reassessed its support

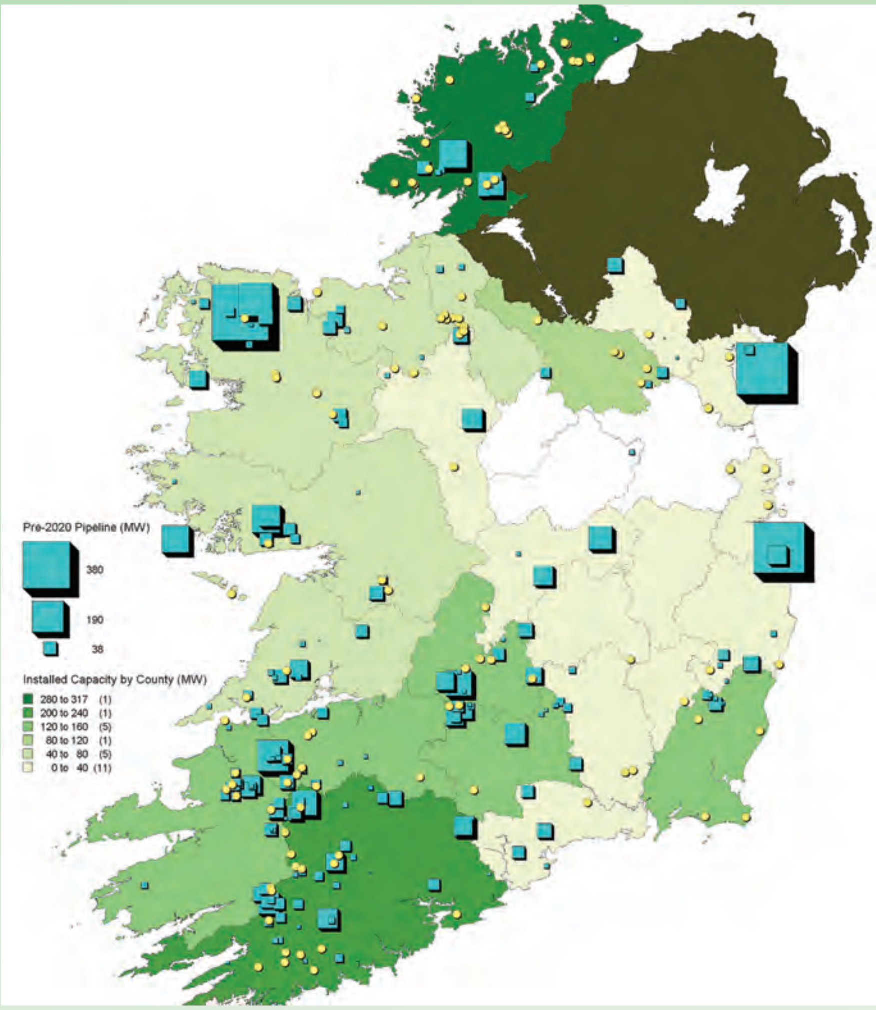


Figure 2. Installed wind farms (yellow points), capacity by county (green shading) and pipeline projects to 2020 (squares)

for offshore wind in light of its high cost and Ireland's underexploited onshore wind resource. In the short to medium term, offshore wind may therefore be primarily viewed as an energy export opportunity.

Other support measures include the Employment and Investment Incentive Scheme which allows individual investors to obtain income tax relief on investments in wind energy in each tax year. It provides a minimum tax relief of 30% with an additional 11% accruing at the end of the third and final year if the business has expanded to employ a designated number of people (or if the investment was used for R&D). A number of financial services companies offered EII Funds or portfolios to investors.

An Accelerated Capital Allowance scheme allows companies to offset the cost of the investment in qualifying wind turbines against their tax liabilities in year one rather than over a period of years, thus aiding their cash flow.

2.4 Issues affecting growth

Although 2011 represented a strong year for new wind farm connections, well-established factors continue to be challenges in Ireland. It can take years for major issues to become visible in the connection rates. Ongoing technical and non-technical challenges include:

- Grid Development: lead times for grid connection and wider/deep reinforcements; connection costs; and way leaves for new lines.
- Planning Constraints: local Authorities are required to designate areas suitable for wind energy development however a consistent methodology for deriving such areas is yet to be devised (see section 4.0); dispersed settlement patterns mean potential wind farm sites not interacting with an inhabited dwelling are scarce; and implementation of the EU Habitats Directive may affect >50% of the next round of projects on, or adjacent to, EU Natural sites.
- Access to finance at an affordable rate. Projects which are currently in receipt of connection offers made their application before 2007.
- Access to the REFIT support mechanism. Projects have not been able to access a support mechanism since 2009. REFIT 2 is expected to be made available in 2012.

In the period to 2020, increasing numbers of wind farms will exit 15-year support mechanism and reach the end of their permitting and design life. Policies addressing the planning, grid access, and support mechanism nuances that will materialize with the potential re-powering of projects will be required.

3.0 Implementation

3.1 Economic impact

The design, development, construction, equipping, and connection of wind farm facilities in Ireland is estimated to have been worth 250-300 million EUR/yr (323-388 million USD/yr) over the past three years, based on the capacity connected and scheduled to connect in the short term. Up to 80% of the outlay is spent on imported equipment, including the turbine and associated electrical equipment. The value to the local and national economy could therefore be estimated to be worth approximately 50 to 60 million EUR/yr (65 to 80 million USD/yr). The value of civil and construction works to local economies is approximately 30 million EUR/yr (39 million USD/yr).

SEAI published three technology road maps in December 2011(Wind Energy, Smart-Grids, and Electric Vehicles), which added to previous road maps for Ocean Energy, Energy Efficiency, and Bioenergy) (13). The roadmaps are developed to inform energy policy in Ireland and demonstrate the potential to positively exploit Ireland's extensive indigenous renewable energy resources, create employment, reduce national CO_2 emissions, and reduce dependence on costly imported fossil fuels.

Reflecting Ireland's abundant wind resource and relatively small market for electricity, potential benefits by 2050 include Irish wind energy contributing 2.5% to EU electricity demand and offsetting up to 10 billion EUR (13 billion USD) of fossil fuel requirement. Further findings include:

- Potential for more than 40,000 MW by 2050 (Figure 3)
- Potential to generate enough wind sourced electricity to exceed domestic demand by 2030
- Potential for onshore and offshore wind to create 20,000 direct jobs by 2040
- Potential economic value of electricity generated by wind could reach almost 15 billion EUR (19 billion USD) by 2050
- Potential for Ireland's wind power to contribute 2.5% of EU electricity demand and just over 5% of EU wind energy generation by 2050,

As the onshore and offshore wind markets mature, repowering and O&M will become key to the retention of a sustainable industry. Preparation for this eventuality will increase Ireland's opportunity.

3.2 Industry status

Development of wind farms in Ireland has historically been undertaken by a wide range of individuals and organizations. The recent trend is towards consolidation and an increasing proportion of the new projects are developed by large utilities, mostly state owned. Factors such as economies of scale and access to finance are thought to be driving this trend. Approximately 1,500 people are directly employed by wind energy companies and supporting services in Ireland. The future O&M needs of the sector will be the key driver of an increase in local employment as generator stock increases and the build rate reaches its long term potential.

Micro-scale wind energy does not benefit from the elevated premium tariffs which have been employed in other jurisdictions. Micro-scale wind turbines do benefit from conditional planning exemptions and tax incentives for some owners. Since the December 2011 budget, small farmers can reclaim VAT on turbines (up to approximately 6 kW in size). Companies registered for corporation tax can benefit from an accelerated capital allowance on the cost of Triple E registered products including wind turbines and solar PV panels (www.seai.ie/aca).

By November 2011 there were 428 sites and 2.23 MW of micro-wind connected to the grid in Ireland. The average micro-turbine installed was 5.2 kW. A number of local manufacturers now have a range of turbines in production from 2.5 kW to 50 kW. C&F Green Energy is a local manufacturer with products undergoing certification with the UK Micro-generation Certification Scheme. Proven Energy, a Scottish manufacturer, was recently purchased by the Irish Kingspan Group.

3.3 Operational details

A return of a more productive wind climate was seen in 2011 and the capacity factor of Ireland's wind portfolio rose to ***31.58%*** (Figure 4). Climatic factors (including prolonged periods of high pressure during the winter months) had caused 2010 to be a poor wind year across northwestern Europe and annual capacity factors were depressed across the region.

Figure 5 shows the instantaneous penetration levels of wind in the Irish electricity system throughout 2011. The system operator currently has a 50% rule of thumb limit for wind penetration. Wind energy is regularly reaching 40% penetration levels.

Analysis of wind farm planning applications shows that the average consenting period for local authority applications over the last ten years has been 0.57 years. The average lead time for a decision by the appeals board (An Bord Pleanála) is 0.58 years. For the 70 cases appealed between 2007 and 2011, the local authority and the appeals board agreed on decisions in 67% of cases. The most common reason for a refusal by An Bord Pleanála, by a large margin, was visual impact. Second was distance from adjacent premises and third was the designation of the land with respect to the county development plan (or wind energy strategy).

3.4 Wind energy costs

Current total capital costs are in the range of 1.6 to 2 million EUR/MW (2 to 2.6 million USD/MW) of installed for wind developments in the 10 MW range. Turbine costs currently range between 0.9 and 1.0 million EUR/MW (1.1 to 1.3 million USD/MW), depending on turbine size and the project. In Ireland, typical project costs can be apportioned as follows: turbines 65%, grid

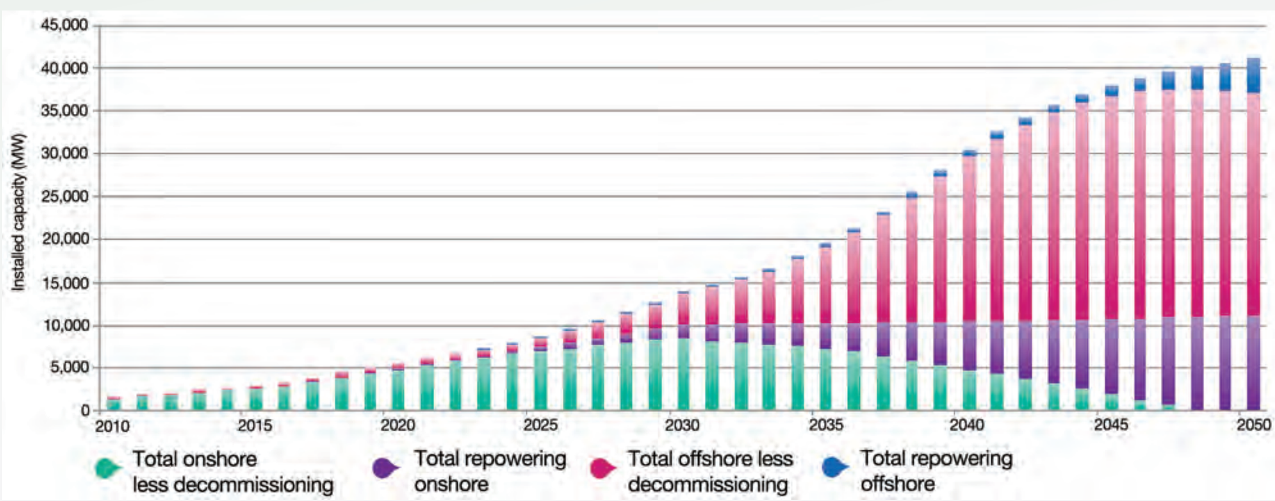


Figure 3. Projected Wind Roadmap to 2050. Source: SEAI

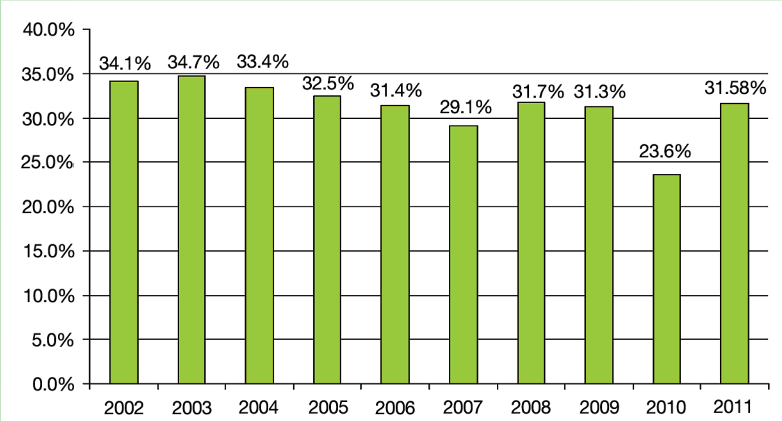


Figure 4. Average national wind generation capacity factor. Data source: EirGrid

connection 12%, onsite electrical 8%, civil engineering 8%, development 4%, and legal/financial 3%.

In February, a study on the wholesale Irish electricity market established that the growing levels of wind generation are not adding to the cost of electricity to consumers (14). The report by SEAI's modeling group and transmission grid operator EirGrid drew on detailed system and market modeling tools to assess the expected wholesale prices of electricity during 2011. The study demonstrated that the cost of supporting wind power via the PSO is offset by wind depressing wholesale market prices and thus comes at a zero net cost to electricity consumers.

4.0 R, D&D Activities

4.1 National R, D&D efforts

Much of the R&D undertaken in Ireland in recent years has been more focused on the integration of large amounts of wind energy to an isolated grid. An SEAI report published in 2011 showed that, even though wind energy is Ireland's key renewable resource for the foreseeable future and primary enabler of RES-E target achievement, only 1% (2 million EUR; 2.6 million USD) of funding of all energy research between 2004 and 2010 was allocated to wind energy.

More substantial funding (15.8 million EUR; 20.5 million USD) was, however, applied to issues of grid integration, which is an indicator of the challenges identified for high penetrations of variable resources on a relatively isolated grid. The Electricity Research Centre in University College Dublin (15) has built an international reputation as a leading center of excellence in the study of power systems and wind power integration. It has contributed to establishing Task 25 as a leading research forum in this field.

Building on the Facilitation of Renewables (FoR) program which itself built on the All-Island Grid Study, the transmission system operators within the Single Electricity Market launched their program for Delivering a Secure Sustainable Power System (DS3). FoR concluded that high instantaneous wind power penetrations (60-80%) could be accommodated on the system if the correct measures are implemented. DS3 aims to deliver the tools that will make such penetration levels sustainable. Such measures include changes to system policies (including operating reserves, and DSM), further implementation of system tools (e.g., near real-time wind assessment: WSAT) and developing system performance (e.g., RoCoF, reactive power, inertia) (16).

The major R, D&D activity for small-scale wind, SEAI's field trials, continued during 2011. The program assesses the performance of the technologies to inform future decisions on possible financial and non-monetary incentives, tariffs, quality assurance schemes, or deployment programs. The data, which is collected at each installation will be made available to researchers during 2012.

Local planning authorities are required to designate areas suitable for wind farm development, Local Authority Renewable Energy Strategies (LARES), but there is no defined methodology for this. SEAI commissioned a project, which seeks to deliver, in close co-operation with planners and stakeholder representatives, a template for local authority renewable energy strategies. An important part of this will be the strategy for wind. The ultimate aim is to develop consistency nationally across all the local authorities. The methodology will be published in 2012.

4.1 Collaborative research

Ireland hosted the 68th IEA Wind ExCo meeting in Dublin in October 2011. The biannual ExCo meetings bring together government appointed representatives from the 21 member countries. This special opportunity to highlight the benefits of IEA Wind participation locally was accompanied by an exchange of knowledge during a local industry encounter and technical tour.

Ireland is participating in IEA Wind Task 25 on the integration of large amounts of wind on power systems. The country also participates in Task 27 on small wind turbine labeling and Task 28 on the social acceptance of wind energy projects. Details of each task are provided in a separate chapter of this IEA Wind 2011 Annual Report. As a small country, Ireland has benefited greatly from participation in IEA Wind and other IEA implementing agreements. Ireland has also contributed to the benefit of these partners.

As part of Ireland's participation in Task 28 Jean Welstead of SQW Ltd. and Geraint Ellis of Queen's University Belfast were commissioned to prepare a report on the 'Options for Enhancing Community Acceptance of Wind Energy in Ireland' (17). The report had the specific aims to:

- Engage stakeholders to work towards a consensus position on the concept of community acceptance of wind energy in an Irish context and increase their appreciation of its role in delivering renewable energy targets;

- Stimulate discussion of the key factors influencing community acceptance of wind energy;
- Highlight issues that should be considered by stakeholders in order to further increase community acceptance; and
- Identify initiatives and next steps to progress this issue with a broad range of stakeholders.

It is anticipated that the report will form the framework for ongoing discussions amongst all stakeholders in wind energy.

Ireland is also participating in the GP Wind project. This European Commission Intelligent Energy Europe funded, co-operation shares case studies to create a tool-kit for community and environmental good practices in onshore and offshore wind development (18). The online toolkit will be published in summer 2012.

Ireland is participating in two marine grid studies. The North Seas Countries' Offshore Grid Initiative involves 10 countries and seeks to address the variability of onshore wind and marine renewables through geographical dispersion and generator mix. Three working groups have been established to study grid, market, and planning issues.

The second collaboration was with Scotland and Northern Ireland on the Irish-Scottish Links on Energy Study (ISLES). ISLES advocated an incremental, radial network that will link up a number of offshore locations and transport their electricity through one or more shared resources. The study concluded that an "ISLES cross-jurisdictional offshore integrated network is economically viable and competitive under certain regulatory frameworks and can potentially deliver a range of wider environmental, economic and market-related benefits" (19).

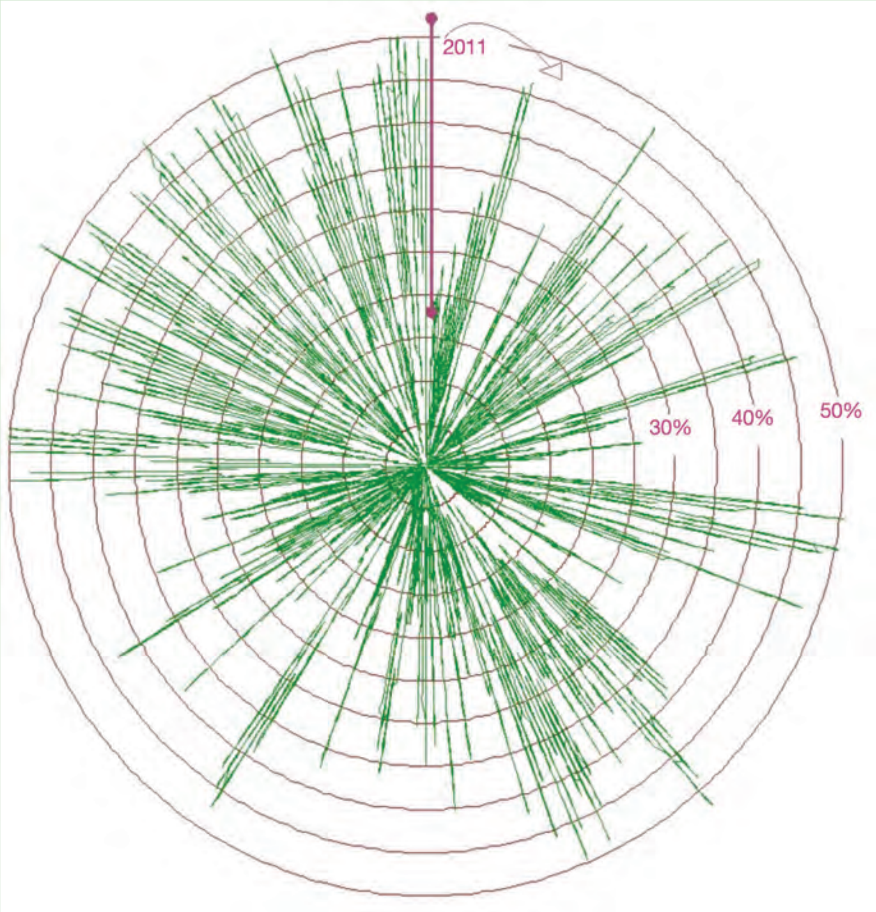


Figure 5. Wind penetration as a percentage of system demand during 2011 (clockwise in hourly samples)

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Author: Martin McCarthy, Renewable Energy Information Office, SEAI, Ireland.

23 Italy

Photo: Leitwind

1.0 Overview

Installation of new wind farms in Italy continued its pace in 2011. Total online grid-connected wind capacity reached 6,878 MW at the end of the year, with an increase of 1,080 MW from 2010. As usual, the largest development took place in the southern regions, particularly in Apulia, Calabria, Campania, Sardinia, and Sicily. In 2011, 590 new wind turbines were deployed in Italy and their average capacity was 1,831 kW. The total number of online wind turbines thus became 5,446, with an overall average capacity of 1,263 kW. All plants are based on land, mostly on hill or mountain sites. The 2011 production from wind farms could provisionally be put at about 10.1 TWh, which would be about 3% of total electricity demand of the Italian system.

The main scheme for supporting RES in Italy is based on a RES quota obligation and Tradable Green Certificates (TGCs). The sale of energy production yielded owners of non-programmable RES plants, such as wind farms, an average price of 74.72 EUR/MWh (96.69 USD/MWh) in 2011. The additional income from the sale of TGCs on the free market was on average 82.25 EUR/MWh (106.43 USD/MWh). Owners of wind plants between 1 kW and 200 kW can opt for other schemes: either a fixed FIT of 300 EUR/MWh (388.20 USD/MWh) or exchange (net-metering) contracts.

The main issues affecting growth came from permitting procedures and from wind production curtailments ordered by the TSO. A decree giving nation-wide permitting guidelines has been in force since 2010 and noteworthy efforts have been made by the Italian TSO Terna to upgrade the grid. In the meantime, the Italian Regulatory Authority for Electricity and Gas (AEEG) has provided for curtailed production to be estimated and wind farm owners indemnified. Uncertainties among investors have arisen because restructuring of RES support schemes was outlined in 2011, but not yet fully defined.

Most new turbines were supplied by foreign manufacturers (Vestas has an establishment in Italy). The Italian manufacturers are currently Leitwind (opening photo) (1-MW to 3-MW turbines) and other firms that supply small-sized units. The market for small wind systems is still at the beginning.

No national R, D&D program exists for wind energy, but work is carried out by ENEA (the second national research institution in Italy), RSE (formerly ERSE) under contract to the Italian government in the interest of Italy's electricity system, some universities, polytechnic schools, and companies.

Table 1 Key Statistics 2011: Italy	
Total installed wind generation	6,878 MW
New wind generation installed	1,080 MW*
Total electrical output from wind	***10.14 TWh***
Wind generation as % of national electric demand	***3%***
Average capacity factor	***18%***
Wind goals from Italy's National Action Plan (PAN) for RES 30 June 2010:	12,680 MW and 20 TWh/yr by 2020
Italy's overall RES target from Directive 2009/28/EC	17% of total energy consumption from RES by 2020

Bold Italic indicates an estimate
*10 MW subtracted from new installed capacity (1,090 MW) to account for decommissioning of old installations

2.0 National Objectives and Progress

2.1 National targets

The Italian government has established new targets for wind energy in response to the new RES policy launched by the European Union, which now aims at

20% of total EU energy consumption coming from RES by 2020. To implement this EU policy, European Directive 2009/28/EC on RES promotion issued on 23 April 2009 has assigned Italy a binding national target equaling 17% of overall annual energy consumption from RES. It also required the government to lay down an RES action plan sharing this target within the various sectors, among which the electricity sector is obviously expected to play a major part.

On 30 June 2010, the Italian government issued Italy's National Action Plan (PAN) for Renewable Energy. PAN directed that 26.39% of total electricity consumption should come from RES by 2020, as a contribution towards the overall target of 17%. According to the PAN, this will mean about 43.8 GW of RES online capacity and 98.9 TWh/yr production from RES should be reached in 2020, compared to 41.4 GW and 84.2 TWh/yr recorded at the end of 2011. This unexpected result is due to the striking increase of PV energy contribution: 267% in installed capacity and 394% in energy production in 2011 alone. Considering that hydropower and geothermal plants are unlikely to grow significantly, expectations have been laid mainly on wind, biomass, and solar energy. As for wind, the 2020 targets have been set at a capacity of 12,680 MW (12,000 MW on land and 680 MW offshore) and a production of 20 TWh/yr (18 TWh/yr on land and 2 TWh/yr offshore). These targets are also nearly in line with the 2020 wind potential already outlined in Italy's Energy Position Paper of 2007.

2.2 Progress

More new wind farms were installed in 2011 (Figure 1) than in 2010 (1,090 MW vs. 950 MW). The total online grid-connected wind capacity reached 6,878 MW at the end of 2011, an increase of 1,080 MW over 2010. A decrease of 10 MW should be taken into account, due to decommissioning of old installations. The growth rate in 2011 was 19% compared to 20% in 2010. As usual, the largest development took place in southern regions, particularly in Apulia, Calabria, Campania, Sardinia, and Sicily. The five regions with the highest wind capacities can therefore be ranked as follows: Sicily (1,676 MW), Apulia (1,365 MW), Campania (1,062 MW), Sardinia (947 MW), and Calabria (772 MW). In Figure 2 wind capacity shares for the Italian regions are shown.

Provisional figures from Terna and Manager of Energy Services (GSE) indicate a 2011 production of about 24 TWh from wind, photovoltaic, and geothermal plants combined. The production from wind farms alone could provisionally be put at about 10.1 TWh, which would equal about 3% of total electricity demand on the Italian system (total consumption plus grid losses). Total electricity demand in 2011 (332.3 TWh) showed a slight increase (0.6%) from 2010. According to Terna's provisional data, 86% of the 2011 demand was met by domestic production and 14% by imports. Gross domestic production by renewable energy sources represents about 24% of the gross domestic consumption.

2.3 National incentive programs

The main RES support scheme continued being based on a RES quota obligation and TGCs, with the exception of solar plants, promoted by specific measures. In 2011, the RES quota rose to 6.05% of the electricity from non-renewable sources produced or imported the previous year and liable to obligation according to the law. Obliged operators must return to GSE an equivalent number of TGCs, either assigned to their own RES plants or bought from other RES producers. TGCs are granted for 15 years to plants put online from 2008 onwards and for 12 years to older plants. One TGC is given per 1 MWh of reference production, resulting from actual output multiplied by a coefficient depending on technology (e.g., 1 for onshore wind, 1.5 for offshore wind).

The number of TGCs on sale exceeded demand in 2011, continuing a trend already noted in previous years and causing the TGC market price to go down. The weighted average of TGC prices in the 2011 trading was 82.25 EUR/MWh (106.43 USD/MWh), according to the Manager of Energy Market. The scheme manager GSE could sell its own TGCs, but only at a price fixed by law (105.28 EUR/MWh; 136.23 USD/MWh in 2011). However, TGCs are valid for three years and, if unsold, are bought

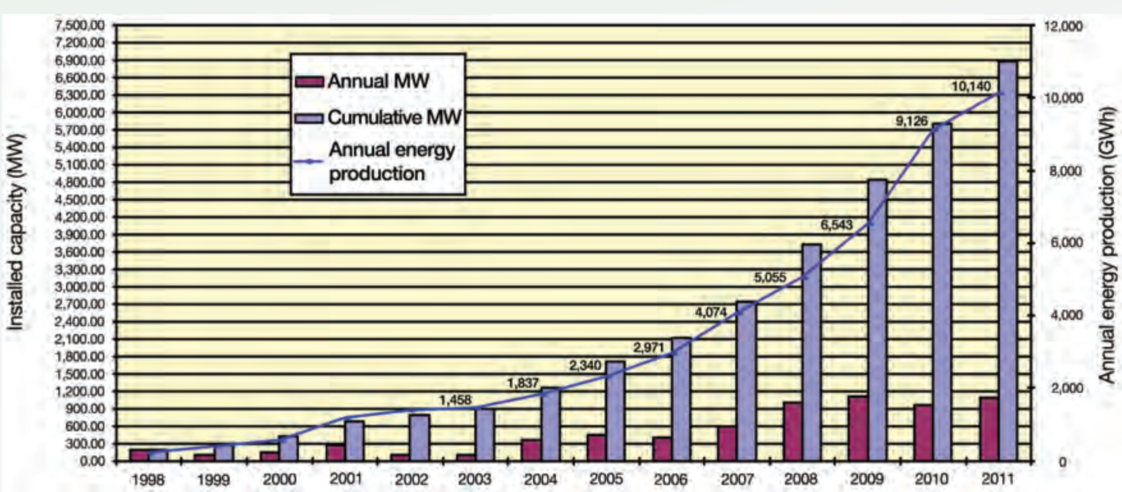

Figure 1. Trend of annual and cumulative wind turbine capacity and electricity production from wind in Italy

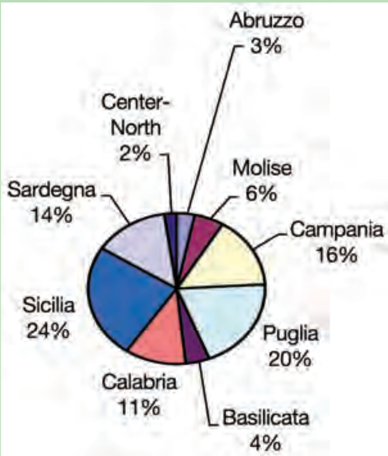

Figure 2. Wind capacities in the regions of Italy at the end of 2011

back by GSE at the average market price of the previous three years. RES producers are thus actually guaranteed an income from their TGCs in any case.

The TGC selling price adds to that of energy fed into the grid. Owners of non-programmable RES plants like wind farms can choose to sell their whole production straight to GSE through dedicated purchase contracts, at prices depending on time and market zone, instead of going straight to the wholesale electricity market. This option is by far the most common and the relevant 2011 average price was calculated at 74.72 EUR/MWh (96.69 USD/MWh) by the AEEG. It should also be noted that smaller RES plants up to 1 MW capacity are guaranteed minimum prices: in 2011, from 103.4 EUR/MWh (133.80 USD/MWh) down to 76.2 EUR/MWh (98.60 USD/MWh) depending on output levels.

Smaller RES plants can apply for other incentives. Specifically, wind plants between 1 kW and 200 kW are entitled to a fixed comprehensive FIT for the energy fed into the grid during the first 15 years. This tariff is currently 300 EUR/MWh (388.20 USD/MWh). A third option for owners of RES plants between 1 kW and 200 kW is a contract for on-the-spot exchange of produced and consumed energy (net metering). Here the income equals the avoided purchase price, very variable, but typically around 200 EUR/MWh (258.80 USD/MWh). In addition, TGCs can be applied for.

Other kinds of incentives could be obtained by RES projects from various authorities in the form of capital cost subsidies or other benefits. If so, however, the possibility to be granted also one of the three support schemes described above would be limited by law.

Lastly, it should be recalled that, in 2011, a number of RES plants (including some wind farms) still benefited from FITs granted by the former CIP 6/92 scheme, long expired but actually having some effect until 2013. For wind, the preliminary CIP 6/92 tariffs were set at 163.4 EUR/MWh (211.44 USD/MWh) in 2011.

This was the situation in 2011. However, it is due to change because, the Italian government issued Legislative Decree No. 28 of 3 March 2011 to implement EU Directive 2009/28/EC on RES promotion. This decree outlined a new incentive scheme concerning RES plants that start operations from 1 January 2013 onwards. Special energy purchase prices depending on technology and plant size should be fixed for RES plants below a capacity threshold to be defined for the various sources (however not lower than 5 MW). RES plants above this threshold should instead be assigned special energy purchase prices by auction (lower bids would gain contracts). All these prices should be granted over the average conventional lifetime established for each type of plant. The present quota/TGC scheme should expire gradually by 2015 and entitled plants should, from then onwards, be supported by transient measures.

The above decree provided for further implementing decrees to carry its principles by giving all necessary details, including values of energy purchase prices etc. At the end of 2011, however, these implementing decrees were still pending, thus raising much concern among RES investors about future profitability of both ongoing plants and projects in the pipeline.

2.4 Issues affecting growth

As in past years, a major issue affecting the growth of RES plants was linked with delays and uncertainties of procedures for getting building permits. The function of evaluating RES projects and granting permits through a single procedure within a prescribed time span was vested by the state in the governments of the regions through Legislative Decree No. 387 of 29 December 2003. Nevertheless, since no nationwide guidelines were issued for some years, the regions set out differing rules and even unnecessary restrictions, which caused developers confusion and unexpected setbacks.

The decree issued by the Ministry of Economic Development on 10 September 2010 provided National Guidelines for Authorization of Plants fed by Renewable Sources. Only offshore installations were left out, because they come under the sphere of the Ministry of Infrastructure and Transports. Later on, Legislative Decree No. 28 of 3 March 2011 also dealt with permitting matters, confirming and sometimes supplementing the provisions of the former decree.

The guidelines set a common framework within which each region has to reshape its own regulations. It is however likely to take time for regions and other authorities to fulfill this process. In 2011, wind developers still complained of permitting procedures as major hindrances to their business. On the other hand, the mistrustful attitude of some local people and environmentalists also contributed to the problem.

Regions are also required to harmonize their needs to safeguard the environment with the obligation to meet their regional RES targets. This will ensue from sharing the burdens taken on by the government with the EU (a decree assigning RES consumption targets to each region was under discussion, but not yet issued, in 2011). The guidelines devote special care to wind farms, advising on how to mitigate all kinds of impact. Projects of wind plants above 1 MW capacity may be liable to VIA (Environmental Impact Assessment - EIA). On the contrary, wind plants below 60 kW are allowed a simplified procedure (PAS) to be filed with the municipality involved (if no environmental restriction applies, this limit may be raised to 1 MW by the region). Very small wind turbines on top of buildings are allowed an even simpler procedure.

Another issue came up in 2011 as a consequence of the restructuring of RES support schemes outlined by Legislative Decree No. 28 of 3 March 2011, but not yet fully defined in detail, as said above. In the persisting absence of implementing decrees quantifying incentives from 2013 onwards and providing other needed information, many wind farm projects were held up with potentially severe consequences on the development of the wind sector in the next few years.

As for 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, also in 2011 wind developers complained of delays in grid connection as well, especially in the permitting of new electrical lines by local Authorities.

Italy's 2010 PAN for renewable energy has bound Terna to plan the upgrading of the grid needed to guarantee full access of RES electricity. Applications for connecting RES plants totaling 130 GW had been submitted to Terna by the end of 2010. A large part (nearly 97 GW) concerned wind plants, to be located in the South of Italy, Sicily and Sardinia, the most suitable areas for windiness, terrain, and space availability. Even though only a small share of this huge capacity is likely to be deployed, this is a challenge for the TSO. Its 2011 Grid Development Plan identified interventions for building new lines and substations on both the 380-220 kV main transmission grid and the 150 to 132-kV grids where most wind farms have so far been connected.

For several years, Terna has been making efforts to connect wind farms also by building dedicated 380/150 kV substations ("power collectors") through which 150-kV lines coming from more developed windy areas can feed power straight into the 380-kV system. Some major links recently built for general purposes, including links from Sardinia and Sicily to mainland Italy, can also help carry wind power from production to consumption areas.

Despite these efforts, 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) that were not yet fully adequate. In 2009, curtailments totaling 700 GWh (10.7% of production) were claimed by wind farm owners. By Deliberation ARG/elt 5/10 of 25 January 2010, the AEEG entrusted GSE, as an independent body, with the task of calculating curtailed energy. Wind data was used from a network of reference measuring masts, in order to have producers fairly indemnified. In 2010, GSE recognized a total loss of 470 GWh (5.6% of production). No data is yet available for 2011, but a downward trend has been foreseen thanks to ongoing upgrading of the grid. Improved methods have also been reducing errors in forecasting wind, thus helping handle larger wind penetrations. Temporary penetrations up to 62% of hourly average power (Sicily, November 2010) have been reported.

3.0 Implementation

3.1 Economic impact

The 590 medium and large sized wind turbines installed in 2011 (totaling 1,090 MW) and the relevant civil and electrical engineering work made up an estimated turnover of around 1.8 billion EUR (2.3 billion USD), nearly as much as the previous year. Even though only a part of these turbines were made in Italy, the impact on employment was remarkable, especially in southern Italy where employment opportunities are poorer. Many Italian firms also supplied components to wind turbine manufacturers based in Italy and abroad.

As to employment, mention should, once again, be made of the study performed by the National Wind Energy Association (ANEV), in co-operation with the Trade Union UIL, in 2008 and 2010. Some figures from this study were further updated in mid-2011, reporting about 8,700 people directly working on wind energy, which would become over 30,000 if also those indirectly involved in the sector were taken into account. The same study estimated that, if the wind potential of 16,200 MW estimated by ANEV were to be exploited in Italy, some 19,500 people would be employed directly in the wind sector by 2020, and this figure would rise to 67,000 including those indirectly involved. These expectations also explain today's concerns that the current uncertainties about future RES incentives (see above) may jeopardize employment prospects especially in less developed regions.

3.2 Industry status

As in previous years, most of the new wind turbines installed in Italy were supplied by foreign manufacturers. The overall market shares of wind turbine manufacturers in Italy at the end of 2011 are shown in Figure 3 as percentages of total online capacity. Of the wind turbines erected in 2011, 265 MW were Gamesa (Spain) and 263 MW were Vestas (Denmark). REpower (Germany) supplied 183 MW, Enercon (Germany) 164 MW, Nordex (Germany) 98 MW, GE Wind (U.S.) 53 MW, Siemens (Germany) 41 MW, Leitwind (Italy) 10 MW, and PowerWind56 (Germany) 5 MW.

Vestas has been operating in the Italian market since 1998 through Vestas Italia, the sales unit in Vestas Mediterranean that handles all sales, operations, and maintenance activities in Italy. The Italian sales unit is also responsible for the business development in the Balkans, Egypt, Jordan, Libya, and Switzerland. Vestas Italia's headquarters and main sales office are in Rome. The company also has an operations office in Taranto, and it has a customer service center in San Giorgio, which monitors and assists more than 1,100 turbines corresponding to a total capacity of more than 1,600 MW. Vestas also has two production facilities for blades and nacelles for the V90 turbines in Taranto.

Leitwind (belonging to the Leitner group) is based at Vipiteno in South Tyrol and is the only Italian manufacturer of large wind turbines. Leitwind headquarters are in Vipiteno, where R&D, product care, project management, and service divisions are located. Manufacturing is shared between two factories. The Telfs factory in Austria produces the "towerhead" (that includes generator, main frame, and hub). The recent expansion of the Telfs factory's office

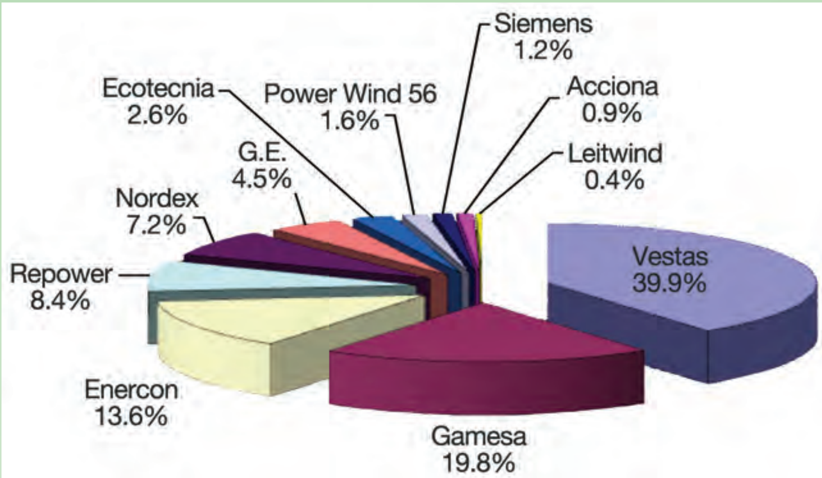

Figure 3. Market shares of wind turbine manufacturers in Italy at the end of 2011 (as percentage of total online capacity)

building, has set up the necessary infrastructure to produce the 3-MW generators. The company's test center is also located in this factory, where the various operational features of the turbines can be simulated to perform further optimization activities.

The Leitwind Chennai factory in India produces for the Asian market. It is part of Leitner Shriram Manufacturing Limited, a joint venture between Leitwind and the Indian company Shriram EPC. Leitwind's market is extended to Asia, Europe, and America. The Leitner products include the LTW77 (1.0 to 1.5 MW, 77 m) and LTW80 (1.5 to 1.8 MW, 80 m). Recently the new LTW70 2.0 MW (70-m rotor diameter), for extreme wind and environmental conditions, LTW86 (1.5 MW, 86-m rotor diameter), for moderate winds, and LTW101 (3 MW, 101-m rotor diameter) turbines have been added to the product line. All models feature a three-bladed, variable-speed rotor, no gearbox, and permanent-magnet synchronous generator.

The Moncada Energy Group based in Aragona near Agrigento (Sicily) has invested substantial resources as a wind farm developer. Moncada has set up wind farms in Sicily through subsidiary companies, and it has several other plants awaiting authorization. The company has a project to build a 500-MW wind farm in Albania, in Valona's region. Other projects of wind farms in Bulgaria, Mozambique, Romania, Tunisia, and the U.S. are being considered. Thanks to the new wind farms recently installed in Sicily (Cammarata, Castronovo di Sicilia, Vallelunga Pratameno) having a total capacity of 84 MW, the cumulative installed wind capacity of the Moncada Group in Italy has reached 240 MW.

In 2011, the top 12 electricity producers from wind in Italy held more than 60% of the market, computed as percentage of overall installed capacity. The highest capacities are owned by International Power and Enel GreenPower. International Power is a multi-national power producer. Enel GreenPower is a subsidiary company of the Enel Group, the Italian leader in electricity production, started on December 2008 and acting in Italy as well as in Europe and America. Other substantial capacity shares are held by ERG Renew, Edens - Edison Energie Speciali, subsidiary of the electricity utility Edison, and the wind developer FRI-EL. Other significant producers include Alerion Clean Power, E.ON Italia, Falck Renewables, Moncada Energy Group, IVPC group, Veronagest, and Sorgenia.

Regarding small-sized wind plants, the number of Italian firms entering this market has been growing as a consequence of the special incentives available (see above). Manufacturers of machines up to 30 kW include En-Eco (vertical-axis, 3 kW), Deltatronic (horizontal and vertical axis, up to 5 kW), Jonica Impianti (horizontal-axis, 30 kW), Layer Electronics (horizontal-axis, up to 20 kW), Ropatec (vertical-axis, up to 20 kW), Salmini (horizontal-axis units, below or just above 1 kW), and Tozzi Nord (horizontal- axis 10 kW turbine). Further horizontal-axis machines in the range of 50 to 80 kW capacity have been developed by ARIA, Eolart, Klimeko, Italtech Wind, Jonica Impianti, Terom, etc.

3.3 Operational details

In 2011, 590 new wind turbines were deployed totaling 1,090 MW, and their average capacity (Figure 4) was 1,831 kW. This confirms that large-sized machines are being used in Italy in spite of sites where the terrain is often rough and access difficult. The total number of online wind turbines is 5,446, corresponding to 6,878 MW and an overall average capacity of 1,263 kW per unit. All plants are based on land, mostly on hill or mountain sites. A number of applications for offshore projects have been submitted, but only one of them has so far gone through the phase of environmental impact assessment successfully.

In spite of complex terrain, some of the new wind farms are fairly large. The largest wind farm built in Italy last year was the Buddusò-Alà dei Sardi (Sardinia) plant, by the Falck company. With 69 Enercon turbines totaling 159 MW, this farm is the largest Italian wind farm in operation. The average capacity of the wind farms completed in 2011 was about 17 MW, and the average number of turbines in the wind farms was nine. Among the largest plants built in 2011 are those of Gasperina-Vallefiorita-Palermiti (Calabria - 97 MW), Bonorva (Sardinia – 74 MW), and Savignano Irpino (Campania – 66 MW).

Assuming the production of 10.1 TWh from wind in 2011 (figure still to be confirmed), an overall annual average capacity factor of 18% could be estimated. The actual performance could obviously have varied markedly from plant to plant and from month to month (the best seasons in Italy are typically winter and spring).

3.4 Wind energy costs

Capital costs of wind farms have generally been higher in Italy than in other countries, as most plants are built at rather remote hill or mountain sites, which increases costs of transportation, installation, grid connection, and operation. Lengthy and uncertain permitting procedures, not to mention negotiations for getting financing from banks etc., also bring about additional costs.

The overall capital cost of typical Italian wind farms could be split as follows: 10-20% for project development (wind surveys, plant design, permitting etc.); 60-70% for wind turbines (including erection and commissioning); and 20-25% for civil and electrical infrastructures (grid-connecting lines, SCADA etc.). As stated in the *IEA Wind 2010 Annual Report,* the specific capital cost of a typical land-based wind farm of medium capacity (20 MW) at a site of medium complexity could be put at about 1,750 EUR/kW (2,265 USD/kW), within a range from 1,500 EUR/kW (1,941 USD/kW) to 2,000 EUR/kW (2,588 USD/kW). Assuming the average capital cost, an annual O&M cost growing over the plant's 20-year lifetime from 1% to 4% of capital cost, and 1,800 hours/yr of equivalent full-capacity operation, the levelized energy cost would turn out about 127 and 138 EUR/MWh (164 and 179 USD/MWh) with discount rates of 5% and 7%, respectively.

Small wind plants (up to 200 kW) have higher specific capital costs, which grow substantially as size decreases, and they can tap less wind power because of their lower hub height. Considering also the uncertainty of wind estimates (wind measuring campaigns are too costly for small plants), in Italy it would be cautious to assume no more than 1,500 hours/yr of full-capacity operation. Unit energy costs vary over a wide range but are however higher than for large machines. That is why a special FIT has been made available to prime deployment of the small wind sector.

4.0 R, D&D Activities

4.1 National R, D&D efforts

Lacking a national R,D&D program on wind energy, activities have, for several years now, been carried out rather independently by a number of entities, among which are the National Research Council (CNR); ENEA, the Polytechnics of Milan, Turin, and Bari; RSE S.p.A.; some universities (Genoa, Naples, Perugia, Trento, Bologna, Florence, Rome, Padua, Lecce, etc.); industrial companies; and associations such as ANEV, the Association of Energy Producers from RES (APER), and Offshore Wind and other renewable Energies in Mediterranean and European Seas (OWEMES). A few highlights of these activities are given below.

CNR, through institutes ISAC, ISMAR, INSEAN, ISSIA, has worked on topics relating to wind conditions: atmospheric boundary layer research on offshore, coastal, and complex terrain; atmospheric and ocean modeling from climate to high resolution; wind mapping using models and space-borne measurements; data assimilation for short-term forecast of wind power production; and the interaction of offshore wind profiles with the ocean. It has dealt with aerodynamics including characterization and modeling of flow around a wind turbine and wakes, environmental impacts, and noise. It also deals with 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.

ENEA has been involved in the mapping of offshore wind resources and other RES potential. It has carried out research on non-destructive inspection methods for composite materials, as well as design and manufacturing processes for use of thermoplastic resins in small wind turbines.

The Department of Aerospace Engineering of the Polytechnic of Milan has been working on aero-servo-elastic modeling of wind turbines, modeling of blades, optimization of blade design, stability of wind turbines, individual blade-pitch control, description of wind field over the rotor disc, aero-elastic wind tunnel models etc. The Department of Energy, too, has also been dealing with wind energy topics.

The Department of Electrical Engineering of the Polytechnic of Turin has been concerned mainly with issues relating to in-field measurement of power performance of wind farms in hilly terrain.

The DICAT Department of the University of Genoa has been working on evaluation of wind fields and potential, as well as on safety and fatigue of wind turbines. The Department of Naval and Electrical Engineering has been concerned with innovative wind turbine control schemes, analysis of wind system capabilities for ancillary service supply, methods for day-ahead production schedule based on short-term wind forecasting and storage, distribution management systems for voltage profile optimization, loss reduction, etc.

The Department of Aerospace Engineering of the University of Naples

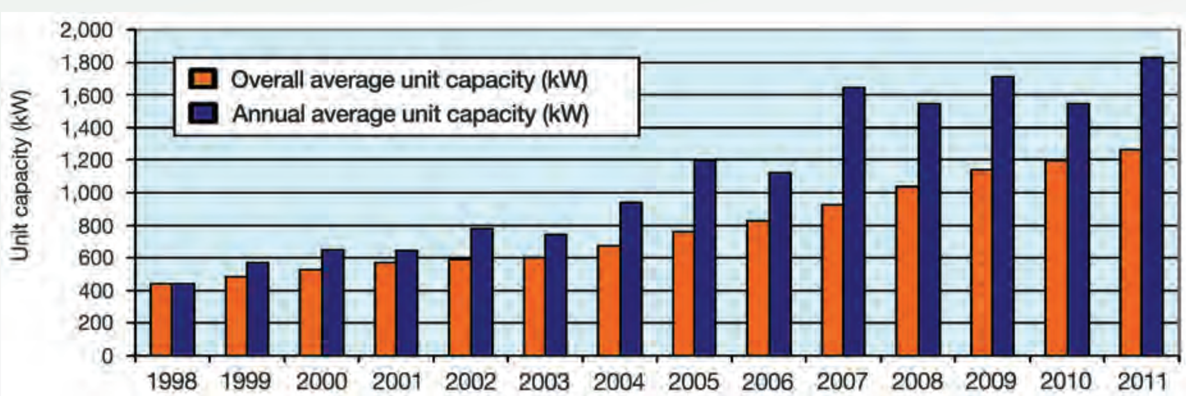

Figure 4. Average annual and cumulative unit capacity of wind turbines in Italy

has, for quite some time, been engaged in designing and wind tunnel testing of small wind turbines. Sizes go from 1.5 to 60 kW for horizontal-axis models and from 1 to 3 kW for vertical-axis ones, also for urban environments.

The University of Trento has, for several years now, focused on the testing of small wind turbines at its own test field in mountain environment; also drawing on this experience, guidelines on the choice and installation of small wind turbines have recently been published for the benefit of Italian users.

The KiteGen Research and Sequoia Automation companies have set up a 3-MW kite wind generator in southern Piedmont for testing. The Polytechnic of Turin, too, has an interest in kite wind generators.

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 6.5 million EUR (8.4 million USD) for 2009-2011.

In 2011, information for two additional themes was added to the Wind Atlas of Italy (http://atlanteeolico.rse-web.it/viewer.htm, now also in English). Installed wind capacity in each municipality (commune) has been added and "exclusion areas" (areas unsuitable for wind farms because of terrain features or technical or environmental constraints). The latter theme was implemented in a study requested by the Ministry of Economic Development for sharing among regions the burdens ensuing from national RES production targets.

Mapping of offshore wind resources was improved by investigating new software tools and measuring wind data at a few suitably located masts (also a wind measuring buoy was prepared for launch in the Channel of Sicily). A survey of prospects of multi-purpose offshore platforms in the Mediterranean Sea was made in the EU-funded project ORECCA, and a GIS-based project also mapped resources (wind and waves), water depth, infrastructure, constraints, etc. in the same area.

The state-of-the-art of small wind turbines was assessed by monitoring a few units at different sites. Control aspects of wind turbines and wind farms were studied, including behavior of floating turbines. Work on environment and social aspects resulted in a report on the effects of wind power on local development, the testing of software tools for spatial planning of integrated RES, and a Web-GIS system (named Tritone) aimed at exploiting offshore energy in harmony with Integrated Coastal Zone Management (ICZM).

Another activity concerned limited-area meteorological models (LAM) for wind farm production forecasts. In 2011, RSE also started supporting GSE in fine-tuning methods and tools for estimating production curtailments suffered by wind farms because of dispatching orders.

4.2 Collaborative research

Italian organizations collaborate mainly with IEA Wind and the European Commission on wind energy research. RSE has long been the Italian participant in IEA Wind Task 11 Base Technology Information Exchange. Terna has joined Task 25 Power Systems with Large Amounts of Wind Power, while the Department of Aerospace Engineering of the University of Naples has joined Task 27 Development and Deployment of Small Wind Turbine Labels for Consumers. In 2011, the Universities of Genoa and Perugia, the INSEAN institute, and the wind farm developer Sorgenia S.p.A. joined Task 31 Wakebench: Benchmarking of Wind Turbine Flow Models.

ENEA is in the Member State Mirror Group (MSMG) of European Wind Energy Technology Platform (TPWind), set up by the European Commission, and various entities (ENEA, Enel, Polytechnic of Milan, Centro Sviluppo Materiali S.p.A.) are taking part in the TPWind Working Groups.

CNR is in the Joint Program on Wind Energy of the European Energy Research Alliance (EERA) as full participant and ENEA is also joining this program.

On behalf of the Italian government, RSE has become a member of the EII Wind Team, which is the committee in charge of managing the European Industrial Initiative on Wind launched by the European Commission in its Strategic Energy Technology Plan (SET-Plan).

5.0 The Next Term

Based on financial commitments of investors to connect wind farms to the grid, Terna foresees continuing development of installed wind capacity. According to the TSO, total wind capacity could reach 9,600 MW by 2013-2014. The development of any offshore wind farms is still uncertain, at least in the next few years. If these expectations were fulfilled, however, most of the 2020 target capacity set by the government's PAN of 30 June 2010 (12,680 MW, of which only 680 MW is offshore) should come on line already by 2015. In practice, much will depend on the public's attitude and especially on the forthcoming development of the incentive framework.

The limited potential envisaged by the 2010 PAN for offshore installations stemmed from the fact that most exploitable windy areas seem to be located where water is too deep for current technologies (wind turbines on fixed foundations). This problem has been confirmed further by recent evaluations carried out by RSE through its newly developed GIS-based tool, whereby an overall offshore potential of about 10.5 GW could be available within 40 km off the country's coastline, but 80% of it would likely require floating wind turbines to be exploited.

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Photo: Wind Power Ibaraki Co. Ltd.

1.0 Overview

In 2011, the total installed wind capacity in Japan reached 2,501 MW with 1,832 turbines, including 25.2 MW from 14 offshore wind turbines. The annual net increase was 167 MW. Total energy produced from wind turbines during 2011 was 4.246 TWh, and this corresponds to 0.49% of national electric demand (859.663 TWh).

On 11 March 2011, the devastating earthquake and associated tsunami struck the wide northeastern region of Japan that is called Tohoku. One hundred ninety wind turbines with capacity of 270 MW were installed in the affected region, and they were shaken very severely. The shaking level was five or six on Japan's seismic intensity scale, which has a maximum level of seven. Almost all wind turbines survived the earthquake. And, most of them restarted soon afterward and contributed to Japan's power supply during the continuing crisis. Wind Power Kamisu semi-offshore Wind Farm was struck by a tsunami with about 5 m height. The SUBARU 80/2.0 wind turbines with rated power of 2.0 MW survived and resumed operation on 14 March, when the utility grid was activated. (opening photo) Only one wind turbine near the Kamisu wind farm suffered damage. Due to severe liquefaction the turbine foundation shifted and the turbine became tilted. This was the only damage to a wind turbine caused by the earthquake, and it has been fixed in 2011. These results suggest that Japan's earthquake-proof wind turbine construction design is very reliable.

2.0 National Objectives and Progress

2.1 National Targets

The national target for total installed wind capacity was 3,000 MW by the end of the fiscal year 2010 (31 March 2011), and this target was not achieved. The reason for that can be attributed to some recent obstacles for wind farm projects in Japan such as strict building codes revised in 2007, negative publicity from noise problems, bird strikes, and restricted grid connection. Moreover, changing the incentive program from investment subsidies to FIT has caused some confusion in wind power development in recent years. New national targets for the next few decades have not been set by the government, although the wind industry and other relevant stakeholders are requesting them. In the government's long-term forecast of demand and supply of energy in Japan, the official goal for total installed wind capacity is 5 GW for fiscal year 2020 as

Table 1. Key Statistics 2011: Japan	
Total installed wind capacity	2,501 MW
New wind capacity installed	167 MW
Total electrical output from wind	4.246 TWh
Wind generation as % of national electric demand	0.5%
Average capacity factor	19%
Target: (Prospect of wind capacity announced by the government)	Not specified (5 GW by 2020)

a maximum. However, the accident at Fukushima Daiichi nuclear power plant, has aroused public opinion in favor of reviewing energy policy. An expert committee convened by the Ministry of Economy, Trade, and Industry (METI) started discussions from October 2011 in order to fundamentally review the basic energy plan formulated by the government. New energy policy will be announced in August 2012.

2.2 Progress

Cumulative wind power capacity reached 2,501 MW (1,832 turbines) with 167 MW of annual net increase in 2011. There is no new increase in offshore wind power capacity (total capacity of 25.2 MW, 14 offshore wind turbines). Figure 1 shows the history of wind power development in Japan. Wind power generation in 2011 was 4.246 TWh in 2011 and the contribution of wind power to the national electric demand accounted for 0.49%.

2.3 National incentive programs

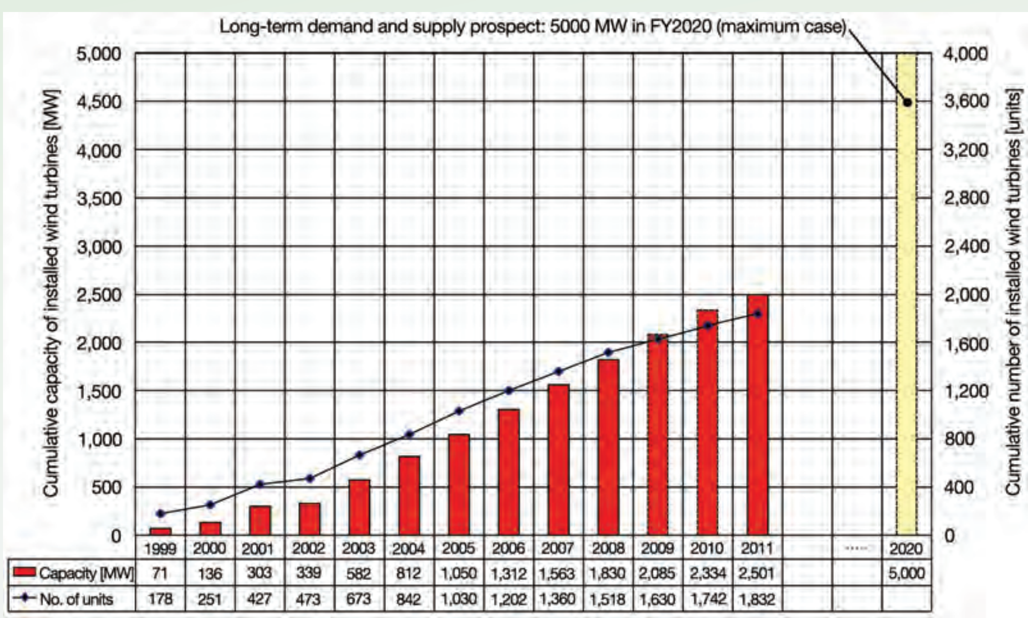
The current main incentive programs are investment subsidies and the Renewables Portfolio Standard (RPS). The standard subsidy rate is 0.8 multiplied by one third of initial investment. The RPS target was set as 12.82 TWh for fiscal year 2011, which corresponds to about 1.49 % of national electricity demand in fiscal year 2011. This target is for the total of new and renewable energy sources and is not broken down into individual renewable energy sources. The main contribution toward the RPS target was made by wind and biomass. The contribution of wind energy to the target has exceeded one third in recent years. However, this framework will finish in at the end of 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). It will come into force on 1 July 2012. The first FIT system that started in November 2009 was only for PV. However, this new FIT system will cover all practical renewable energy sources such as wind (including small wind), small- and medium-scale hydropower, geothermal, and biomass. The procurement price and the procurement period have not been decided yet, and these will be discussed and decided in an independent committee convened by METI. The procurement price will be reviewed every fiscal year in consideration of technological innovations and decline in power generation costs.

2.4 Issues affecting growth

It is expected that the new FIT system beginning from July 2012 will stimulate the market. The procurement price and the procurement period have not been decided yet. METI's original plan suggested 15-20 JPY/kWh (0.149-0.198 EUR/MWh; 0.195-0.260 USD/MWh) for 15 to 20 years. In the FIT law, the higher price should be set for the investor's profit for the first three years. And priority access to the grid is secured for renewables, however, the electric companies could potentially refuse the grid connection when there are concerns about their smooth supply of electricity.

The Ministry of the Environment (MOE) conducted the "Study of Potential for the Deployment of Renewable Energy." The amount of energy resources, deployment potential, and possible deployment amount under scenarios were evaluated for wind along with PV, small- and medium-scale hydropower, and geothermal. As a result, the deployment potential that includes both onshore and offshore wind was estimated to be 1,900 GW. This amount was larger than the potential deployment of



	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	.....	2020
Capacity [MW]	71	136	303	339	582	812	1,050	1,312	1,563	1,830	2,085	2,334	2,501		5,000
No. of units	178	251	427	473	673	842	1,030	1,202	1,360	1,518	1,630	1,742	1,832		

Figure 1. Total installed wind capacity and number of units in Japan

small- and medium-scale hydropower, tenfold of potential deployment of non-residential PV and hundredfold of the deployment potential of geothermal. The possible deployment amount under scenarios for wind was estimated to be 24 GW to 410 GW. This value is also larger than the values for residential PV, small-scale and medium-scale hydropower, and geothermal. METI also conducted a study on the wind energy resource, potential, and possible deployment amount. As a result, for onshore wind, wind energy resource potential and possible deployment amount in consideration of profitability, willingness of introduction, and social acceptance were estimated to be 1,550 GW, 291 GW and 38.9 GW, respectively. For offshore wind, they were estimated to be 368 GW, 335 GW and 6.84 GW, respectively.

The Federation of Electric Power Companies of Japan (FEPC), an industry organization of major electric utilities in Japan, has reviewed the integration limit of wind power based on past records and results. It announced that a total capacity of 5 GW of wind turbines could be connected to its grid without degradation of grid stability. Although this reviewed value of prospect of total wind capacity is modest compared with the possible deployment amounts estimated by METI and MOE, the attempt itself was welcomed by the wind industry.

The government made a cabinet decision to amend the "Environmental Impact Assessment Law" on 11 November 2011, and development projects of wind power generation plants will be subjected to this law from 1 October 2012. This law obliges developers of wind projects that have capacity of more than 10 MW to conduct an environmental impact assessment of the project. The assessment and approval process may take three to five years, and it is expected that this may cause deceleration of wind power development in Japan in the next few years.

3.0 Implementation

3.1 Economic impact

Seventy-five companies with 2,500 people are manufacturing wind turbines and their components in Japan, and their annual sales are estimated about 181.8 billion JPY (1.80 billion EUR; 2.36 billion USD), according to the research report by Economic Research Institute in Japan Society for the Promotion of Machine Industry.

3.2 Industry status

Three Japanese wind turbine manufacturers produce turbines above 1 MW: Mitsubishi Heavy Industries (MHI), The Japan Steel Works, and Fuji Heavy Industries & Hitachi (FHI-Hitachi). They have a major share of the domestic market. They produced 110 MW and represented 66% of the market in Japan in 2011. MHI produces 1-MW, 2.4-MW, and 2.5-MW wind turbines and announced plans to develop a 7-MW offshore wind turbine with hydro-drive train. JSW produces 2-MW, gearless, PMSG wind turbines (Figure 2) and their 2.7-MW turbine is coming soon. FHI-Hitachi produces 2 MW "SUBARU" downwind type wind turbines.

Japanese manufacturers are competitive at 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 developed by the Japanese automobile companies. Hitachi, TMEIC, Meidensha and Yasukawa Electric are producing generators for wind turbines. Hitachi announced plans to invest 4 billion JPY (396,000 EUR; 520,000 USD) to increase their annual production up to 2,400 units by 2013.

3.3 Wind energy costs

Updated values/costs are estimated as follows:

- Total installed cost: 300,000 JPY/kW (2,970 euro/kW; 3,900 USD/kW),
- COE: 11.0 JPY/kWh (0.109 euro/kWh; 0.143 USD/kWh),
- Wind electricity purchase price 7 to 9 JPY/kWh (0.069 to 0.089 euro/kWh; 0.091 to 0.117 USD/kWh),
- O&M costs: 6,000 JPY/kW/unit/yr (59.4 euro/kW/unit/yr; 78.0 USD/kW/unit/yr)
- Subsidy: 0.8 multiplied by one third of initial investment

4.0 R, D&D Activities

4.1 National R, D&D efforts

The national R&D programs by METI are as follows:

A. Research and Development of Next-Generation Wind Power Generation Technology (2008 to 2012)

Figure 2. Kunimiyama windfarm, with 15 of JSW's 2-MW turbines. Operation began in March 2011. (Source: Eurus Energy Holdings Co.)

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. Research and Development of Offshore Wind Power Generation Technology (2008 to 2013)

Because the new FIT system that goes into effect from July 2012 will be applied to small wind turbines, it was recognized securing the safety and the reliability of small wind turbines is important. The small wind industry association (Japan Small Wind Turbines Association, JSWTA) has activities to introduce a certification system of small wind turbine systems. The goal is to expand the small wind market in Japan while securing safety and reliability. The national project "A1: R&D of Basic and Applied Technologies, Research and Development of Next-Generation Wind Power Generation Technology," has technically supported these domestic activities and participation in IEA Wind Task 27 Consumer Labeling of Small Wind Turbines. In the Japanese national project, a field test site for small wind turbines was constructed in Rokkasho, Aomori, and various types of small wind turbines are now being field-tested (Figure 3). The technical specification of safety requirements, reliability, and performance of small wind turbines was developed in consideration of domestic circumstances and took account of the IEC, American Wind Energy Association, and British Wind Energy Association standards. Based on this technical specification, JSWTA established the “Small Wind Turbine Performance and Safety Standard”, and it was released by JSWTA on 4 November 2011. Nippon Kaiji Kyokai (NK), originally a ship classification society, began to conduct Type certification of small wind turbines based on the JSWTA standard from 10 December 2011.

In another NEDO project "B: R&D of Offshore Wind Power Generation Technology," two offshore wind turbines will be installed in fiscal year 2012. These turbines will demonstrate their reliability against Japan’s severe external conditions such as typhoons. The first, MHI’s 2.4-MW turbine, will be installed in the Pacific Ocean 3 km offshore of Choshi, 100 km east from Tokyo. The second, JSW’s 2-MW turbine will be installed in the Japan Sea near Fukuoka city. R&D of very large offshore wind turbines has also been supported by NEDO. An innovative hydro-drive train and 80- m class long rotor blade for very large offshore wind turbines were developed in this project.

In another MOE project, FHI-Hitachi’s 100kW and 2-MW wind turbines on the spar type floats will be installed

Figure 3. Field test site for small wind turbines in Rokkasho, Aomori (From left to right, Nasu Denki-Tekko “Aura 1000”, Sinfonia Technology “V-II WK18-20”, Nikko “NWG-1K”, Mayekawa “MDS-01A“) (Photo credit: HIKARUWIND.LAB)

in the East China Sea near offshore of the Goto islands in 2012 and 2013.

Recently, a new demonstration project of floating offshore wind farm supported by METI was announced. In this large-scale demonstration project, several offshore wind turbines with various types of floats will be installed in the Pacific Ocean more than 20 km offshore of Fukushima. This project is planed as one of the symbols of Fukushima's revival by renewable energy.

Japan has severe external conditions such as high turbulence and extreme wind caused by typhoons and highly complex terrain. In the national projects (e.g., A1 and B), the severe wind conditions were clarified, and a wind turbine class for tropical cyclone regions was developed. A high turbulence model and category for complex terrain regions were developed based on results obtained in the national projects. These R&D activities and results were shared with experts worldwide at the IEA Wind Task 11 "Topical Expert Meeting on Wind Conditions for Wind Turbine Design" that was held in Tokyo, in December 2010. Moreover, the Japanese national committee for IEC TC88 has proposed the revision of design requirements for wind conditions in tropical cyclone regions and in complex terrain regions.

5.0 The Next Term

Drastic changes in national incentive programs and in the implementation of environmental impact assessment are scheduled in 2012. These may cause confusion in wind energy development in Japan for a few years. After the Fukushima nuclear accident, a fundamental review of the national basic energy plan is underway. The new basic energy plan will be released in 2012 and it is expected that the contribution of wind energy will be increased.

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25 Republic of Korea

Courtesy Korea Energy Information Center

1.0 Overview

The cumulative installed wind power in The Republic of Korea was 379 MW in 2010 and 406 MW in 2011, increasing by 7% over the previous year. Most wind turbine systems installed in 2011 were supplied by local turbine system manufacturers. An RPS proposal for new and renewable energy was approved by Congress and the government prepared to enact the program in 2012. The required rate of the RPS in 2012 is 2% and will increase to 10% by 2022. A plan for a 2.5-GW offshore wind farm to be built on the west coast over nine years was announced in 2010. The first stage of that project, construction of a 100-MW wind farm, began in 2011. The 2.5 GW of offshore wind farm construction and the RPS are expected to stimulate dramatic growth of wind energy in Korea. Since 2009, the government has concentrated on the development of local component suppliers to secure the supply chain. The government R&D budget continues to include funds to localize component supply and develop core technologies for wind power.

2.0 National Objectives and Progress

The Republic of Korea has focused on the wind energy as a clean energy resource replacing fossil fuels and as a new area of heavy industry to contribute to the Korean economy. Therefore, the Korean government has increased the R&D budget continuously to support wind turbine and component manufacturers to develop their own technologies and products. Most major shipbuilding and heavy industry companies have become involved in the renewable energy business, especially wind energy. In 2011, total installed wind generators with output of more than 200 kW was 406 MW, almost 7% growth over 2010.

Table 1. Key Statistics 2011: Korea	
Total installed wind generation	406 MW
New wind generation installed	27 MW
Total electrical output from wind	.812 TWh (2010)
Wind generation as % of national electric demand	0.18 % (2010)
Average capacity factor	
Target:	7.3 GW by 2030

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. This is stipulated in the Third National Energy Plan 2030, sharing about 12.6% among the new and renewables. Also, another goal is to improve the technology associated with wind energy and lead the wind energy industry.

2.2 Progress

In 2011, 27 MW of new wind power were installed, increasing 7% of total wind generation in Korea. The opening photo shows Youngyang wind farm. Although the amount of wind capacity installed in 2011 is less than 2010, most of the turbine systems were supplied by domestic manufacturers. Domestic manufacturers have developed their systems and started recording operational performance.

The net sales of the wind energy business in 2010 increased 76% over the previous year to an estimated 1.565 million USD (1.164 million EUR). This amount represents 22.6% of all renewable energy industries. The number of manufacturers doubled from 12 to 24 since 2004, and the number of employees was estimated to be around 1,103 in 2010. Most manufacturers still concentrate on developing the products and technologies, so the majority of the

Table 2. Total installed wind capacity in Korea												
Year	~2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
Capacity (MW)	7.9	4.7	5.4	50	31	79	18	108	44	33	27	406
Electrical Output (GWh)	25	15	23	38	125	234	371	421	678	812	-	

employees are dedicated to R&D rather than production.

The history of wind energy in Korea is still short compared with countries that have established manufacturing of wind systems. Korean communities have strived to catch up with core technologies. The level of technology has been improved and by 2010 was nearly comparable to equipment from the leading countries in 2010.

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 cost burden. The government has specially focused on school buildings, warehouses, industrial complexes, highway facilities, factories, and electric power plants. For wind power installations, especially for demonstration 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 the one million green home program for diversifying and optimizing renewable energy use. The target is to construct one million houses equipped with green energy resources by 2020. By the end of 2011, 111,400 houses 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 have been required to invest more than 5% of their total construction expense in the installation of new or renewable energy systems.

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 (0.068 EUR/kWh) as a flat rate for 15 years in 2011. The FIT is being applied to wind farms installed by 2011. New farms constructed from 2012 will be supported with RPS.

RPS (Renewable Portfolio Standards): RPS was approved by Congress and it has been prepared to enact the program from 2012. It specifies that more than 2% of electric power should be supplied with renewable resources in 2012. This regulation will be applied to electric power suppliers that provide more than 500 MW. The required rate of renewable generation will increase to 10% in 2022. The weight factors for onshore wind farms is 1.0, for offshore farms less than 5 km from land the weight factor is 1.5, and for offshore wind farms more than 5 km from land the weight factor is 2.0.

In addition, Loan & Tax Deductions, Local Government NRE Deployment Programs, and others are available as national incentive programs.

2.4 Issues affecting growth

Two issues are playing major roles escalating the growth of wind energy. The first issue is the construction of 2.5 GW of offshore wind farms in the west sea. According to the roadmap announced by the government, the 2.5-GW farm will be constructed in three stages over nine years starting in 2011. For the first four years, 100 MW of wind power will be installed to gain experience with the technology and for site design. Then 400 MW of wind power will be installed for accumulating operational experience and commercial use over the next two years. At the final stage, a 2-GW wind farm will be constructed with 5-MW wind turbines for commercial use. The total budget is estimated to be 7.5 billion USD (5.6 billion EUR).

The other issue increasing wind power in Korea 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. The rate will increase to 10% in 2022. This regulation will encourage power suppliers to invest in renewable resources generation.

3.0 Implementation

3.1 Economic impact

As reported in the *IEA Wind 2010 Annual Report*, major shipbuilding and heavy industry companies develop their own wind turbines and some companies have accumulated track records. The export of turbine systems began in 2009 with sales of 50 million USD (37 million EUR). In 2010, more turbines were exported and total sales are estimated at 207 million USD (154 million EUR). Employment also increased dramatically due to rapid growth of the industry. Half

Table 3. Total sales of wind energy business in Korea							
Year	2004	2005	2006	2007	2008	2009	2010
Total Sales (million USD)	87	167	397	532	1,070	889	1,566

Table 4. Offshore wind farm construction plan for 2.5 GW			
	Demonstration	Standardization	Deployment
Objective	Test record set up accumulation of track record site design	Operational experience validation of commercial operation	Cost effectiveness of GW site development and commercial operation
Wind Power	100 MW	400 MW	2,000 MW
Schedule	2011~14 (4 yrs)	2015~2016 (2 yrs)	2017~2019 (3yrs)

of employment is related to R&D and total employment is about 1,000 people.

3.2 Industry status

Some manufacturers have expanded their business into other renewable resources such as solar energy, tidal energy, and others to provide stable renewable energy. However, the global economic crisis has reduced the prospects for renewable energy and new investment plans are being reviewed carefully.

3.3 Operational details

In 2011, 27 MW of wind power were newly installed and most turbines were supplied by domestic manufacturers. Five 1.5-MW turbines were from Hanjin, one 2-MW turbine was from Unison, and two 1.5-MW turbines were from STX. Doosan and Samsung heavy industries provided one 3-MW and one 2.5-MW turbines respectively.

3.4 Wind energy costs

Newly installed wind turbines, especially those supplied by domestic manufacturers, are not operated for commercial purposes but for system check and accumulating a track record. So there is not enough records of electric output and it is still difficult to estimate the real cost of wind energy.

4.0 R, D&D Activities

4.1 National R, D&D efforts

The government has continuously increased the R&D budget and demonstrated strong support for wind energy. Even the Korean president mentioned wind energy as one of the candidates to expand the Korean economy at New Year's news conference in 2011. The government has allocated a significant R&D budget for local production of wind turbines and also realizes the importance of stable supply chain. The government, therefore, has increased the budget to develop technology for component and several government-sponsored R&D projects are under way. More component development projects, as shown in Table 5, are launched every year. Table 5 shows the proportion of the R&D budget allocated for each category. Overall, 40% of the R&D budget was provided to support component

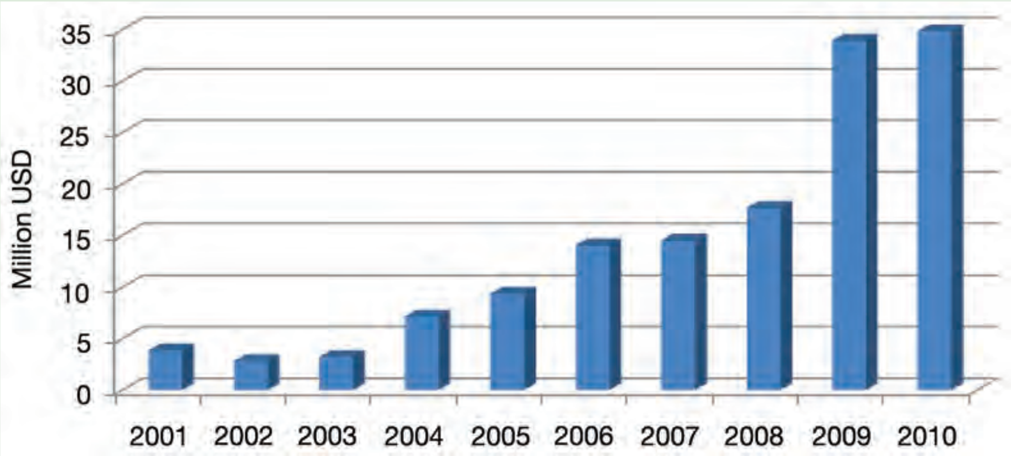

Figure 1. The budget trend of government sponsored R, D&D

Table 5. Government R&D budget allocation in 2009 & 2010						
Category	2009			2010		
	No. of Projects	Budget	Rate (%)	No. of Projects	Budget	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

development in 2010. The components being developed for local production are brake calipers, pitch system and controllers, offshore floating simulation codes, condition monitoring, yaw bearings, blade damage smart sensing, LVRT converter algorithms, shrink disks, gearboxes, yaw and pitch drives, and others.

5.0 The Next Term

The first stage of a 2.5-GW offshore wind farm was initiated in 2011 and RPS was enacted in 2012. These major issues are expected to encourage 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 predict future activities about wind energy in detail.

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26 México

1.0 Overview

During 2011, 20 new wind turbines were commissioned in México, bringing the total wind generation capacity to 571 MW.

Table 1. Key Statistics 2011: México	
Total installed wind generation	570 MW
New wind generation installed	50 MW
Total electrical output from wind	***1.3 TWh***
Wind generation as % of national electric demand	***0.6 %***
Average capacity factor	***~30%***
Target:	1.2 GW by the end of 2012 ***2% of 2013 national electric demand***
Bold italic indicates an estimate.	

The Law for Renewable Energy Use and Financing of Energy Transition (enacted in November 2008) is successfully achieving its main objectives. Wind energy is now a competitive option within the Mexican electricity market, and the Secretariat of Energy (Sener) issued a Special Program for the Use of Renewable Energy. A 2,000-MW, 400-kV, 300-km electrical transmission line for wind energy projects in the Isthmus of Tehuantepec is under construction. Five 100-MW wind power plants are under construction and will be commissioned during 2012 under the Independent Power Producer (IPP) modality.

The Energy Regulatory Commission has granted permits for a total of 3,147 MW of wind power capacity. Currently, it is estimated that full implementation of technologically and economically feasible projects would lead to the construction of more than 12,000 MW of wind generation capacity. 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 m/s to 10 m/s, measured at 30 meters 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 over 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

By the end of 2012 wind energy installed capacity in México will be close to 1,200 MW. Assuming this capacity operated at an average of 35% during 2013, contribution of wind generation to national electric demand would be around 2%.

2.2 Progress

Remarks:

- 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.
- La Venta III is the first IPP wind energy project; the contract

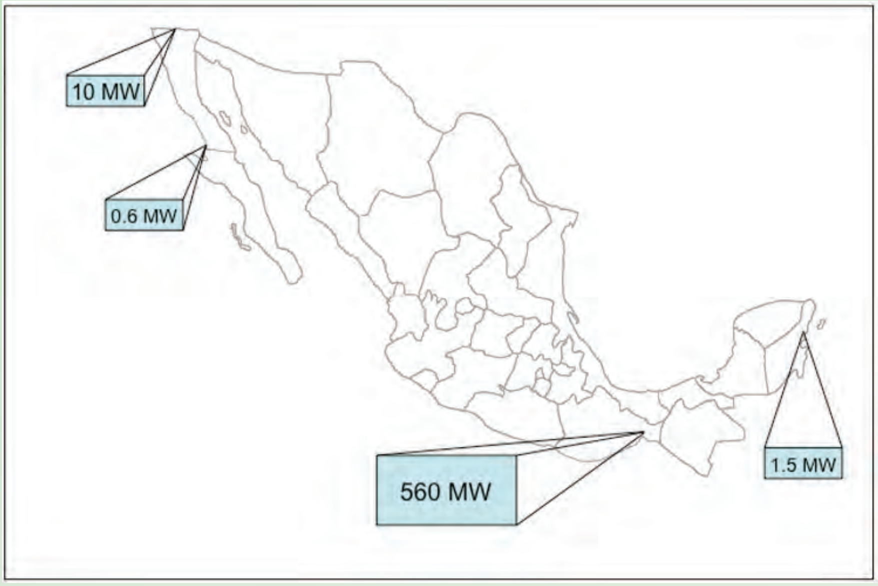

Figure 1. Wind generating capacity installed in México as of December 2011

awarded includes a complement to the electricity buyback price of about 0.015 USD/kWh (0.20 EUR/kWh) that will be granted by GEF through the World Bank.

- Bii Nee Stipa is owned by Iberdrola.

2.2.1 Contribution to electrical demand

During 2011, total electrical output from wind was around 1.3 TWh, which is equivalent to around 0.6 % of national electric demand.

2.2.2 Environmental benefits

Reduction of CO_2 emissions due to wind generation for the year 2011 was 780,000 tons, considering a mitigation rate of 0.6 tons CO_2 per each wind generated MWh.

2.3 National incentive programs

The Law for the Use of Renewable Energy and Financing of Energy Transition is a sound signal from the government of México regarding both political will and commitment for implementing energy diversification toward sustainable development. The main elements of the strategy in the law include: presenting strategic goals; creating a special program for renewable energy; 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

Figure 2. La Venta II 83.3-MW wind farm in the Isthmus of Tehuantepec, México

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	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	FGOB	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	50.0	Commissioned	POSS	2011	OAX
La Venta III	121	850	Gamesa	102.9	U. Construction	IPP	2012	OAX
Oaxaca I	51	2,000	Vestas	102.0	U. Construction	IPP	2012	OAX
Oaxaca II	68	1,500	Acciona	102.0	U. Construction	IPP	2012	OAX
Oaxaca III	68	1,500	Acciona	102.0	U. Construction	IPP	2012	OAX
Oaxaca IV	68	1,599	Acciona	102.0	U. Construction	IPP	2012	OAX
DEMSA	113	2,000	Gamesa	227.0	U. Construction	POSS	2013	OAX
Eoliatec Istmo	82	2,000	Gamesa	164.0	U. Construction	POSS	2013	OAX
Eoliatec Pacífico				160.5	Not initiated	POSS	2013	OAX
EE Mareña				180.0	Not initiated	POSS	2013	OAX
E.A. Istmeña				215.6	Not initiated	POSS	2013	OAX
Bii Hioxo				227.5	Not initiated	POSS	2013	OAX
C. Tamaulipas				54.0	Not initiated	POSS	2014	TAM
F.E. B. Cal.				300.0	Not initiated	POSS	2014	BC
San Matías				20.0	Not initiated	POSS	2014	BC
Rumocannon				72.0	Not initiated	POSS	2014	BC
B.Cal. 2000				10.0	Not initiated	POSS	2014	BC
Sta. Catarina				17.5	Not initiated	POSS	2014	NL
GSER				161.0	Not initiated	POSS	2014	TAM
Dominica EL				200.0	Not initiated	POSS	2014	SLP
Papaloapan				40.0	Not initiated	POSS	2014	JAL
Accumulated				3,147.6				

(1) FGOB=Federal Government, SGOB= State Government, POSS= Private owned self-supply, IPP= Independent Power Producer, IIE = Instituto de Investigaciones Eléctricas
(2) Commissioning year

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) 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 2011, it was estimated that the total investment in the construction of wind power plants was around 1.14 billion USD (855 million EUR). Assuming that around 80% of this amount corresponds to the cost of the wind turbines, the rest, around 228 million USD (171 million EUR) could be considered as the economic distribution to México. Nevertheless, a substantial portion of the work is carried out by foreign employees.

3.2 Industry status

The Spanish wind turbine manufactures Acciona Windpower and Gamesa Eólica are leading the Mexican wind turbine market, but other companies like Vestas and Clipper Windpower 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 selling electricity to both big- and medium-sized electricity consumers under the creation of self-supply consortiums. With the support of the federal government, the government of the state of Baja California implemented a 10-MW wind energy project for public municipal lighting. This project was commissioned during 2010.

More than 200 Mexican companies have the capacity to manufacture some parts required for wind turbines and wind power plants. Trinity Industries de México, S. de R.L. de C.V. is manufacturing towers in for a number of wind turbine companies. The Mexican firm Potencia Industrial S.A. de C.V. is 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. During 2011, the total average capacity factor for wind energy was around 30%. Being that 50 MW of new wind power plants were commissioned along the year, it means that capacity factor of individual wind power plants could be over 30%. In general terms, one can say that wind turbine manufactures are learning to deal with the outstanding wind regime of the Isthmus of Tehuantepec.

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). 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 Komai Tekko, Inc. According to the 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

Figure 3. The Wind Energy Technology Center operated by the IIE

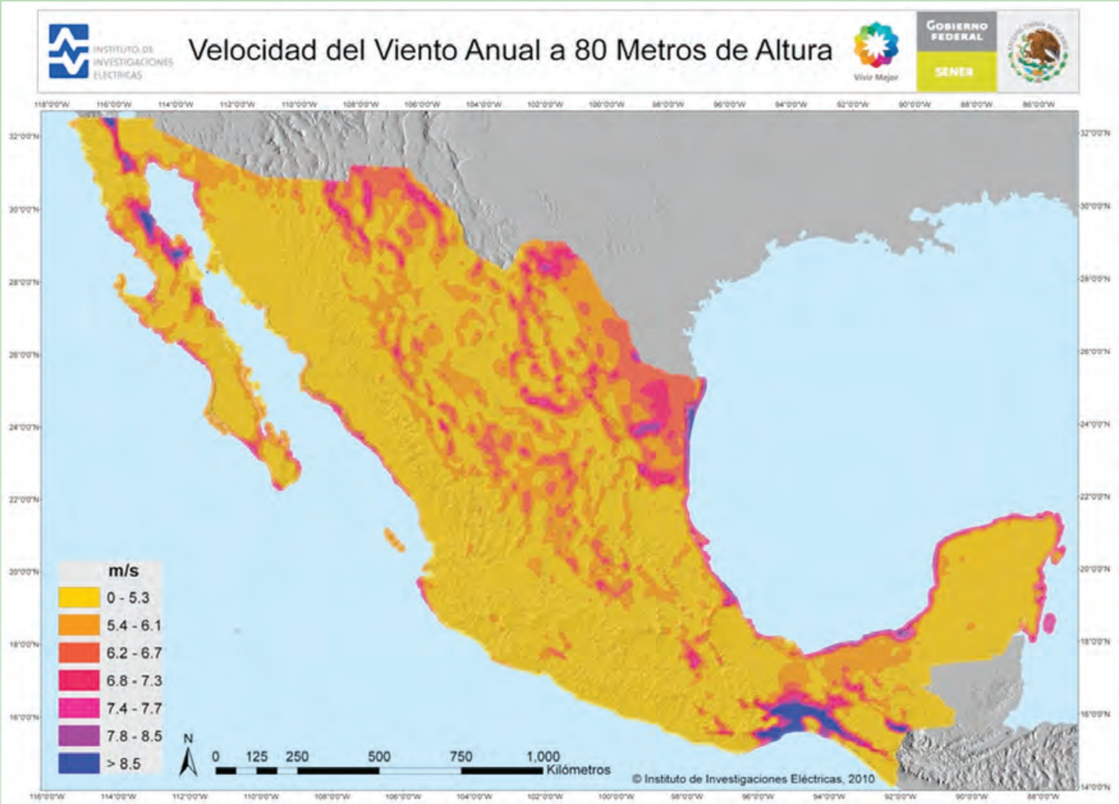

Figure 4. Mexican Wind Energy Atlas

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 538 MW of new wind power capacity has been secured. This will bring the total generation capacity to at least 1,058 MW by the end of 2012. It is expected that, private companies are capable of building the projects that they have been developing under the self-supply modality for bringing the total installed capacity to around 1,500 MW by the end of 2012.

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27 the Netherlands


Photo credit: André de Boer, NL Agency

1.0 Overview

Total Dutch installed capacity has increased last year by 5.5% from 2,245 MW to 2,368 MW. The contribution of wind at sea capacity remained unchanged at 228 MW. With this capacity a year overall average production of 4.18% of the national electric demand was reached. 2011 was more or less a standard wind year. In the Netherlands it is common to correct the annual production with a windex based on a ten years average (1996-2005). EU regulation nowadays requests corrections based on a five years average. According to Dutch methodology the windex (2011) was 0.96 meaning the wind was slightly less than average in the years 1996-2005 in the Netherlands. According to the EU methodology the windex (2011) was 1.076, meaning the wind in 2011 was 7.6% more than the last five years in the Netherlands.

Normalised at the mentioned ten years windex, the wind energy production increased from 5,19 TWh (2010) to 5.31 TWh (2011). Although offshore turbines cover ~10% of the total installed capacity, the production from wind offshore is around 16% of the total wind energy production (Table 1)

2.0 National Objectives and Progress

2.1 National targets

The centre-right government took control in October 2010 and completed its first full year of operation in 2011. Already in 2010, national renewable energy targets for 2020 were reduced to the EU targets: 20% CO_2 reduction compared to the 1990 level and a share of 14% renewable energy in 2020. The main tools to achieve these targets are:

- Introduction of the SDE (stimulering duurzame energie)-plus production subsidy for renewable energy replacing the previous SDE subsidy
- Support of research and development for new energy sources
- Increased use of Kyoto flexible mechanisms
- Implementation of nuclear energy
- Signing of more than 50 'Green Deals' with society, aiming at energy efficiency and production of renewable energy
- Preparation of the newly introduced 'Innovation Contracts' (to be signed in 2012).

This means that the government broke with the past in terms of subsidy of energy research as explained in Section 4.

Within these renewable energy targets, no official targets for wind are currently set. The official vision and ambition in 2011 is, "National government

Table 1. Key Statistics 2011: Netherlands	
Total installed wind generation	***2,368 MW***
New wind generation installed	***123 MW***
Total electrical output from wind	***5.1 TWh***
Wind generation as % of national electric demand	***4.18 %***
Average capacity factor	
Target 2020	***14% renewable energy***
Target 2020	20% reduction CO_2 as compared to 1990 level
Bold italic indicates estimate	

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. In addition, national government will designate enough space for 6,000 MW wind at sea. Because not all parts of the Netherlands are suitable for large-scale wind on land, national government will allocate–in cooperation with provinces–preferred area for large scale wind on land."

2.2 Progress

Progress was limited to net installation of 123 MW and the reorientation of the national incentive programs.

2.3 National incentive program

The main incentive program for renewable energy is the SDE-plus production subsidy. By introducing the SDE-plus, the government responded to critics of the preceding SDE (effective 2008-2010), which gave subsidy to less expensive kinds of renewable energy as well as more expensive kinds. Accepted techniques for SDE-plus are energy from waste incineration, biomass including biogas, wastewater, landfill, geothermal sources, osmosis, hydro, wind, and photovoltaics (≥15 kW_{peak}). Compared to the preceding SDE, biogas and renewable heat are new in the list. The main thought behind the new SDE-plus is to get as much renewable energy as possible for each subsidy-euro. For SDE as well as for SDE-plus, the subsidy is meant only to fill the gap between the pay-back tariff (depending on the quality of the power, in actual practice ± 0.05 EUR/kWh; 0.06 USD/kWh) and the 'basic tariff,' which is at most the cost price of the renewable energy. To apply SDE-plus, a producer of renewable energy has to claim a certain basic tariff of its renewable energy and has to inform about the pay-back tariff of the energy company. SDE-plus can be received for the difference of these kWh-prices. In a certain sense, the term 'basic tariff' is misleading, since it is the sum of the pay-back tariff and the SDE-plus. Currently, a maximum basic tariff is determined by the Netherlands research institute (ECN) and DNV KEMA Energy & Sustainability consultancy (KEMA). Submission for a price lower than the cost price of the renewable energy is possible too. In that case, the SDE-plus will be correspondingly less.

The SDE-plus was planned to have a maximum of four rounds in 2011, starting 1 July, 1 September, 1 October, and 1 November, having a grand total of 1.5 billion EUR (1.6 billion USD) and all working according the first-come-first-served principle. In the first round, submission could be made for projects with a claimed basic tariff up to 0.09 EUR/kWh (0.11 USD/kWh), in practice meaning a subsidy of at most ± 0.04 EUR/kWh (0.05 USD/kWh). For the budget left over by the end of August, in September applications could be made for projects with a claimed basic tariff up to 0.11 EUR/kWh (0.14 USD/kWh), in practice meaning a subsidy of at most ± 0.06 EUR/kWh (0.08 USD/kWh). For the budget left over after these two rounds, in October applications could be made for a basic tariff up to 0.13 EUR/kWh (0.17 USD/kWh) (subsidy of at most ± 0.08 EUR/kWh; 0.10 USD/kWh). Finally in November applications could be done for a basic tariff up to 0.15 USD/kWh (0.19 USD/kWh) (subsidy of at most ± 0.10 EUR/kWh; 0.13 USD/kWh). One of the main features of the SDE-plus is that it is always possible to apply for a lower basic tariff in an earlier round. This would results in a lower SDE-plus subsidy but increases the chance of allowance, because the chance of depletion of the budget is lower when applying to an earlier round. These applications at a lower basic tariff are called free categories.

By the end of July, during the first round, the whole budget of 1.5 billion EUR (1.9 billion USD) was already claimed. Therefore, a second, third, and fourth round was not necessary. Broadly speaking the allocation was:

- ~60% of the budget allocated for green gas generation (digestion, excluded manure) and green gas upgrading
- ~10% was allocated for electricity from green gas
- ~9% was allocated for wind on land,
- other renewables have lower percentages: ~7% co-digestion with manure, ~6% waste incineration, 5% biomass (thermal) and ~2% photovoltaic.

Because 89% of the budget was claimed in the free categories, meaning the projects accept a lower SDE-plus than the maximum, it has been suggested that the basic tariffs were too high. Projects granted with SDE-plus have to be realized within three years. Therefore, the exact amounts of energy involved in it are not known yet.

2.4 Issues affecting growth

In the Netherlands, the availability of good wind farm locations is an issue. 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 of 400 persons/km^2, the space for wind farms is limited. For wind at sea, lack of space is an important issue as well.

Further, the government reduced the fiscal advantages for private citizens on green savings accounts, green bonds, and green stocks, resulting in reduced amounts of money available for banks to spend on green projects. In addition, the general tendency of banks to have stricter rules on financing of projects also leads to less money available to spend on green projects. Both effects result in the need a higher financial participation of the project owner, making projects more difficult to be developed.

A third important factor affecting growth is the lack of harmonization of policies. This can result, for example, in difficulties in obtaining SDE-plus benefits. SDE-plus applications can only be submitted after 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 at the moment when the SDE-plus allowance to make a project profitable is far from certain.

3.0 Implementation

3.1 Economic impact

The total investment in wind energy installations in the Netherlands for 2011 can be estimated at 163 million EUR (211 million USD), assuming an average investment cost for land-based wind of 1,325 EUR/kW (1,715 USD/kW) for the 123 MW installed. The total investment in wind energy installations built up to 2011 is, at the price level of 2011, estimated at approximately 3.55 million EUR (4.50 million USD).

In 2011, a report about the economic impact of the wind at sea sector was published (1). This was the result of extensive research at 112 companies. Based on the research, it can be stated that the employment of the sector is at least 1,800 full-time employees but is very likely around 2,200 full time employees. Regarding employment, 11% is in R&D, 3% in project development, 74% in construction, and 12% in O&M. In construction seven companies in the construction sector generate two-thirds of the employment in the wind at sea sector. The turnover of the wind at sea 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).

3.2 Industry status

XECM Darwind

XECM Darwind developed its XD115/5-MW offshore wind turbine with a 115-m rotor. The first prototype was installed in June 2011 at the ECN Wieringermeer test site (opening photo). The official opening ceremony was in September, attended by important persons from the Chinese embassy, XEMC, the Ministry of EL&I, and the province. The turbine is being tested for Type certification and for further validation. Simultaneously the turbine is now being used for experimental research, amongst others experiments from the FLOW program (see Section 4).

3.3 Operational status

RWE/Essent Meteomast

In October a new offshore metmast was installed, 75 km west of IJmuiden in Tromp Binnen windparkearea. This IJmuiden metmast is a twinning project with the German Nord Sea Ost metmast. The lattice, triangular-shaped mast is 96 m high. Part of this is the support structure, being a monopile of 62 m with a 3.2-m diamete. The total weight of the foundation is 370 tons. The monopile was rammed to a depth of 32 m, the local sea depth is 26 m (Figure 1).

Meteorological instruments are placed at four levels (96 m, 85 m, 58.5 m, and 27 m). At platform height, two precipitation monitors are installed to detect rain, snow, etc. At the 85, 58.5 and 27 meter levels, three booms are installed pointing in 0, 120, and 240 degree directions respectively, where wind speed and/or wind direction are measured. The temperature, relative humidity, and air pressure are also measured at each level.

On top, one sonic anemometer and two cup anemometers measure wind speed. Wind direction can be derived from the sonic anemometer. At 58.5 and 27 m, boom lengths are sufficient to accommodate both cup anemometers and wind vanes, at 85 m there are three wind vanes. Temperature sensors are installed at platform level and on top. Besides these sensors in the mast, a Lidar is installed for additional wind speed measurements and a wave and current buoy with acoustic Doppler current profiler (ADCP) system is installed to monitor current and wave data. Additional wave radar can be deployed depending on available power and resources.

The meteorological station is completely self-supporting regarding energy requirements, and sends the measured data to the mainland using a satellite connection. The measurements are being carried out by ECN.

3.4 Wind energy costs

A report on the economic impact of offshore wind energy has been published in Dutch (1).

4.0 R, D&D Activities

4.1 National R, D&D efforts

As written in Section 1.0, the present government broke with history in terms of granting new subsidies on energy research. While in 2010 a total of 38 million EUR (49 million USD) were awarded as subsidies for wind R&D, in 2011 only the direct governmental support of ECN and Technical University of Delft (TUD) were still funded (approximately 7.1 million EUR; 9.2 million USD).

EOS (Energy Research Subsidy) and EWOZ (Wind offshore Subsidy):

EOS and EWOZ are two closed subsidy programs, but with projects still running that were awarded in 2010. No new budget was allocated in 2011. The most important project in progress in 2011 are (marked by * are described in the *IEA Wind 2010 Annual Report*)

- XEMC Darwind*: further development (testing, validating) of the XD 115 wind turbine
- 2-B-Energy*: development of the 2 B Energy 6-MW downwind rotor off shore wind turbine
- EWT (Emergya Wind Technologies)*: demonstration of the DW90 2-MW, DDPM, outside rotor wind turbine
- ActiFlow*: Research on porous turbine blades and/or blades with air inlets, leading to better aerodynamic performances
- ECN: sustainable control, development of new control system

Figure 1. The RWE/Essent metmast, just after installation, without the booms

including a.o. fault tolerant control, extreme event control, etc.
• ECN: rotor flow, development of new ways of designing, using improved calculating methods of aerodynamic loads and dynamic loads
• CortEnergy: VG airfoil, the introduction of vortex-generators on turbine blades (Figure 2)
• DotX Control Solutions: Development of a non linear predictive controller
• ECN: North Sea Transnational Grid (NSTG). Research on configurations of HVAC and HVDC, determination of a NSTG on national nets, research on management and legislation issues.

Far and Large Offshore Wind (FLOW):

In December 2010, the Ministry of Economic Affairs, Agriculture and Innovation granted a 23.5 million EUR (30.4 million USD) subsidy to the FLOW consortium with its 47 million EUR (60.8 million USD) research program. The FLOW consortium is a mix of parties from industry (offshore, wind industry), utilities, TenneT, and research/knowledge institutes. The FLOW program has five research lines: wind farm design, support structures, peripheral infrastructure, turbine development, and societal items. In 2010, only the outline of the research was available, during the course of the FLOW program, the outline will be filled in. Therefore, twice a year an internal tender of elaborated projects will be organized. In 2011, the first (of four) full years, 11 million EUR of 47 million EUR (14 million USD of 60.8 million USD) on projects have been allocated. The most important projects include:

• Far offshore wind modeling, wind park wake modeling, and wind park turbulence modeling (Figure 3)
• Coupling between near wake and far wake models
• Offshore wind power plant control for minimal loading
• Availability-based design of offshore wind power stations
• Meteodashboard
• Development of a noise mitigation under water screen, reducing sound pollution, enabling a longer permitted installation period (Figure 4)
• Development of tools to design integrated and optimized wind turbine/support structure
• Wind farm electrical lay-out and optimization
• Development of load analysis tools
• Passive stall research to design/develop new blades using planform modifications and complete fibrepath definitions for blades.

Many of the projects are in close cooperation between industrial partners and research institutes/university.

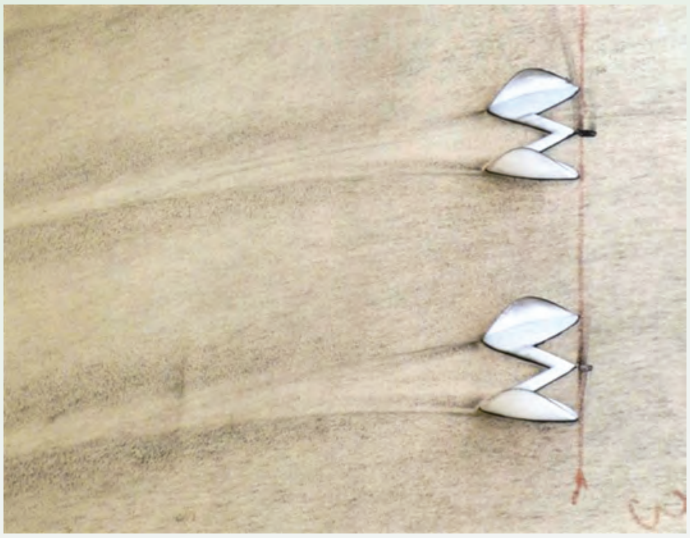

Figure 2. Vortex generators, to obtain better blade performance (Photo credit: CortEnergy)

Offshore Windfarm Egmond aan Zee (OWEZ):

The Monitoring and Evaluation Program (MEP) of OWEZ, formerly known as NSW, consists of two parts: technology/economy and ecology/environment. In 2011, the technology/economy part was completed and the results were presented in an IJmuiden-workshop in December (2). In addition to many conclusions in the field of technology and economy, one of the most important lessons was that an offshore wind farm and a monitoring/evaluation program can survive many governments, involved ministers, policy changes, and even project managers. For example, during the 15 years of this program (from concept to 2011), four Ministers of Economic Affairs were seen. This means that special attention has to be paid to the consolidation of procedures, agreements, experience, and knowledge. Even the way data are stored, processed, and presented via computer systems and websites needs special care (2).

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 participation of the Netherlands research institute ECN and the direct involvement of the Ministry of Economic Affairs, Agriculture and Innovation. Also Task 28 on Social Acceptance of Wind Energy, includes direct participation of the NL Agency. Participation may include new Tasks under formulation (Task 30 and 31). Participation in the IEA Wind tasks is a cost-effective way to conduct research. On average, each euro spent in the Netherlands on research gives access to five euro value of research spent in the other participating countries.

5.0 The Next Term

5.1 Innovation Contracts

The most significant change in 2012 will be the introduction of the Innovation Contracts, which can be seen as replacements for several energy research subsidy programs. In autumn 2011, the government started the first initiative for Innovation Contracts. It is foreseen that Innovation Contracts will be signed in the seven fields of bioenergy, gas, built

Figure 3. The nine small wind turbines at the ECN Wieringermeer test field are used to measure and model the wake in a wind farm (Photo: ECN)

environment, industry, smart grids, wind at sea, and photovoltaics. The leading idea behind the Innovation Contracts is the wish from politics/government to have the market parties (businesses, research centers, universities) directing and determining the research and development to be done. Before Innovation Contracts are awarded, a long route has to be passed in which all the seven mentioned sectors have to organize themselves. They have to develop a common vision, a shared approach to R&D topics to be handled, and a list of proposed projects to be financially supported.

Figure 4. The IHC Noise Mitigation System, reducing impact on sea life due to offshore construction activities (Photo: IHC Offshore Systems)

5.2 SDE-plus in 2012

SDE-plus 2012 will not be very much different from the way worked for 2011. Some small adjustments include a total budget increased to 1.7 billion EUR (2.2 billion USD) and introduction of a new category called wind on land (< 6 MW, with increased year production). Wind offshore is not included in the SDE-plus 2012 approach although it still can be applied under a free category and therefore at a lower SDE-plus subsidy rate.

5.3 Q10 wind farm

In 2013, the Netherlands energy company Eneco will start building the Q10 wind farm. The base case of the farm will be 43 Vestas V112 3-MW turbines. It has been agreed with the government that innovative elements will be included in the wind farm. For example, the installation and testing of one, two, or three innovative wind turbines. Those innovative turbines of a minimum of 4-MW will need to be: 1) certified as a Prototype Class C onshore WTG according to the IEC Type Certification System at the time of contract signing, 2) producing power to the grid in at least one onshore location at the time of application, 3) out of serial production, and 4) having a maximum rotor diameter of 115 m. Wind turbines that are already fully certified and commercially available are not considered to be innovative. Innovations can be made in three fields: the design of the foundation (e.g., a light weight monopile, new kind of connections between transition piece and monopile or an integrated transition piece/monopile, a non steal monopile, suction techniques, jacket construction, drilling/vibrating); in the field of innovative installation techniques (e.g., sound mitigation techniques, avoiding scour protection, reduction (-20%) of the number of lifting movements); or in a open category of innovations.

References

(1) http://www.agentschapnl.nl/content/sectoronderzoek-offshore-windenergie (Dutch)

(2) The results can be downloaded at http://www.agentschapnl.nl/programmas-regelingen/results-windpark-egmond-aan-zee (in Dutch). General informal about the Monitoring and Evaluation Program can be found under the link at www.offshorewind.nl (mostly in English)

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28 Norway

(Photo: Bernhard Kvaal, Trønder Energi AS)

1.0 Overview

In 2011, the new capacity installed was 85.1 MW. However, about 8.6 MW of capacity were also taken out of production or downgraded, resulting in a net capacity installed in 2011 of 76.5 MW. Total production of wind power was 1,308 GWh compared to 906 GWh last year. The calculated wind index for 2011 was at 113%, resulting in an average capacity factor at 31.3% for the wind power plants in normal operation. Wind generation constitutes 1% of the total electric production in the country. Electric energy in Norway is generated using a very high share of renewable energy. The dominant energy resource is hydropower, but there is also a keen interest in wind power as a commercial source of energy. Most of the remaining economical renewable resources are wind power, but there is also a potential for about 30 TWh of hydropower, mostly small-scale hydropower. The key statistics for 2011 are shown in Table 1 and Figure 1.

Table 1. Key Statistics 2011: Norway	
Total installed wind generation	511 MW
New wind generation installed	76.5 MW
Total electrical output from wind	1.3 TWh
Wind generation as % of national electric demand	1.0%
Average capacity factor	31.3%
Target:	No target

2.0 National Objectives and Progress

2.1 National targets

There is no separate target for wind energy production in Norway. The former national goal for 2016 is still effective. According to this goal, the production from renewable energy sources and energy efficiency should be at least 30 TWh above the level of 2001. A new target, set in 2011, is to increase the production of renewable electricity with 13.2 TWh in 2020.

2.2 Progress

Renewable sources of electricity supplied 99% of the national electrical demand in 2011. About 1% of the renewable supply came from wind power. Since electricity production in Norway mainly comes from hydropower, the share of renewable energy varies considerably from one year to the next. It turns out that 2010 was a rather wet year resulting in a net power export of 3.1 TWh. Since most of the electricity produced in Norway is already based on renewable energy, the national environmental benefits of wind power are insignificant since new wind power capacity only contributes to excess power for export to the European market.

2.3 National incentive programs

For renewable power production, the support system has so far been administrated through the state-owned organization Enova SF. Since 2001, Enova has signed contracts with energy utilities for 18 wind power projects for 2.6 billion NOK (3.3 million EUR; 4.3 million USD), and an energy result of 2.1 TWh. In January 2012, Norway and Sweden established a common green certificate program. The economic incentive is expected to stimulate the development of 26.4 TWh of new renewable power in both countries and up to 50 billion NOK (6.5 million EUR; 8.4 million

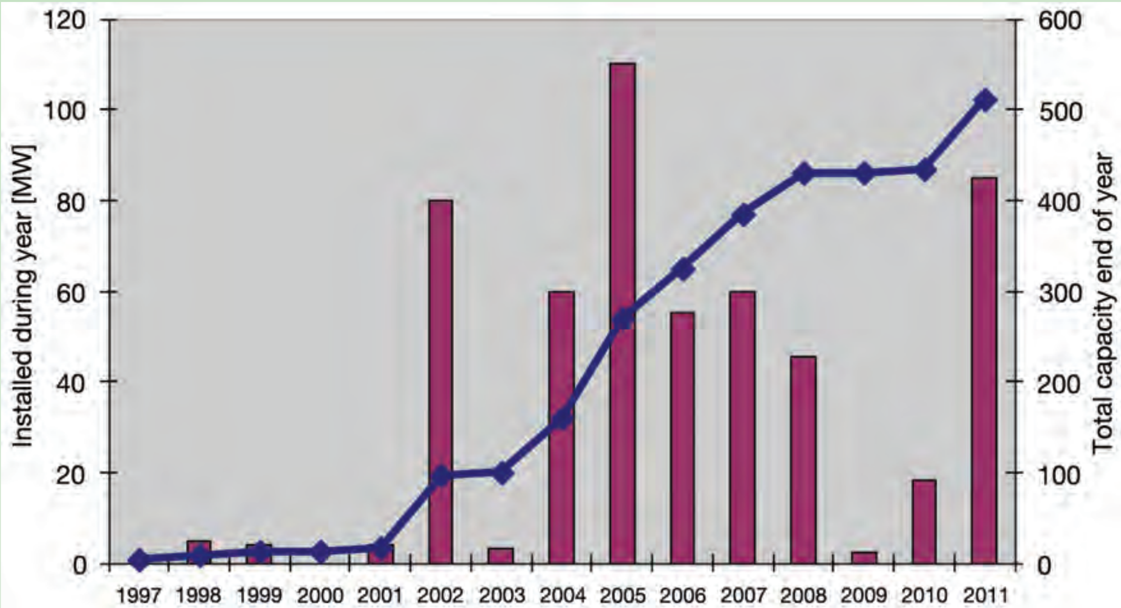

Figure 1. Installed wind capacity in Norway 1997-2011

USD) in investments towards Norwegian climate friendly electricity production, mostly via wind power. Enova will from 2012 support technology development connected to wind power.

This program has been terminated in 2011, and from 2012 it was replaced by a new scheme for marketable electricity certificates. The certificate system will move 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 electricity certificates. They can be sold independent of each other.

The demand for certificates is created by a requirement under the act that all electricity users purchase certificates equivalent to a certain proportion of their electricity use, known as their quota obligation. The price of certificates is determined in the market by supply and demand, and it can vary from one transaction to another.

All renewables are included in the system, and there are no specific quotas for wind power. Nevertheless it is expected that theses electricity certificates will primarily stimulate new production from hydro and wind power plants, since other renewables (e.g., power from biomass and solar) will hardly be able to compete.

The objective of the electricity certificate system is to increase the production of renewable electricity with 13.2 TWh by year 2020 compared to year 2012, and it is estimated that new wind power will contribute with 6 to 7 TWh.

3.0 Implementation

3.1 Economic impact

Some of the Norwegian industry takes part in component production for wind energy systems, e.g., wind turbine blades and nacelles. Companies with experience from the offshore oil industry (OEWC Tower and Aker Solutions) have widened their scope of interest and engagement to the offshore wind industry. The companies offer offshore wind turbine substructure solutions like Jacket Quattropod and Tripod.

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 big national energy companies. Some Norwegian companies (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 2011, the capacity factor of wind turbines varied between 29% and 50%. The average capacity factor was 31%. The technical availability of new wind turbines in Norway is usually in the range of 95% to 99%. Some wind farms are exposed to very harsh and turbulent wind. In those areas, the availability is considerably lower, and in some places is even less than 80%. The mechanical impact of turbulent wind has apparently been underestimated. The average availability is 95%.

3.4 Wind energy costs

The total wind farm installation costs are estimated between 11.5 and 12.5 million NOK/MW (1.5 and 1.6 million EUR/MW; 1.9 and 2 million USD). Annual maintenance is reported to be between 0.12 and 0.16 NOK/kWh (0.014 to 0.02 EUR/kWh; 0.020 to 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 are focusing 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) is working on issues such as integration of wind energy.

The governmental research program for sustainable energy is called RENERGI. The budget increased slightly in 2011, and the following wind energy R&D projects were approved for funding.

- Rapidly updated forecasts for wind energy production: Metrologisk Institutt
- Fluid structure interactions for wind turbines: SINTEF
- Cranefree fundament for offshore vind: SEATOWER
- Far offshore operation and maintenance vessel concept development and optimisation: Statkraft Development
- Optimised planning, foundation design and installation procedures for offshore wind farms: Norwind Installer
- Time-dependent models for the calculation of energy production in wind farms: Kjeller Vindteknikk
- Add-on instrumentation system for wind turbines: Kongsberg Maritime
- A new material systems for high output and low energy production process of wind turbine blades: Reichold.

In addition to this, several projects have been funded through the RENERGI budget the last few years. One of them is SWAY. SWAY has developed a floating wind turbine. A 1:6 down-scaled model is being tested in the sea outside Bergen under real conditions. The conditions for a down-scaled model are harsher than for the full scale, which has given important and valuable experience.

The world's first full-scale floating wind turbine (Hywind concept developed by Statoil) is operational. Statoil is testing the wind turbine over a two-year period and has attained a high availability. Hywind has survived the heavy storm Berit followed by other storms with winds over 40 m/s and maximum waves over 18 m. The increased production is of course partly related to good wind conditions at site. But Statoil's continuous focus of chasing downtime and alarms are paying off. Reduced downtime for alarms have been achieved through rapid response, a switch to remote resets, being an active and demanding customer, flexible vessel contract, accurate production and weather forecasts. Improved access to the turbine, motion control, and a proactive approach are all focus areas that have resulted in the increased production.

4.2 Collaborative research

In 2009, Norway participated in the following IEA Wind Tasks: Task 11 Base Technology Information Exchange; Task 19 Wind Energy in Cold Climates; Task 23 Offshore Wind Energy Technology and Deployment; Task 24 Integration of Wind and Hydropower Systems; Task 25 Power Systems with Large Amounts of Wind Power; Task 28 Social Acceptance of Wind Energy Projects; and Task 29 MexNEXT Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models.

5.0 The Next Term

The next term will be dominated by the impetus given to the wind power industry by the increased profitability offered by the electricity certificate scheme. As of early 2012, six wind farms were under construction.

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29 Portugal

1.0 Overview

During 2011, Portugal experienced a strong reduction of electricity demand. With a decrease of 2.3%, the total consumption was 50.5 TWh (1). Due to a mild winter season, the most relevant renewable generation facilities (hydro and wind) experienced a strong production reduction in comparison with 2010. In 2011, Portuguese wind farms produced 21 GWh less than the previous year. It is only because of the decrease in consumption that wind penetration achieved a value of 18%.

The growth of the wind sector has maintained the pace of 2010, and 315 MW were added. This amounts to a total installed capacity of 4,302 MW, representing 22% of the electric system's installed capacity (1). In November 2011, a milestone for Portuguese offshore wind development was achieved with the successful deployment of its first offshore floating wind turbine – WindFloat (opening photo).

2.0 National Objectives and Progress

2.1 National targets

The targets for installed capacity currently in place were established in June 2010 by the former government through the Plano Nacional de Acção para as Energias Renováveis (PNAER plan) (1). During 2011, a Memorandum of Understanding (MoU) was signed by the Portuguese government, the European Commission (EC), European Central Bank (ECB), and the International Monetary Fund (IMF) (3) that specifically addressed the renewable energy sector, aiming to reduce its economic impact on Portuguese industrial production costs. Actions regarding the renewable energy sector were studied focusing globally on the reduction of the cost of electricity in Portugal. As a consequence of the economic climate and the public's perception of wind energy as introducing an extra cost on the country's electricity, in 2011 only 11 MW of new wind plants were licensed (2).

2.2 Progress

During 2011, 315 MW of wind power were deployed in Portugal. This figure is on the same level as 2010 but reveals the decreasing trend of the last few years as displayed on the dark green bar graph of Figure 1. The new capacity was distributed over 10 new wind farms that added 207 turbines. The total number of deployed wind turbines in Portugal is now 2,349 of which 2,239 are installed in mainland Portugal (2) and 110 in Madeira and Azores (4).

Considering only mainland Portugal, the yield of generated wind energy was

Table 1. Key Statistics 2011: Portugal	
Total installed wind capacity	4,302 MW
New wind capacity installed	315 MW
Total electrical output from wind	9.0 TWh
Wind generation as % of national electric demand	18%
Average capacity factor	26%
Target:	Onshore: 6,800 MW Offshore: 75 MW by 2020

9,003 GWh which is 23 GWh less than in 2010. Nevertheless, wind energy accounted for 18% of the total consumption, a figure 1% above that obtained in the previous year. This was only possible because an historic 2.3% decrease of consumption was recorded (1).

The average production at full capacity was 2,093 hr/MW, which is substantially lower than the 2,348 hr/MW of 2010. The wind energy production by classes of number of hours at full capacity (NEPs) was concentrated (52%) in wind farms with NEPs between 1,750 and 2,250 hours. In 2010 a similar proportion was obtained for wind farms with NEPs between 2,250 a 2,750 hours. Wind farms with NEPs below 1,750 hours increased their production from 1% to 6%. The trend in 2011 was to have the production concentrated in parks that produce less (58%). Therefore, reductions were felt on more productive wind farms, with NEPs between 2,250 and 2,750, reduced from 53% in 2010 to 29% in 2011, and wind farms with NEPs above 2,750 hours saw a reduction of 3% recording 13% in 2011.

The year was atypical for renewable electricity production and far below what Portugal showed it can produce. Renewable energy sources accounted for 45.3% of the gross electric demand which was a severe reduction in the pace established by the 51.6% of 2010. The largest share of renewable production came from hydro power plants which accounted for 49.1%, a figure 8% below what was obtained in 2010. With the reduction of the largest player, the remaining sources were able to augment their contribution, wind energy yielded 37% of production, the biomass sector represented 12.4%, and PV grew from 0.8 to 1.1%.

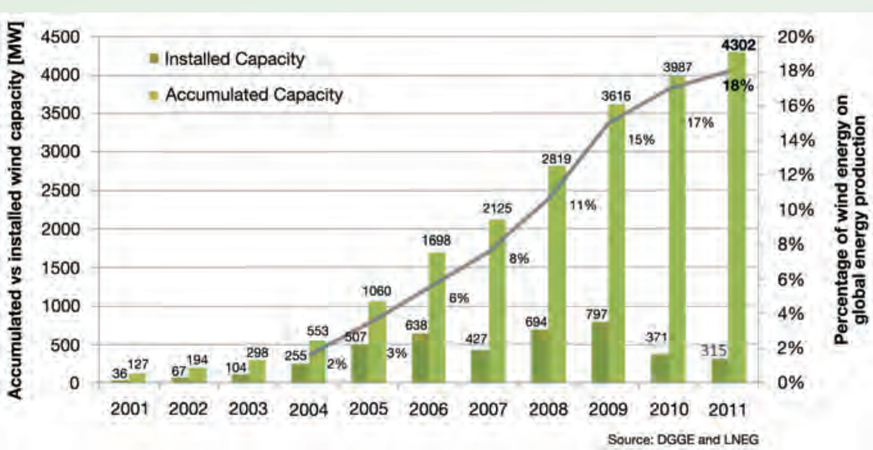

Figure 1. Installed versus accumulated wind capacity (bar graph) and percentage of wind energy production (line graph)

2.3 National incentive programs

The strategy and incentives for renewable energy investments in Portugal are set by the PNAER plan approved in 2010. The milestones defined by it are set to 2020 and foresee a quota for the renewables contribution to the several energy sectors. The plan considers 2005 as a baseline, where the contributions from renewables were of 0.2 % in transportation, 29.3% in electricity, and 31.9% in heating and cooling. The targets for 2020 are to raise the contribution to 10% in the transportation sector, 30.6% in heating and cooling, and to 60% in electricity (5).

Other incentive programs currently in place in Portugal target micro-generation (up to 11 kW) and mini-generation (up to 250 kW) renewable energy installations. For micro-generation, the yearly feed-in tariffs and limits for grid-connected power are established by dispatch until 31 December of the previous year. The tariffs for 2011 were established on 30 December 2010 by the Energy Sector Regulator Direcção Geral de Energia e Geologia (DGEG) to a value of 380 EUR/MWh (491.7 USD/MWh) and a limit of 29.6 MW of grid-connected power was set. The mini-generation program was established in 2010, but only in March 2011 the Decree-law 34/2011 setting its rules was published (6). This program allows small companies to install renewable-based production centers of up to 250 kW. There are limitations on the yearly amount of energy which will be rewarded at a maximum of 250 EUR/MWh (323.5 USD/MWh).

2.4 Issues affecting growth

In May 2011, the Portuguese government agreed with the EU, the ECB, and the IMF on a settlement due to the Euro zone crisis. The agreement resulted a document known as the MoU on Specific Economic Policy Conditionality (3). Regarding the energy markets, the objectives established in the MoU include: complete liberalization of the electricity and gas markets, reduction of the energy dependence from external sources and renewable energy promotion ensuring limited additional costs, a consistent overall energy policy by reviewing existing instruments, and further integrate the Iberian market for electricity and gas (MIBEL and MIBGAS). The most important measures regarding renewable energy are to review the efficiency of support schemes for renewables, covering their rationale, their levels and other relevant design elements; and to assess the possibility to reduce eventual extra costs associated with the renewable sector. For mature technologies, mechanisms alternative to FIT (such as feed-in premiums) are being investigated. Reports on action are to be taken in the third quarter of 2011, third quarter of 2012, and third quarter of 2013.

To follow the trends and evolution of emissions during the implementation period of the Kyoto protocol (2008-2012), the Portuguese company E.Value publishes a monthly index on energy consumption and CO_2 emissions from electricity generation (Figure 2). The month of December 2007 is used as the reference (value 1,000). After reaching record values by the end of 2010 (a value of approximately 1,042), during 2011 the energy index has steadily decreased, ending the year with a value of 1,010. The CO_2 index inverted its tendency,

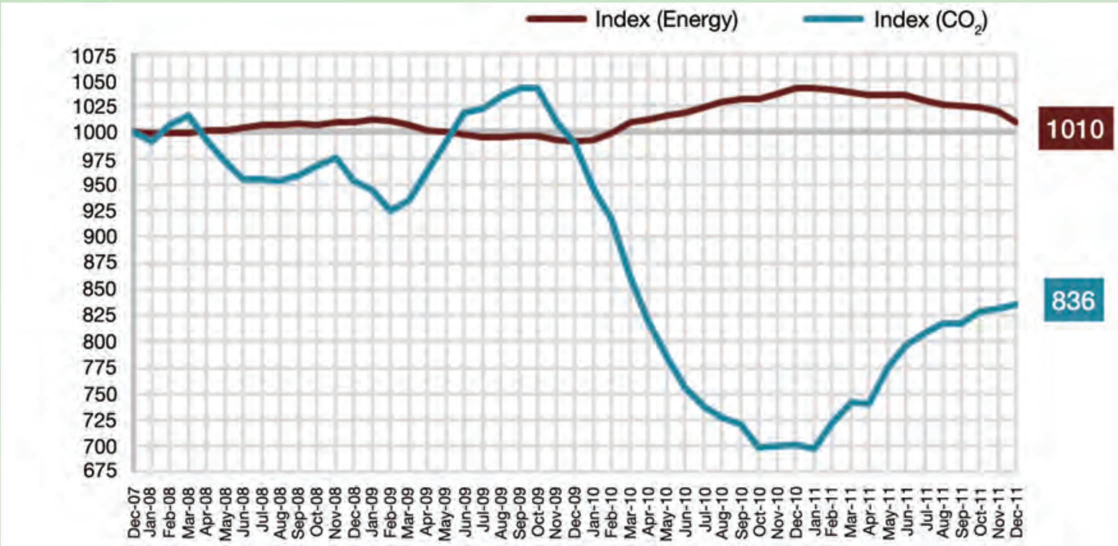

Figure 2. Electricity consumption and CO_2 emission from electricity generation E.Value index for Portugal (Source: www.evalue.pt)

because 2011was a difficult year for renewable energy generation, reflected by a growth of 130 points throughout the year.

A design parameter limit of electric systems like the Portuguese is the extreme penetration of renewable, non-dispatchable sources (e.g., wind power or river run-off hydropower). After 2010 where the records for highest wind instantaneous penetration and daily consumption supplied by wind were set, 2011 saw those figures surpassed again. The highest instantaneous wind penetration was recorded on 13 November 2011 at 4:30 AM with a value of 93%. On this day, 81 GWh of wind energy were produced, which meant 70% of consumption, also a record (1). Figure 3 describes the wind energy timing on the maximum demand day, highest wind penetration, and highest contribution from wind.

3.0 Implementation

3.1 Economic impact

The current wind capacity together with the Portuguese wind industry account for an estimated number of 3,200 jobs. In 2011, wind generated electrical energy produced an estimated income of 842 million EUR (1.090 billion USD) and allowed for savings of 3.1 million tons of CO_2 emissions. The newly installed capacity (315 MW) represented a private investment by wind power developers of more than 400 million EUR (517 million USD). The wind energy sector has an economic impact of nearly 1.3 billion EUR (1.7 billion USD).

In 2011, the Portuguese Renewable Energy Association (APREN) and Roland Berger Strategy Consultants published the study "Assessment of costs and benefits of electricity production from renewable energy sources" (7). This study reviews the period between 2005 and 2010, estimates the costs of energy from renewable sources and conventional sources for the period between 2011

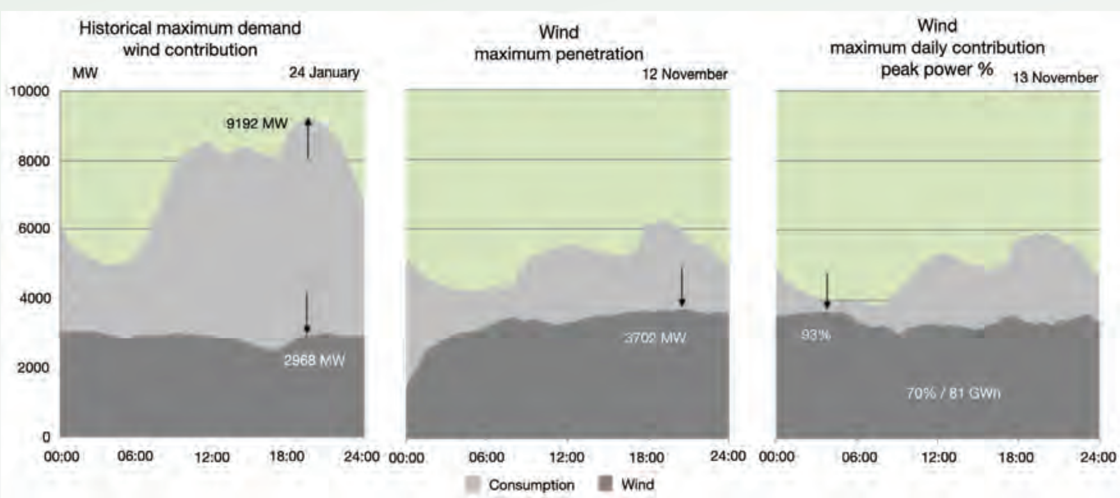

Figure 3. Record wind power penetration and energy generation during 2011 (13 November) (1)

and 2030, and analyzes the current tariff's structure.

3.2 Industry status

The onshore manufacturers market is again led by Enercon in 2011. With 207 wind turbines, Enercon has 87.7% of the market. The closest competitor is Nordex with a share of 7%. The remaining wind turbines (12) were installed in equal parts by REpower and Vestas, amounting to a share of 2.6% each. With this scenario, Enercon increased its share of the overall Portuguese market to 52.2% of the installed capacity. In second place is Vestas with a 14.3% share, followed by Gamesa (9.8%), Nordex (9.4%), REpower (4.2%), GE Wind (2.4%), Ecotecnia (2.4%), Suzlon (2.4%), Izar Bonus (1.7%) and other manufacturers (1.2%) (2 and 4).

An important milestone for offshore wind development in Atlantic waters was achieved in November 2011. The WindFloat, a semi-submersible structure holding a multi-megawatt wind turbine, has been deployed at Aguçadoura, a site located 6 km offshore of Póvoa do Varzim, north of Portugal with a depth of 50 m. It is the outcome of the WindPlus joint venture from EDP – Energias de Portugal, Principle Power, A. Silva Matos (ASM), Vestas Wind Systems A/S, InovCapital and Fundo de Apoio à Inovação (FAI). The assembly, installation, and preparation were performed on a dry dock in Setenave, Setubal, and the WindFloat was towed more than 350 km to its final location.

3.3 Operational details

Ten new wind farms were connected to the grid in 2011. Of these, 92.2% have an installed capacity between 10 and 50 MW, while the remaining 7.2% were installed with a capacity below 10 MW. With the exception of two wind farms, all the new parks have deployed 2.0 MW rated power wind turbines (2). The largest new wind park is composed of 22 wind turbines. The overall installed capacity is distributed mainly in small (<10 MW) and medium sized (10-50 MW) wind farms. The first have a quota of 51.4%, the second of 40.8%, while only 7.8% of the wind farms have a capacity above 50 MW (2).

In Portugal, 2011 was an atypical year for wind availability and production. Here wind turbines operate in two different environments, the coastal or the mountainous region. In both regions, the indexes maintained by LNEG for wind and production (Figure 4) show a pronounced decrease from previous years. The wind availability was far below average, an index of 0.93 was recorded in the coastal region and 0.92 in the mountainous region. Regarding production, wind farms in the coastal region were able to yield a figure close to average (index of 1.0), whereas in the mountainous region only an index of 0.91 was recorded. Data from the Portuguese TSO (1) is in line with the one from LNEG and points to an overall production index of 0.97 in 2011 when considering the period between 2001 and 2010.

3.4 Wind energy costs

During 2011, the average installed cost, excluding grid connection and land contracting, was 1.4 million euro/MW (1.81 million USD/MW). The mean tariff paid during 2011 was 93.5 EUR/MWh (121 USD/MWh) to the wind power plants and 103.4 EUR/MWh (134 USD/MWh) for the renewable independent producers, according to the Portuguese energy regulator (ERSE) (8).

4.0 R, D&D Activities

4.1 National R, D&D efforts

The national R&D efforts during 2011 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:

- Project NORSEWiND: made up of 15 organizations between research institutes and industrial organizations with the Portuguese participation of LNEG funded by EC FP7. The project aims to characterize and evaluate the wind resource on the northern seas.
- Project ROADMAP: a Portugal-based project funded by the Portuguese Science and Technology Foundation (FCT), with the purpose of identifying the constraints and barriers to the development of offshore energy in Portugal.
- Project 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.
- Project REIVE: a consortium of leading industrial and energy companies with R&D institutes led by INESC-Porto with the

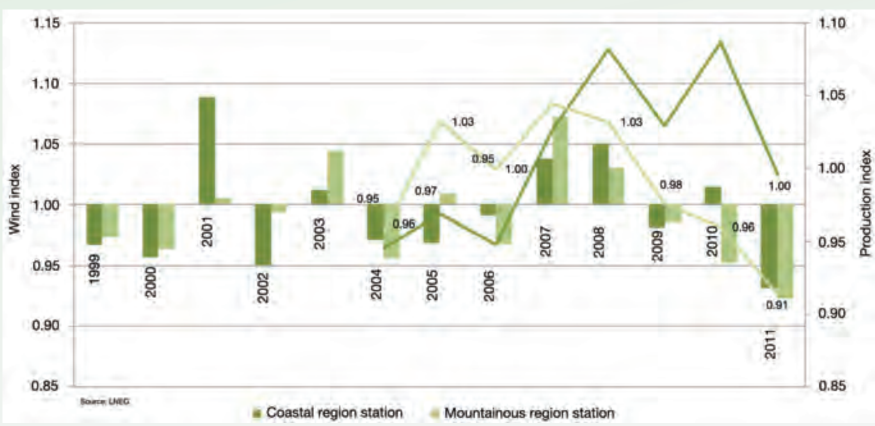

Figure 4. Wind (bar graph) and production indexes (line graph) on coastal and mountainous regions of Portugal

participation of LNEG. A project to deliver the "Smart Vehicle to Grid" funded by FAI (Portugal).
• 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. Is funded by EC FP7 and has the PT participation of INESC-Porto.
• Project MERGE: a consortium of European partners with the Portuguese participation of INESC-Porto and the National Grid Operator (REN), funded by EC FP7 aiming to prepare Europe's grid for electrical vehicles.
• Project MARINA: a project that brings together companies, technology centers and universities from twelve EU countries. Is led by Acciona Energy and funded by EC FP7. The objective is to develop deep water structures that can exploit the energy from wind, waves, tidal and ocean current energy sources.
• Project ORECCA: a collaboration between European organizations and two North American research institutes is funded by EC FP7 and has the Portuguese participation of WavEC and LNEG. The project will stimulate collaboration in research activities leading towards innovative, cost efficient and environmentally benign offshore renewable energy conversion platforms.
• Project 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 partners involved in the joint venture led by EDP. LNEG will coordinate a WP to address the deep offshore wind energy challenges.

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. 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

Due to the Euro zone crisis, 2012 is expected to be a year adjustment. The onshore wind energy market was stagnant in 2011 when only a few megawatts were licensed. The key players will concentrate on the wind farms already built and turn to emergent markets like Brazil or Eastern Europe. Expectations are high in regards to project WindFloat, after its deployment, the first tests and commissioning will take place in the first quarter of 2012.

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30 Spain


Photo credit: Francisco Cambra

1.0 Overview

Installed wind capacity in Spain reached 21,673 MW in 2011 with the addition of 1,050 MW, according to the Spanish Wind Energy Association's (AEE) Wind Observatory. Smaller growth was expected for 2011 after the increase of 1,515.95 MW in 2010. Spain is the fourth country in the world in terms of installed capacity and produced 41,799 GWh of electricity from wind in 2011.

The mandatory Pre-allocation Register established by the Spanish central government has slowed wind energy deployment since 2010. As a result, the percent increase in capacity has been declining. The addition of 1,050 MW in 2011 represents an increase of 5.1% compared with a 7.9% increase in 2010.

Electrical energy demand decreased 1.3% from 2010 to 254.78 TWh. Wind energy met 16.3% of this demand and was the fourth largest contributing technology in 2011. Other big contributors to the system were nuclear power plants (22.6%), gas combined-cycle power plants (19.8%) and coal (17.0%) (Figure 1).

During 2011, the government implemented new decreases to incentives for wind energy. The wind sector must share the burden of helping the country 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 post 2012. However, lobbyists are arguing the 2020 target will not be achieved if the bill is passed.

The draft bill sets rules for wind farms from 2013 onward and proposes a system of variable premiums. These premiums will diminish for capacity installed each year in excess of the annual target of 1.4 GW (required to reach the 2020 target of 35 GW). For the first 1.4 GW, all producers will receive a 20 EUR/MWh (26 USD/MWh) premium over market prices. The guaranteed floor price will decrease from the current 55 EUR/MWh to 77 EUR/MWh (71 USD/MWh to 100 USD/MWh), and it will be reviewed annually. The draft decree also limits subsidies for wind projects to 12 years compared with the previous projects. Developers would receive premium payments only during the first 1,500 operating hours each year. Finally, premiums will not be revised in line with inflation.

The AEE warned that these measures will introduce a level of volatility into support levels that could make financing projects impossible. It claimed that the proposed measures will result in a 40% reduction in support for wind farms installed after 2012. Wind sector developers and investors in Spain, and across Europe, will be waiting nervously over the coming months to see whether the draft decree will be passed.

The government deferred decision on the draft decree 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 system. A new law will likely come early in 2012.

During 2011, the Spanish wind sector installed about 1,050 MW, the lowest

Table 1. Key Statistics 2011: Spain

Total installed wind generation	21,673 MW
New wind generation installed	1,050 MW
Total electrical output from wind	41.79 TWh
Wind generation as % of national electric demand	16.40%
Average capacity factor	
Target 1. Official Network Planning	29,000 MW by 2016
Target 2. New National Renewable Energies Action Plan (NREAP)	38,000 MW by 2020

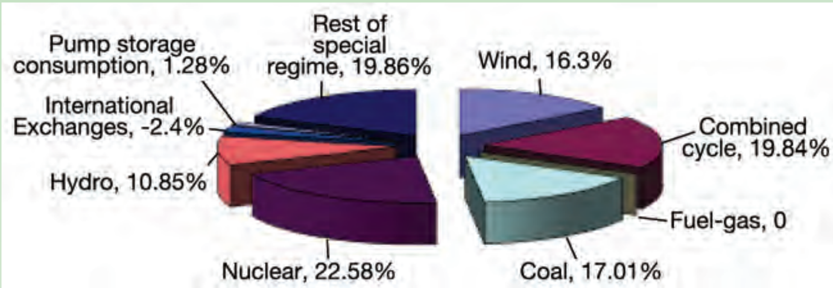

Figure 1. Percentages of the 2011 power supply mix in Spain (Source: REE, AEE)

figure since 2000. Possibly the worst news for the sector, whose projects need from three to five years to mature, is that after December 2011, it is unclear if new projects will receive any feed-in tariff. This uncertainty will stop the installation of new wind farms for several years.

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 to 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 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.

The REP 2011-2020 includes 87 measures, half of which are sector-specific. The measures are divided into five groups:

- Support schemes: new feed-in tariffs (to be continued, adapting to the costs), net metering for small wind
- Economic proposals: public incentives for investments and activities for 2011-2020, mainly dedicated to R&D projects for offshore wind
- Regulation: new regulations will aim to simplify administrative procedures and authorizations, as well as reduce deployment times
- Changes in energy related infrastructures: technical interventions to facilitate the integration of renewable energy installations in the Spanish energy system, including demand management systems and an increase of electricity exchange capacities with France
- Activities for the planning, promotion, information, and training.

2.2 Progress

The electrical generation capacity in the Spanish mainland system increased more than 1,879 MW during 2011 for a total of 100,176 MW, according to the Spanish TSO Red Eléctrica de España (REE) (3). The technologies that contributed most to this growth were wind (1,050 MW) and solar power (674 MW). With more than 21,673 MW of wind power installed, more than 19,450 turbines are operating in Spain, grouped among 930 wind farms. The average size of an installed wind farm in 2011 was 26 MW.

Wind energy is present in 15 of the 17 autonomous communities (Figure 3). Castilla-Leon has the most installed power among them, with 5,233 MW. This autonomous community has had the biggest growth with 462 MW added in 2011. The Valencian Community experienced 18.5% growth, the second biggest, with 183 MW installed in 2011. It has 1,170 MW of wind capacity. The third biggest growth has been in Cataluña with 18% (154 MW new) reaching 1,003 MW total. Then Andalucia with 92 MW (3.1% growth) reaches 3,367 MW. Andalucia is followed by Asturias, which added 73 MW for a total of 428.45 MW. Then Aragon installed 50 MW in 2011 for 1,811.31 MW total wind capacity. With only 26.5 MW of new capacity installed in 2011 in Castilla-La Mancha region, it stays in second place with total capacity of 3,737 MW. Castilla-La Mancha is followed by Navarra, which added just 8.5 MW for a total of 977 MW. The Canary Islands added 1.8 MW for a total capacity of 146 MW. Despite having their respective development plans approved, the two communities of Galicia and Cantabria have not increased their wind capacity due to different political reasons. Only two autonomous regions, Extremadura and Madrid, have not yet installed any wind power capacity. However, they

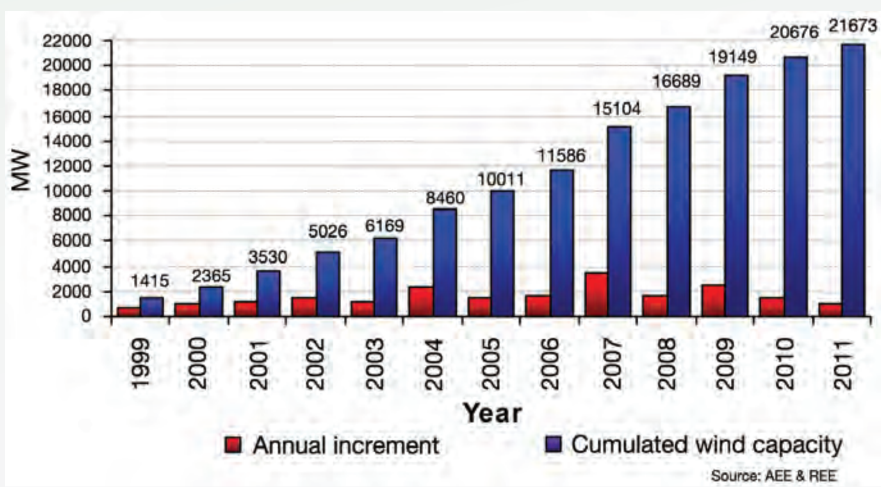

Figure 2. Annual and cumulative installed wind capacity in Spain

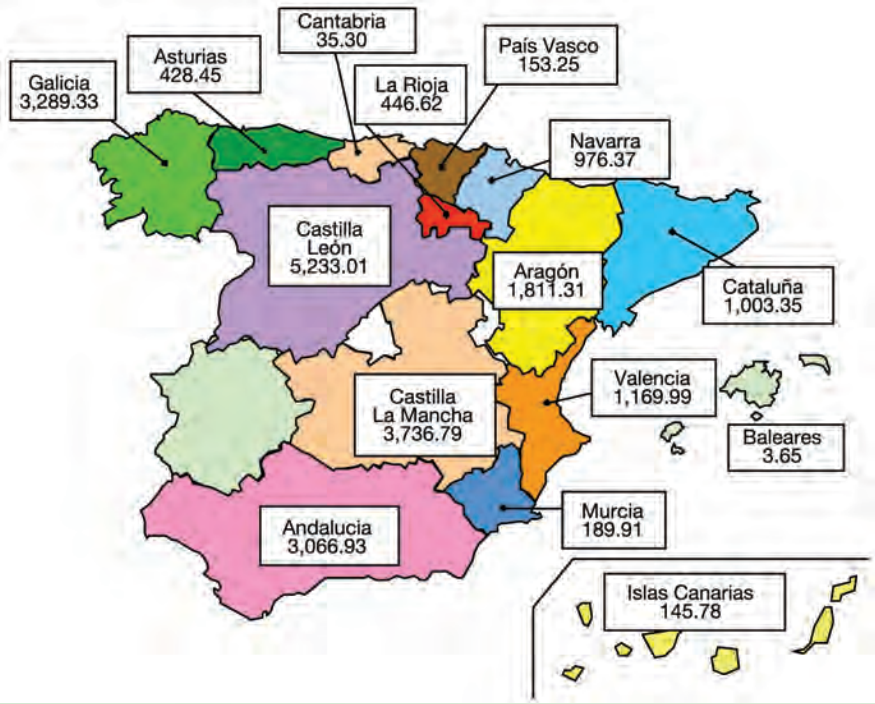

Figure 3. Wind energy capacity distributions by autonomous communities (MW)

have advanced projects and regulations to start wind energy activities, especially in the Extremadura region.

Unlike many countries with significant wind development, Spain has increased its distribution throughout the country. Figure 3 shows wind energy development and annual growth by region.

The use of wind power has lowered CO_2 emissions by about 22.5 million tons during 2011. Furthermore, wind generation has saved up to 8.3 million tons of conventional fuels and has supplied the electrical consumption of more than 13.1 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:

- A payment and support mechanism enacted by the Parliament through Electric Act 54/1997: Producers of renewable energy sources may connect their facilities and transfer the power to the system through the distribution or transmission grid and receive remuneration in return.
- The NREAP (2005-2010), which included midterm objectives for each technology, has been fulfilled. The new NREAP (2011-2020) has been launched, and the intention is to continue guarantying tariff schemes.
- Royal Decree (RD) 661/2007 regulates the price of electricity from renewable sources in Spain. The regulation has been in force since June 2007. Wind farm installations governed by previous regulations (RD 436/2004) had until January 2009 to decide whether they would continue to follow RD 436 or choose the new RD 661/2007.
- Royal Decree Act (RDA) 6/2009 established a mandatory instrument called "Pre-allocation Register" where all new promotions must be included before obtaining the required permit. This instrument defines RES progress taking into account energy prices, electricity tariff deficit, and network capacity.
- To facilitate the integration of wind energy into the grid, supplemental incentives are based on technical considerations (reactive power and voltage dips). These incentives apply only for existing wind farms (after January 2008), and it is mandatory to satisfy Grid Code P.O.12.3.

Payment for electricity generated by wind farms in Spain is based on a feed-in scheme. The owners of wind farms have two options:

1) A regulated tariff scheme: payment for electricity generated by a wind farm is independent of the size of the installation and the year of start-up. For 2011, the value was 79.08 EUR/MWh (94.84 USD/MWh). The update was based on the Retail Price Index minus an adjustment factor.

2) A market option: payment is calculated as the market price of electricity plus a premium, plus a supplement, minus the cost of deviations from energy forecasting. There is a lower limit to guarantee the economic viability of the installations and an upper limit (cap and floor). For instance, the values for 2011 are reference premium 20.142 EUR/MWh (24.170 USD/MWh), lower limit 76.975 EUR/MWh (92.37 USD/MWh), and upper limit of 91.737 EUR/MWh (110.884 USD/MWh).

A new order ITC/3353/2010 established the access fees from 1 January 2011 and the rates and premiums (feed-in tariffs) for the wind installations included in the RD 661/227.

Finally a new Royal Decree 1699/2011 was approved in November to regulate the grid connection of small power production facilities (up to 100 kW). This new act will be decisive for the development of small wind generation for the owners' use. To facilitate the economic feasibility of these small generators, a new net balance based support scheme is under development.

2.4 Issues affecting growth

The economic slowdown affected the wind industry in 2011. 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 5,000 jobs have been lost. Installations in 2012 may be as low as 1,000 MW.

3.0 Implementation

3.1 Economic impact

The number of installations during 2011 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 16.4% of the Spanish electrical demand implies a huge accomplishment by the developers and manufacturers.

3.2 Industry status

During 2011, the largest manufacturers were Gamesa (461.15 MW new capacity), Vestas Wind Power (207.4 MW new capacity), GE Wind (163.44 MW new capacity), Acciona Wind Power (102 MW new capacity), Alston Wind (68.11 MW new capacity), and Siemens Wind Power (48 MW new capacity).

Gamesa is still the top manufacturer in Spain with 11,510.16 MW total wind capacity installed (53.1% of the total wind capacity installed). In the second position is Vestas Wind Power with 3,733.49 MW total wind capacity installed (17.2% of the total wind capacity installed), and Alston Wind moved into third place with 1,629.54 MW (7.5% of the total wind capacity installed). The Spanish manufacturer Acciona Wind Power is in the fourth position with 1,556.13 MW (7.2% of the total wind capacity installed).

Several manufacturers are developing small wind turbines from 3 kW to 100 kW for grid-connected applications, and two manufacturers are working on mid-sized wind turbine prototypes from 150 kW to 300 kW (Electria Wind And ADES).

Iberdrola Renovables, the largest Spanish utility, has the largest accumulated capacity (5,327.65 MW) thanks to the addition in 2011 of 101.08 MW. However, the company installed more than 1,059 MW outside of Spain in 2011, leading the wind power installations and total capacity among the leading international developers.

Acciona Energy, in second place, has accumulated capacity of 4,164.32 MW with 127.50 MW installed in 2011. Also, this Spanish developer installed around 524 MW in other countries in 2011. The Portuguese company EDPR, with 1,997.6 MW total, installed 155.01 MW during 2011. The Italian utility Enel Green Power España is in the fourth position with a total capacity installed of 1,380.50 MW with 129.45 MW installed in 2011. Several other developers have installed wind power in 2011 (Figure 5).

3.3 Operational details

The number of wind turbines in Spain increased by more than 580 in 2011, and the total number of turbines is more than 19,606 units. The average size of a wind turbine installed in 2011 was 1.8 MW and the average size of the total installed capacity is 1.1 MW.

Wind turbines operating in Spain show important seasonal behavior. Annual electricity generated by wind farms was more than 41,661 GWh. During 2011, equivalent hours at rated power were slightly higher than 1,800 hours for all of the wind farms. This shows that 2011 was not a good wind resource year overall. However on several occasions, wind power exceeded previous historical instantaneous power peaks and maximum hourly and daily energy production. On 6 November 2011 (2:00 am), 59.6% of total power demand was covered by wind energy.

Regulations for the grid code have been completed successfully. Every wind farm is assigned to a control center and only 30% of wind capacity has not complied with the low voltage ride-through requirement.

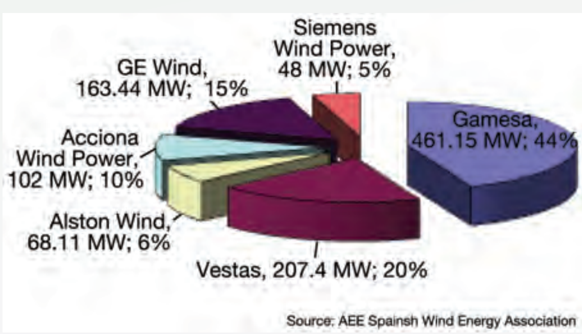

Figure 4. Installed wind capacity in 2011 by manufacturer (in MW and percentages)

3.4 Wind energy costs

In spite 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 820 EUR/kW (1,000 USD/kW).

4.0 R, D&D Activities

4.1 National R&D efforts

The R&D activities in Spain are structured in Research, Development, and Innovation programs funded by the central government and by the governments of the autonomous communities. The Spanish national R&D plan covers 2008 to 2011. It is based on the national science and technology strategy instead of thematic areas as in previous plans. The national has a basic research program and a national innovation strategy (e2i). The basic research program is not oriented research and the leaders are researchers from universities and public and private R&D centers.

The national innovation strategy has integrated actions to promote innovation. The innovation plan (INNOVACCION) was developed to implement the innovation strategy and two programs (INNFLUYE and INNPACTO) are designed to stimulate public-private collaboration.

The INNPACTO Program promotes stable collaboration between the productive sector and the agents of research, development, and innovation. It also guides R&D demand. Projects can be awarded to companies (public and/or private companies, small medium enterprises, or big companies), public research organisms, technological centers, universities, R&D centers, etc. At least 60% of the budget for these projects should be covered by the companies and a minimum of 20% covered by the R&D agents. The project must last from two to four years and have a minimum budget of 700,000 EUR (900,000 USD). The idea is to promote experimental development projects. In 2011, a special allocation of 200 million EUR (258 million USD) was made for energy projects. The energy special allocation received 138 proposals with 80 projects approved and

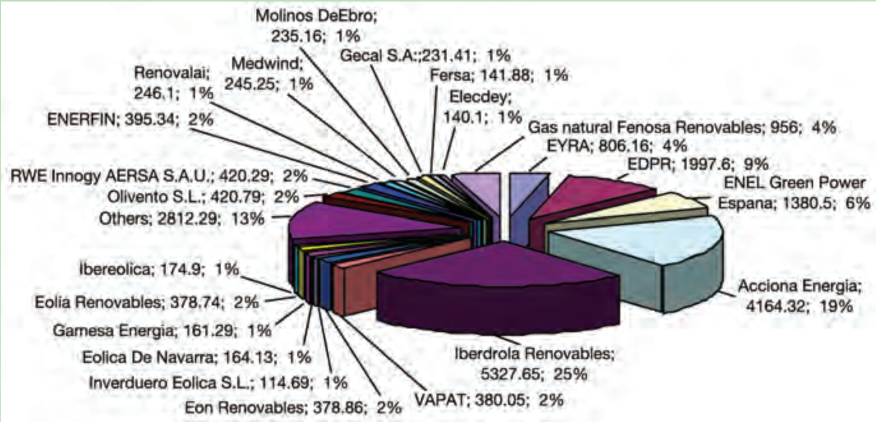

Figure 5. Total MW and percentage of installed wind capacity by developer at the end of 2011

funded. Only 12 projects dealing with wind energy were funded (12% of the total funding). Eight projects concerned onshore wind, three offshore wind, and one small wind. Some of these INNPACTO projects granted in 2011 are described below.

SUPERTURBINES Project

The SUPERTURBINES Project will develop and demonstrate a new 10-MW superconductor wind turbine to provide increased power generators for future wind farms on land and off shore. The project will define specifications and requirements of the superconductive generator, design the new wind turbine concept, and design the demonstration machine, develop and validate the demonstration machine and conduct tests and prepare final conclusions. The project goes from July 2011 to December 2014 with a budget is 1.5 million EUR (1.9 million USD). The participants are ACCIONA Energy, ACCIONA Wind Power, and TECNALIA.

WETSITE Project

The WETSITE Project will develop methodologies, tools, and guidelines for use in deep water offshore wind. Spain has significant energy resources available in demanding marine operating environments where current technology cannot meet the challenges. This project brings a multidisciplinary consortium involving both research centers and companies with experience in wind and marine power. The consortium is composed by ACCIONA Windpower Inc, Tecnoambiente and Technology centers as TECNALIA Foundation for Research and Innovation, AZTI and National Renewable Energy Centre (CENER). The funding is 2.45 million EUR (3.2 million USD).

FLOAT SOLUTIONS Project

The FLOAT SOLUTIONS project will develop and validate innovative solutions for very high wind turbines for future offshore wind developments. The project plan has four activities:

1) Aeroelastic/hydrodynamic tank testing definition (CEHPAR Model) to improve the testing methodology of scaled models of floating wind turbines. The system will be improved to introduce aerodynamic loads in the scaled wind turbine during the tests.

2) New logistic processes development, studies, and simulation of operations. This activity comprises the analysis of different manufacturing and logistic processes, installation of offshore platforms under certain boundary conditions, and different scenario and analysis conditions for the implementation of proper land, port, and maritime conditions. It also will establish a procedure to install the mooring lines of the wind turbine as simple convenient, safe, and low cost as possible.

3) New manufacturing processes, optimized production of structures. The will optimize the wind turbine support structure through new manufacturing processes or by optimizing the structures for more precise knowledge of loads to reduce cost.

4) Dynamic design of the cable. This activity will develop a cable with some technical features to withstand the stress, motion, and energy transport, generated in offshore platforms. This activity seeks to design the cable, set its properties, define the simulation parameters, establish cable qualification tests, and analyze the interaction of the cable with the floating structure. The project will last from April/2011 to December 2012, with a budget of 2.3 million EUR (2.9 million USD). The partnership is composed by ACCIONA Energía, ACCIONA Windpower, TECNALIA, General Cable, CENER, Vincinay Cadenas and Engineea.

MONOPALA Project

Design and development of a new 2-MW, single-blade wind turbine with balanced torque. The scientific and technological objective of the project is the design and development of a 2-MW rated power wind turbine with compensated torque. Partnership: ADES and AITIIP Technological center. Duration: 2011-2014.

ROTORES MONOPALA Project

The project will develop and manufacture a high-speed, single-bladed rotor for wind turbine applications. This rotor will have better characteristics of weight and level of finish than previous designs for similar configurations, also in terms of power rating, loads, stability, and acoustic noise emissions. Partnership: ADES and AITIIP Technological Center and Composites Aragon S.L. The duration of this project from 2011 to 2013.

TEEV Project

Experimental development project of a new concept of a vertical axis wind turbine adapted to urban environments. This project will develop a low-cost, small wind turbine without major maintenance requirements. Although it will have lower efficiency than those installed in large wind farms, it will be capable of exploiting the available wind resources in populated areas. This wind resource is not very favorable because of the complexity of the sites. The partnership includes PROEMISA S.L:, INGEVAL and Universidad Politécnica of Valencia.

The strategic consortia for technical research sub program, which was launched to increase the collaboration between companies and research centers, there are clearly defined objectives: to build capacities in private strategic consortiums, to address technical challenges, and to make these companies leaders in innovative technologies. The leaders of the consortiums must be market leaders with interest to develop innovative technology for the future. Most of the funding available is as grants to the companies (up to 50% of the total budget). The balance must be funded by the companies themselves. The public research centers and private research centers must be subcontracted by the companies.

In this subprogram, the most important instrument is called INNPLANTA (former CENIT projects). It finances large, integrated industrial research projects of a strategic nature, that develop new technologies with economic and commercial prospects at the international level. This INNPLANTA Program is carried out by the Center for Industrial Technological Development (CDTI) from the Spanish Ministry of Science and Innovation. It is a Spanish government program to increase investment in R&D for both public and private initiatives over the next few years, with the objective of reaching 2% of GPD. The program CENIT started in 2006, and so far four R&D projects were approved: Windlider 2015 (completed), Eolia (completed), Ocean-Líder (in progress), and Azimut (in progress).

The "support actions" subprogram is funding the Spanish Wind Power Technological Platform REOLTEC. REOLTEC has an important role in the coordination and definition of Spanish R&D activities in wind energy (4). REOLTEC was created with the support of the Spanish Ministry of Education and Science as a place for exchange of ideas among all Spanish R&D entities to define priorities. In addition, it establishes procedures for optimizing the acquisition of forecasted results, and it establishes priorities in wind energy R&D to advise the government. Those priorities are studied by working groups that focus on wind turbine technology, wind resources and site assessment, grid codes, certification and standardization, offshore wind farms, applications, environmental affairs, and social acceptance studies.

The 'HiPRWind' project is developing specific elements to support floating structures for offshore turbines installed in high wind power platforms. It is a research umbrella that comprises the FP7 European Union funding for the HiPRWind project by itself, and it also has co-funding by the Spanish government through the project titled "FLOATING WINDTURBINE STRUCTURE: Specific elements that allow a floating Wind Turbine." This project gives additional support for some validation tests, mainly basin tests and also some research and development in areas not contemplated or funded by the FP7 HiPRWind project.

The two projects described above were approved in September 2011 under the Spanish INNPACTO Call. They cover site assessment (Ocean and Meteo conditions), the "WETSITE" Project, and the "Float SOLUTIONS" Project, to design dynamic cables with clear focus on the needs of the HiPRWind floating wind turbine.

Additionally, a bilateral project known as "FloatMET" is developing a new type of floating met station (over 70 m height) for deep water applications. It will involve the fabrication and installation of a floating met mast at the same site where the HiPRWind floating wind turbine will be installed. The aim is to assess the resource, follow the efficiency of the HiPRWind turbine, provide information over the power curve of floating wind turbines, and define a set of standards for the use of measuring devices. This project has been launched by Acciona Energia (leader) and Navantia (biggest Spanish ship builder), and D2M (small-medium enterprise), Leosphere (small-medium enterprise) and Vincinay Cadenas as collaborators. Funding comes from the Spanish agency CDTI.

It also important to highlight the "FloatGEN" project, with FP 7 European funding, which aims to install, test, and evaluate three different floating wind turbines. This project leaded by Gamesa and Alston Wind and Acciona Wind Power as wind turbine manufacturers, with different floating platforms designed in collaboration with Navantia (potential platform would be built in the Navantia Shipyard), Blue H Technologies, Olav Olsen, Frauhoffer Institute, University of Stuttgart, RSk Environment and Green novate Europe is going to start in 2012 and the duration is four years. This project has a budget of 36.5 million EUR (47.2 million USD), with a grant of 19.6 million EUR (25.4 million USD).

In Spain there are also R&D&I projects funded by the autonomous communities. A good example of this the "FLOTTEK" project, which is a new source of energy based on deep sea offshore wind energy. The Basque country autonomous government funds this project through the program called ETORGAI with a grant of 1.37 million EUR (1.77 million USD). The project budget of 4.4 million EUR (5.7 million USD) is going to be finished in 2012. The company leader is Gamesa and the consortium is composed by Iberdrola Ingeniería y construcció, Lemona Industrial, Vincinay Cadenas, Ormazabal, ECN, and Itsaskorda.

Two new research facilities are under development, and several interesting facilities were operating in 2011.

CENER Experimental Onshore Wind Farm:

This new test facility operated by CENER is located in Aoiz (Navarra). The topography is complex terrain and there are six calibrated positions to install prototypes of large wind turbines up to 5 MW each (separation of 280 m), and five additional meteorological towers, 120 meters high. The main purpose of this facility is to test prototypes and certify wind turbines. The experimental wind farm has continuous operation measurement instrumentation, offices for clients, and meeting rooms. It has been carefully studied, characterized, and analyzed to offer the best conditions for prototypes.

ZÈFIR Offshore Wind Turbine Test Station:

This new offshore test station is still under development by the Catalonia Institute for Energy Research (IREC). This activity will develop and set up a deep-sea offshore Wind Turbine Test Station off the coast of Tarragona (Spain) to test new technology so that it can be marketed. This important initiative will stimulate the collaboration between major research centers, the industry, and universities.

The development is structured in two phases. Phase 1: Four bottom-fixed turbines will be installed with a maximum total capacity of 20 MW, 3 km off the coast and at 40 m water depth. Construction is planned for fourth quarter

2012. Phase 2: Eight wind turbines will be installed using floating technology with a maximum total capacity of 50 MW, 30 km off the coast, at 110 m water depth. Construction is planned for fourth quarter 2013. Within this phase, a project has been submitted to the EU NER300 Program for funding. The project is lead by IREC and Gamesa, Alston Wind and Acciona Windpower as partners; has a budget of 80 million EUR (103 million USD); and will continue for five years (2015-2020).

Biscay Marine Energy Platform (BIMEP):

The objective of BIMEP is to offer an open sea test infrastructure for research and demonstration of offshore wave and wind energy converters. The facility can test full-scale prototype devices as single devices or arrays to assess and monitor performance. The funding source is the Basque country government through regional funds assignment as a funding mechanism.

Centro de Desarrollo de las Energías Renovables:

The small wind test laboratory of CEDER-CIEMAT, located a few kilometers from the city of Soria (Spain), can test small wind turbines up to 50 kW (power performance curve, acoustic noise emissions, duration test, and operation and function tests) in several test sites (class I/II). It can also test wind turbine blades up to 10 m length (static and fatigue test) in a fully instrumented blade test bench. Full-scale blade testing provides structural information to optimize and improve manufacturer's designs and is a requirement for many certification standards.

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 Task 31 Wakebench: Benchmarking Wind Farm Flow Models, a new task lead by Spanish experts in wind flow modeling in complex terrain.

5.0 The Next Term

Expectations for the Spanish wind energy industry for 2012 are not very optimistic. If the slowdown in 2011 was caused by funding problems related to the financial crisis and by the Register of Pre-Assignment, created by the central government to control more precisely the RES capacity growth, the forecast of the coming situation is even worse. Because the high national deficit created partially by the feed-in tariff cost must be reduced, a potential decision of the government could be the temporally suspension of the support scheme. This decision will be dramatic for the wind sector until a new support scheme is developed. This situation will push the Spanish wind sector even more to the internationalization. During 2012 and coming years, technology and installation costs are expected to be lower to compete in the marketplace.

The price of electricity is likely to remain flat in 2012, because of excess installed power capacity and reduced power demand. However, the dependence of the Spanish energy sector on imported fuel could result in increased electricity prices if prices of that fuel rise.

The new NREAP 2011-2020 and the REP approved in 2011 with new objectives and tariffs will start slowly because of the economic situation and the deficit created by the existing subsidy scheme based on the feed-in tariff. If this situation is overcome, it is realistic to estimate that 35,000 MW of onshore and 750 MW of offshore wind capacity could be operating by 2020, providing close to 30% of Spain's electricity.

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31 Sweden

Source: Brian Domino

1.0 Overview

The new wind energy installations in 2011 had a capacity of 755 MW (604 MW were installed in 2010). 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 to 2012 and has a total budget of about 80 million SEK (8.6 million EUR; 11.1 million USD). Vindval is a knowledge program focused on studying the environmental effects of wind power. Vindval runs between 2009 and 2012 with a budget of 35 million SEK (3.8 million EUR; 4.9 million USD). The SWPTC at Chalmers institute of technology runs between 2010 and 2014 and has a total budget of 100 million SEK (11 million EUR; 14.2 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

In 2008, the Swedish government expressed a planning target 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. Electricity generation from wind power has increased from 3.5 TWh in 2010 to 6.1 TWh in 2011 (Figure 1).

The Swedish electricity end use in 2011 was 139.2 TWh, an increase of about 1% compared to 2010. The wind power electricity generation share is now 4.4%

2.1 National incentive programs

There are two main incentive programs for the promotion of wind power: electricity certificates and support for technical development in coordination with market introduction for large-scale plants offshore and in arctic areas. The work done in assessing areas of national interest for wind power can also be considered a sort of "soft incentive."

2.1.1 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

Table 1. Key Statistics 2011: Sweden	
Total installed wind generation	2,899 MW
New wind generation installed	755 MW
Total electrical output from wind	6.19 TWh
Wind generation as % of national electric demand	4.4 %
Average capacity factor	
Target:	30 TWh of wind generation by 2020

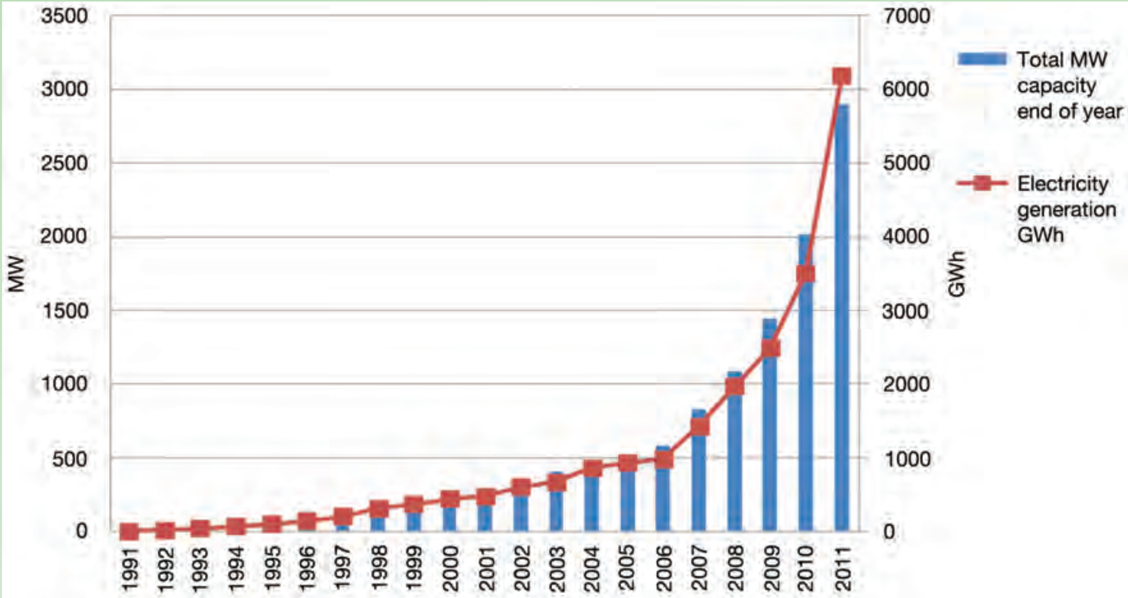

Figure 1. Installed wind power capacity in Sweden 1991 to 2011

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.

2.1.2 Support for technical development

In 2003, the Swedish Energy Agency launched a program to support technical development, in coordination with market introduction, for large-scale plants offshore and plants in arctic areas. The aim is to stimulate the market, achieve cost reduction, and gain knowledge about environmental effects. For the years 2003 to 2007, the budget was 350 million SEK (38 million EUR; 49 million USD). The market introduction program has been prolonged another five years with an additional 350 million SEK (38 million EUR; 49 million USD) for the period 2008 to 2012. The projects funded up to date are shown in Table 2.

2.1.3 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.

2.1.4 Network for wind utilization (1)

The Swedish Energy Agency is the expert authority appointed by the government to promote the development of wind power, taking a holistic approach to encouraging the rapid expansion of wind power. Therefore, the Swedish Energy Agency has started a national network for wind utilization. A national network important for putting to use the opportunities offered by the expansion of wind power for local and regional development. The purpose of the network is to disseminate knowledge of the natural resource of wind, safeguard the availability of information for facilitating the expansion of wind power, and support regional initiatives of national importance. An essential part of the network is to strengthen existing initiatives and contribute to the formation of new regional nodes in the field of wind power. An important task is also to coordinate other authorities in their work on wind power.

2.1.5 Vindlov.se (2)

One of the key obstacles prolonging the permission process for wind power is the huge number of stakeholders in the process. Hence information a developer must consider is widespread, of different formats and quality, or simply is not accessible. Furthermore staying up-to-date on this information requires considerable amounts of work. In this process some stakeholders might also be overlooked.

The website Vindlov.se (i.e. wind permit), takes a unique approach to target this bottleneck. The website follows the concept of a one stop shop providing joint service of information on permitting issues from nearly twenty public authorities from a wide range of sectors. This includes permission information over the whole life cycle of wind power and features a dynamic web map application as well as contact tools to wind power handlers at all authorities. Further development is planned and an English version is in progress.

The dynamic web map application (www.vindlov.se/kartstod) enables the wind power developer 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 and can also be accessed via a so called WMS service in order to easily combine own wind park layouts and localizations with public stakeholder interests and basic conditions for wind power. This includes 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

Table 2. Projects with support from the market introduction program				
Project	Recipient company	Support	Location	Estimated production and estimated year of operation
Lillgrund	Örestads vindkraftpark AB (owned by Vattenfall)	213 million SEK (23 million EUR; 29 million USD)	Offshore	330 GWh; operating since late 2007
Vindpark Vänern	Vindpark Vänern Kraft AB	40 million SEK (4.3 million EUR; 5.6 million USD)	Largest Swedish lake	89 GWh; operation in 2009
Uljabouoda	Skellefteå Kraft AB	35 million SEK (3.8 million EUR; 4.9 million USD)	Onshore arctic	100 GWh (2008)
Kriegers Flak	Sweden Offshore Wind AB (Vattenfall AB)	9.45 million SEK (1 million EUR; 1.3 million USD)	Offshore	No production. Only development program, reported
Storrun	Storun AB	26.25 million SEK (2.8 million EUR; 3.6 million USD)	Onshore	80 GWh; 2009
Large scale wind power in northern Sweden	Svevind AB	115 million SEK (12.4 million EUR; 16 million USD)	Onshore	197 GWh; 2009-2011
Large scale wind power in southern Swedish forests	Arise Windpower AB	50 million SEK (5.4 million EUR; 6.9 million USD)	Onshore	140 GWh; 2009-2010
Large scale wind power in highland areas	O2 Vindkompaniet	72.5 million SEK (7.8 million EUR; 10.1 million USD)	Onshore	260 GWh; 2011
Havsnäs	NV nordisk Vindkraft AB	20 million SEK (2.2 million EUR; 2.8 million USD)		256 GWh; 2009-2010
Vindval		35 million SEK (3.8 million EUR; 4.9 million USD)		Environmental research program

cultural environments, and concession areas for mineral excavation.

3.0 Implementation

The expansion of wind power onshore is mostly driven by large utilities like Vattenfall and E.ON but also by others. A number of utilities, developers, real estate companies, and private persons are developing small and large projects.

The large, international manufacturers of turbines, Enercon, Nordex, Vestas, and others have sales offices in Sweden. On the component side (supply chain), the value of manufactured goods is large. The market consists of subcontractors such as SKF (roller bearings and monitoring systems), ABB (electrical components and cable), Vestas Castings (formerly Guldsmedshytte Bruk AB), Dynavind (tower production), and EWP Windtower Production. Other companies worth mentioning are Oiltech (hydraulic systems and coolers), Nexans (cables), and ESAB (welding equipment). The subcontractors are mainly multinational companies, but smaller entities that find the wind power market

Figure 2. Large scale wind power in highland areas, O2 Vindkompaniet (Photo: Brian Domino)

relevant to their know-how are also established in Sweden.

3.1 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, see also information in IEA Wind Task 11 base technology information exchange. It is a general understanding that wind turbines in such areas have to be equipped with special cold climate packages. Such packages may include special steel qualities in towers and nacelle structures, and special types of oil and grease. The most essential thing is to equip blades with equipment for de/anti icing. To support the deployment in cold areas the Swedish Energy Agency is supporting a number of projects financially (Table 2).

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 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 2011 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 to 2012, with a total budget of 20 million SEK/yr (2.2 million EUR/yr; 2.9 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; wind power in the power system.

The SWPTC runs from 2010 to 2014. The program is financed by the Swedish Energy Agency, by industry, and by Chalmers University. SWPTC has organized its work in five theme groups: power and control systems; turbine and wind load; mechanical power transmission and system optimization; structure and foundation; maintenance and reliability.

Vindforsk, Vindval, and SWPTC together invited interested actors to a conference where researchers and organizations participated and presented research projects. During 2011, 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 (3.9 million EUR; 5 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.

Some of the projects in these programs and other R&D projects that have been funded include the following:

- Wind turbine drive train dynamics, system simulation, and accelerated testing. The project deals with the development of methods, mathematical models and validated computational tools for advanced analysis of drive train dynamics and load transmission in multi-MW wind turbines.
- Aerodynamic loads on rotor blades. The project will develop computational methods for predicted unsteady aerodynamic loads on wind turbine rotor blades.
- Load- and risk-based maintenance management for wind turbines. The project aims to reduce the overall costs of maintenance management of wind turbines.

5.0 The Next Term

The research programs Vindval, Vindforsk, and SWPTC continue with new research projects in 2012. The Vindval research program will also continue synthesizing and spreading knowledge. A lot of the expected growth in wind generation capacity will be in forest areas and also in the northern parts of Sweden in the "low-fields." The interest in those regions is prompted by the rather good wind potential as estimated by Swedish wind mapping. Substantial uncertainty, however, exists in the energy capture and loads of turbines in forested areas. The character of wind shear and turbulence is less explored in these areas and projects in the coming research program will be set up to increase the knowledge in this area. The SWPTC activities will continue developing wind turbines and to optimize maintenance and production costs.

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Authors: Andreas Gustafsson, Swedish Energy Agency; and Sven-Erik Thor, Vattenfall Vindkraft AB, Sweden.

32 Switzerland

Photo: Martin Heiniger, Brugg, Switzerland

1.0 Overview

By the end of 2011, 30 wind turbines of a considerable size were operating in Switzerland with a total rated power of 45.5 MW. These turbines produced 70 GWh of electricity. Since 1 January 2009, a cost-covering feed-in-tariff (FIT) for renewable energy has been implemented in Switzerland (1). This change of policy in promoting wind energy led to a boost of new wind energy projects. Financing was requested for additional 1,938 MW under the FIT scheme. Due to various obstacles in the planning procedures and acceptance issues, only two new turbines with a rated power of 3.2 MW were installed in 2011 (opening photo: Feldmoos turbines).

In Switzerland, an ancillary industry for wind turbine manufacturers and planners has developed, which acts mainly on an international level. The total turnover is about 1.4 million EUR (1.88 million USD). 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

2.1 National targets

With the introduction of the FIT, one of the goals of Switzerland's energy policy is to increase the proportion of electricity produced by "new" renewable energy (without large-scale hydro) by 5,400 GWh, or 10% of the country's present-day electricity consumption, by 2030 (Figure 1). Wind energy should contribute 600 to 1,200 GWh to these targets. The Swiss wind energy concept (plan) also identifies the calculated wind energy potential for Switzerland, based on the real existing wind conditions on 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 (2).

2.2 Progress

Today, approximately 56% of Switzerland's overall electricity production comes from renewable sources, with hydropower by far the biggest contributor (96.5%). In 2011, two turbines were put in operation with an average rated power of 1.6 MW (opening photo). In total, 30 wind turbines of a considerable size are installed with a rated capacity of 45.5 MW. These turbines produced 70 GWh (Figure 2). During an average wind year, these turbines would generate 77 GWh. Due to various obstacles in the planning procedures, there is only one additional project under construction, but projects with possible energy yield of 828 GWh have been submitted to planning bodies, 382 GWh are already authorized.

2.3 National incentive programs

The revised Energy Act from 1 January 2009 also contains a package of measures for promoting renewable energy and efficient electricity use. The FIT is the most significant measure and concerns cost-covering remuneration for

Table 1. Key Statistics 2011: Switzerland	
Total installed wind generation	45.5 MW
New wind generation installed	3.2 MW
Total electrical output from wind	0.07 TWh
Wind generation as % of national electric demand	0.1%
Average capacity factor	<20%
Target:	0.6-1.2 TWh/yr in 2030

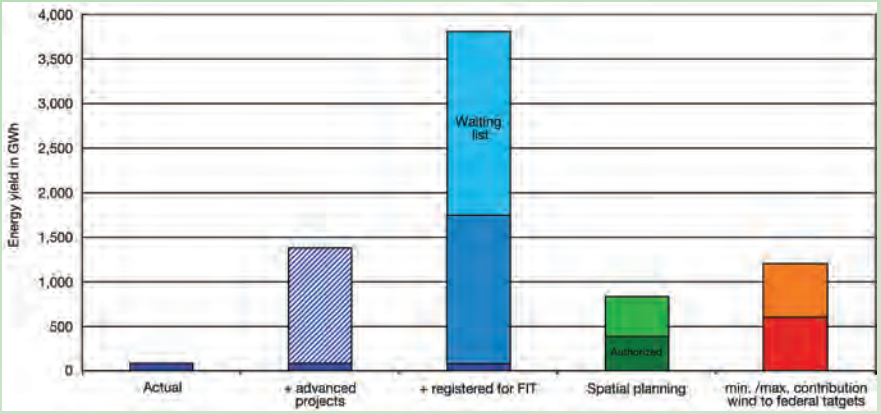

Figure 1. Actual and future energy yield of wind turbines in Switzerland 2011

the input of electricity produced from renewable energy sources into the network. Renewable resources include hydropower (up to 10 MW), photovoltaics, wind energy, geothermal energy, biomass, and waste material from biomass. In the year 2011, the actual figures are: 220 million EUR/yr (285 million USD/yr), financed by a 0.37 EUR / kWh (0.48 USD/kWh) fee on electricity sold in Switzerland, will be available for offsetting the difference between the cost-covering FIT and market price.

The tariffs for remuneration for electricity from renewable energy sources (green power) have been specified on the basis of reference facilities for each technology and output category. Remuneration will be applicable for a period of between 20 and 25 years, depending on the technology. A gradual downward curve is foreseen for these tariffs in view of the anticipated technological progress and the entrance of a growing number of technologies in the market. For wind energy, the same system Germany uses has been applied, whereby the higher price is 0.18 EUR /kWh (0.23 USD/kWh) and the lower price is 0.11 EUR /kWh (0.14 USD/kWh) (3). Producers who decide in favor of the FIT option cannot simultaneously sell their green power on the free ecological electricity market. Yet they can decide every year whether they will sell the electricity on the market or apply the FIT system. The developers can register their facilities with Swissgrid, the national grid operator.

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 supply, the Federal Council, as part of its new Energy Strategy 2050, is placing emphasis on increased energy savings (energy efficiency), the expansion of hydropower and new renewable energies, and, if necessary, on fossil fuel-based electricity production (co-generation facilities, gas-fired combined-cycle power plants) and imports. Furthermore, Switzerland's power grid should be expanded without delay and energy research strengthened.

This new strategy means also a change from central to increasingly decentralized and variable electricity generation, a fundamental change in the available types of power plant. The necessary reserve and storage capacities will have to be made available in the future. The Swiss energy system will have to be transformed while taking account of potential conflicts of interest and targets already set in various sectors, such as: climate protection; conservation of lakes, rivers, and the countryside; spatial planning; and the established division of tasks between the federal government and the Cantons will have to be maintained (4).

Wind energy is an important element within this new strategy. Suisse Eole, the Swiss Wind Energy Association, is the leading authority 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) institutes of energy, energy suppliers, and energy planners. A special focus will be on social acceptance issues (5).

2.4 Issues affecting growth

The high number of registrations within the FIT scheme (also for other technologies) led to the the Swiss Federal Office of Energy (SFOE) declaring a moratorium from 1 February 2009 for all technologies. Based on a new legislation, the available amount will be 420 million EUR (545 million USD), financed by 0.74 EUR /kWh (0.96 USD/kWh), beginning from 2013. Other issues affecting growth include:

- 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

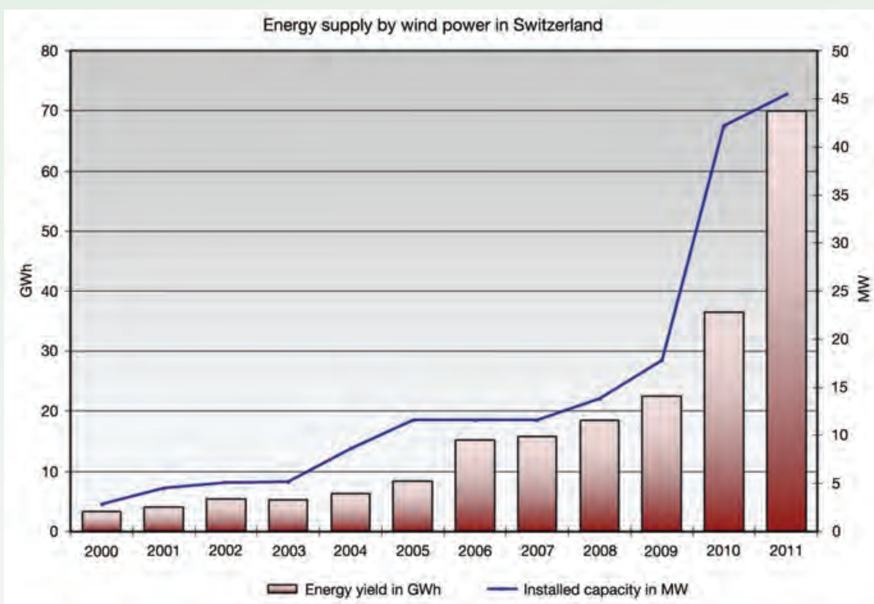

Figure 2. Development of wind energy in Switzerland 2011

Acceptance continue to play an important role.

• Planning procedures and construction permits in Switzerland are in general very time and cost intensive and the outcomes are often uncertain.

• Based on the important changes in the FIT, a dramatic rise in players on the Swiss market occurred. Establishing a high quality reference standard for future projects will be a major challenge for the Swiss Wind Energy Association.

3.0 Implementation

3.1 Economic impact

A study of McKinsey (6) from 2009 quantifies the world wide turnover of Swiss companies in the field of wind energy with 1.6 million EUR (2.15 million USD) underestimates a potential in the year 2010 of 8.6 billion EUR (11.6 billion USD).

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, and 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.

3.4 Wind energy costs

The specific costs of existing large wind power plants is about 1,450 EUR /kW, including installation the figure rises to 2,100 EUR /kW. The regulation for the compensatory feed-in remuneration scheme provides 0.11 to 0.18 EUR/kWh (0.18 to 0.23 USD/kWh) for wind energy – based on the same mechanism as the German model. Swiss participation in IEA Wind Task 26 Cost of Wind Energy generates important information for this discussion.

4.0 R, D&D Activities

4.1 National R, D&D efforts

The wind energy research program for 2008 to 2011 (7) focuses on developing innovative turbine components for specific application in harsh climates, increasing availability and energy yield at extreme sites, increasing of the "value" of the wind energy, 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 2011, the budget for wind energy related R&D projects was 375,000 EUR (494,657 USD). An amount of 506,000 EUR (667,000 USD) is spent on promotional activities.

Several innovative research projects were underway in 2011.

• Development of wind turbines for safe operation in alpine environments (phase II) Influence of upstream wakes on turbine power in complex terrain (8). Phase II of this project by ETH Zürich focused on quantifying wind turbine performance losses due to wakes, understanding the flow phenomena responsible for these losses, as well as proposing loss mitigation strategies (Figure 3). The primary outcome of this project, detailed in this report, is a new wake model, based on free shear flow mixing theory, that yields an average error of 3.6% in the predicted wind turbine performance, compared to 7% to 12% error for the more commonly used wake models.

• Test Sites for wind turbines in alpine regions (9). On the occasion of the conference on the research program "wind energy" of 9 December 2011, the experts present underlined the need for a wind energy test site in Switzerland. As part of a preliminary project, the following research areas have been identified: Influence of topography, influence of climatic conditions, and evaluation of new means of transportation (Figure 4).

• Increase of the acceptance of wind energy (10). Three years of experience within the working group and supporting institutions of IEA Wind Task 28 on social

Figure 3. The novel approach of using an instrumented Unmanned Aerial Vehicle (UAV) to measure the wind speed and turbulence in wind parks has been developed at ETH Zürich

acceptance of wind energy have shown the international exchange on social acceptance issues to be extremely valuable for those involved such as administrations, the research community, IEA Wind members, and for further wind energy promoters in the respective countries, e.g. wind energy associations. The development of wind energy, especially the debates surrounding the projects in the field, have also proven that social acceptance is a topic to be further researched if the policy targets for renewable energy production are to be accomplished. Specific projects require social acceptance to be realized and proponents and opponents need support to work together to improve the projects. This seems to be increasingly recognized by the industry as well as administrative institutions, but to achieve long-term acceptance of wind power, the topic needs further attention and accompanying projects such as Task 28 with their interdisciplinary and trans-national approach.

4.2 Collaborative research

In addition to IEA Wind Task 28, 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.

5.0 The Next Term

If significant economic effects of the wind energy for the Swiss industry are to be realized, a substantial rise in research and promotional activities is crucial. In 2011, the energy research concept 2013 to 2016 was being elaborated by the SFOE. The following key issues should be included:

- Quantifying production losses and downtimes due to icing; 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 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.

Figure 4. Transport solutions for difficult access in mountainous areas, e.g., tilting blade adapter

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33 United Kingdom

Photo: Martin Phelps of Westmill Wind Farm Co-operative

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 an 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.

In 2011, total wind capacity in the UK was 6.47 GW, representing 4.24% of the UK's national electricity demand, an increase of 1.09 GW from the 2010 figure (a 20% increase) (1). A significant increase in electricity generation from wind was seen in 2011 in the UK. The largest absolute increase in generation was from onshore wind, rising from 7.1 TWh in 2010 to 10.4 TWh in 2011 (30% increase), partly due to increased capacity, but mainly due to much higher wind speeds (1.4 knots higher than in 2010). Also as result of increased capacity and high wind speeds, offshore wind generation increased by 68%, from 3.0 TWh in 2010 to 5.1 TWh in 2011 (a 68% increase).

The government is committed to driving the deployment of renewable electricity and other forms of low-carbon electricity generation. During 2011, the Electricity Market Reform (EMR) White Paper was published, which set out key measures to attract investment, reduce the impact on consumer bills, and create a secure mix of electricity sources including gas, new nuclear, renewables, and carbon capture and storage. Other key advances in 2011 are listed below.

The UK Renewables Energy Roadmap (2): Published in July, this set out a comprehensive action plan to accelerate the UK's deployment and use of renewable energy, and put us on the path to achieve our 2020 target, while driving down the cost of renewable energy over time. It identifies the eight technologies (including onshore and offshore wind) that have either the greatest potential to help the UK meet the 2020 target in a cost-effective and sustainable way, or offer great potential for the decades that follow.

Offshore wind Cost Reduction Task Force: As announced in the Renewables Roadmap, significant cost reduction was identified as being required in order to maximize the potential size of the sector. To help achieve this, an industry led task force was established to set out an action plan for cost reduction to 2020. The task force will drive the work necessary to realize the vision of reaching 100 GBP/MW/h (113 EUR/MW/h; 162 USD/MW/h) for offshore wind and will report to the Department for Energy and Climate Change (DECC) Ministers and Devolved Administration Ministers by Spring 2012.

Renewables Obligations Banding Review: The government and devolved administrations undertook consultations on proposals for the levels of banded support available for renewable electricity generations under the Renewables Obligation (RO) for the period 2013-2017. Separate consultations took place for England and Wales, Scotland, and Northern Ireland.

Green Investment Bank: Work continued to prepare the Green Investment Bank for its opening in 2012. The Green Investment Bank is designed to accelerate private sector investment in the UK's

Table 1. Key Statistics 2011: United Kingdom

Total installed wind generation	6,470 MW
New wind generation installed	1,092 MW
Total electrical output from wind	15.5 TWh
Wind generation as % of national electric demand	4.24%
Average capacity factor	Onshore: 27.4% Offshore: 36.7%
Target	15% renewables by 2020

transition to a green economy. Offshore wind power generation, commercial and industrial waste processing and recycling, energy from waste generation, non-domestic energy efficiency, and support for the Green Deal will be the first priority sectors for the bank, subject to approval by the European Commission. It will work to simulate the deployment of private sector capital and debt. In this way it can play a key role in facilitating accelerated investment in the development and construction phases of projects, potentially enabling initiatives which may not otherwise have been able to proceed.

Investor Conference: In London a conference was held with potential investors (such as pension funds, investment funds, and sovereign wealth funds) in offshore wind projects to establish what can be done to increase investment in this area. The UK needs around 200 billion GBP (225 billion EUR; 291 billion USD) of investment in new energy infrastructure to help reduce dependence on imported fossil fuels and boost our energy security. Much of this will need to come from sources beyond the UK's current major energy suppliers.

Aviation and Radar: During 2011, a Second Memorandum of Understanding (MOU) Aviation Plan was signed. Wind turbines can have a significant effect on radar, which in turn is a major barrier to deployment in the UK. The signatories to the MOU commit to working together to implement the Aviation Plan and to ensure the timely and effective delivery of solutions to mitigate the effects of wind turbines on aviation. The goal is to promote the deployment of wind energy generation, whilst taking all necessary steps to protect air safety and air defense requirements.

Offshore Renewable Energy Catapult: A competition was run by the Technology Strategy Board (TSB) to form an Offshore Renewable Energy Catapult, one of a new network technology and innovation centers aiming to transform the UK's capability for innovation in seven specific sectors and to help drive sustainable economic growth in those areas. The Offshore Renewable Energy Catapult will focus on technologies for offshore wind, wave, and tidal stream power generation. It will help to commercialize the best outputs of Britain's world-class research base and facilitate business access to testing facilities and expertise to help commercialize new and emerging technologies that can capture a share of emerging global markets.

Offshore Wind Accelerator (OWA): A novel turbine foundation design for North Sea conditions – the Keystone 'twisted jacket' – was successfully demonstrated 100km offshore in 30m water depths at the Hornsea zone to support a met mast; this is the first of four foundations identified in a 2009 competition to be demonstrated.

Planning and Consenting Task Force: A short-life planning and consenting task force was established in October 2011 to bring together offshore renewable developers with marine Scotland and environmental regulators to produce a report promoting greater streamlining and efficiency of Scotland's marine planning and consenting regimes. The aim being to enable Scotland to meet its offshore renewable ambitions, as set out in the 2020 Routemap for Renewable Energy in Scotland. In April 2011 the Scottish government initiated a one-stop-shop for offshore wind, wave, and tidal developers to obtain consents and licenses in Scottish waters.

2.0 National Objectives and Progress

2.1 National targets

In 2009, the UK agreed, (as part of the EU target to provide 20% of primary energy, electricity, heat and transport), to a target of providing 15% of its primary energy from renewables sources. Up to two-thirds of the electricity component of the UK's legally binding 2020 renewable energy target is likely to be provided by wind energy, and a high percentage of this is likely to be offshore. We envisage that by 2020 in order to meet this target the UK will deliver 30% of its electricity from renewables, and 12% of its heat.

Table 2. Wind Projects Prospects at End of 2011

Description	MW
Planning application submitted	8,079
Planning approved (awaiting/ under construction)	9,141
Total planned and/or in construction	17,220

2.2 Progress

UK electricity is generated from a range of sources. Of electricity generated in 2011, provisional data highlights that gas accounted for 40% (a decrease of 6% since 2010) and coal accounted for 30%. Nuclear energy's share increased by 3% since 2010, to contribute 19% of the total, while renewable energy's share of generation increased by 2.5% since 2010 to a record 9.5%.

Generation from wind increased significantly in 2011 due to an increase in capacity and also due to higher wind speeds. The largest absolute increase in generation was from onshore wind, rising from 7.1 TWh in 2010 to 10.4 TWh in 2011 (30% increase). This was partly due to increased capacity, but mainly due to much higher wind speeds (1.4 knots higher than in 2010). Also as a result of increased capacity and high wind speeds, offshore wind generation increased by 68%, from 3.0 TWh in 2010 to 5.1 TWh in 2011. In 2011, onshore wind's load factor averaged 27.4%, a 5.8% increase from 2010's 21.7%. Meanwhile, offshore wind's load factor rose by 6.2%, from 30.4% to 36.7%. This was due to the high wind speeds experienced, particularly in the final quarter.

In 2011, 1,092 MW of new wind generation capacity was commissioned, bringing the total UK capacity to 6.47GW, an increase of 20% above the 2010 level. This includes 1.84 GW of offshore wind. The UK continues to be the world leader in the development and deployment of offshore wind.

2.3 National incentive programs

2.3.1 Renewables Obligation

The Renewables Obligation (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

Figure 1. Thanet Offshore Wind Farm, completed in 2010 (Photo: DECC)

Britain and Northern Ireland to provide a specified and increasing number of RO Certificates (ROCs) as evidence that an increasing proportion of their electricity comes from eligible renewable sources, or pay a buy-out price.

The RO Banding Review consultation looks at the level of support each technology will receive under the RO from 2013 to 2017(1 April 2014 for offshore wind). The consultation opened on 20 October and ran until 12 January 2012. Banding reviews ensure that as market conditions and innovation within sectors change and evolve; renewables developers continue to receive the appropriate level of support necessary to maintain investments.

The RO system works on the basis of 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. This will allow many people to invest in small-scale low-carbon electricity, in return for a guaranteed payment from an electricity supplier of their choice for the electricity they generate and use as well as a guaranteed payment for unused surplus electricity they export back to the grid. Small-scale low-carbon electricity technologies eligible for FITs are: wind; photovoltaics (PV); hydro; anaerobic digestion; and domestic scale microCHP (with a capacity of 2 kW or less). DECC has published data regarding the first year of the scheme – from 1 April 2010 to 31 March 2011 which can be accessed from (3).

2.3.3 Electricity Market Reform (EMR)

The UK government published the Electricity Market Reform White Paper in 2011 which set out key measures to attract investment, reduce the impact on consumer bills, and create a secure mix of electricity sources including gas, new nuclear, renewables, and carbon capture and storage. Key elements of the reform package include:

- the government would put in place a Carbon Price Floor to reduce investor uncertainty, putting a fair price on carbon and providing a stronger incentive to invest in low-carbon generation now;
- new long-term instruments will be introduced: FIT with Contracts for Difference (CfD) to provide stable financial incentives to invest in all forms of low-carbon electricity generation. A contract for difference approach has been chosen over a less cost-effective premium feed-in-tariff;
- an Emissions Performance Standard will be set at 450g CO_2/kWh to reinforce the requirement that no new coal-fired power stations are built without carbon capture and sequestration (CCS), but also to ensure necessary investment in gas can take place; and
- a capacity mechanism, including demand response as well as generation is needed to ensure future security of electricity supply.

The measures introduced as part of EMR will ensure that the UK will meet renewables targets for 2020 and have secure, affordable, and low-carbon electricity to 2030 and beyond. EMR has been designed to provide more revenue certainty to investors in low carbon electricity while reducing the impact on consumers, which when combined with Ofgem's work on market liquidity will be key to attracting new developers and finance providers as well as encouraging investment by the existing utilities. The package of measures being introduced through the EMR process includes a new support scheme for all low carbon, including renewable generation.

In addition to the EMR White Paper, the government published a Technical Update paper. This Technical Updater sets out the following features.

- the government's decision to legislate for a capacity mechanism in the form of a capacity market, designed to ensure consumers continue to enjoy reliable electricity supplies and avoid the higher prices that could result from tight capacity margins;
- the government's view that the system operator, part of the national grid, best meets the criteria for delivering the FIT with CfD and the capacity mechanism;

• detail on work to enable investment decisions for early projects;
• the next steps for the EMR program; and
• more detail on arrangements for Renewable Obligation Certificates from 2027 onwards.

It is recognized that transitional arrangements need to be established whilst the new market arrangements are established.

2.3.4 Transitional Arrangements

The UK government recognizes that significant investments have been made under the current RO. Throughout the EMR process, clear and transparent transition arrangements have been set out from the RO to the new support mechanism, with the aim of preventing a hiatus in renewables investment while the new arrangements are being put in place.

Existing investments under the RO will continue to receive their support through the RO mechanism. The new scheme will be for new generation only, and the RO will remain open to new accreditations until 31 March 2017. After which the system will be 'vintaged' to ensure that projects already supported under the RO mechanism can continue to receive support under that mechanism.

Between the introduction of CfDs (from 2014) and the RO closing in 2017 new renewable generation will have a choice between the two mechanisms. Existing RO generation will remain in that scheme.

The Electricity Market Reform White Paper set out proposals for the RO transition, including that the RO is calculated by headroom until 2027, then the priced is fixed of a Renewables Obligation Certificate (Fixed ROC) to 2037. This is to provide confidence in the final years of ROC income. The Technical Update provides more detail on how the Fixed ROC scheme will operate, to assist investors and developers taking long-term investment decisions.

3.0 Implementation

3.1 Industry status

Although no established wind turbine manufacturer is currently based in the UK, overseas manufacturers were more interested in the UK as a base for manufacturing as a result of the 2010 announcement of Round 3 leasing competition. In addition, the UK government committed up to 60 million GBP (67 million EUR; 97 million USD) to support offshore wind manufacturing at port sites so that offshore wind manufacturers can locate new facilities in assisted areas in England. The Scottish government will make available up to 70 million GBP (78 million EUR; 113 million USD) of similar funding to stimulate the offshore wind industry. A number of wind turbine manufacturers have since signaled their intention to establish UK manufacturing bases.

3.2 Operational details

In 2011, the UK saw key achievements in wind power development. Two large onshore wind farms came into operation in Scotland during 2011. Arecleoch, a 120 MW wind farm and the first phase of Clyde Wind Farm came on-line (130 MW). The biggest English onshore wind farm, the 66-25MW Fullabrook came on line. Offshore construction activities began on two separate wind farms with a total capacity of 813 MW. These are the Walney 2 (183 MW) and London Array (first phase) (630 MW) wind farms. Walney 1 (183 MW) was fully brought into operation. First electricity was also generated from a number of offshore wind farms although these were not fully brought into operation in 2011.

4.0 R, D&D Activities

To order accelerate development of wind energy, the UK government provides funding for R&D projects in partnership with industry. Technology innovation reduces the cost of commercial

Table 3. Offshore Wind Projects Completed by the End of 2011

Wind farm name	Turbine type	Number of turbines	Total capacity (MW)	Date online
Walney 1	3.6-MW Siemens	51	183.6	July 2011
Thanet	3-MW Vestas V90	100	300.0	September 2010
Robin Rigg	3-MW Vestas V90	60	180.0	April 2010
Gunfleet Sands I + II Offshore Wind scheme	3.6-MW Siemens	48	172.8	April 2010
Rhyl Flats	3.6-MW Siemens	25	90.0	December 2009
Inner Dowsing	3.6-MW Siemens	30	108.0	November 2008
Lynn	3.6-MW Siemens	24	86.4	November 2008
Burbo Bank	3.6-MW Siemens	25	90.0	October 2007
Beatrice	5-MW REPower	2	10.0	July 2007
Barrow	3-MW Vestas V90	30	90.0	July 2006
Kentish Flats	3-MW Vestas	30	90.0	October 2005
Scroby Sands	2-MW Vestas	30	60.0	March 2004
North Hoyle	2-MW Vestas	30	60.0	December 2003
Blyth Offshore	2-MW Vestas	2	3.8	December 2000

deployment, making it more cost effective for business to invest in our energy infrastructure and ensure security of supply. Innovation support is needed from early stage development through to demonstration and pre-commercial deployment.

Test facilities are important for accelerating the deployment of renewables technology. The New and Renewable Energy Centre (NAREC), based at Blyth docks in northeast England is currently the main offshore test facility. It was announced in 2011 that the Energy Technologies Institute (ETI) will invest 25 million GBP (28 million EUR; 40 million USD) into a state-of-the art, open access, wind turbine drive train test rig at NAREC. The indoor rig will be capable of testing complete drive trains and nacelles up to 15 MW. It should be available for commercial testing from June 2013. There are also plans to open another offshore wind turbine centre, in Scotland, near Aberdeen (European Offshore wind Deployment Centre).

4.1 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.

The group has been working together on a number of work streams including the Technology Innovation Needs (TINA) project. This project aims to identify and value the key innovation needs of specific low carbon technology families, including offshore wind, to inform the prioritization of public sector investment in low carbon innovation. The LCICG worked with representatives from the offshore wind industry to ensure that the most robust data possible was fed into the TINA process.

4.2 Research Councils UK Energy Programme

The Research Councils UK Energy Programme 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 530 million GBP (596 million EUR; 772 million USD) in research and skills to pioneer a low carbon future. This builds on an investment of 360 million GBP (405 million EUR; 583 million USD) over the past five 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.

Doctoral Training Centre at the University of Strathclyde has awarded ten prestigious EPRSC research studentships to talented engineering and physical science graduates to undertake a four year PhD in 2009. The Centre is now recruiting another ten graduates to start their PhDs in October 2011.

The Technology Strategy Board (TSB) is an executive, Non-Departmental Public Body (NDPB), established by the government in 2007 and sponsored by the Department for Business, Innovation and Skills (BIS). The TSB activities are jointly supported and funded by BIS and other government departments, the devolved administrations, 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. It provides support to businesses conducting research and development in certain technology areas through match-funded grants. As well as investing in programs and projects, much of its work is in spreading knowledge, understanding policy, spotting opportunities, and bringing people together to solve problems or make new advances.

In the face of climate change, issues of energy security and rising fuel costs there are major market opportunities for UK businesses working in the energy sector and the TSB is looking to support innovation in energy generation and supply technologies, which will create wealth for the UK and help meet the country's energy needs. 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.

4.3 Energy Technologies Institute (ETI)

The ETI is a UK-based company formed from the UK government and global industries, including BP, Caterpillar, EDF Energy, E.ON, Rolls-Royce, and Shell, bringing together projects and partnerships accelerating the development of affordable, clean, and secure technologies to help the UK meet its legally binding 2050 climate change targets. The ETI makes targeted commercial investments in projects covering heat, power, transport, and their supporting infrastructure that accelerate the development of affordable, clean and secure energy technologies. Offshore wind is seen as an important area of focus. Cost, reliability and maintenance are paramount to accelerating the offshore wind market further and the ETI has commissioned projects in all three areas. The ETI focus is on achieving significant cost reductions and enhanced reliability for offshore wind. The current on-going Wind Energy Program projects are as follows:

Condition Monitoring: The project is led by wind turbine blade monitoring specialists Moog Insensys in partnership with EDF Energy, E.ON, Romax Technology, SEEByte, and the Univeristy of Strathclyde. This project aims to develop a system that can detect the causes of faults and component failures in offshore wind turbines. It will provide offshore wind operators with sufficient warning to allow a suitable maintenance strategy to be planned, predicting faults before they occur, identifying potential causes and overall, reducing turbine downtime. The system has the capability to reduce the cost of generating electricity from offshore wind turbines. In summer 2011 the system started testing on onshore wind turbines.

Offshore Wind Drivetrain Test Rig: ETI will invest 25 million GBP (28 million EUR; 40 million USD) into a state-of-the art, open access, wind turbine drive train test rig seen as crucial for the continued success and further expansion of the UK's offshore wind industry. A consortium of GE Energy Power Conversion and MTS will design and develop the rig, which will be sited at Narec in Blyth, Northumberland and will be capable of testing complete drive trains and nacelles up to 15 MW. The test rig is being designed to allow the whole turbine nacelle to be tested onshore and indoors before being taken offshore. This approach should reduce the technical and commercial risks of mass production and deployment, lower the cost of deploying and testing turbines offshore, and accelerate the development of new prototypes. It should be available for commercial testing from autumn 2013.

Offshore Wind Floating Platform: The ETI plans to invest up to 25 million GBP (28 million EUR; 40 million USD) in an offshore wind floating system demonstration project which would open up new areas off the coast of the UK and help bring generation costs down. The project will see the design, construction, and installation of a floating system demonstrator by 2016 at a relatively near shore site with high wind speeds up to about 10 m/sec in water between 60 and 100 m deep. It will be operated for at least two years to show that it can generate high levels of electricity, be maintained without using specially designed vessels and demonstrate the predicted technical and economic performance. A decision on who will carry out the work on behalf of the ETI is expected in early 2013.

Next Generation Bigger Blades: A project to develop long high-performance blades for the next generation of large offshore wind turbines was also commissioned by the ETI in 2011. Developers will be asked to design, build, and test blades in excess of 90 m long – each blade will be nearly the same height of Big Ben in London. These blades would be used on the next generation of large offshore wind turbines with a capacity of 8 to 10 MW. The ETI expects to invest around 10 million GBP (11 million EUR; 16 million USD) in the project, and a decision on who will carry out the project is expected towards the end of 2012.

4.4 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
- Manage our energy legacy responsibly and cost-effectively

In the UK Renewables Roadmap, published in July 2011, DECC announced funding of up to 30 million GBP (33 million EUR; 48 million USD) of innovation support – subject to value for money assessments – for offshore wind cost reduction. Up to 15 million GBP (17 million EUR; 24 million USD) of this support has been allocated to the Offshore Wind Component Technologies Development and Demonstration Scheme.

The first call of the Offshore Wind Component Technologies Development and Demonstration Scheme was launched on 21 November 2011 for innovators to apply for support for the development and demonstration of innovative component technologies across the offshore wind system. With a call budget of around 5 million GBP (5.6 million EUR; 8 million USD) capital, the funding will help companies with novel ideas that could further improve offshore wind systems. DECC and the TSB are working together on this scheme. The first call is funded and managed by DECC but the TSB is participating in the appraisal process. The aim of the scheme is to support the demonstration of component technologies that will lead to cost reduction in offshore wind energy and increase deployment levels by 2020 and in the following decade. This first call closed on the 23 December 2011. A second round of the Offshore Wind Component Technologies funding will be launched in early May 2012.

Projects from the Environmental Transformation Fund: Offshore Wind Demonstration Scheme were coming to completion in 2011, with a few carried over into 2012. The fund, offered support for the development of innovative technologies with the potential to reduce the cost of deploying offshore wind and enable faster deployment of offshore wind technology.

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 achieved a number of milestones in 2011.

- 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 will take 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 will contribute significantly to that requirement.

5.0 The Next Term

In 2012, further announcements and activities in wind are expected. The offshore wind Technology Innovation Needs Assessment (TINAs) report will be published. The TINAs aim to identify and value the key innovation needs of specific low carbon technology families to inform the prioritization of public sector investment in low carbon innovation. It is intended that publication of a TINA for each low carbon technology and offshore wind is anticipated to be the first to be published.

The government response to the Renewable Obligation review is expected to be published in spring 2012. The Green Investment Bank will begin making investments in green projects from April 2012 and a draft Energy Bill will be published in May 2012 for pre-legislative scrutiny by the UK parliament. This Bill will establish a legislative framework for delivering secure, affordable, low carbon energy. A second call of the Offshore Wind Component Technologies Scheme is expected to be launched in May 2012. The Offshore Renewable Energy Catapult Centre will open for operation in 2012. It will be headquartered in Glasgow, Scotland with an operations center in Blyth, north-east England. The Cost Reduction Task Force will report to DECC Ministers and Devolved Administration Ministers by Spring 2012.

In 2012, the government will undertake a consultation on a comprehensive review of the tariffs for non-PV technologies under the FIT scheme, and also on scheme administration issues. The first offshore renewable energy leasing is underway in Northern Irish waters and The Crown Estate expects to offer development rights, for an area that could deliver up to 600 MW, by autumn 2012.

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34 United States

Photo: Todd Spink

1.0 Overview

The United States added about 6.8 GW of wind generating capacity in 2011, about 30% more than was added in 2010 (1). The administration's goal is to generate 80% of the nation's electricity from clean energy resources by 2035. In support of that goal, the U.S. Department of Energy Wind Program conducts research to improve wind technology, decrease costs, and increase wind generating capacity. In 2011, the Wind Program made significant progress by dedicating a new large blade test facility, installing three new multimegawatt turbines for testing, expanding activities at university-led research centers, and completing significant research projects on grid integration, cost estimation, offshore foundation design, technology development, and more. The Energy Department, along with the U.S. Department of the Interior, also published a *National Offshore Wind Strategy* (2) in 2011 that outlines the actions it will pursue to support an offshore wind industry in the United States. The Energy Department signed contracts with national laboratories and with industry and university partners to conduct research that will advance this important offshore wind effort, and it awarded up to 50 million USD (65 million EUR) in funding for 47 projects for research into technology development and market barriers. The work will span advanced drivetrain and turbine design to environmental impacts and supply chain assessment.

Table 1. Key Statistics 2011: United States	
Total installed wind generation (1)	46,916 MW
New wind generation installed (1)	6,816 MW
Total electrical output from wind (3)	119.75 TWh
Wind generation as % of national electric demand	2.9%
Average capacity factor (9)	33%
Target:	80% of electricity from clean sources by 2035

2.0 National Objectives and Progress

2.1 National targets

The Energy Department Wind Program directly contributes to the administration's goal for the United States to achieve 80% of its electricity from clean energy sources (including renewable energy technologies, nuclear, clean coal, and natural gas) by 2035. The Energy Department's report *20% Wind Energy by 2030* (4), published in 2008, examined the feasibility, costs, and benefits of supplying 20% of the nation's electricity from wind by 2030. The report identified offshore wind as a key element in reaching high contributions to electrical supply. In 2011, the Energy Department and the Department of the Interior published a *National Offshore Wind Strategy* (2) that outlines how the departments will guide a national effort to enable a scenario of 54 GW of offshore wind generating capacity by 2030 at a cost of energy of 0.07 USD/kWh (0.09 EUR/kWh).

2.2 Progress

In 2011, the U.S. wind industry installed 6,816 MW of generating capacity, a 30% increase over the capacity that was added in 2010, according to the American Wind Energy Association (AWEA) (1). In the last quarter of 2011, 3,446 MW came online and another 8,300 MW were under construction at the end of the year. The new capacity in 2012 will be added in more than 100 projects in 31 states and Puerto Rico. Wind power now contributes nearly 3% of the total U.S. electricity supply.

Initial numbers from the small wind industry show that the market declined by 11.3% in 2011. By the end of the year, cumulative capacity topped 200 MW with 151,000 turbines deployed (1).

2.3 National incentive programs

Federal tax and grant incentives and state renewable portfolio standards have played important roles in the growth of wind capacity, especially over the past five years. The production tax credit, a performance-based tax credit for kilowatt-hours produced by a wind farm after it is built, was enacted as part of the Energy Policy Act of 1992. In 2009, the American Recovery and Reinvestment Act added a 30% investment tax credit, extended loan guarantees to wind, and provided other incentives including the 30% cash grant program that expired at the end of 2011. The production tax credit and various levels of bonus depreciation are effective through 2012. Efforts to renew or expand these incentives are underway in Congress in 2012. If the tax, loan, and grant incentives are allowed to expire, experts believe that installations will be minimal in 2013 and the U.S. wind industry will face hard times.

Another driver of wind installations is state-mandated renewables portfolio standards (RPS) that require utilities to purchase a percentage of their overall generating capacity from renewable resources. As of June 2011, mandatory RPS programs existed in 29 states and Washington, D.C. 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 deployment.

2.4 Issues affecting growth

The United States is addressing the challenges to achieving 20% wind energy by 2030, which include the need for stable national energy policies, transmission interconnection barriers, siting issues that include wind/radar interference and wind/wildlife interactions, making wind energy cost competitive, increasing reliability and performance, developing technologies required for offshore development, and increasing the workforce.

2.4.1 Use conflicts

To address conflicts that have arisen between wind energy and other resources, significant efforts were continued or launched in 2011. The U.S. Fish and Wildlife Service worked with stakeholders in 2011 to develop voluntary guidelines for wind developers to assess and mitigate potential impacts to wildlife resulting from their projects. These guidelines were developed in 2011 for release in 2012.

Global information system (GIS)-based tools are being perfected to help wind developers find construction sites that will avoid potential conflicts with uses such as military radar, aircraft flight paths, and threatened wildlife. For example, the Natural Resources Defense Council (an environmental group) and the U.S. Department of Defense created an interactive database that highlights potential impacts of a particular site to nearby military facilities and ranges, radar installations, airspace and designated flight paths, and wildlife distributions. The database can be viewed at www.nrdc.org/energy/readgdb.asp. A similar Landscape Assessment Tool that focused solely on potential conflicts between wildlife and wind energy was launched by the American Wind Wildlife Institute in partnership with The Nature Conservancy, and can be found at http://wind.tnc.org/awwi/.

To validate commercial off-the-shelf technologies that have the potential to mitigate electromagnetic interference from wind turbines on radar systems, the Energy Department, the Department of Defense, the Department of Homeland Security, and the Department of Transportation's Federal Aviation Administration established the multi-agency Wind-Radar Interagency Field Test & Evaluation partnership. The interagency partnership is sponsoring two national laboratories to conduct three demonstration campaigns on ten mitigation technologies over two years.

In 2011, the Energy Department continued working with its national laboratories, the National Wind Coordinating Collaborative (NWCC), environmental groups, other government agencies, and industry members to understand and mitigate the effects of wind energy development on wildlife species with high potential conflict with wind development. The NWCC published a revised version of its *Comprehensive Guide to Studying Wind Energy/Wildlife Interactions* (5), which includes consensus best-practice methods and metrics for assessing wildlife-wind turbine interactions. The NWCC is conducting three studies on the impacts of wind energy on the greater Sage-Grouse and continued ongoing studies of the Greater Prairie Chicken to determine the potential impacts of wind on these species. The Bats and Wind Energy Cooperative completed studies identifying two promising mitigation measures—cut-in-speed adjustment and acoustic deterrence—with the potential to substantially reduce bat mortality at wind facilities. Small increases in cut-in wind speed (1 – 3 m/s) have shown reductions in mortality of 44% to 93% with minimal impacts to project revenue.

Potential conflicts with existing uses such as military airspace and radar, environmental protection, fisheries, and navigation may turn out to be even greater issues for deployment of offshore wind, particularly in the near-term while the interactions between offshore wind and these uses remain uncertain. To address these barriers, in 2011, the Energy Department initiated additional research projects through a major funding opportunity announcement. More information on the studies initiated under this opportunity can be found in 4.1.3.

2.4.2 Economics

Low prices for natural gas have been identified as stiff competition for wind power. One way to increase the value of wind-generated electricity to the utility is to accurately forecast when it will be available. According to a study conducted by the National Renewable Energy Laboratory (NREL), using day-ahead wind power forecasts for unit commitment can dramatically improve system operation and reduce overall operation costs (6). To improve forecasting, NREL, Xcel Energy, and the National Center for Atmospheric Research developed a dynamic integrated forecast system that combines the outputs of various numerical weather forecasting models and real time observations at wind plants (7). The forecasting error measured in terms of mean-absolute-percent-error decreased dramatically in the three Xcel plants that had the new system installed.

The Energy Department also launched a 6 million USD (7.8 million

USD) project with the National Ocean and Atmospheric Administration (NOAA) and private partners to collect data and assess utility benefits of improved forecasting. The research teams will use LIDAR, SODAR, and other instrumentation to improve NOAA's models that are used by commercial wind power forecasters.

2.4.3 Education and training

According to AWEA, as of February 2012, 256 educational programs offered coursework related to wind energy education and workforce training. Of those programs, 46% are offered by community colleges, technical schools, and training centers; 41% are university programs; 9% are specialty online or research programs; and 4% are in primary and secondary schools (1).

AWEA instituted the Wind Turbine Service Technician Program Seal of Approval and issued three approvals to workforce training programs in Iowa, Oregon, and Texas in 2011.

The Energy Department's Wind for Schools project raises awareness in rural America about the benefits of wind energy and works to develop a wind energy workforce. The project is active in 11 states and has installed 97 small wind systems in host primary and secondary schools. These schools are paired with Wind Application Centers at in-state universities where university students learn by doing and provide host primary and secondary schools with technical assistance related to wind resource and energy usage analysis, siting, permitting, land use, financial analysis, installation of power and data acquisition systems, and analysis of performance data. In 2011, more than 60 university students graduated having been involved in Wind Application Center activities such as engaging in wind-energy-related educational opportunities in and out of the classroom, supporting K-12 schools involved with Wind for Schools, and on-campus employment opportunities.

3.0 Implementation

3.1 Economic impact

Wind energy development in the United States supports at least 472 manufacturing facilities across the nation. In 2011, the U.S. wind industry provided an estimated 75,000 jobs - 30,000 of which were in the manufacturing sector. Nineteen new manufacturing facilities that produce everything from towers and generators to subcomponents came online in 2011 (1).

3.2 Industry status

3.2.1 Utility-Scale sales

GE Energy continued to lead the utility-scale wind turbine manufacturing market in 2011 providing 2,006 MW of wind turbine capacity. Vestas rose to a close second and gained market share to supply 1,969 MW in 2011 compared to 221 MW in 2010. Siemens sales grew to 1,233 MW from 828 MW in 2010. Gamesa sales declined to 152 MW in 2011 from 564 MW in 2010. New sales appeared in 2011 for Aeronautica, Alstom, Goldwind, Hyundai, Kenersys, Sany, Sinovel, Unison, and VENSYS.

3.2.2 Offshore deployment

A resource assessment released by NREL (Figure 1), estimated that the United States has an offshore wind gross resource potential of 4,000 GW at 90 m. This is roughly four times the generating capacity currently carried on the entire U.S. electric grid. Although this number does not consider environmental and socioeconomic constraints, developing even a small percentage of this potential would make offshore wind a substantial contributor to the U.S. electric supply. No offshore wind facilities were installed in 2011, but 15 different projects across 10 states have been proposed as well as an offshore transmission line (1).

3.2.3 Small wind sales

According to preliminary reports from AWEA (1), the small wind systems market declined slightly from 25.6 MW in 2010 to 22.7 MW in 2011. The sales consisted of 2,700 turbines and 135 million USD (174 million EUR) in installed system revenue.

The Small Wind Certification Council (SWCC) certified the first two small wind turbines and issued consumer labels in 2011. Twenty-seven additional turbine models are pursuing certification, which requires conforming to the AWEA Small Wind Turbine Performance and Safety Standard and completing the SWCC or other accredited certification body's review process.

3.3 Operational details

More than 38,000 wind turbines with capacity ratings greater than 1 MW are in commercial operation in the United States, and almost 3,500 turbines were installed in 2011. The average capacity of new turbines installed in 2011 was 1.97 MW, compared with 1.77 MW for 2010. At least 96 projects were completed in 2011. The average project size was 71 MW, up from 48 MW in 2010.

Electricity production from the U.S. wind fleet was 26.5% greater in 2011 than in 2010, and it met 2.9% of total U.S. electrical demand (3). The performance of wind facilities in the United States is being tracked in a reliability database funded by the Energy Department. The Continuous Reliability Enhancement for Wind (CREW) Database enables analysis to improve the performance of wind facilities. Data from the first CREW Benchmark Report (8) covers three seasons and 58,000 turbine-days (the number of turbines times the number of days in the time period) of data.

3.4 Wind energy costs

According to the *2011 Wind Technologies Market Report* (9) the capacity-weighted average sales price in 2011 for bundled power and renewable energy certificates was roughly 74 USD/MWh (55 EUR/MWh). This price is based on a sample of projects built in 2011 and is essentially unchanged from the average of 73 USD/MWh (54 EUR/MWh) for the sample of projects built in 2010, but higher than 61 USD/MWh (45 EUR/MWh) for the sample of projects built in 2009. When grouped by the year in which each project's power purchase agreement ("PPA") was executed rather than by the year in which each project achieved commercial operations, however, the full project sample exhibits *falling* prices since 2009. Specifically, the capacity-weighted average levelized PPA price among those wind power projects with PPAs signed in 2011 is 35 USD/MWh (26 EUR/MWh), down from 59 USD/MWh (44 EUR/MWh) for PPAs signed in 2010 and 72 USD/MWh (54 EUR/MWh) for PPAs signed in 2009.

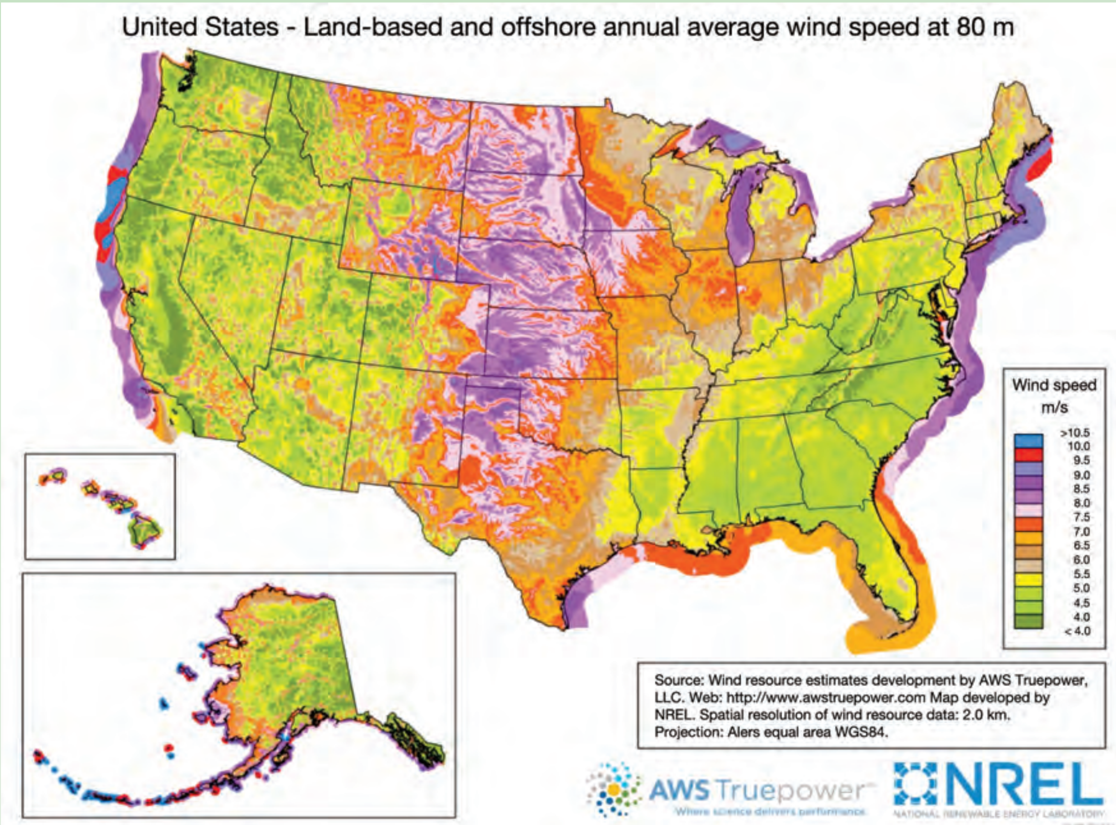

Figure 1. A new 80-m wind resource map produced by NREL and AWS Truepower in 2012 shows the predicted mean annual wind speeds at an 80-m height (Source: NREL)

This discrepancy in price between project and PPA vintage is attributable to an unusually long lag time between when PPAs were signed and when projects achieved commercial operations. For example, some projects that were built in 2011 signed PPAs as far back as 2008 – i.e., at the height of the market for turbines – thereby locking in prices that ended up being above market in 2011 once those projects were finally operational.

Another study published in 2011, *Understanding Trends in Wind Turbine Prices Over the Past Decade* (10), examines seven primary drivers that may have contributed to higher-than-expected turbine prices. Drivers include labor costs, warranty provisions, manufacturer profitability, turbine scaling, raw materials prices, energy prices, and foreign exchange rates. The analysis found that all of the factors contributed to higher prices through 2008. Since 2008, however, turbine prices have declined by roughly one-third. Unlike the other drivers analyzed, increased cost per installed kilowatt due to up-scaling resulted in a lower levelized cost of energy.

To understand factors driving U.S. offshore wind costs, Energy Department researchers developed a pro-forma cash flow model to calculate the levelized cost of energy and the break-even price required for financial viability. They identified input values from their analyses of capital markets and assessment of 35 operating and planned projects in Europe, China, and the United States. They ran the model for inputs appropriate to U.S. policies, electricity markets, and capital markets to assess how changes in policy incentives, project inputs, and financial structure affect the break-even price of offshore wind power. The model and documentation are publicly available (11).

4.0 RD&D Activities

4.1 National RD&D efforts

The Wind and Water Power Program (WWPP) in the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy supports the development and deployment of wind and water power technologies. WWPP is one program that contains two distinct focus areas: wind and water. The Wind Program and the Water Power Program operate as integrated, but separate subprograms within WWPP. The Wind Program makes competitive awards to the wind industry, universities, and 12 U.S. national laboratories to reduce the levelized cost of wind energy through innovative research, specifically in the areas of wind plant performance improvement, increased wind plant reliability, and the development of next-generation wind turbine systems and components. 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 80 million USD (103 million EUR) in fiscal year 2011 and will rise to 93.5 million USD (120.9 million EUR) in 2012. The Energy Department requested 95 million USD (122 million EUR) for the Wind Program for 2013 (12).

Figure 2. Large wind turbines commissioned at Energy Department-supported test sites in 2011. Left to right: Clipper Liberty 2.5-MW; Gamesa G97 2-MW Class IIIA; Alstom 3-MW Eco 100

4.1.1 Test facilities update

Megawatt-scale turbine testing

The Energy Department is currently conducting testing on four full-scale wind turbines at NREL's National Wind Technology Center (NWTC); a GE 1.5-MW turbine purchased by the Energy Department, a Siemen's 2.3-MW turbine, an Alstom 3-MW turbine, and a Gamesa 2-MW turbine (Figure 2). The Alstom and the Gamesa turbines, which were installed in 2011, will undergo power quality, acoustic noise, and system performance tests. The measurements will be carried out according to IEC standards.

Also in 2011, the Energy Department funded university-led consortia with industry to acquire utility-scale wind turbines, conduct R&D, and train the next generation of wind industry technicians and engineers. The University of Minnesota installed its first large wind turbine, a 2.5-MW Clipper Liberty wind turbine, at the new Eolos Wind Energy Research Station in Rosemont, Minnesota, and the Illinois Institute of Technology installed a 1.5-MW GE wind turbine located at a wind farm in Marseilles, Illinois.

The Energy Department is building a new test site near Texas Tech University in Lubbock, Texas, to help manufacturers and developers improve turbine reliability and wind farm performance. Initially, the site will include two 225-kW wind turbines and three anemometer towers, with the potential to expand to nine or more wind turbines. Sandia National Laboratories, Texas Tech, and Group National Institute of Renewable Energy will operate the facility to explore turbine-to-turbine interactions; evaluate innovative rotor technologies; and investigate aero-acoustics, aero-elasticity, and structural health monitoring using embedded sensor systems.

New blade test facility opens

The Wind Technology Testing Center in Boston, Massachusetts, was opened in May 2011 and it completed its first test on a commercial blade. Constructed with funding from the Energy Department through the Recovery Act and from the state of Massachusetts, it is the first facility in the United States equipped to test blades up to 90 m long. The facility's high bay features three test stands and an overhead bridge crane rated for 100 tons. The facility provides industry partners with commissioning testing, prototype development, blade repair, and workforce training (Figure 3).

Drivetrain test facilities

In 2011, construction began on a 5-MW dynamometer test facility funded under

Figure 3. A 46.7-m blade undergoing commissioning tests at the new Wind Technology Testing Center in Boston, Massachusetts (Source: NREL/PIX 19939)

the Recovery Act at NREL's NWTC. The facility will test the largest wind turbine drivetrains used in land-based markets. It will simulate wind loads in six degrees-of-freedom, the most complete simulation of wind turbine operating conditions available in North America. The dynamometer test facility will also simulate the grid connection for tests of low-voltage ride-through capability, response to faults, and reaction to other abnormal grid conditions.

Also through the Recovery Act, the Energy Department is funding the construction of a test facility for large drivetrains in South Carolina. The new facility is being built by Clemson University at the Charleston Naval Complex. It will have 7.5-MW and 15-MW dynamometers for testing land-based and offshore wind turbine drivetrains and will feature power analysis equipment capable of performing highly accelerated endurance testing.

4.1.2 Selected research progress

Offshore wind development

Floating wind turbine platforms will be needed to take full advantage of the vast offshore wind resources in the United States because most of that resource is located over water with depths greater than 60 m. To account for dynamic responses of floating platforms, a new NREL-enhanced simulation tool (13) combines the computational methodologies used to analyze land-based wind turbines with hydrodynamic computer programs and methodologies developed for the offshore oil and gas industries. The tool was used to analyze three floating-platform concepts: a tension-leg platform, a spar buoy, and a barge system.

Components

The Energy Department awarded 7.5 million USD (9.7 million EUR) to six companies in 2011 to support the development of the next generation of advanced drivetrains for both land-based and offshore wind turbines. The recipients will conduct technology cost and readiness assessments for six months and then compete to receive additional funds to conduct performance tests on their new designs.

Drivetrains

To validate the typical gearbox design process, the Energy Department and NREL launched the Wind Turbine Gearbox Reliability Collaborative in 2006. The collaborative brought together the world's leading turbine manufacturers, consultants, and experts from more than 30 companies and organizations to conduct a comprehensive dynamometer and field-test program on extensively instrumented gearboxes. The group's first report, published by NREL in 2011 (14), describes the project's major objectives, the activities conducted to date, and findings that will help to improve wind turbine gearbox reliability. The report also contains recommendations for future research.

Blades

Sandia National Laboratories (Sandia) began field-testing its Structural and Mechanical Adaptive Rotor Technology blades in 2011. The new blades are based on the Sandia CX-100 blade design and incorporate small trailing-edge flaps along the outer 6 ft of each 30-ft blade. The small, lightweight flaps are driven by individual electric actuators and are designed to respond quickly to wind velocity changes caused by gusts or vertical wind shear. They have internally mounted structural sensors and surface-mounted aerodynamic sensors. The result should be improved control during peak loads. The experimental data will be used to quantify the benefits of this approach.

The Blade Reliability Collaborative is a project lead by Sandia with participation of industry partners active in the blade supply chain. The Collaborative works to address the reliability of wind turbine blades as they are delivered to the field and operated for the turbine lifetime. The Collaborative is using a database of blade failures, analyses on the effects of defects, and evaluation of inspection techniques in order to better design, test, and certify wind turbine blades for higher reliability.

The Advanced Manufacturing Initiative at Sandia is working with industry to improve manufacturing processes and create U.S. jobs by improving labor productivity in wind turbine blade construction. In 2011, this effort completed a virtual factory model for a plant owned by research partner TPI Composites. The team also demonstrated a true 3-D laser projection system coupled to 3-D composite part simulation software that resulted in labor savings of 10.4% for blade molding and 3.75% for total labor per blade.

Grig integration studies

Phase 1 of the Western Wind and Solar Integration Study (15) found that penetration levels up to 30% of wind and 5% of solar energy would be feasible if significant changes were made to operating practices, such as balancing area cooperation and intra-hour scheduling. Phase 2 of the study, launched in 2011, will explore the increased maintenance costs resulting from more frequent ramping and cycling of conventional coal and gas generators to accommodate wind and solar energy. The work will identify when it makes sense to upgrade a conventional generator to better accommodate wind and solar, and it will develop options to lower overall costs by reducing the cycling and ramping of conventional generators.

4.1.3 Selected new projects

Offshore wind technology

The Energy Department awarded 43 million USD (55 million EUR) (subject to Congressional appropriations) for 41 offshore wind R&D projects across 20 states over the next five years. Nineteen projects will address technical challenges that include R&D for key components such as floating support structures and turbine rotor and control subsystems that reduce capital costs; advancement of the current state-of-the-art modeling and analysis tools; and development of conceptual designs that enhance energy capture, improve performance and reliability, and reduce costs. Twenty-two projects will address factors limiting deployment of offshore wind, including market and economic analysis; environmental risk reduction; manufacturing and supply chain development; transmission planning and interconnection studies; optimizing infrastructure and operations; resource characterization; and impact on electronic equipment and the marine environment.

Continuing grid integration studies

New research at NREL is exploring the ability of wind power plants to provide active power control or ancillary services. The research includes the economic, dynamic, and structural impacts to the utility system and to the wind turbine and its components. The study seeks to document how allowing wind to provide these controls will serve to support system reliability and earn potential additional revenues in ancillary services markets.

The Eastern Renewable Generation Integration Study, begun in 2011, addresses items identified in previous studies and explores how to plan and operate the Eastern Interconnection in the face of generation and transmission uncertainty. The study will evaluate the ability of greater inter-regional cooperation, geographic diversity and sub-hourly scheduling to provide operational flexibility, identify the need for any mitigation strategies (e.g., demand response, energy storage, wind curtailment) at high levels of penetration, develop and test various reserve strategies to accommodate ramping requirements (e.g., renewable generation, load, and net load ramps), explore the impact of key assumptions on analytical results (e.g., transmission reinforcements, emissions rules, fuel costs), and provide more detailed analysis of results (e.g., regional and inter-regional impacts).

4.2 International collaborative research

In 2011, the Energy Department published the results of a global examination of successful wind energy grid integration practices. The project gathered insights from 33 grid operators in 18 countries for the integration of more than 141 GW of installed wind capacity. The resulting report outlines the best practices discovered (16).

The Energy Department Wind Program is collaborating with SWAY AS, Norway, to collect and analyze data for a 1/5 scale prototype deployed offshore near Rong, Norway. The data will be used to validate numerical models for simulating offshore wind turbines. The Energy Department is also collaborating with Principle Power on a project in Portugal to assess the performance and viability of WindFloat, a 2-MW demonstration project that supports a Vestas V80 turbine with a semisubmersible support structure. WindFloat places the turbine on one of the three columns rather than at the center of the platform.

Other international collaborations in 2011included work with the International Electrotechnical Commission, the Institute of Electrical and Electronics Engineers, Underwriters Laboratory, the International Measuring Network of Wind Energy Institutes, and the IEA Wind Implementing Agreement.

U.S. researchers benefit from IEA Wind topical expert meetings sponsored by IEA Wind Task 11, Base Technology Information Exchange. The Energy Department Wind Program supported U.S. researchers, who acted as managers (operating agents) for Task 24, Integration of Wind and Hydropower Systems (which issued final technical reports in 2011); Task 26, Cost of Wind Energy; Task 30, OC4; and Task 31, Benchmarking of Wind Farm Flow Models. U.S. experts participate in Task 25, Power Systems with Large Amounts of Wind Power, which addressed issues of grid integration that are relevant in all countries. The U.S. representatives worked with Task 27, Consumer Labeling of Small Wind Turbines, to develop a labeling protocol for small wind turbines. The United States also will participate in the new IEA Wind Task 32, Lidar Systems for Energy Development.

5.0 The Next Term

In March 2012, the Energy Department announced that 180 million USD (232 million EUR) (subject to Congressional appropriations) will be made available over the next six years to accelerate the development and deployment of breakthrough offshore wind power technologies. An initial 20 million USD (26 million EUR) will be available in 2012 as the first step in supporting up to four innovative offshore wind energy installations across the country. Also in early 2012, the Energy Department held a workshop to identify opportunities for improvements in wind plant performance though a better understanding of complex aerodynamic phenomena. Given that power losses from wake interactions and other complex aerodynamics can be as high as 20%–30% in operating wind farms, research in this area can have a significant impact on reducing the cost of wind energy. In the coming term, complex flow R&D will be a vital part of the Energy Department's research portfolio. The Energy Department also will expand its efforts on market acceleration and continue its ongoing R, D&D activities.

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Opening photo: The Red Hill Wind Farm, located north of Elk City, Oklahoma, comprises 82 1.5-MW wind turbines (NREL/PIX 16491)

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Appendix A

ExCo Meeting 67 Amsterdam, the Netherlands

Appendix B

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Appendix C

Currency Conversion Rates IEA Wind Annual Report 2011			
Country	Currency	1 EUR	1 USD
Australia	AUD	0.786	0.983
Austria	EUR	1	1.294
Canada	CAD	0.757	1.021
China	Yuan	0.123	0.159
Denmark	DKK	0.134	0.174
Finland	EUR	1	1.294
Germany	EUR	1	1.294
Greece	EUR	1	1.294
Ireland	EUR	1	1.294
Italy	EUR	1	1.294
Japan	JPY	0.0099	0.013
Korea	KRW	0.000599889	0.0008642
Mexico	MXP	0.055	0.072
Netherlands	EUR	1	1.294
Norway	NOK	0.129	0.167
Portugal	EUR	1	1.294
Spain	EUR	1	1.294
Sweden	SEK	0.112	0.145
Switzerland	CHF	0.823	1.064
United Kingdom	GBP	1.126	1.62212
United States	USD	0.744	1
"Source: Federal Reserve Bank of New York (www.x-rates.com) 30 December 2011"			

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

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.
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

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.

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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Front cover photo: The ECN scaled wind farm at Wieringermeer, the Netherlands consists of 10 (relatively small) 10-kW turbines for conducting research on wind farm effects and innovative methods to increase the output of a wind farm. Photo: Rick Hinrichs

Back cover photo: Lisheen wind farm of 2-MW Vestas V90 turbines located at a Zinc mine of Borda Gáis Energy, Ireland. The turbines provide electricity for the mining operations. Cattle graze around the wind turbines and above the deep mine. The animals are tested regularly to monitor any environmental impacts of the operations. Photo: Rick Hinrichs

IEA WIND

World wind capacity now generates enough electricity to meet about 3% of the world's electricity demand. In 2011, 85% of the world's wind generating capacity resided in the member countries of the International Energy Agency Wind Implementing Agreement (IEA Wind). During that year, these countries added nearly 34 GW (33,600,000,000 Watts) of wind generation for a total of about 203 GW of wind generating capacity.

Through IEA Wind, the participating countries work together to increase the contribution of wind energy to their electrical generation mix. Sharing information and working in co-operative research tasks greatly multiplies the efforts of each country and advances wind energy development. Members come from Europe, North America, Asia, and the Pacific. Potential new member countries are encouraged to attend meetings and begin the process of joining.

This *IEA Wind 2011 Annual Report* presents the work of the co-operative research tasks, including contributions to IEC standards development for grid integration, aerodynamic model advances, research supporting offshore wind deployment, work to label small wind turbines, work to understand public acceptance of wind energy projects, and development of analysis tools to advance the technology and reduce the costs of wind energy.

The 20 member countries, the Chinese Wind Energy Association, the European Commission, and the European Wind Energy Association have contributed information for 2011 about how they have progressed in the deployment of wind energy, how they are benefiting from wind energy development, and how they are devising strategies and conducting research to increase wind's contribution to the world energy supply.

iea wind

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