

# IEA *Wind*

2010 Annual Report



iea wind



# IEA WIND

## 2010 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 2011

ISBN 0-9786383-5-2



# Message from the Chair



Welcome to the 2010 IEA Wind Annual Report on the cooperative research, development, and deployment (R,D&D) efforts of our member governments and organizations. With great pleasure, we present information from our newest member, the Chinese Wind Energy Association (CWEA), which represents more than 800 groups (institutes, companies, etc.) and several thousand individual experts on wind energy in China. We look forward to this broadening of participation in our information exchange and research tasks. With the addition of organizations from China, IEA Wind helps advance wind energy in countries representing 84% of the world's wind generating capacity.

Working together, we accomplished a lot this year to help our members get the most from precious research investments. We published five important technical reports on offshore wind issues, code comparison for offshore support structures, integration of wind and hydropower systems, the cost of wind energy, and public

acceptance of wind energy projects. Full proceedings were published of Topical Expert Meetings on radar, radio, and links with wind turbines; sound propagation models and validation; and remote wind speed sensing techniques using SODAR and LIDAR. Four new Topical Experts Meetings were held on wind conditions and wind turbine design; high-reliability solutions and innovative concepts for offshore wind turbines; micrometeorology inside wind farms and wakes between wind farms; and wind farms in complex terrain. We approved a new research task to improve our ability to design the most productive wind farms and to predict energy output from wind farms both on land and offshore.

Next year, we expect to approve several new IEA Wind Recommended Practices to provide pre-normative guidelines for the wind community while formal standards efforts are under way. These will include consumer labeling of small wind turbines, remote wind speed sensing techniques using SODAR and LIDAR, and good practices for public acceptance of wind energy projects. In addition, six active research tasks will generate technical reports based on their terms ending in 2011.

To make best use of our time and resources, we used the IEA Technology Roadmap for Wind Energy and the mid-term report to IEA of our accomplishments and goals to update our strategic plan through 2014. Under this framework, our active research tasks will prepare proposals for work beyond 2011 and new tasks will be approved.

It is with great confidence that I pass the Chair to Hannele Holtinen who will guide IEA Wind through another landmark year.

A handwritten signature in black ink that reads "Brian Amthor".

Chair of the Executive Committee,  
2009 to 2010



EXECUTIVE SUMMARY .....	4
SECTION I The Implementing Agreement and Active Research Tasks	
Chapter 1 The Implementing Agreement .....	20
Chapter 2 Base Technology Information Exchange – Task 11 .....	25
Chapter 3 Wind Energy in Cold Climates – Task 19 .....	29
Chapter 4 Power Systems with Large Amounts of Wind Power – Task 25 .....	31
Chapter 5 Cost of Wind Energy – Task 26 .....	35
Chapter 6 Consumer Labeling of Small Wind Turbines – Task 27 .....	38
Chapter 7 Social Acceptance of Wind Energy Projects – Task 28 .....	41
Chapter 8 MexNex(T): Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models – Task 29 .....	44
Chapter 9 Offshore Code Comparison Collaboration (OC4) Project – Task 30 .....	48
Chapter 10 WAKEBENCH: Benchmarking of Wind Farm Flow Models – Task 31 .....	51
SECTION II Member Country Activities	
Chapter 11 Australia .....	54
Chapter 12 Austria .....	58
Chapter 13 Canada .....	62
Chapter 14 Chinese Wind Energy Association .....	68
Chapter 15 Denmark .....	75
Chapter 16 The European Commission/EWEA (European Wind Energy Association) .....	82
Chapter 17 Finland .....	89
Chapter 18 Germany .....	95
Chapter 19 Greece .....	101
Chapter 20 Ireland .....	105
Chapter 21 Italy .....	110
Chapter 22 Japan .....	117
Chapter 23 Republic of Korea .....	121
Chapter 24 Mexico .....	124
Chapter 25 The Netherlands .....	128
Chapter 26 Norway .....	134
Chapter 27 Portugal .....	138
Chapter 28 Spain .....	143
Chapter 29 Sweden .....	150
Chapter 30 Switzerland .....	154
Chapter 31 The United Kingdom .....	158
Chapter 32 The United States .....	164
APPENDICES	
Appendix A Photo of The Executive Committee .....	171
Appendix B List of Executive Committee Members and Operating Agents .....	172
Appendix C Currency Exchange Rates .....	174
Appendix D Abbreviations and Terminology .....	175



# Executive Summary

## 1.0 Introduction

In 2010, worldwide wind power capacity increased by 38.3 GW, or a little more than 24% to around 200 GW (1 and 2) (Tables 1–3). In 2010, the IEA Wind membership represented more than 85% of the world's wind capacity with the addition of the Chinese Wind Energy Association as the newest member. The IEA Wind member countries added 31.86 GW of capacity in 2010. With about 170 GW of generating capacity, electrical production from wind met 2.3% of the total electrical demand in the reporting IEA Wind member countries including China (Table 2). For the countries reporting in 2009 (excluding China), 2010 generation met 2.8% of their total electrical demand up from 2.5% in 2009.

In this *IEA Wind 2010 Annual Report*, the IEA Wind member countries report 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. This Executive Summary synthesizes the information presented in the country chapters and in the reports of the IEA Wind research tasks undertaken by participants for their shared benefit. As background for 2010, data from the past 15 years as reported in documents of IEA Wind (3) are also included.

## 2.0 National Objectives and Progress

Eighty-five percent of the world's wind generating capacity is operating in the member countries of IEA Wind (Table 2). Governments and industry in IEA Wind member countries recognize that renewable energy in general, and wind energy in particular can help reduce overall carbon emissions of the power industry, reduce the cost of electricity, and decrease reliance on imported fuels. They have set national targets for renewable energy and wind energy and designed incentive programs to help reach these targets.

### 2.1 National targets

The member countries of IEA Wind have targets and goals for increasing the amount of renewable energy, or low-carbon

energy, in the electrical generation mix. 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. For example, in 2008, the European Union (EU) agreed to an overall 20% renewable energy target for 2020 divided into legally binding targets for the 27 member states. During 2010, all EU member states submitted National Renewable Energy Action Plans (NREAPs) detailing sectoral and technology-specific targets and policy measures to reach their 2020 RES target. Summing the 27 NREAPs, it is expected that more than 34% of EU electricity demand will be covered by RES, almost half of that (14%) by wind energy. According to the NREAPs, installed wind capacity in the EU will increase from 84.3 GW at the end of 2010 to 213.4 GW in 2020 with 170.1 GW onshore and 43.3 GW offshore. By 2018, the EC will publish a Renewable Energy Roadmap for the post-2020 period.

Outside the EU, the other IEA Wind member countries are also setting ambitious targets. In Australia, the expanded Renewable Energy Target (RET) scheme, which took effect 1 January 2010, mandates that 20% of Australia's electricity supply be sourced from renewable energy in 2020. The RET is expected to unlock more than 20 billion AUD (14.68 billion euro; 19.74 billion USD) in investment over the next decade. 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. Individual Canadian provinces have goals

as well. China reached its five-year-plan goal of 10 GW of wind by 2010 in 2008. The Chinese government has the strategic objective that non-fossil energy will represent 15% of the energy mix by 2020. The United States announced a goal to generate 80% of the nation's electricity from clean energy sources by 2035 and a shorter-term goal to double the nation's electricity generation capacity from renewable sources by 2012.

## 2.2 Progress

### 2.2.1 Capacity increases

Capacity in the IEA Wind member countries as a whole has increased from less than 5 GW in 1995 to about 170 GW in 2010 (Figure 1). In 2010, wind generation capacity increased in every IEA Wind member country, and in all they added more than 31.8 GW. Fifteen countries added more than 100 MW of new capacity, and four countries added more than 1 GW of new capacity: China (19.9 GW); the United States (5.2 GW), Spain (1.5 GW), and Germany (1.5 GW) (Tables 3 and 5). Canada, Denmark, Italy, Portugal, Sweden, and the United Kingdom also added 300 MW or more.

Although overall rates of increase are slowing or leveling out, record increases in capacity were reported in Austria, China, and Switzerland thanks to improved incentive schemes. Increases in capacity were less than hoped for in other countries because of uncertainty about government programs, very low prices for competing energy, or the general economic slowdown. Switzerland had the highest growth—a 137% increase—largely due to a new cost-covering feed-in-tariff (FIT) for renewable energy. By the end of 2010, financing was requested

**Table 1 Key Statistics of IEA Wind Member Countries 2010**

Total installed capacity	169.70 GW
Total offshore wind capacity	2.93 GW
Total new wind capacity installed	31.86 GW
Total annual output from wind	298 TWh
Wind generation as % of national electric demand	2.3%

Table 2 Worldwide Installed Capacity for 2010*			
IEA Wind Members*		Rest of World**	
Country	MW	Country	MW
China	44,773	India	13,065
United States	40,267	France	5,660
Germany	27,204	Others	2,881
Spain	20,676	Japan	2,304
Italy	5,797	Turkey	1,329
United Kingdom	5,270	Poland	1,107
Canada	4,124	Brazil	931
Portugal	3,987	Belgium	911
Denmark	3,802	Egypt	550
Japan	2,304	Taiwan	519
Netherlands	2,245	New Zealand	506
Sweden	2,163	Morocco	286
Australia	1,880	Chile	172
Ireland	1,415	Costa Rica	123
Greece	1,210	Tunisia	114
Austria	1,011	Caribbean	99
Mexico	520	Iran	92
Norway	435	Argentina	60
Korea	381	Philippines	33
Finland	197	Pacific Islands	12
Switzerland	42	Total	30,754
TOTAL	169,703	Grand Total	200,457
		* Numbers reported by IEA Wind member countries.	
		**Numbers reported by GWEC (1)	

the year. In Spain, the capacity reached in 2010 met the 2010 objective of the Renewable Energies Plan 2005–2010.

Among the IEA Wind member countries, about 3 GW of offshore wind systems were operating at the close of 2010. Offshore wind farm capacity increased by nearly 1 GW in 2010 in the IEA Wind member countries. In the EU, 883 MW of offshore wind was installed, bringing cumulative installations to 2.95 GW in 45 wind farms in nine countries. Offshore wind installations represented 3.5% of the wind power capacity in the EU at the end of 2010.

### 2.2.2 Electrical production

Annual national electrical demand for 2010 increased in 11 IEA Wind member countries, decreased in 6, and stayed the same in the rest of the 21 countries reporting (3) (Table 2). The 170 GW of wind generating capacity met 2.3% of the total electrical demand in the reporting IEA Wind member countries including China (Table 2). For the countries reporting in 2009 (excluding China), 2010 generation met 2.8% of their total electrical demand up from 2.5% in 2009. Denmark's wind capacity contributed 21.9% of that country's electrical demand. In Portugal, contribution from wind increased from 15% in 2009 to 17% in 2010, even though Portugal's national electrical demand increased during 2010. Portugal's wind contribution surpassed Spain's impressive increase from 14.4% in 2009 to 16.4% in 2010.

### 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 7). FITs were used by 15 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 or renewable portfolio standards (RPS).

Some new incentive programs were employed or announced by the IEA Wind member countries. In January 2011, Australia separated the incentive scheme into the Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES) to ensure a better market for household technologies that would not crowd out

for additional 1,212 MW in Switzerland under the new tariff scheme. In Austria, a new FIT stimulated the addition of 16 MW in 2010 after four years of no new installations. Another 800 MW of projects in Austria have received planning permits. China increased its capacity more than 73% in 2010 thanks to concerted government efforts to develop renewable energy sources.

In the EU, wind power installations accounted for 17% of new power installations in 2010, and wind represented 10% of the total EU power generation capacity. That wind power capacity will produce

181 TWh, meeting 5.3% of gross EU final power consumption in an average wind year, avoiding about 115 million tons of CO<sub>2</sub> annually.

Several countries reported meeting or exceeding their targets in 2010 or before. China exceeded its goal of 10 GW by 2010, when more than 12 GW were already operating in 2008. Figures from the Danish Energy Agency show that the national target of 20% of gross energy consumption supplied from renewable energy sources by 2011 was fulfilled in 2010. Portugal met its EU Directive 2001/77/CE target for 2010 during the first half of

**Table 3 National Statistics of the IEA Wind Member Countries for 2010**

Country	Total installed wind capacity (MW)	Offshore installed wind capacity (MW)	Annual net increase in capacity (MW)	Total no. of turbines	Average new turbine capacity (kW)	Wind-generated electricity (TWh/yr)	National electricity demand (TWh/yr)	% of national electricity demand from wind*
Australia	1,880	0	167	1,058	2,000	<b>5.10</b>	<b>261</b>	2.0%
Austria	1,011	0	16	625	2,000	2.10	70.7	3.0%
Canada	<b>4,124</b>	<b>0</b>	<b>836</b>	<b>2,510</b>	<b>2,000</b>	<b>**9.98</b>	<b>**549.9</b>	<b>**1.8%</b>
China	44,773	102	18,928	34,485	1,467	50.10	4,192.0	1.2%
Denmark	3,802	868	320	5,033	2,200	7.81	35.6	21.9%
Finland	197	26	50	130	3,076	0.29	<b>86.3</b>	0.3%
Germany	27,204	180	1,488	<b>21,585</b>	<b>2,057</b>	<b>36.50</b>	<b>604.0</b>	<b>6.0%</b>
Greece	1,210	0	101	1,357	1,145	2.71	<b>57.0</b>	4.0%
Ireland	1,415	25	115	<b>1,000</b>	<b>2,000</b>	<b>2.89</b>	<b>27.5</b>	<b>10.5%</b>
Italy	5,797	0	948	4,852	1,541	8.38	326.2	<b>2.6%</b>
Japan	2,304	25	211	1,742	1,586	3.94	901.5	0.4%
Korea	381	0	33	234	1,381	0.81	451.1	0.2%
Mexico	520	0	105	430	1,200	1.30	219.0	0.6%
Netherlands	2,245	228	29	2,000	1,982	4.60	115.0	4.0%
Norway	435	2	4	201	2,300	0.91	130.4	0.7%
Portugal	3,987	0	371	2,067	2,000	9.02	52.2	17.0%
Spain	20,676	0	1,516	18,933	1,854	42.70	259.9	16.4%
Sweden	2,163	133	604	1,723	1,987	3.50	132.2	2.6%
Switzerland	42	0	24.5	<b>47</b>	<b>1,900</b>	<b>0.03</b>	<b>57.7</b>	<b>0.05%</b>
United Kingdom	5,270	1,341	876	3,324	1,900	10.02	381.2	2.6%
United States	40,267	0	5,113	35,892	1,769	94.65	4,120.0	<b>2.3%</b>
Totals	169,703	2,930	31,855	139,228	1,878	297.34	13,030.4	2.3%

\*% of national electricity demand from wind = (wind generated electricity/national electricity demand) × 100  
 Bold italic = estimated; \*\*value from 2009.

investment in industrial-scale development. Austria introduced a FIT in 2010. Finland is moving to a FIT and away from investment subsidies. In Germany, wind turbines, which can support electricity grids in critical conditions (e.g., low frequency), receive a bonus of 5 euro/MWh (6.7 USD/MWh). In Greece, a new law accelerates licensing procedures, reduces administrative burdens on the renewable energy sector, promotes the development of offshore wind parks, and provides priorities regarding license procedure of RES projects combined with desalination. Italy will make a transition from tradable green certificates to a FIT

for energy production, some of which would be awarded through calls for tenders. Japan will change from RPS and investment subsidies to a FIT system in 2012. Korea is adding an RPS effective in 2012. The Netherlands has a different incentive scheme for offshore projects than for projects on land. That country also revised incentives such that turbines larger than 6 MW or operating up to 3,095 full load hours per year could qualify. Norway is planning a green certificate program to replace grant and subsidy programs. Now there are sellers and purchasers of certificates, and the market brings them together. The United Kingdom increased

the level of support for offshore wind projects accredited between April 2010 and March 2014.

In Sweden, the website Vindlov.se, launched in February 2010, takes a unique approach targeting permitting bottlenecks. The website provides information on wind project permitting issues from nearly twenty public authorities from a wide range of sectors. This includes permission information over the life cycle of wind power projects, features a dynamic web map, and provides contacts to wind power handlers at all authorities.

In several countries, special incentive programs are being introduced to



encourage small wind development. In Canada, the province of Nova Scotia introduced a new FIT specifically for small wind—the first in the country. The UK introduced a FIT scheme to incentivize small-scale (less than 5 MW) low-carbon electricity generation including small-scale onshore wind.

#### 2.4 Issues affecting growth

Nearly 12 GW of wind energy projects were under construction at the close of 2010 in the IEA Wind member countries, and another 39 GW had received planning

approvals (Table 8). These statistics project more than 50 GW of added capacity for 2011 in the IEA Wind member countries as compared with the 32 GW installed in 2010. Another 75 GW of projects have applied for permits by the close of 2010. 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 2010 and likely to reduce growth in 2011.

Government programs to increase access to financing, provide larger subsidies, and issue targeted grants are mentioned to reduce the effects of this problem. A German study in 2010 concluded that the worldwide financial crises hampered the acquisition of debt capital and slowed the growth of the German market, especially offshore. Acquisition of debt capital was seen to be the number one obstruction to increasing wind energy capacity.

In many countries, the electrical grids are adapted to the needs of centralized, large-scale power plants, and their

Table 4 Renewable Energy and Wind Targets for Member Countries		
Country	Official Target RES	Official Target Wind
Australia	45 TWh by 2020	----
Austria	1.951 GW by 2015; 2.578 GW by 2020	----
Canada	----	----
China	----	90 GW (5 offshore) by 2015; 150 GW (30 offshore) by 2020
Denmark	20% of gross energy consumption in 2011 and 30% in 2020	----
European Commission	20% renewable generation by 2020	----
Finland	6 TWh/yr (2.5 GW) in 2020	----
Germany	35% of electrical energy consumption by 2020	10 GW offshore by 2020
Greece	----	10.7%
Ireland	15% in 2010; 40% by 2020	----
Italy	17% by 2020	12.68 GW and 20 TWh/yr by 2020
Japan	25% reduction of CO <sub>2</sub> by 2020 as compared to 1990 level	3.0 GW by FY2010
Korea, Republic of	----	7.3 GW by 2030
Mexico	----	2.5 GW by end of 2012; 3% of national electric demand
The Netherlands	14% of gross energy consumption by 2020; 20% reduction CO <sub>2</sub> in 2020 as compared to 1990 level	----
Norway	----	----
Portugal	----	6.875 GW by 2020
Spain	Official network planning of 29 GW by 2016; 38 GW by 2020	
Sweden	----	----
Switzerland	----	0.600 TWh/yr in 2030
United Kingdom	15% by 2020	----
United States	----	----
* ---- = no official target available		

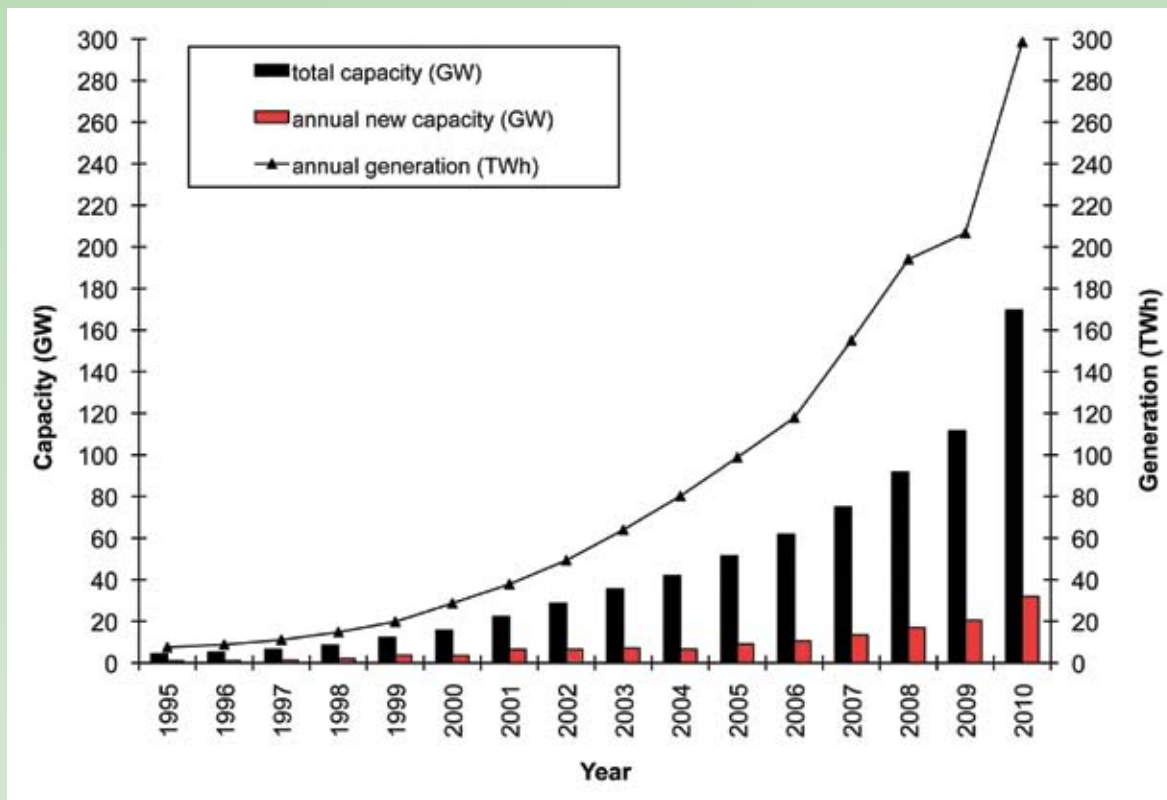


Figure 1 Annual installed capacity, cumulative installed capacity, and annual generation as reported by IEA Wind member countries, 1995–2010 (Note: China is first represented in 2010.)

capacity is limited to existing generation and demand. Some of these systems must absorb large amounts of wind power. In Italy, wind farm owners reportedly suffered production losses totaling about 467 GWh because of curtailments in southern Italy during 2010. The Italian utility regulator issued a document on dispatching, with a view to indemnifying producers, saying that wind models with inputs from reference anemometers should be applied.

Delays due to permitting requirements have limited wind developments in several countries. The European Wind Energy Association (EWEA) published a report on construction and grid consenting processes across Europe. EWEA found that the average construction consent lead time for onshore wind in the EU was 42.3 months, during which consultation with an average of 18 relevant authorities was required. These statistics only include successful project applications and do not account for the projects that were rejected. Italy addressed differing rules from one area of the country to another by issuing decrees jointly with the state government and the conference of regions providing a

common framework to design state regulations. The United States reports concerns about radar interference as a significant barrier in some areas. In Japan, strict building codes revised in 2007 have limited wind energy development somewhat.

In several countries, government cost-cutting measures have targeted funds allocated for incentive programs. An improved support scheme is credited with restarting the wind energy market in Austria. However, annual funds for new projects (21 million euro; 28.2 million USD) is too low to give contracts to all 800 MW of projects that have applied for contracts. Negotiations were underway to increase the funds. Uncertainty about future support schemes has slowed markets in several countries (Australia, Italy, Norway, and Spain).

China faces a shortage of qualified wind industry personnel and strives to increase the number of graduates from domestic universities with degrees in wind energy. In Germany, although the job market is very attractive there is a shortage of highly qualified people, which will limit industrial growth. Therefore—partly supported by the industry—several

universities and universities of applied sciences opened new positions for wind energy professorships. China also sees the need for enforcement of standards to regulate the rapidly expanding market and to guarantee reliability of operation and quality control in manufacturing.

### 3.0 Implementation

#### 3.1 Economic impact

Wind energy development provides significant positive economic impacts. Table 9 shows reported effects for 2010. In Australia, new financial investment in wind power in the 2009–2010 Australian financial year was almost 1.6 billion USD (2.15 billion euro), according to Bloomberg New Energy Finance. According to the Canadian Wind Energy Association, every 1,000 MW of new installed wind generation capacity provides a minimum of 3 million CAD (2.23 million euro; 2.99 million USD) in annual lease payments for farmers and other rural landowners as well as a similar amount in new taxes for rural municipalities. The Chinese Wind Energy Association estimates that more than 297,000 people worked in the Chinese wind power industry in 2010. In that

<b>Table 5 Wind Energy Capacity Increases in IEA Wind Member Countries</b>			
Country	Total capacity 2009 (MW)	Capacity added in 2010 (MW)	Increase (%)
Switzerland	18	24	137.2
China	25,845	18,928	73.2
Sweden	1,448	604	41.7
Finland	147	50	34.0
Mexico	415	105	25.3
Canada	3,319	836	25.2
United Kingdom	4,394	876	19.9
Italy	4,849	948	19.5
United States	35,086	5,115	14.6
Japan	2,056	211	10.3
Portugal	3,616	371	10.3
Australia	1,712	167	9.8
Denmark	3,480	320	9.2
Greece	1,109	101	9.1
Ireland	1,264	115	9.1
Korea	392	33	8.4
Spain	19,148	1,516	7.9
Germany	25,777	1,488	5.8
Austria	995	16	1.6
Netherlands	2,216	29	1.3
Norway	431	4	0.9
Overall	137,717	31,857	23%

same year, wind-generated electricity supplied the power needs of more than 33.4 million families in China.

In Italy, a study by the national wind energy association and a trade union estimated that, if a wind potential of 16,200 MW were to be fully exploited in Italy, some 67,000 people would be employed in the wind sector by 2020, including indirect employment.

In Mexico, the need to include fair social benefits to wind landowners (especially to peasants) in the negotiation of wind power projects has been recognized. Planning studies for deploying wind power at the national level have not yet been carried out.

### 3.2 Industry status

The wind industry is growing, and several countries make concerted efforts to attract

wind turbine manufacturers to their domestic economies. In 2010, domestically manufactured wind turbines represented 89.5% of installed capacity in China. Sixty Chinese wind turbine manufacturers had at least developed prototypes in 2010. Of these, 25 had started batch production. Four of these manufacturers had annual production of more than 1,000 units of MW-class turbines; another three produced 500 units per year; 13 manufacturers produced 100 units per year; and the other five manufacturers have annual production between 50 and 100 units. The local supply chain for these manufacturers is improving; more than five manufacturers make blades for 3-MW turbines. International players have increased their investments in the Chinese market. Vestas and Suzlon are setting up new R&D centers

in China to support technology R&D for the Chinese market.

Among newly installed wind turbines in Korea in 2010, 70% were supplied by domestic manufacturers. Net sales of the Korean wind energy business increased 76% over the previous year with an estimated 1.565 billion USD (1.164 billion euro). The number of manufacturers has doubled from 12 to 24 since 2004, and an estimated 1,103 people were employed by the wind industry in 2010. The export of turbines began in 2009 with sales of 50 million USD (37.2 million euro). In 2010, sales were estimated at 207 million USD (154 million euro).

The major Denmark-based manufacturers of large commercial wind turbines of 1 MW or larger are Siemens Wind Power (formerly Bonus Energy A/S) with around 5.9% of the 2010 world market and Vestas Wind Systems A/S, the leading manufacturer with around 14.8% of the 2010 world market. The Danish wind industry's total export was 46.2 billion DKK (6.2 billion euro; 8.3 billion USD) in 2010, an increase of 11% from 2009. In Spain, investment in wind energy was more than 1.4 billion euro (1.9 billion USD), and about 50% of wind energy equipment was exported. In the United States, GE, Vestas, Siemens, and others are setting up factories across the country to manufacture large components or complete systems.

Canadian small wind manufacturing capacity is growing, with Canadian firms now representing over half of the world's manufacturers of small wind turbines in the 30 kW to 100 kW range. According to a recent market study conducted for CanWEA, 2009 sales for small wind energy systems in Canada grew by 55% over sales in 2008.

Ownership of wind plants is described in the country chapters. Ontario, Canada, encourages community ownership through its FIT program, and contracts for 384 MW of community-owned renewable energy projects have been signed in the province. In China, slightly more than half of the generation capacity is owned by state-owned enterprises. Local power and energy investing enterprises have a market share of 15% and central energy enterprises represent about 13.8% of the market. Private enterprises and foreign capital groups have a relatively small share of the market and fewer projects compared to the first three kinds of enterprises. Some joint development agreements have been formed with central or local enterprises to

<b>Table 6 Contribution of Wind to National Electricity Demand 2010 (estimates)</b>			
Country	2009 national electricity demand from wind (%)	2010 National electricity demand (TWh/yr)	2010 national electricity demand from wind (%)
Denmark	19.3	35.6	21.9
Portugal	15.0	52.2	17.0
Spain	14.4	259.9	16.4
Ireland	10.5	27.5	10.5
Germany	6.5	604.0	6.0
Greece	4.4	57.0	4.0
Netherlands	4.0	115.0	4.0
Austria	3.0	70.7	3.0
United Kingdom	1.7	381.2	2.6
Italy	2.1	326.2	2.6
Sweden	1.8	132.2	2.6
United States	1.9	4,120.0	2.3
Australia	1.6	261	2.0
Canada	1.8	549.9	1.8
China	NA	4,192.0	1.2
Norway	0.8	130.4	0.7
Mexico	0.2	219.0	0.6
Switzerland	0.04	57.7	0.05
Japan	0.4	901.5	0.4
Finland	0.3	86.3	0.3
Korea	0.2	451.1	0.2

invest in wind power. In Mexico, CEMEX, a global leader in the building materials industry, is investing in wind energy projects to supply electricity for their factories. The state of Baja California implemented a 10-MW wind energy project for public municipal lighting in 2010.

### 3.3 Operational details

In the IEA Wind member countries, the average size of new turbines decreased slightly in 2010 to 1,878 kW with the addition of China's turbines that averaged 1,467 kW each. Project sizes varied from small repowering efforts to large new power plants. China has more than 700 wind power projects, and the largest wind farm built in 2010 was 300 MW. In Denmark, although the total capacity increased, the number of turbines decreased due to repowering. In Germany onshore, 11.8% of the new capacity was the result of repowering.

In the United States, more than 2,890 turbines were installed in 2010 and the average project size was 69 MW. The trend in the United States is to develop less windy sites due to transmission constraints and other barriers.

Capacity factors varied markedly among plants, months, and seasons. The best areas of the United States and Mexico saw capacity factors up to 40%. In Mexico, the average capacity factor was around 28%. However, since 105 MW were commissioned over the year, the capacity factor of individual wind power plants could be over 30%. In 2010, it seemed that wind turbine manufacturers have learned to take full advantage of the outstanding wind regime of the Isthmus of Tehuantepec.

Several countries reported lower than expected capacity factors due to a low wind year (Denmark, Finland, Germany, Ireland, the Netherlands, and Norway). In Portugal, the resource was below average

in the mountains and above average on the coast, yielding a production year slightly above average.

Wind power contribution to the generation mix (penetration) is reaching high levels in several countries, and the impacts of this vary depending on the infrastructure of the grid. Instantaneous wind power penetration levels in the Irish electricity system exceeded 45% at times during 2010 with no security or stability issues reported by the grid operators. However, because 2010 proved to be a poor wind year in Ireland, the contribution from wind to the energy mix actually dropped slightly from 2009 levels. Wind energy in Ontario—Canada's largest wind generating province—produced 1,056 MW of power on 26 October 2010, meeting more than 5% of Ontario's total electricity demand over the entire day. No problems were reported. During the winter



**Table 7 Types of Incentive Programs in IEA Wind Member Countries for 2010 into 2011**

Countries implementing	Type of program	Description
Australia, Austria, Canada, China, Denmark, Finland, Germany, Ireland, Italy, Korea, the Netherlands (special definition), Portugal, Spain, Switzerland, UK (15 countries)	Feed-in tariff (FIT)	An explicit monetary reward is provided for wind generated electricity, paid (usually by the electricity utility) at a guaranteed rate per kilowatt-hour which may be higher than the wholesale electricity rates being paid by the utility.
Australia, Canada, China, Italy, Japan, Korea (2012), Portugal, Sweden, United Kingdom, United States (10 countries)	Renewable portfolio standards (RPS), renewables production obligation (RPO), or renewables obligation (RO)	A requirement is mandated that the electricity utility (often the electricity retailer) source a portion of its electricity supplies from renewable energies.
Australia, Austria, Canada, Finland, Netherlands, Sweden, Switzerland, United States (8 countries)	Green electricity schemes	Customers may purchase green electricity based on renewable energy from the electric utility, usually at a premium price.
Canada, Finland, Italy, Japan, Korea, Norway, United States (7 countries)	Capital subsidies	Direct financial subsidies are aimed at tackling the up-front cost barrier, either for specific equipment or total installed wind system cost.
Canada, Ireland, Mexico, Netherlands, United States (5 countries)	Income tax credits	Some or all expenses associated with wind installation may be deducted from taxable income streams.
Canada, Denmark, Italy, Korea, 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.
China, Korea, Mexico, Sweden, Switzerland (5 countries)	Special planning activities	Areas of national interest are officially considered for wind energy development.
Greece	Special licensing to reduce administrative burden	RES plants are exempt from the obligation to attain certain licenses; for RES plants in islands, which are combined with water desalination plants get priority.
Netherlands (small wind only), Portugal (microgeneration only), United States (3 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.
Canada, Sweden, Switzerland, United States (4 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.
Finland, Sweden, Switzerland, United States (4 countries)	Wind-specific green electricity schemes	Customers may purchase green electricity from wind plants from the electricity utility, usually at a premium price.
Australia, Canada, Switzerland, and United Kingdom (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.
Ireland	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 avail of financial incentives to retrofit renewable technologies.
Australia	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.
China	Relief from import tax	Large wind turbine technology and related components are included on lists of imports exempt from customs and import VAT charges.
Switzerland	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.
Canada, United Kingdom	Special incentives for small wind	Can include microFIT.

**Table 8 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	4,355	4,238	1,047	9,640
Austria	680	120	---	800
Canada	---	---	---	4,544
China	50,000	18,000	---	68,000
Denmark	20	422	---	442
Finland	36	8	3	47
Germany	---	---	---	---
Greece	---	---	---	---
Ireland	500	200	200	900
Italy	3,750	0	700	4,450
Japan	246	143	281	670
Korea	---	---	420	420
Mexico	419	1,328	538	2,286
Netherlands	---	---	---	---
Norway	4,366	2,060	258	6,684
Portugal	2,000	320	347	2,667
Spain	---	1,446	1,418	2,864
Sweden	---	2,762	499	3,261
Switzerland	52	2	---	54
United Kingdom	9,249	8,717	---	17,966
United States	---	---	5,600	5,600
Totals	75,673	39,766	11,311	131,295

--- = 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.

of 2010, the Portuguese power system reached the highest instantaneous penetration (75%), and on the same day a record 61% of consumption was supplied by wind energy. No technical problems were reported during these extremely high atypical wind penetration events. In Spain, wind energy met 16.4% of electrical energy demand and was the third largest contributing technology in 2010.

### 3.4 Wind energy costs

Table 10 shows reported turbine costs in 2010, and Figure 2 shows trends of installed costs for wind projects by country. The Chinese Wind Energy Association reports that 50% to 60% of project costs

are the cost of equipment, nearly 20% is transmission line cost, and the other costs (land expense, financing, and labor cost) represent 25% to 30%. Typical project costs in Ireland include turbines (65%), grid connection (12%), onsite electrical (8%), civil engineering (8%), development (4%), and legal/financial (3%). In Italy, the overall plant cost includes 10% to 20% for project development (wind surveys, plant design, permitting process with related environmental impact assessment etc.); 60% to 70% for wind turbines, including their transportation, erection and commissioning; and 20% to 25% for civil and electrical infrastructure, grid-connecting lines, and other facilities.

The German Wind Energy Association mentions investment costs for offshore wind energy far from the coast as 4.3 million euro/MW (5.8 million USD/MW) compared to 1.4 million euro/MW (1.9 million USD/MW) onshore. The KPMG 2010 Market Report calculated costs of 3.7 million euro/MW (5 million USD/MW) for a typical future German offshore wind farm. On the positive side, the German offshore test platform data show that offshore wind farms can produce electricity at their maximum capacity during about double the average annual full-load hours for onshore wind farms.

A study of the wholesale Irish electricity market concluded that the growing

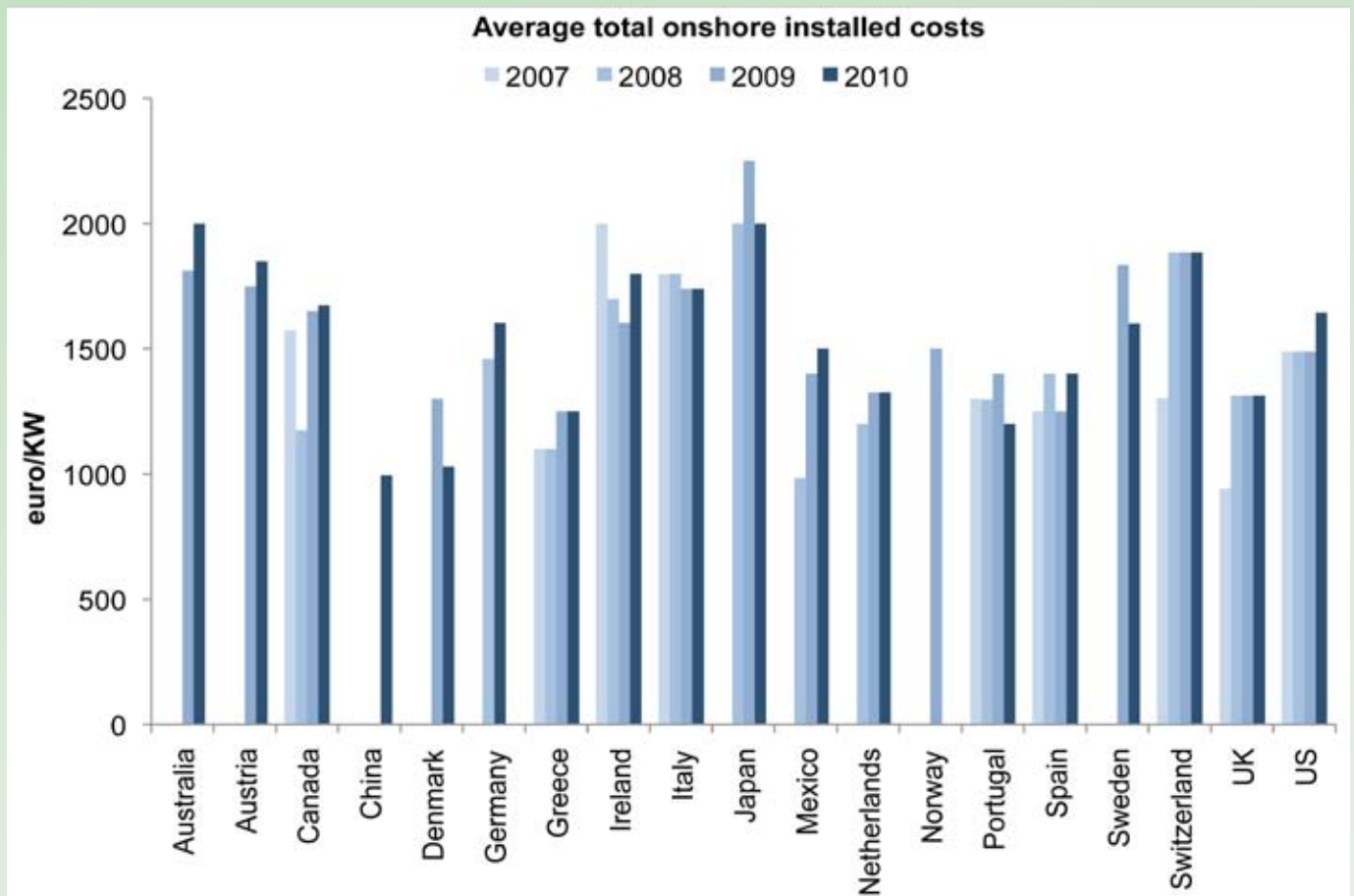


Figure 2 Average total installed costs of wind projects 2007–2010 as reported by IEA Wind member countries. These include costs for turbines, roads, electrical equipment, installation, development, and grid connection.

levels of wind generation are not adding to the wholesale price of electricity. The issue of how to calculate the cost of electricity from wind energy is being explored in IEA Wind Task 26 Cost of Wind Energy, and a state-of-the-art report was published in 2010. Eventually, a consistent methodology developed through that work will be used to report costs.

#### 4.0 R, D&D Activities

In 2010, IEA published a Technology Roadmap for Wind Energy (4). That roadmap targets 12% of global electricity from wind power by 2050 and found 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 (5). Figure 3 illustrates the timeline of IEA Wind research projects through the end of the next term.

#### 4.1 National R, D&D efforts

The major research areas discussed in the individual country chapters are listed in Table 11. 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). It is difficult to calculate the total research dollars supporting wind energy technology. Table 12 lists budgets reported by some countries.

In the EU, around 20 R&D projects were running in 2010 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 TPWind platform produced strategies for strategic research and market

deployment of wind energy and a long-term strategy for R&D in wind energy. To maintain sustainable wind power development in China, a wind energy technology roadmap is being formulated.

##### 4.1.1 New test and research facilities

Several important new research centers opened, were under construction, or were planned in 2010. In Canada, a 10-MW Wind Energy R&D Park with an energy storage system has been funded to demonstrate how energy storage can be used to maximize renewable energy production and to stabilize the grid. China has the goal of creating many more test facilities and labs to develop wind energy technology in the near term. In Denmark, Green Lab DK is a new support scheme for the construction of large-scale test facilities. With 600 million DKK (80.4 million euro; 108.1 million USD) from the government's Business Climate Strategy a better framework will be created for Danish enterprises to exploit opportunities

<b>Table 9 Capacity in Relation to Estimated Jobs and Economic Impact</b>			
Country	Capacity (MW)	Estimated number of jobs	Economic impact (million euro*)
China	44,733	279,000	---
United States	40,180	75,000	14,450
Germany	27,204	96,100	5,650
Spain	20,676	16,970	---
Italy	5,797	28,000	1,700
United Kingdom	5,270	---	---
Canada*	4,124	4,124	1,500
Portugal	3,987	3,000	1,296
Denmark	3,802	24,700	12,260
Japan	2,304	3,000	2,690
Netherlands	2,245	---	38
Sweden	2,163	---	---
Australia	1,880	2,000	1,190
Ireland	1,425	1,500	60
Greece	1,210	---	---
Austria	1,011	3,300	470
Mexico	520	1,500	208
Norway	435	---	---
Korea	381	1,103	1,092
Finland	197	2,000	780
Switzerland	42	12,600	1,400
<b>Total</b>	<b>169,586</b>	<b>553,897</b>	<b>44,784</b>
(-- = no data available)			

that arise in the wake of climate challenges. Also in Denmark, the Lindoe Offshore Renewables Center (LORC) was established as a European center for 1:1 testing, demonstrations, and research into offshore renewable energy. Facilities for testing wind turbine drivetrain components of 10 MW to 20 MW rated peak power are being established.

A unique full-scale onshore test of an offshore gravity foundation in Germany will provide fundamental knowledge on the long-term stability of such foundations. A 7-m-deep hole near the coast holds the foundation of water-saturated sediment similar to the open sea bottom. Wave forces are simulated by hydraulic devices, and up to 170 sensors measure the displacements of the foundation and sediment as well as other physical parameters. Also, the German rotor blade test center

at Fraunhofer IWES began testing blades up to 70 m using cyclic biaxial fatigue test methods. Developed in the InnoBlade-TeC project, the method will simulate 20 years of operation in four months. In 2010, construction began of a second 90-m test rig at IWES to begin operation in 2011.

The Research Council of Norway has founded eight Centers for Environment-friendly Energy Research (CEER) to lead the world 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 euro; 3.4 million USD) annually for five years with the possibility that funding will continue at that level for another three years. Two of the CEERs focus on offshore wind energy. A third is

working on issues such as integration of wind energy.

In Spain, two new facilities are under development: 1) An experimental onshore wind farm located in complex terrain has six calibrated positions to install prototypes of large wind turbines up to 5 MW. 2) A deep-sea offshore test station will test new technology and stimulate collaboration among major research centers, the industry, and universities.

The new Swedish Wind Power Technology Center focuses on complete design of an optimal wind turbine which takes into account the interaction among all components. The U.S. government is building and expanding test facilities at its national laboratories and universities. The new facilities will include a 5- to 15-MW drivetrain test facility in South Carolina, a 90-meter blade test facility in Massachusetts, and full-scale turbine test sites at universities in Illinois, Maine, and Minnesota.

#### 4.1.2 Highlights of research

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. Addressing issues of wind turbines interfering with radar, a recently completed analysis and test project in Germany concluded that compatibility problems can be solved for ATC radars using a "Turbine-Modkit." The addition of moderate turbine modifications such as absorption measures can ensure full compatibility of wind turbines and radar.

High penetrations of wind energy (60% to 80%) could be accommodated on the Irish system if mitigating measures are implemented, according to the Facilitation of Renewables program completed by the TSO there. Another Irish project is investigating a novel system of distributed energy storage systems to deliver variable wind and ocean energy electricity on the Aran Islands.

Using boundary layer suction technologies, researchers in the Netherlands are striving to change the aerodynamic properties of wind turbine blades, extend the lifetime, and improve the fouling properties of different porous materials.

Tools for measuring and predicting the resource are also being developed.

—————→

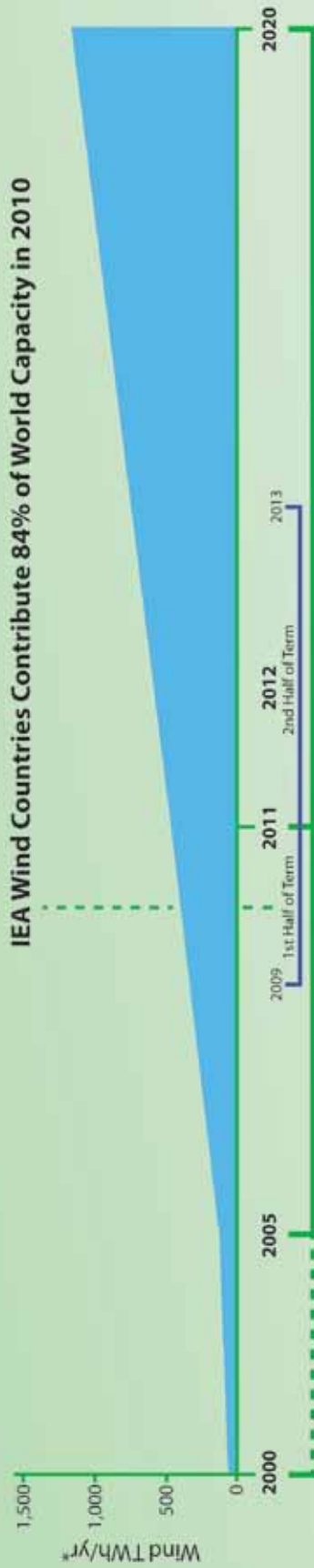
Figure 3 Timeline of IEA Wind research tasks





# IEA Wind Contribution to Wind Energy (2000-2020)

IEA Wind Countries Contribute 84% of World Capacity in 2010



## WIND TECHNOLOGY

1987 Task 11 - Base Technology Information Exchange

2001 Task 19 - Wind Energy in Cold Climates 2011

2008

Task 27 - Labelling Small Wind Turbines 2011

2008

Task 29 - MexNext Aerodynamics 2011

## POWER SYSTEMS

2004

Task 24 - Integration of Wind and Hydropower Systems 2010

2005

Task 25 - Power Systems with Large Amounts of Wind Power 2011

## WIND RESOURCE and PERFORMANCE ASSESSMENT

2010

Task 31 - WAKEBENCH - Benchmarking Wind Farm Flow Models 2013

## OFFSHORE WIND

2004

Task 23 - Offshore Wind Energy Technology and Deployment 2010

2010

Task 30 - Comparison of Dynamic Computer Codes and Models for Offshore Wind Energy 2013

## SOCIAL, EDUCATIONAL and ENVIRONMENTAL ISSUES

2008

Task 26 - Cost of Wind Energy 2011

2007

Task 28 - Social Acceptance of Wind Energy Projects 2011

## COMMUNICATIONS

2011

Communication Strategy 2013

\* Generation numbers from the IEA Technology Roadmap: Wind Energy, 2010.

<b>Table 10 Estimated Average Turbine Cost and Total Project Cost for 2010</b>		
Country	Turbine cost (euro/kW*)	Total installed cost (euro/kW*)
Australia	1,100 to 1,500	1,500 to 2,500
Austria	1,400 to 1,800	1,700 to 2,000
Canada	---	1,488 to 1,860
China	720	970 to 1,020
Denmark	---	1,030 onshore 2,680 offshore
Germany	---	1,336 to 1,756 onshore 3,323 to 3,561 offshore
Greece	---	1,100 to 1,400
Ireland	1,100	1,800 onshore
Italy	1,200	1,740
Japan	1,500	2,250
Mexico	1,100 to 1,200	1,500
Netherlands	---	1,325 onshore 3,200 offshore
Portugal	900 to 1,000	1,000 to 1,400
Spain	---	1,400
Sweden	1,400	1,600
Switzerland	1,450	1,885
United States	818 to 1,042	1,603
*Applicable conversion rate to USD: 1.344. --- = no data available		

In Austria, a high-resolution wind map combines numerical flow models with a geo-statistical approach. This calculation of the theoretical wind potential strives to estimate the feasible wind energy potential of the country. An open WebGIS application will allow users to individually set the technical and economic parameters that are the basis for the subsequent wind potential calculation. A new U.S. wind resource map and new state resource maps based on a hub height of 80 m were released in 2010. The new maps depict the nation's wind resources at three times previous estimates using hub height of 50 m previously used. The 80-m estimates correspond to the height and expected future size of multi-megawatt turbines.

#### 4.1.3 Small wind

Small wind turbines are attracting considerable interest in research programs. In Austria, four projects are addressing a new small turbine design, identifying

legal and economic barriers, developing resource assessment tools for the urban environment, and exploring issues of power quality. In Canada, two small wind demonstration projects are underway. In Ireland, field trials continued during 2010. The Irish program will assess the performance of the technologies and inform future decisions on possible incentives, tariffs, or deployment programs. The data collected at each installation will be made available in 2011. In the United States, the Small Wind Certification Council began certifying that turbine test results have met the AWEA performance and safety standard, and DOE's Small Wind Turbine Independent test project tested three small turbines to IEC standards.

#### 4.2 Collaborative research

The collaborative research conducted by organizations in the IEA Wind member countries made significant progress in 2010.

Task 11 Base Technology Information Exchange now has 18 countries participating. In 2010, four Topical Expert Meetings gathered invited experts on the following topics: Wind Farms in Complex Terrain; Micrometeorology Inside Wind Farms and Wakes Between Wind Farms; High-Reliability Solutions and Innovative Concepts for Offshore Wind Turbines; and Wind Conditions for Wind Turbine Design. These meetings and proceedings were available to researchers in the 18 IEA Wind countries that participate in Task 11. One year after the meetings, the reports are publicly available. In 2009, the proceedings were released from 2008 meetings on Radar Radio and Links with Wind Turbines; Sound Propagation Models and Validation; and Remote Wind Speed Sensing Techniques Using SODAR and LIDAR. Meetings planned for 2011 include: Failures Database; Control Strategies for Integration of Wind Farms on Weak Grids; Offshore Foundation Technology and Knowledge (shallow, middle and deep waters); and Smart Wind Turbine Rotor Blade Techniques. Task 11 participants are also developing Recommended Practices on SODAR in Wind Energy Resource Assessment and Wind Speed Measurement Using LIDAR Anemometers.

Task 19 Wind Energy in Cold Climates continued its work sharing information on wind turbine solutions for cold-climate applications, including blade heating technologies, ice detection, and anti-icing strategies. Participants are preparing a Recommended Practices document to summarize the best available practices for the development and construction of wind farms at cold-climate sites.

Participants in Task 23 Offshore Wind Technology and Deployment and Task 24 Integration of Wind and Hydropower Systems finished their research programs. Final reports were published in 2010.

Task 25 Power Systems with Large Amounts of Wind Power now has 15 country participants and serves as an international forum on the topic. System operators have joined task meetings, and representatives from TSO working groups at International Council on Large Electric Systems (CIGRE) and the European Transmission System Operators (ETSO) European Wind Integration Study (EWIS project) have observed Task 25 meetings. The latest published report found that large balancing areas and aggregation benefits of large areas help in reducing the variability and forecast errors of wind

Table 11 Reported Research Activities in IEA Wind Member Countries		
Type of program	Country activities reported	IEA Wind co-operative activities in 2010
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, resource assessment, and reliability of operations and maintenance.	Task 30 Comparison of Dynamic Codes and Models for Offshore Wind Energy (structures)
	Data acquisition and model development at alpha ventus offshore test site.	Task 31 WAKEBENCH: Benchmarking 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" 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.	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
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 12 National R&D Budgets 2009, 2010, and 2011 in Reporting Countries**

Country	R&D Budget 2009	R&D Budget 2010	R&D Budget 2011
Germany	28,200,000 euro; 37,900,000 USD	53,000,000 euro; 71,400,000 USD	---
Ireland	300,000 euro; 400,000 USD	300,000 euro; 400,000 USD	300,000 euro; 400,000 USD
Italy	3,000,000 euro; 4,030,000 USD	3,000,000 euro; 4,030,000 USD	3,000,000 euro; 4,030,000 USD
Japan	7,240,000 euro; 9,730,000 USD	24,300,000 euro; 32,660,000 USD	40,470,000 euro; 54,390,000 USD
Netherlands	8,000,000 euro; 10,750,000 USD	38,000,000 euro; 51,070,000 USD	---
Norway	54,000,000 euro; 72,580,000 USD	54,000,000 euro; 72,580,000 USD	54,000,000 euro; 72,580,000 USD
Sweden*	---	10,800,000 euro; 14,510,000 USD	10,800,000 euro; 14,510,000 USD
United States	40,180,000 euro; 54,000,000 USD (Recovery Act Appropriation: 79,530,000 euro; 106,900,000 USD)	59,520,000 euro; 80,000,000 USD	91,150,000 euro; 122,500,000 USD

--- = No data available  
\*Swedish Energy Agency part of National R&D budget

power and in pooling more cost-effective balancing resources. System operation and electricity markets operating at less than day-ahead time scales help reduce forecast errors of wind power. Transmission is the key to aggregation benefits, electricity markets, and larger balancing areas.

Task 26 Cost of Wind Energy began work in 2009 to develop an internationally accepted, transparent method for calculating the cost of wind energy. Its first report was released in 2010. Each participant conducted an analysis of deviations between individual country cost elements and the reference project. In this way, insight related to features of project development in each country is captured. Summaries of the current industry status, individual project features, and deviations from the reference are included in the report.

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. Ten countries now have participants in this task. An annual report on small wind activities for 2009 was

released in 2010. In 2011, an international sector guide, Recommended Practice for Consumer Labeling of Small Wind Turbines will be issued as an IEA Wind document. In addition, Task 27 will assemble a small wind tester association that will work to increase the number of accredited test facilities of small wind turbines. Task work holds meetings in conjunction with IEC MT2 to help develop the Recommended Practice on labeling.

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 report contains an overview of relevant knowledge and projects from participating as well as non-participating countries. The report introduces the issue of social acceptance of wind energy projects and presents what we know today and what remains to be done. Nine country reports are available

from participants in connection with the state-of-the-art report.

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. A final report will be issued in 2011.

Task 30 Comparison of Dynamic Codes and Models for Offshore Wind Energy is working to improve the accuracy of existing computer codes and models for estimation of structural loads for offshore wind turbines.

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, both onshore and offshore, from flat to very complex terrain.

### 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 2011. The co-operative research efforts of IEA Wind will publish significant reports on wind energy in cold climates, 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. Recommended practices will be published in labeling small wind turbines, use of LIDAR, and use of SODAR. The work of these tasks should provide the basis for international standardization work within IEC, and support efforts worldwide to increase the contribution of wind energy.

### References and notes:

For the latest information, visit: [www.ieawind.org](http://www.ieawind.org)

(1) Global Wind Energy Council (GWEC). 2010. Global Wind Report: Annual Market Update 2010. [http://www.gwec.net/fileadmin/images/Publications/GWEC\\_annual\\_market\\_update\\_2010\\_-\\_2nd\\_edition\\_April\\_2011.pdf](http://www.gwec.net/fileadmin/images/Publications/GWEC_annual_market_update_2010_-_2nd_edition_April_2011.pdf).

(2) 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 2011.

(3) International Energy Agency (IEA). (1995–2009). IEA Wind Annual Reports.

[www.ieawind.org](http://www.ieawind.org). Boulder, Colorado, USA: PWT Communications, LLC.

(4) International Energy Agency. (2010). Technology Roadmap: Wind Energy. [http://www.iea.org/papers/2009/Wind\\_Roadmap.pdf](http://www.iea.org/papers/2009/Wind_Roadmap.pdf)

(5) IEA Wind. (2011). Strategic Plan for 2009–2014, [http://www.ieawind.org/IndexPathPOSTINGS/042811/Strategic\\_Plan\\_update\\_for%20posting.pdf](http://www.ieawind.org/IndexPathPOSTINGS/042811/Strategic_Plan_update_for%20posting.pdf).

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

### 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 within member countries should contact their country representative (Appendix B) 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 work together to develop and deploy wind energy technology through vigorous national programs and through cooperative international efforts. They exchange the latest information on their continuing and planned activities and participate in selected IEA Wind research tasks.

This is the thirty-third *IEA Wind Energy Annual Report*. In Section I, Implementing Agreement and Active Annexes, the managers (Operating Agents or OAs) of the IEA Wind research tasks report progress for the year and plans for the coming year. In Section II, Member Country Activities, experts describe activities in the research,

development, and deployment of wind energy within their countries during the year just ended. The Executive Summary compiles information from all countries and tasks in a shorter format suitable for decision makers. The *IEA Wind 2010 Annual Report* is published by PWT Communications, LLC in Boulder, Colorado, United States, on behalf of the IEA Wind Executive Committee (ExCo).

### 2.0 Collaborative Research

Organizations located in member countries of IEA Wind (Table 1) may choose to participate in any of the cooperative research tasks (Table 2). Countries choose to participate in tasks that are most relevant

to their current national research and development programs. A lead institution within 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 2010, participants in the IEA Wind Agreement completed two research tasks, continued work on eight tasks, and approved the start of one new research task. Research tasks are approved by the ExCo as numbered annexes to the Implementing Agreement text. Additional tasks are planned when new areas for cooperative research are identified by Members.

This Annual Report describes progress of the cooperative research tasks in Chapters 2 through 10. Tasks are referred to by their annex number. The numbers of active tasks are not sequential because some tasks are extended and some have been completed and do not appear as active projects in this report.

Task 30 Offshore comparison of dynamic computer codes and models offshore code comparison collaborative (OC4) extension project was approved in 2009 and began work in 2010. This task is continuing work begun under sub-task 2 (OC3) of Task 23 Offshore Wind Energy Technology and Deployment, which was completed in 2009. Task 31 WAKEBENCH: Benchmarking of Wind Farm Flow Models, was approved late in 2010 to begin work in 2011.

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



iea wind



Photo credit Patricia Weis-Taylor

is presented in the Executive Summary of this Annual Report. Individual country activities are presented in chapters 11 through 32.

#### 4.0 Executive Committee

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

#### Officers

In 2010, Brian Smith (United States) served as Chair. Hannele Holttinen (Finland) and Joachim Kutscher (Germany) served as Vice Chairs. Hannele Holttinen was elected Chair to succeed Brian Smith in 2011. Joachim Kutscher was elected to continue as Vice Chair in 2011.

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 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 cooperative research.

- Task 23 Offshore wind energy technology and deployment  
Contribution per participant: 18,675 USD (12,960 euro) plus in-kind effort. Total value of shared labor received: 4.63 million USD (3.2 million euro) of labor for Subtask 2.
- Task 24 Integration of wind and hydropower systems  
Contribution per participant: 16,430 USD (11,797 euro) plus in-kind effort. Total value of shared labor received: 6.24 million USD (4.48 million Euro)

- Task 25 Power systems with large amounts of wind energy.  
Contribution per participant: 7,002 euro (9,747 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 2010, 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](http://www.ieawind.org). Table 3 shows participation by members in active research tasks in 2010.

To obtain more information about the cooperative research activities, contact the OA representative for each task listed in Appendix B, or visit our website at [www.ieawind.org](http://www.ieawind.org) (follow the links to individual task web sites or check the Contact List).

#### 3.0 National Programs

The national wind energy programs of the participating countries are the basis for the IEA Wind collaboration. These national programs are directed toward the evaluation, development, and promotion of wind energy technology. An overview and analysis of national program activities

---

\* 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 organisations may participate. For more information, visit [www.iea.org](http://www.iea.org).

† The IEA Wind implementing agreement functions within a framework created by the International Energy Agency (IEA). Views and findings within 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 2010**

Country/Organization	Contracting Party to Agreement
Australia	Australian Wind Energy Association
Austria	Republic of Austria
Canada	Natural Resources Canada
Denmark	Ministry of Business and Economic Affairs, Danish Energy Authority
European Commission	The European Commission
Finland	TEKES, Finnish Funding Agency for Technology and Innovation
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	NL Agency
Norway	Norwegian Water Resources and Energy Directorate (NVE) and Enova SF
Portugal	National Laboratory of Energy and Geology (LNEG)
Spain	Instituto de Energias Renovables (IER) of the Centro de Investigación; Energetica Medioambiental y Tecnologica (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
<b>Sponsor Participants</b>	
CWEA	Chinese Wind Energy Association
EWEA	European Wind Energy Association

### Participants

In 2010, the IEA Wind members were pleased to welcome the Chinese Wind Energy Association (CWEA) as a new Sponsor Member. Sponsor Members are important organizations in wind energy development that contribute to the work of IEA Wind. As always, there were also several personnel changes among the Members and Alternate Members. (See Appendix B IEA Wind Executive Committee for members, alternate members, and OA representatives who served in

2010.) For the latest and most complete ExCo member contact information, please click the Members tab at [www.IEAWind.org](http://www.IEAWind.org).

### Meetings

The ExCo meets twice a year 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 is devoted to reports on R&D activities in the member countries and in the research

tasks, and the second meeting is devoted to reports from member countries and tasks about deployment activities.

The 65th ExCo meeting was hosted by Sweden in the city of Malmö on 29 and 30 June and 1 July 2010. There were representative from 16 of the contracting parties. Attendees included eight operating agent representatives of the tasks and observers from IEA Paris, China, The Netherlands, Spain, and Sweden. The ExCo approved the IEA Wind audit report of the Common Fund for 2009. The ExCo unanimously approved a motion to the Chinese Wind Energy Association to join as a Sponsor Member. On July 1, the meeting participants visited the Lillgrund Offshore Wind Park and Enercon Wind-tower Production facility.

The 66th ExCo meeting was hosted by Italy in the city of Palermo, Italy on 26, 27, and 28, October 2010. Participants from 14 contracting parties were represented and OA representatives from all of the active tasks gave reports. The ExCo approved by email ballot a motion to invite the government of France or its representative to join IEA Wind. Task 11 Base Technology Information Exchange was extended through 2012. Final reports were approved for Task 23 Offshore Wind Energy and Deployment and Task 24 Integration of Wind and Hydropower Systems. The ExCo approved the technical report for work package 1 of Task 26 Cost of Wind Energy. Task 28 Social Acceptance of Wind Energy Projects issued a State-of-the-Art report that was approved by the ExCo. The ExCo approved the budgets for the ongoing tasks and for the Common Fund for 2011. A new task to contribute to improving wind farm flow models was approved: Task 31 WAKE-BENCH: Benchmarking of Wind Farm Flow Models with CENER, Spain and NREL, United States as Operating Agents. A working group prepared a draft update to the IEA Wind Strategic Plan, which will be approved in 2011. Hannele Holttinen of VTT, Finland was elected Chair for 2011 to 2012 and Joachim Kutscher was elected to continue as Vice Chair. On October 28, meeting participants visited the Moncado farm at Montanelle and the laboratories of the Moncado company.

### 5.0 Outreach activities

The 32nd issue of the *IEA Wind Energy Annual Report* was published in July 2010 and the website, [www.ieawind.org](http://www.ieawind.org) continued to expand coverage of IEA Wind



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)

activities. Three Task 11 Proceedings of Experts Meetings from 2009 were posted on the public website. In all, eight technical reports of IEA Wind were approved for release by IEA Wind in 2010. Countless journal articles, conference presentations, and poster presentations drew upon the work of the IEA Wind research tasks. Recommended Practices are under development for labeling small wind turbines and for using LIDAR and SODAR for wind energy development.

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 cooperation activities between ExCo meetings. Support for IEA Paris initiatives has been provided by the Planning Committee. This support included attending

IEA-sponsored Network Communication meetings, presentation of a Mid-term Report to the Renewable Energy Working Party (REWEP) meeting, supplying materials for ministerial meetings, reviewing draft IEA documents that address wind technology, especially the Wind Energy Technology Roadmap issued by IEA in 2010.

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](mailto:ieawind@comcast.net).

<b>Table 3 Participation of Member Countries in Tasks During 2010 (OA indicates operating agent that manages the Task)</b>									
Research Task Number									
Participant	11	19	25	26	27	28	29	30	31
Australia					x				
Austria		x							
Canada	x	x	x		x	x	x		
CWEA	x				x				
Denmark	x		x	x	x	x	x	x	
European Commission	x								
EWEA			x	x					
Finland	x	OA	OA			x			
Germany	x	x	x	x	x	x	x	OA	
Greece									
Ireland	x		x		x	x			
Italy	x		x		x				
Japan	x		x		x	x	x		
Korea	x				x		x	x	
Mexico	x								
Netherlands	x		x	x		x	OA	x	
Norway	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			
United Kingdom	x		x		x				
United States	x	x	x	OA	x	x	x	OA	OA
Totals	18	8	15	8	13	10	10	9	

\* For the latest participation data, please visit the task websites at [www.ieawind.org](http://www.ieawind.org).

# Chapter 2

## Task 11 Base Technology Information Exchange



### 1.0 Introduction

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

Table 1 lists the countries participating in this Task in 2010. These countries pay a fee to support the work of the Operating Agent (OA), that manages the Task. In December 2010, the Chinese Wind Energy Association (CWEA) formally joined the task. Greece withdrew from the Task in 2010. The Spanish National Centre of Renewable Energies (CENER) is the current OA.

Task 11 is an important instrument of IEA Wind. It can react quickly to new technical and scientific developments and information needs. It brings the latest

knowledge to wind energy players in the member countries and collects information and recommendations for the work of the IEA Wind Agreement. Task 11 is also an important catalyst for starting new tasks within IEA Wind. Documents produced are available immediately following the meetings to organizations in countries that participate in the Task. After one year, documents can be accessed on the IEA Wind public Web pages ([www.ieawind.org](http://www.ieawind.org)).

### 2.0 Objectives and Strategy

The objective of the 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

**Table 1 Task 11 participants**

	COUNTRY	INSTITUTION
1	Canada	National Resources Canada (NRCan)
2	Republic of China	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 Umwelt, 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
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)

Table 2 Topical Expert Meetings (2006-2010)			
TEM No.	TITLE	YEAR	LOCATION
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

attended by invited active researchers and experts from the participating countries. The topics are selected by the IEA Wind Executive Committee 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. During the past 32 years of activity to promote wind turbine technology through information exchange, more than 85 expert meetings have been organized. Table 2 lists the TEM arranged in the last five years (2006-2010).

A second activity of Task 11 is to develop IEA Wind Recommended Practices (RP) for wind turbine testing and evaluation. So far, 11 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 2010

Four TEM were organized in 2010 and proceedings were published on the ftp-server for participants. Proceedings are available to the public after one year on [www.ieawind.org](http://www.ieawind.org). Meeting topics for 2011 have been selected by the IEA Wind Executive Committee. At the close of 2010, two IEA Wind Recommended Practices were in preparation dealing with measuring wind speed and direction using SODAR and LIDAR type instruments. Other issues for beginning new RP were suggested during ExCo meetings and are under consideration.

#### 3.1 Topical Expert Meetings

##### 3.1.1 Wind farms in complex terrain

TEM 61 was hosted by POSTECH and the Korean Institute of Energy Research (KIER) in Pohang, Republic of Korea,

6-8 April 2010. Twelve experts, mainly from research organizations and universities, registered for this meeting from Finland, Japan, Republic of Korea, Spain, the United Kingdom, and the United States. Nine presentations were given about the state of the art of designing and operating wind farms in the complex terrain of mountainous and forested areas.

At the conclusion of the meeting, participants recommended creating a new research Task within the IEA Wind. This Task would compare and validate computational fluid dynamics (CFD) codes that are used to analyze the wind resource in complex terrain. Javier Sanz Rodrigo (CENER, Spain) was designated to coordinate the proposal for a new Task that would include the elaboration of best practice guidelines for complex terrain flow modelling. The resulting proposal was



approved in October 2010 as IEA Wind Task 31 WAKEBENCH Benchmarking of Wind Farm Flow Models. Work is expected to begin in 2011. The Proceedings of the TEM were published in 2010 on the ftp-server for task participants and will be available to the public on 5 May 2011 on [www.ieawind.org](http://www.ieawind.org).

### 3.1.2 Micrometeorology inside wind farms and wakes between wind farms

TEM 62 was hosted by CENER in Pamplona, Spain, 5–6 May 2010. The TEM was originally scheduled for December 2009, but was postponed because a similar meeting had been organized by the European Mechanics Society (EUROMECH) in 2009. TEM 62 attracted 15 experts from Denmark, Germany, Japan, Netherlands, Norway, Spain, Sweden, the United Kingdom, and the United States. Thirteen presentations were given and the proceedings were published on the ftp-server for participants. Proceedings will be available to the public on 14 June 2011.

The participants favored development of a benchmarking framework for wind turbine wakes and wind farm modelling to gain insight into the benefits and drawbacks of a set of modelling assumptions for a wide range of applications. Much of this work would involve benchmarking models of wakes against other models and verifying models using good quality measured data. Blind tests would probably be the most transparent way of evaluating models and user-dependencies. The new IEA Wind Task 31 WAKEBENCH will address many of the needs identified by these participants.

### 3.1.3 High reliability solutions and innovative concepts for offshore wind technology

TEM 63 was hosted by SINTEF in Trondheim, Norway, 5–6 October 2010. This meeting gathered 30 experts from Denmark, the European Union, Finland, Germany, Greece, Japan, Norway, Spain, Sweden, the UK, and the United States. An observer from France also attended the meeting. The participants, from industry, research organizations, and universities attended 17 presentations on the topic. The proceedings were published on the ftp-server for participants. Proceedings will be available to the public on 2 September 2011.



Figure 1 TEM at CENER, Pamplona, Spain

The participants agreed that another TEM on this topic would be very useful to continue the exchange of information. It was suggested that the next TEM be organized in parallel with one of the meetings of IEA Wind Task 30 Offshore Code Comparison Collaboration Continuation (OC4). NREL (the operating agent for Task 30) offered to host a TEM on this topic in 2011 in parallel with one of the workshops of Task 30.

### 3.1.4 Wind conditions for wind turbine design

TEM 64 was hosted by AIST, the University of Tokyo and the Japan Electrical Manufacturers' Association (JEMA) in Tokyo, Japan, 14–15 December 2010. Twenty-four experts from China, Germany, Japan, Sweden, and the United States represented research organizations, universities, and consultants. Fourteen presentations were given on the topic. The proceedings were published on the ftp-server for participants. Proceedings will be available to the public on 15 December 2011.

During the discussion, several actions were identified as crucial to improve knowledge on wind conditions for wind turbine design. A new Task under IEA Wind in coordination with IEC working groups was discussed, but no consensus was reached during the meeting to move forward. Rather, participants recommended a TEM on this topic in 2013, to report knowledge being generated from existing research actions.

### 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 (years in most cases) required for elaboration of new IEC standards. IEA Wind RP could be prepared in a shorter period of time and would be an important input for the future elaboration of the IEC standards.

Currently two IEA Wind RP are under development. Both documents deal with measuring wind speed and direction using SODAR and LIDAR type instruments.

- SODAR in Wind Energy Resource Assessment

The draft IEA Wind RP document on SODAR was nearly finished at the close of 2010. It is expected to be distributed for final review during first trimester of 2011 to Task 11 members for comments.

- Wind speed measurement using LIDAR anemometers

Preparation of the LIDAR Best Practices document resumed in late 2010 and participants decided to convert it to the format of the IEA Wind RP on SODAR.

## Task 11

Three 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)
- Noise Measurement Immision (Update existing IEA Wind RP)

The first two RP will be prepared in cooperation with Task 19 Wind Energy in Cold Climates and Task 26 Cost of Wind Energy.

### 4.0 Plans for 2011 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 2010 according the procedure approved at ExCo 65. A list of topics was sent by the OA to the task members. According to the responses, the topics selected with the highest priority were:

1. International statistical analysis on wind turbine failures

2. Offshore foundation technology and knowledge, for shallow, middle and deep waters
3. Smart wind turbine rotor blade techniques (active control, etc.)
4. Optimization of offshore construction and maintenance logistics
5. Internal grids and grid connection for offshore wind farms
6. Advanced numerical flow models (numerical site calibration), techniques for power performance prediction of wind turbines at complex terrain sites, etc.

#### Planned TEM for 2011 year are:

- Failures Database, TEM 65, Kassel, Germany
- Control Strategies for Integration of Wind Farms on Weak Grids, TEM 66, Cuernavaca, Mexico
- Offshore Foundation Technology and Knowledge (shallow, middle

and deep waters), TEM 67, Esbjerg, Denmark

- Smart Wind Turbine Rotor Blade Techniques, TEM 68, Spain.

Work related to the development of a Recommended Practice on the use of SODAR and LIDAR for measuring wind speeds will continue. The OA 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 Memorables (CENER), Spain.

# Chapter 3

## Task 19 Wind Energy In Cold Climates

### 1.0 Introduction

The deployment of wind turbines to sites where climate conditions are outside the standard operational limits is increasing. Such sites require more prudent measures during the project development phase due to demanding climate conditions. 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 on hills above the surrounding landscape or located in high northern latitudes. During the last 10 years technology has been developed to meet those challenges. As new icing and low temperature specific technology is being demonstrated, the need is growing to collect experiences in a form that can be used by developers, manufacturers, consultants, and financiers.

IEA Wind set up Task 19 as an international co-operation that collects and evaluates information on all aspects of turbine operation in cold climates and in icing conditions, e.g. site assessment, economic and safety issues, mitigation strategies, etc. Table 1 lists the participating countries and organizations in 2010. These countries pay a fee to support the work of the Operating Agent (OA) of the Task and contribute in-kind labor according to the approved work plan.

Since 2002, Task 19 participants have gathered information about wind turbine operation in icy and low temperature environments. The most recent report that summarized the available adapted technology and its current state was published



Photo Credit: C. Durstewitz

in 2009 (1). The best practice guidelines report, *Wind Energy Projects in Cold Climates* (2), that summarizes the recommended practices was published in late 2009.

### 2.0 Objectives and Strategy

The objectives of Task 19 for 2009-2012 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 as the commonly used standard tools do not address cold climate specific issues
- Clarify the significance of extra

**Table 1 Task 19 participants**

	Country	Institutions
1	Austria	Austrian Federal Ministry for Transport, Innovation, and Technology; Energiewerkstatt
2	Canada	Natural Resources Canada
3	Finland	TEKES; Technical Research Centre of Finland
4	Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety; Fraunhofer IWES
5	Norway	Kjeller Vindteknik
6	Sweden	Energimyndigheten; WindREN AB
7	Switzerland	Swiss Federal Office of Energy; Meteotest
8	United States	National Renewable Energy Laboratory (NREL)

loading that ice and cold climate induce on wind turbine components

- Perform a market survey for cold climate wind technology, including wind farms, remote grid systems, and stand-alone systems
- Define recommended limits for the use of standard technology (site classification)
- Create and update the Task 19 state-of-the-art report and expert group study on guidelines for applying wind energy in cold climates

The items above have been identified as key topics that are slowing wind power development in cold climates. The ongoing national R&D activities in participating countries tackle specific challenges and provide new information on the subject. The results of the ongoing national activities will enable improvement of the overall economy of wind energy projects, especially in cold climates and thus significantly lower the risks involved in areas where low temperatures and atmospheric icing are frequent.

The collaboration actively disseminates results through the Task 19 website ([www.ieawind.org](http://www.ieawind.org)), and through conferences and seminars. At the end of the current Task 19 period (2012), a final report will be published. The report will describe state-of-the-art of cold climate technology and will report on recommended practices for minimizing and mitigating the cold climate effects associated with additional risks of wind energy projects in cold climates. One important dimension

of this work is beginning the conversation about whether cold climate issues should be recognized in future standards that set the limits for turbine design. The most recent reports produced within the framework of Task 19 are the State-of-the-Art of Wind Energy in Cold Climates and Wind Energy Projects in Cold Climates (<http://arcticwind.fi>).

### 3.0 Progress in 2010

Two meetings of participants were organized in 2010:

The first meeting to discuss progress in the national research programs was held in May in St. John's, Canada hosted by Natural Resources Canada. Invited presentations were given by Compusult on how to manage various kind of data and by Eco-TEMP on heating and anti-icing systems for wind turbines. The second task meeting was held in October in Espoo, Finland hosted by Technical Research Centre of Finland. Invited presentations were given by Winwind (new blade heated turbine) and Labkotec (ice detector manufacturer).

The results of the Task 19 have been disseminated and are scheduled to be presented in various conferences, including:

- EWEC 2010, 20-23 April, Warsaw, Poland
- Ice & Rocks III 2010, 5-6 May, Zadar, Croatia
- DEWEK 2010, 17-18 November, Bremen, Germany
- WINTERWIND 2011, 9-10 February, Umeå, Sweden
- EWEA 2011, 14-17 March, Brussels, Belgium

- IWAI 2011, 8-13 May, Chongqing, China.
- CWEC 2011, 13-15 October, Beijing, China.

### 4.0 Plans for 2011 and beyond

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 that will summarize the best available practices for the development and construction of wind farms for a cold climate sites.

It is foreseen that cold climate deployment will continue and moreover, speed up in various countries in the northern hemisphere between 2012 and 2016. It has been estimated that capacity of 4,000-5,000 MW (Figure 1) annually will be installed in cold climate sites in the present Task 19 member countries. Thus, discussion for a possible fourth term for Task 19 will be initialized during the second half of 2011.

#### References and Notes:

- (1) State-of-the-art of wind energy in cold climates (pdf) available at <http://www.vtt.fi/inf/pdf/workingpapers/2010/W152.pdf>
- (2) Wind Energy Projects in Cold Climates (pdf) available at <http://www.vtt.fi/inf/pdf/workingpapers/2010/W151.pdf>

Author: Timo Laakso, Pöyry Finland Oy, Finland.

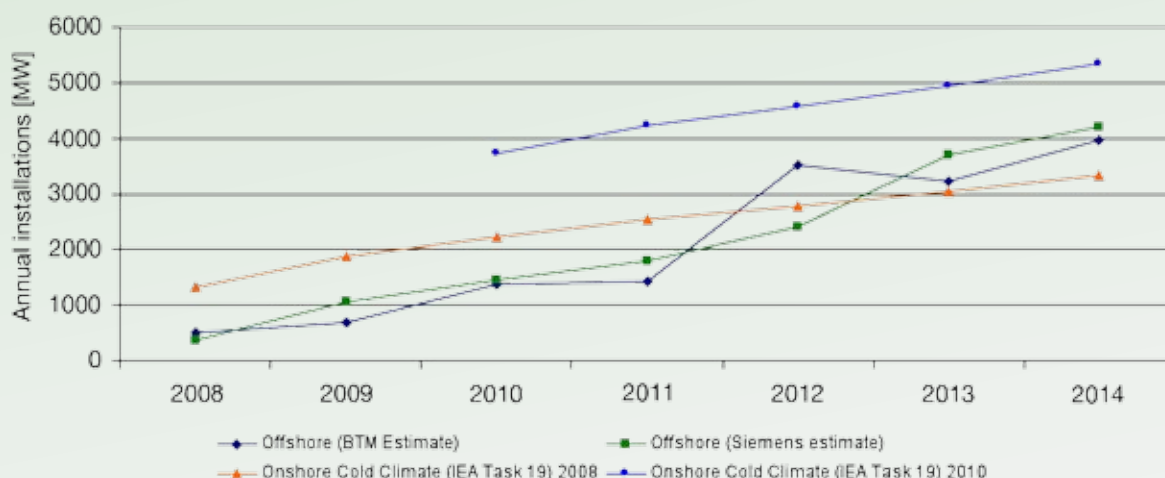


Figure 1 Estimated size of cold climate wind power market



# Chapter 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; it is variable and partly unpredictable. To meet this challenge, there will be a need for more flexibility in the power system. How much extra flexibility is needed depends on how much wind power there is, and on how much flexibility already exists in the power system. To explore issues of wind power's effects on the power system, Annex 25 to the IEA Wind Implementing Agreement was approved for three years (2006 to 2008) and was extended for a second term (2009 to 2011). During the first term, 11 countries and the EWEA participated in the Task. In the second term, Canada, Japan, and Italy also joined (Table 1).

The existing targets for wind power anticipate quite a high penetration in many countries. It is technically possible to integrate very large amounts of wind capacity in power systems, with the limits arising from how much can be integrated at socially and economically acceptable costs. Valuable experience on wind integration has been gained from several countries: Denmark (20% penetration as yearly electrical energy), Spain and Portugal (14% to 15%), Ireland (11%), and Germany (7%, with North Germany exceeding 30%). These countries have shown that considerable amounts of wind power can be integrated into existing systems without investing in extra reserves. This is possible if the system operator has information on the forecasting of wind power and the on-line production levels, as well as ways to control the wind input in critical situations.

The integration of wind power into regional power systems has mainly been studied on a theoretical basis, for future anticipated wind power penetration levels. In recent years, however, several reports have been published investigating the actual power system impacts of wind power. Unfortunately, the results on the costs of integration differ substantially 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 for different power systems (Figure 1). Because system impact studies are often the first steps taken toward 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 operations with large amounts of wind power. The challenge is to create coherence between parallel activities with Transmission System Operators (TSOs), the International Council on Large Electric systems

Table 1 Task 25 Participants, Second Term (2010–2011)		
	Country	Institution(s)*
1	Canada	National Resources Canada (NRCan); TSO Hydro Quebec
2	Denmark	Risø National Laboratory (Risø-DTU); TSO Energinet.dk
3	EWEA	European Wind Energy Association (EWEA)
4	Finland	VTT Technical Research Centre of Finland
5	Germany	Fraunhofer IWES; TSO RWE
6	Ireland	Ecar Ltd., University College Dublin (UCD); TSO Eirgrid
7	Italy	TSO Terna
8	Japan	National Institute of Advanced Industrial Science and Technology (AIST)
9	The Netherlands	Energy Research Center of the Netherlands (ECN), TUDelft
10	Norway	SINTEF Energy Research; TSO Statnett
11	Portugal	National Laboratory of Energy and Geology (LNEG); TSO REN
12	Spain	University of Castilla- La Mancha (UCLM); TSO REE
13	Sweden	Royal Institute of Technology (KTH)
14	United Kingdom	Centre for Distributed Generation & Sustainable Electrical Energy (DGSEE); TSO National Grid
15	United States	National Renewable Energy Laboratory (NREL); Utility Wind Integration Group (UWIG)

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

(CIGRE), IEA Wind research tasks, and other IEA Implementing Agreements task work and to remain an internationally accepted forum for wind integration.

The participants collect and share information on the experience gained in current and past studies. Their case studies address different aspects of power system operation and design: reserve requirements, balancing and generation efficiency, capacity value of wind power, efficient use of existing transmission capacity and requirements for new network investments, cross-border trade, bottlenecks, and system stability issues. The main emphasis is on technical operation. Costs are assessed as a basis for comparison. Also, technology that supports enhanced penetration is addressed: wind farm controls and operating procedures, dynamic line ratings, storage, demand side management (DSM), etc.

The task work began with a state-of-the-art report that collected the knowledge and results so far (1). This report, published in 2007, was updated as a final report of the 2006 to 2008 work and

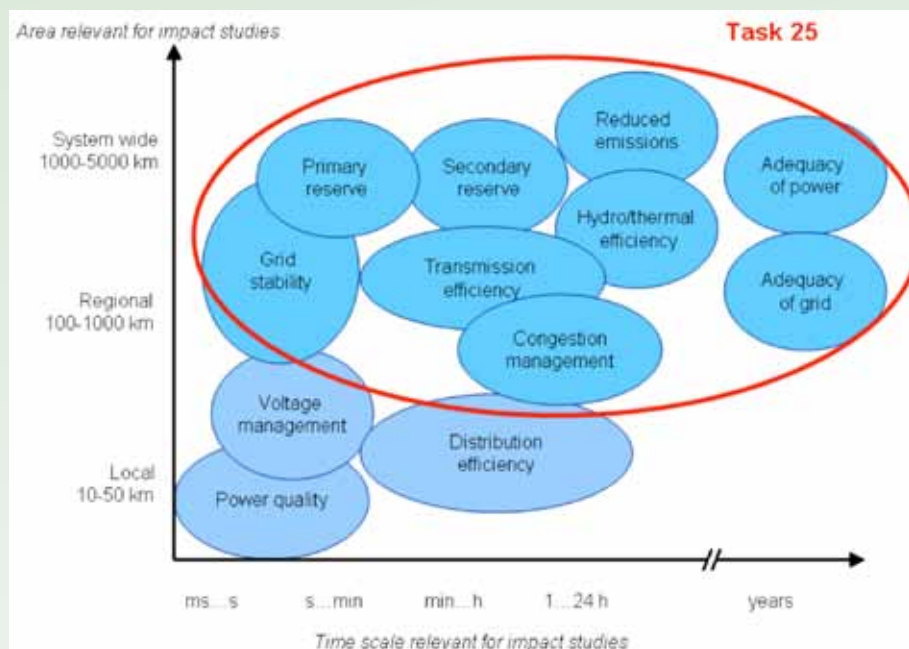


Figure 1 Impacts of wind power on power systems, divided into different time scales and size of area relevant for the studies. Primary reserve is denoted for reserves activated in seconds (frequency activated reserve; regulation) and secondary reserve is denoted for reserves activated in 5 to 15 minutes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

published in 2009 (2). The task will end with developed guidelines on the recommended methodologies when estimating the system impacts and the costs of wind power integration.

### 3.0 Progress in 2010

#### 3.1 Activities

The meetings organized by Task 25 have established an international forum for exchange of knowledge and experiences. The spring task meeting in 2010 was organized in Toledo, Spain, hosted by University Castilla la Mancha and regional Energy Authority, and the autumn meeting was hosted by Hydro Quebec in Montreal, Canada.

Coordination with other relevant activities is an important part of the Task 25 effort. The meetings in 2007 were organized together with IEA Wind Task 24 Integration of Wind and Hydropower Systems. The system operators of Denmark, Germany, Ireland, Portugal, Spain, the United Kingdom have joined the meetings organized so far. Links between TSO working groups at CIGRE, and the European Transmission System Operators (ETSO), and the European Wind Integration Study (EWIS project) have been formed, and observers have been joining Task 25 meetings from 2008 to 2009. The IEA Secretariat's work on integrating renewable energies has also been followed, and links to other IEA Implementing Agreements have been formed (Demand Side Management, Electricity Networks

Analysis, Research and Development (ENARD), and Ocean Energy Systems).

Publication of the work is a key goal of Task 25 co-operative research. A paper summarizing results from the final report 2006 to 2008 was published in journal *Wind Energy* in 2010 (3), and work is on-going on several joint articles – a first version of this work was published in the 9th International Workshop on Large-Scale Integration of Wind Power into Power Systems in Quebec as Task 25 session papers.

Task 25 work and results were disseminated at two workshops for TSOs in 2010: in Europe on 20 May, Brussels for ENTSO-E Working Group on Renewable Energy Sources meeting, and in North America on 13 October, Quebec for UWIG User Group Meeting. Additionally, Task 25 work and results were presented at the IEA Secretariat Electricity Grid Coordination Meeting in April 2010, the EERA grid integration workshop in October 2010, and the EWEA Grid Conference in November 2010. Task 25 has participated in the IEA Secretariat study on integrating renewable energy sources (GIVAR project) work on a simplified assessment of wind integration effort and power system flexibility.

The Task 25 web site 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 a literature bibliography listing publications related to system integration

that was completed in 2008 together with Task 24. The members-only section details the meeting presentations and information relevant to task participants.

#### 3.2 Results

The report of Phase One (2006 to 2008) was published in 2009 and is available through the task web site. In 2010, collaborative work concentrated on three issues: modeling wind power in unit commitment models, reserve requirements due to wind power, and transmission planning with large amounts of wind power. The first versions of the joint articles were published at the 9th International Workshop on Large-Scale Integration of Wind Power into Power Systems, Quebec, on 17-18 October 2010 (4).

Power system operations and scheduling (with Unit Commitment process) are more complex with a large amount of wind power in the system. The net load (load less wind) that must be served by the non-wind generation fleet will be more variable and more uncertain than the load alone. The unit commitment process must consider wind power uncertainty (the forecast errors), and also additional reserve to manage the increase in variability and uncertainty. When variable wind power replaces generation from conventional units, it is likely to increase the number of conventional unit start-ups as well as their part-load operation so models should also be able to handle restrictions on ramping, start-up, and shut-down times.

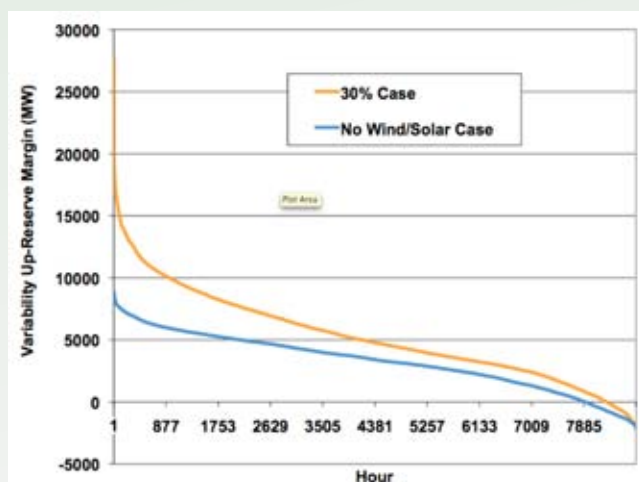


Figure 2 More are available in the high renewables case than in the no wind/solar case because the additional renewable energy generation causes many conventional units to be backed down (6,8).



## Task 25

A summary of recent reserve requirement work for wind integration pointed out that although the integration studies discussed considered similar types of reserves, the methods for determining the quantity of required reserves varied widely. The studies used different data based on different assumptions of their system operations. One finding was that there may be more availability of reserves from conventional plants during high wind events (Figure 2).

Transmission has become recognized as a key enabler to reach wind energy targets and carbon reduction goals. Policy initiatives in Europe aim to catalyze the process of transmission expansion. Policy initiatives at the national level in the United States are underway to establish interconnection-wide transmission planning processes, enable interconnection-wide transmission cost allocation for a high voltage backbone system, and provide federal backstop transmission line siting authority. Transmission planning for wind is becoming an iterative process consisting of generation expansion planning, economic-based transmission planning, system reliability analysis, and wind integration studies.

### 4.0 Plans for 2011 and beyond

Task 25's second phase is 2009–2011 and two reports are in preparation: 1) Recommended Practices for Wind Integration Studies and 2) Summary Report (2009–2011). The Summary Report will update the summaries of results from national and regional wind integration studies and list the main findings of the collaborative article writing. The articles were written on reserve requirements, modeling wind power in dispatch and unit commitment models, transmission planning, variability of large scale wind power and experience on frequency control with large penetration situations.

The 2011 meetings will be in Stockholm, Sweden in April (hosted by KTH) and Lisbon, Portugal in September (hosted by LNEG). Task 25 work and results will also be presented at several other meetings in 2011, such as at the 2011 EWEC and 10th International Workshop on Large-Scale Integration of Wind Power into Power Systems Oct 2011 in Denmark.

The topic being addressed by Task 25 is growing exponentially in importance within the member countries and more broadly. There is a consensus that a third phase 2012–14 is still needed and would be useful for the participating countries.

During the third term, participants will expand into high penetration studies, broadening the scope to other (like PV and electric vehicles). Operation and planning time scales in power systems are merging and that will become an issue for methods and tools. The task aims to work further on implications to market design and operation and create a database of large-scale wind power production data needed for integration study inputs. Work on creating simple rules of thumb stating the probable impacts and cost ranges for different power systems with different levels of wind penetration will be continued. The library in the web pages of Task 25 will be completed and updated.

### References:

(1) Design and Operation of Power Systems with Large Amounts of Wind Power, State of the art report (2007) <http://www.ieawind.org/AnnexXXV/Publications/W82.pdf>

(2) Final Report, IEA Wind Task 25, Phase one 2006–2008 (2009) <http://www.ieawind.org/AnnexXXV/PDF/Final%20Report%20Task%2025%202008/T2493.pdf>

(3) Impacts of large amounts of wind power on design and operation of power systems, results of IEA collaboration (2010) Wind Energy, Vol. 14 Issue 2, Wiley, DOI: 10.1002/we.410, pp 179–192.

(4) 9th International Workshop on Large-Scale Integration of Wind Power into Power Systems (2010) <http://www.opal-rt.com/events/9th-international-workshop-large-scale-integration-wind-power-power-systems-well-transmission>

(5) “Impact of wind power on the unit commitment and power system operations.” (2010). Kiviluoma J, O’Malley M, Tuohy A, Milligan M, Lange B, Holttinen H, Gibescu M, Meibom P, Viguerras-Rodríguez A, Gómez-Lázaro E. IN: Proceedings of the 9th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well

as on Transmission Networks for Off-shore Wind Power Plants. Québec City, 18–19.10.2010.

(6) “Operating reserves and wind power integration: An International Comparison.” (2010). M. Milligan, P. Donohoo, D. Lew, E. Ela, B. Kirby, H. Holttinen, E. Lannoye, D. Flynn, M. O’Malley, N. Miller, P. Børre Eriksen, A. Göttig, B. Rawn, J. Frunt, W. L. Kling, M. Gibescu, E. Comez Lazaro, A. Robitaille, I. Kamwa. IN: Proceedings of the 9th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Off-shore Wind Power Plants. Québec City, 18–19.10.2010.

(7) “Transmission planning for wind energy: Status and prospects.” (2010). Smith JC., Osborn D, Zavadil R, Lasher W, Gómez-Lázaro E, La Mancha C, Trötscher T, Tande JO, Korpås M, Van Hulle F, Estanqueiro A, Dale L, Holttinen H. IN: Proceedings of the 9th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Off-shore Wind Power Plants. Québec City, 18–19.10.2010.

(8) Western Wind and Solar Integration Study (2010) prepared for NREL by GE Energy, NREL/SR-550-47434, [http://www.nrel.gov/wind/systemsintegration/pdfs/2010/wwis\\_final\\_report.pdf](http://www.nrel.gov/wind/systemsintegration/pdfs/2010/wwis_final_report.pdf)

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



# Chapter 5

## Task 26 Cost of Wind Energy

# 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 euro/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. As wind is becoming an important source of electricity generation in many markets and competes with other technologies—notably natural gas—in terms of new installed capacity, it is crucial that governments and the wind research community are able to discuss the specific costs of wind systems on the basis of a sound methodology. Without a clear impartial voice regarding

the costs of wind systems, organizations without a clear understanding of wind systems are left to determine and publicize the costs of these 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 the 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, and 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; assessment of methodologies and results for estimating the value of wind energy.

Providing transparency in the cost elements of wind projects among all 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

**Table 1 Task 26 Participants**

	Country	Contracting Party; Organizations
1	Denmark	Risø National Laboratory (Risø-DTU), EA Energy Analyses
2	EWEA	European Wind Energy Association
3	Germany	WindGuard
4	Netherlands	Energy Research Centre of the Netherlands (ECN)
5	Spain	Spanish Wind Energy Association (AEE)
6	Sweden	Swedish Energy Agency, Vattenfall
7	Switzerland	Swiss Federal Office of Energy
8	United States	National Renewable Energy Laboratory (NREL), Lawrence Berkeley National Laboratory (LBNL)

## Task 26

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 1980's, 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 2010

In 2010, activities included:

- Collection of representative cost and performance input data for wind projects installed in 2007 and 2008 for each participating country
- Application of a transparent, discounted cash flow spreadsheet model to estimate the levelized cost of wind energy (LCOE)
- Analysis of each individual country's wind energy costs relative to a

common reference. A report summarizing this analysis was published (2).

Representative onshore wind project cost data was collected by each participating country to represent the cost of projects installed in 2007 and 2008. Various methods and sources were used by each participant. Details vary among participating countries, but total installed capital cost, annual energy capture, operation and maintenance cost, finance parameters and incentive schemes are all provided at a high level. This data forms the basis for the development of a reference wind project representing an "average" across all participating countries.

Each participant conducted an analysis of deviations between individual country cost elements and the reference project. In this way, insight related to features of project development in each country is captured. Summaries of the current industry status, individual project features, and deviations from the reference are included in the report.

This analysis used a spreadsheet-based cash flow model developed by the Energy Research Centre of the Netherlands (ECN) to estimate the LCOE. The ECN model is a detailed discounted cash flow model used to represent the various cost structures in each of the participating countries from the perspective of a domestic financial investor in a wind energy project. The ECN model has been customized in this analysis to exclude

country-specific wind energy incentives, resulting in unsubsidized LCOE estimates and is shown in figure 1.

The magnitude of the unsubsidized LCOE variation has been attributed to differences in country-specific energy production, investment cost, operations cost, and financing cost. As expected, the largest LCOE impact from country to country was the anticipated energy production component that could be due to the inherent wind regime, site selection, wind turbine design, or other factors. Market forces such as electricity market structuring or the perception of risk in a wind project investment also impacted the LCOE through large variations in both capital expenditures and financing costs. Costs attributed to the operations of a wind project ranged broadly across countries and had a sizable LCOE impact as well, though caution with the reported data for operations and maintenance costs were common. The unique factors contributing to the variations in LCOE across countries are explored further in the comparative analysis and country-specific wind energy chapters of the report.

Web-based meetings were held nearly monthly throughout the year to maintain communication and progress. An in-person meeting was held in June in Berne, Switzerland to assess progress. Initial presentation of work related to estimating future cost of wind energy and valuing wind energy was the primary activity.

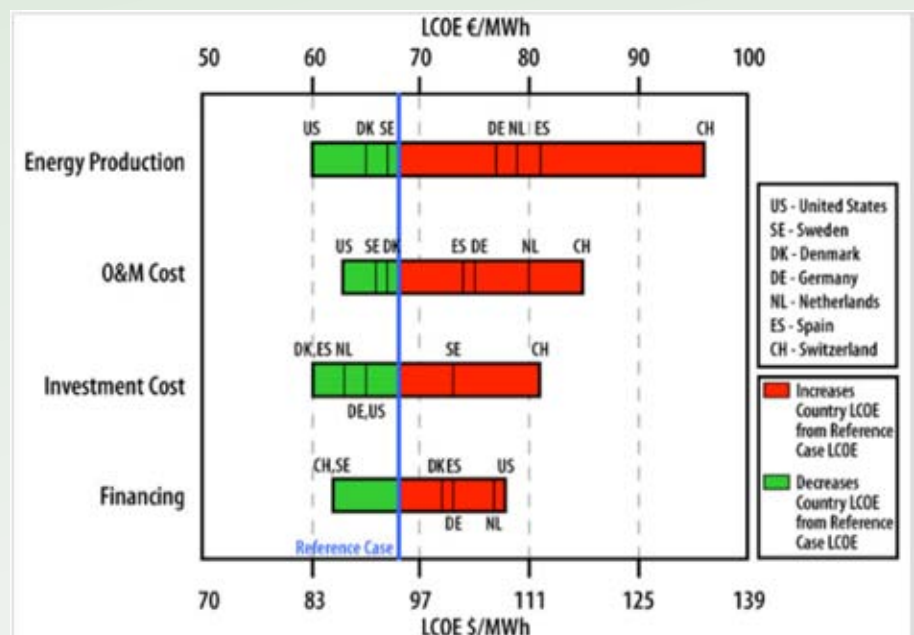


Figure 1 Range of LCOE associated with variation of each primary cost parameter

#### 4.0 Plans for 2011

During 2011, work packages 2 and 3 reports will be completed. The work package 2 report will summarize methods and approaches for estimating the future cost of wind energy. The work package 3 report will survey methods in use by each participating country for estimating the value of wind energy. Web meetings will occur throughout the process for completing these reports. An in-person meeting is planned for March 2011. The work for this task formally began in January 2009 and is expected to continue for until the end of 2011.

#### References:

- (1) 2009 Wind Technologies Market Report (2010) Wisler, R. and M. Bolinger, DOE/GO 102010-3107.
- (2) Multi-national Case Study of the Financial Cost of Wind Energy, IEA Wind Task 26 Work Package 1 Final Report (2011) <http://www.ieawind.org/IndexPagePOSTINGS/IEA%20WIND%20TASK%2026%20FULL%20>

REPORT%20FINAL%203%2010%2011.pdf

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



## Task 27 Small Wind Turbine Labels for Consumers



Photo courtesy NREL

### 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<sup>2</sup> 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. The final outcome will be the production and

publication as soon as possible of an international sector guide in the form of an IEA Wind Recommended Practice.

From the beginning of this task in December 2009 through December 2010, nine IEA Task 27-IEC MT2 liaison meetings have been conducted. Those meetings have been held in Madrid (Spain), London (United Kingdom), Wausau (United States), Toronto (Canada), Tokyo (Japan), Kaiser-Wilhelm-Koog (Germany), Glasgow (United Kingdom), Boulder (United States), and Perth (Australia).

### 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 and performance of small wind turbines. This task is expected to have a large impact on the SWT sector. It 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 are to be 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 deceptive investments in less than optimum equipment.

Expected results include:

- Report about state-of-the-art regarding SWT testing and reporting
- Recommendations for labeling reporting
- Internationally accepted SWT customer label
- Development of a Small Wind Association of Testers (SWAT)

### 3.0 Progress in 2010

#### 3.1 Meetings of participants

Three IEA Wind Task 27-IEC MT2 Liaison meetings were held during 2010. Experts on this subject from certification bodies, research institutes and universities, and the SWT industry were invited to exchange knowledge and to come to a common understanding of the developments, conflicts, and their solutions. The first meeting in Glasgow, United Kingdom, was attended by 17 experts from 11 countries. Results were presented from tests on the AIR Dolphin SWT performed at the WEIcan test facility in Canada. A presentation was given on urban integration and 3-D TI measurements taken in Japan. Each participant presented an overview of its SWT sector. A review of SWT testers’



**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	Chinese Wind Energy Association (CWEA)
4	Denmark	Risø National Laboratory (Risø-DTU)
5	Germany	ISET-Kassel University
6	Ireland	Dundalk Institute of Technology
7	Italy	University of Napoli
8	Japan	National Institute of Advanced Industrial Science and Technology (AIST)
9	Korea (New partner)	Korean institute for Energy Research (KIER)
10	Spain	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)
11	Sweden	Flexenclosure AB
12	United Kingdom	National Engineering Laboratory (TUV-NEL)
13	United States	National Renewable Energy Laboratory (NREL)
	France (observer)	ADEME

activities was completed. SWAT governance and membership matters are under definition, with potential barriers analysis.

The second IEA Task 27-IEC MT2 Liaison meeting of 2010 was held in Boulder, Colorado, United States in September 2010. The 20 participants represented mainly research organizations, manufacturers, and universities. They represented Australia, Denmark, Germany, Greece, Japan, Spain, Sweden, the United Kingdom, the United States, and France as observer.

The third IEA Task 27-IEC MT2 Liason meeting of 2010 was held in Perth, Australia in December 2010. The 14 experts came from certification bodies, research organizations, and the SWT industry. Australia, Denmark, Japan, Spain, Sweden, the United Kingdom, and the United States were represented. The recommended practices document (Draft 9) was reviewed. The transition procedure from IEA label to 3rd edition of IEC was analysed. The IEA Wind 2009 Small Wind Annual Report was reviewed. The SWAT Summary report (Rev 2) was reviewed.

### 3.2 Reports and decisions

Three key deliverables were nearly ready for release in early 2011.

- The 2009 Small Wind Annual Report is the first such report collecting the status of activities in the participating countries. It will be released to [www.ieawind.org](http://www.ieawind.org).

- The draft of Recommended Practices for Wind Turbine Testing and Evaluation: 12 Consumer Labels for Small Wind Turbines was ready for final approval by the task participants in 2011. A draft bilingual label (French/English) was drafted (Figure 1).

- Governance principles were developed for the Small Wind Association of Testers. The four levels of accreditation from the SWAT test agency were defined.

- A = accredited certification body (EN 45011 and ISO/IEC guide 65),
- B = independent accredited test organization
- C = independent unaccredited test organization (SWAT Members)
- D = observers (manufacturer, non-validated test sites or others).

Manufacturers may participate through their certification body or as an observer. Test organizations and certification bodies wishing to issue a consumer label must become a member of SWAT. New SWAT members shall be nominated by an existing SWAT member. Validation of an application is made by simple majority of current members (one vote per

Test Report/Rapport d'essai	
Manufacturer/Fabricant	Manufacturer
Model/Modèle	Model
Reference Annual Energy/ Référence d'énergie annuelle	### kWh/yr
<small>@5 m/s average wind speed actual production will vary depending on site conditions @ 5 m/s vitesse moyenne du vent production réel peut varier selon les conditions du site</small>	
Declared Sound Power Level/ Bruit Déclaré Puissance	## dBA
Turbine Test Class/ Classe de Test de Éolienne	II
<small>(L V or/ou 3 for Special/For Special)</small>	
Tested by/Testé par	Wind Energy Institute of Canada
Issued date/Date d'émission	12/02/2010
<a href="http://www.smallwindtesters.org">www.smallwindtesters.org</a>	

Figure 1 Draft consumer label in English and French

## Task 27

organization). Potential SWAT members are invited to participate as an observer (observer has no voting rights). SWAT membership can equally be revoked by a vote of simple majority of SWAT members. The balloting process will be handled via email (all the SWAT member should vote YES/NO/Abstention).

The following sequence leads to issuing a customer label:

- SWAT member application form is filled out.
- SWAT member qualification procedure to be deemed competent for full scope of the label: energy production, acoustics, duration. SWAT member applicants should submit a capability statement (e.g. an example of previous work). Before joining or every three years, at least some type of Round-Robin validation test should be done.
- SWAT member submits SWAT summary report and issued label to the IEA Task 27 blog web page or its successors.
- Questions or comments would be dealt with by exception and submitted to the IEA Task 27 blog, web page, or its successors.
- Issuing SWAT member is responsible for label; modifications, updating, new models.

Table 2 lists the data classes from SWT test facilities owned by the IEA Task 27 participants.

### 4.0 Plans for 2011 and beyond

The Recommended Practices document and the IEA Wind Task 27 2009 Small Wind Annual Report will be issued.

The participants plan to write informative annexes to the Recommended Practices on the following topics:

- variants and changes to turbines
- typhoon wind conditions
- extreme heat and sand external conditions
- cold weather external conditions
- building-integrated SWTs
- support structures
- electrical Systems
- turbulence conditions as a function of wind class.

The deployment of SWAT will be completed.

The participants will submit a proposal to the ExCo to extend the work of

Country	SWAT Test Sites Available	Level	Data availability
Australia	RISE Facilities	C	Low turbulence data available
Canada	WEICan / DEWI	C / B	Low turbulence and very cold weather data available
Denmark	RISØ	C	Low turbulence data available
Germany			
Greece	TEI	B	
Ireland			
Japan	Not available yet	C	High turbulence data available
Spain	CIEMAT-CEDER	Going to B	Low turbulence data available
Sweden	Not available yet	Going to A & B	
United Kingdom	TUV-NEL	A & B	Mid turbulence data available
United States	NREL	B	High turbulence data available
United States	SWCC	Going to A?	
United States	Regional Test Centers	C	
France (observer)	SEPEN /Narbone	C	High turbulence data unavailable

Milestone	Contributors	Month Due
Meeting to present final results of SWT labeling procedure. Finalize the Recommended Practices Proposed: Madrid, Spain	All	February 2011
Meeting to present the results of the applications and urban integration approach Proposed: PEI, Canada	All	June 2011
Meeting to finalized peer review task Proposed: Gottland, Sweden	All	September 2011
Meeting to complete Final Report and prepare recommendations and future work Proposed: Shanghai, China	All	December 2011

the task for another term (2012 to 2013). The main objective of the extension will be to develop a Recommended Practice for Design of Small Wind Turbines in the Built Environment. The Recommended Practice will address the special resource assessment needed for the built environment and the special testing and design

standards needed for SWTs operating in the built environment. This new Recommended Practice will extend the consumer label to SWTs in the built environment.

Author: Ignacio Cruz, Ciemat, Spain.

# Chapter 7

## Task 28 Social Acceptance of Wind Energy Projects



### 1.0 Introduction

The need for development of renewable energy production is increasingly recognized by various stakeholders. Many promoters of wind energy and other renewable energy projects have realized that

the issue of acceptance of these facilities in institutions, environmental organizations, market actors, and local communities is crucial to the development of wind energy in countries worldwide. The local communities play an especially important

role as people will have to accept energy production facilities in their vicinity to a much larger extent than before.

Wind turbines are seen as a green and clean energy source, but they do impact the lives of the people living with them

**Table 1 Task 28 Participants**

	Country	Contracting Party; Institution(s)
1	Canada	Natural Resources Canada, CANMET Energy Technology Centre; University of Québec at Montréal
2	Denmark	Danish Energy Authority; private consultant
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 Nagoya
7	Netherlands	Agentschap NL, NL Energy and Climate
8	Norway	Norwegian Water Resources and Energy Directorate; Enova SF; Norwegian University of Science and Technology,
9	Switzerland	Federal Department of the Environment, Transport, Energy and Communications, Swiss Federal Office of Energy; ENCO Energie-Consulting AG,
10	United States	U.S. Department of Energy, National Renewable Energy Laboratory Wind Technology Center



## Task 28

(see opening photos). To avoid conflicts, for example, lighting at night for security reasons has to be optimized, and impacts on the local ecosystem, such as on birds, has to be minimized. A further implication of wind energy and its geographical incidence is the necessity to build transmission lines which in some countries can provoke more opposition than the turbines themselves!

Research and projects about social acceptance are ongoing in many countries, but we need to look beyond national borders to learn from each other and to complement each other's approaches. In the framework of the IEA Wind Implementing Agreement, Task 28 collects and disseminates the current knowledge on how to increase acceptance of wind energy projects with the aim of facilitating implementation of wind energy and climate targets. Ten countries have officially committed to Task 28 (Table 1).

### 2.0 Objectives and Strategy

The objective of IEA Wind Task 28 is to assist countries in reaching their ambitious renewable energy goals and to support the industry in getting their wind parks built. During the last few decades, knowledge on how to "win hearts and minds" has been built up, but the results mostly from social sciences have to be translated into the language of developers, planners, and administrative bodies. This translation

of knowledge might help prevent misunderstandings, reduce the time for project development, and therefore minimize project risks.

The work packages and time schedule are illustrated in Figure 1, and the objectives of this task are as follows.

- Establish an international forum to exchange knowledge and experiences related to social acceptance and other societal issues of wind energy development. This network is composed of a working group that meets twice each year and support groups organized in each country in the form of national gatherings or conferences (see 3.0 Progress in 2010 and 4.0 Plans for 2011 and beyond). Additionally, workshops at international conferences are used to gather feedback from the stakeholders.
- Compose a State-of-the-Art Report on the knowledge and results so far on social acceptance of wind energy projects. This report was published in 2010 (1). An online library, accessible to the public, complements this report. It gathers papers, documentation of various kinds of projects, links, etc. from countries all over the world in their respective languages. The State-of-the-Art Report and the online library are available on [www.socialacceptance.ch](http://www.socialacceptance.ch)
- Establish Good Practices and tools

for policy makers and planners to reduce project risks and to help realize the full potential of wind energy and of political tasks. Additionally, successful participation and involvement models and a social marketing strategy for wind energy will be developed.

- Establish strategies and communication activities for disseminating knowledge on how to improve or to maintain the image of wind power. This communication might support the "debunking of myths" concerning issues such as landscape, health, or impacts on ecosystems.

### 3.0 Progress in 2010

The working group focused on the State-of-the-Art Report and an exchange with national expert groups in 2010. First steps into the development of Good Practices were made as well.

- Third meeting in Warsaw, Poland (spring 2010): Further development of work and contents. Discussion of online library and content of State-of-the-Art report. Discussion of possible dissemination activities and reflections on possible presentation of Good Practices. Representatives presented on the current situation and discussions in their respective countries.
- Third meeting in connection with side event and presentation at EWEC 2010 in Warsaw, Poland: Presentation of Task 28 and its work on State-of-the-Art in an official Acceptance session of EWEC 2010. Organization of a Task 28 side event and discussion with the interested public.
- Fourth meeting in Dublin, Ireland (autumn 2010): Further development of work and contents, finalization of State-of-the-Art Report, first attempts on Good Practices recommendations. Representatives presented on the current situation and discussions in their respective countries.
- Fourth meeting in connection with the first national gathering of Irish experts: around 40 researchers, grid operators, wind planners, NGOs and further actors presented and discussed social acceptance of wind energy in Ireland with the working group members of Task 28 present.
- IEA Wind Task 28 introduced additional discussions by web meetings as a preparation for the meeting and

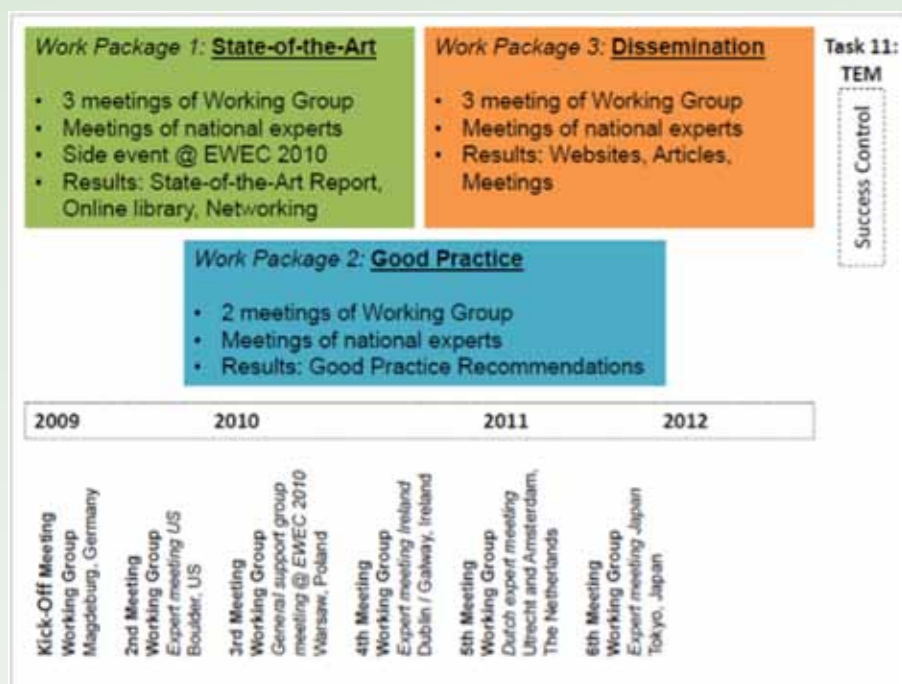


Figure 1 Schedule, work packages, and anticipated results of Task 28



an update for the working group members. In 2010, three web meetings were held (in February, June, and September) with about five to ten participants.

- The working group was regularly updated by email on Task 28 issues and on interesting projects in participating countries by presentations at the working group meetings.

- The web site [www.socialacceptance.ch](http://www.socialacceptance.ch) was expanded and is regularly updated. A web database including about 150 documents on the topic of social acceptance of wind energy is now available. The presentations given by the working group members at various conferences as well as the agenda and presentations from the national expert meetings are available on the website. A contact form was implemented on the web site for interested stakeholders to get in touch with national representatives in Task 28.

- The State-of-the-Art Report was finished (Figure 2). The report contains an overview of relevant knowledge and projects on social acceptance from participating as well as non-participating countries. The report also contains an introduction to the issue of social acceptance of wind energy projects and conclusions on what we know today and what has yet to be done.

- Nine country reports from participating countries have been published in connection with the State-of-the-Art Report on [www.socialacceptance.ch](http://www.socialacceptance.ch).

- An abstract for the 2011 European Wind Energy Association Annual Event in Brussels was submitted to present the work of IEA Wind Task 28 during the session “Siting challenges” and preparations for participation at the IEA side event during the conference were launched.

- As part of the dissemination activities, the Operating Agent and the Swiss representative began an article about Task 28 for a stakeholder bulletin, linking Swiss and Task 28 experience and presenting Good Practices to the Swiss wind energy actors.

- Contacts with non-participating countries such as the United Kingdom and Australia were sought by the Operating Agent to promote participation in the task.

- Two progress reports were written for the attention of the IEA Wind Executive Committee (65 and 66). The Operating Agent participated in one Executive Committee meeting.

#### 4.0 Plans for 2011 and beyond

Work Package 1, State-of-the-Art, will be followed by the publication and dissemination of the Report and the corresponding country reports. In 2011, the working group will concentrate on the formulation of Good Practice recommendations (Work Package 2, Good Practice). They will also explore effective ways to disseminate the results. (Work Package 3, Dissemination), e.g. papers or presentations of the Operating Agent and working

group members. In 2011, the Dutch and Japanese working group members will organize further national gatherings of social acceptance experts in connection with working group meetings.

Participants will discuss continuation of the task at the working group meetings, based on feedback also from the ExCo and taking into account social acceptance issues in other, so far non-participating, countries.

#### References:

(1) State-of-the-Art Report on Social Acceptance of Wind Energy, (2010) Task 28 report, [http://www.socialacceptance.ch/images/IEA\\_Wind\\_Task\\_28\\_technical\\_report\\_final\\_20110208.pdf](http://www.socialacceptance.ch/images/IEA_Wind_Task_28_technical_report_final_20110208.pdf)

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

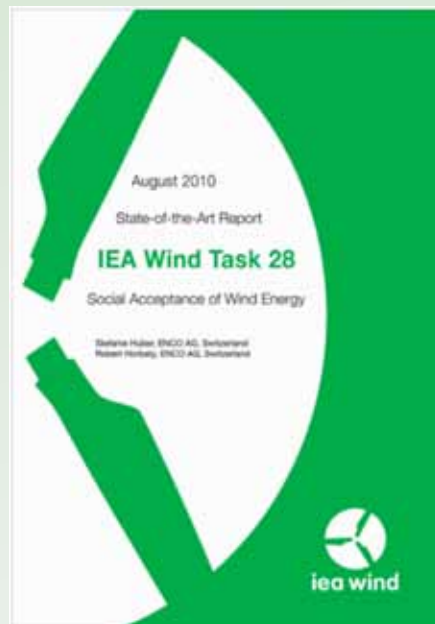


Figure 2 Task 28 State-of-the-Art Report on Social Acceptance of Wind Energy

Opening photo credits from top left clockwise: SEAI REIO; Espen Lie Dahl; <http://www.cedren.no/News/Article/tabid/3599/ArticleId/1153/Kan-redusere-fugledod.aspx>; BWEA; [www.northcountyleader.ie](http://www.northcountyleader.ie)

## Task 29 Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models



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, ten 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<sup>2</sup> 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 (3). An obvious difference between the two types of experiments lies in the larger size of turbine diameter for

### 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

**Table 1 Task 29 Participants**

	Country	Contracting Party; 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, Wind-guard
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	United States	National Renewable Energy Laboratory (NREL)

\* Technion in Israel is a subcontractor to Task 29.

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 then 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 makes it possible to share tasks. Added value also lies in the fact that the task will serve as a forum for discussion and interpretation of the results. The outcome of the data analysis will be 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 will be compared with the insights that were gained within IEA Wind Task 20 (2) on the NASA-Ames experiment and other wind tunnel experiments. The Operating Agent is the Energy Research Center of the Netherlands and the participants are listed in Table 1.

## 2.0 Objectives and Strategy

The objective of the IEA Wind Task 29 MEXNEX(T) is to improve aerodynamic models used for wind turbine design. Participants will conduct a thorough investigation of the measurements that were carried out in the EU sponsored MEXICO project. Special attention will be 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 will be

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 will also be carried out. As such, the Task will provide insight on the accuracy of different types of models and (descriptions for) improved wind turbine models. In order to reach the objective, the work-plan is divided into five work packages:

- WP1: Processing/presentation of data, uncertainties. The aim of this work package is to provide high quality measurement data to facilitate and compare calculations. To that end, the quality of the data is assessed and the data is 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 by 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 will be studied with advanced CFD models. Supporting information on tunnel effects will also be obtained from eight pressures, which were measured with taps in the collector entrance. These pressures measure the speedup in the outer flow (outside the wake) needed for the mass conservation of the tunnel flow.
- 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 are compared with the data from the MEXICO experiment. It is meant to be a thorough validation of different codes and it provides insights into the phenomena that need further investigation (see WP4).
- WP4: Deeper investigation into phenomena. In this work package, the phenomena will be investigated with isolated sub-models, simple analytical tools, or by physical rules. Some of the phenomena which will be investigated include 3-D effects, instationary effects, yawed flow, non-uniformity of the flow between the blades (i.e. tip corrections), and the wake flow at different conditions, among others.
- WP5: Comparison with results from other (mainly NASA-Ames)

measurements. The results from WP3 and WP4 are expected to provide many insights on the accuracy of different codes and their underlying sub-models. Within WP5 it will be 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).

## 3.0 Progress in 2010

In 2010 the project was well under way and many results have been produced in all of the above mentioned Work Packages. These results are presented at many occasions and for more information the reader is referred to the papers which have been presented at the European Wind Energy Conference (EWEC) in April 2010 (7) and the European Academy of Wind Energy (EAWE) conference 'The Science of Making Torque from the Wind' which was held on 28-30 June 2010.

This latter conference was followed by the third plenary meeting which was attended by almost all participants. At this meeting a large variety of subjects were presented and discussed. Amongst other things the comparison between calculations and measurements was discussed. Most interesting in this comparison is the fact that measurements of local aerodynamic blade loads can be related to the measurements of the underlying flow field. It was then very striking to find that the axial force coefficient as measured with two independent measurement techniques and at two rotational speeds is only 0.72 at a design tip speed ratio of 6.66 (Figure 1) where a value of 0.89 would be much more consistent. Such value is expected at design conditions and it yields a velocity decay which more or less obeys the relation from the axial momentum theory (Figure 2). The low value of  $C_{Dax}$  is not understood yet but it leads to the fact that the results from all calculational parties over predict the loads and/or they over predict the velocities (19).

Furthermore, attention was paid to the vortex shedding which occurs at the inner part of the PIV measurement range and which is attributed to the change from the DU-91-W2-250 airfoil to the RISO-A1-21 airfoil but it was then striking to see that this vortex shedding is not predicted by any of the codes, even though some codes do include the details of the blade geometry.



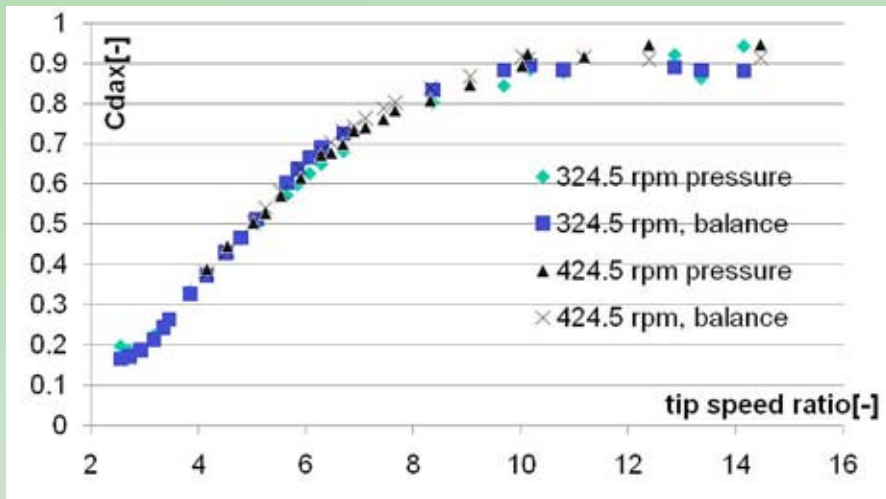


Figure 1 Axial force coefficient from pressure distributions and balance as function of tip speed ratio for two rotational speeds: 324.5 and 424.5 rpm.

#### 4.0 Plans for 2011 and Beyond

There is much work to be done in order to complete the task by the deadline of the middle of 2011. A meeting was held in January 2011 in Amsterdam, where discussion continued on the differences between calculations and measurements. The results obtained at yawed conditions were extremely interesting. A surprisingly good agreement in flow details has been found for this complicated situation. These results will be published soon. Furthermore it was decided that the actual geometry of the Mexico blades will be measured. This might shed some light on the question why the vortex shedding at the inner part of the blade is not predicted by even the most detailed calculational codes.

The last plenary meeting will be held in June 2011 in Jeju, Korea after which the final report and the task reports will be produced. These reports will give a concise description of the project results and they will mainly be compiled from the various articles and conference papers which have been made until now (4-19). Two conference papers have been approved for oral presentation at the European Wind Energy Conference (EWEC) in March 2011 (18) and (19). Six presentations on Mexico data will also be given at the "Wake Conference" held on 8-9 June 2011 in Gotland, Sweden

It is believed that some of the questions from the MEXNEX(T) project can only be answered from additional dedicated measurements. Attempts are being made to find funding for a 'New Mexico' project, possibly in relation to

the ESWIRP project, see <http://www.eswirp.eu/>.

During the meeting in January 2011, all participants expressed their wish for a follow-up IEA Task on aerodynamics but some discussion took place on the precise form of such Task. A well-liked option was a 'dual purpose' Task with, on one hand, some well-defined Work Packages which focus on very specific subjects, e.g. the use of aerodynamic measurements from different sources, and on the other hand a separate 'free-wheeling' Work Package. The underlying idea for this latter Work Package lies in the belief that new aerodynamic ideas might more easily be

generated in an environment without such strict constraints.

#### References

- (1) J.G. Schepers et al. Verification of European Wind Turbine Design Codes, VEWTDC. European Wind Energy Conference, EWEC, Copenhagen, July 2001.
- (2) H. Snel, J.G. Schepers and B. Montgomerie. The Mexico project the database and first results of data processing and interpretation In 'The Science of Making Torque from the Wind', August 2007.
- (3) S. Schreck. IEA Wind Annex XX: HAWT Aerodynamics and Models from Wind Tunnel Measurements. NREL/TP-500-43508, The National Renewable Energy Laboratory, NREL, December 2008.
- (4) A.K. Kuczaj. Virtual Blade Model Simulations of the Mexico experiment. NRG- 21810/09.97106, NRG Petten, the Netherlands, November 2009.
- (5) D. Rozendal. Flow field measurements on a small scale wind turbine model in the DNW PLST wind tunnel NLR report-CR-2003-484, The Dutch National Aerospace Laboratory, NLR, 2003.
- (6) H. Snel, J.G. Schepers, and A. Siccamo. Mexico, the database and results of data processing and analysis. 47th AIAA Aerospace Sciences meeting, January 2009.
- (7) J.G. Schepers, L. Pascal and H. Snel. First results from Mexnext: Analysis of detailed aerodynamic measurements on a 4.5 m diameter rotor placed in the large German Dutch Wind Tunnel DNW. Presented at the European Wind Energy

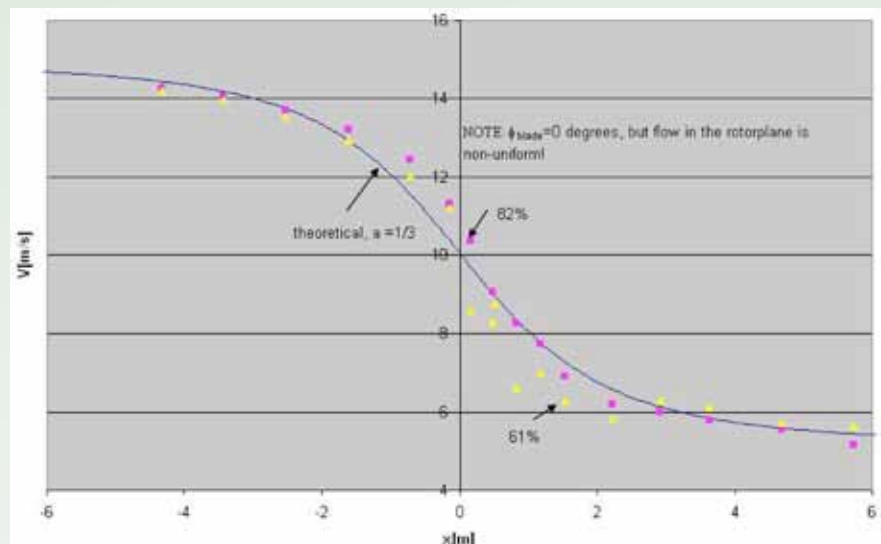


Figure 2 Measured axial traverse of velocities at 61 and 82% span compared with calculations from axial momentum theory



Conference, EWEC, April 2010, Warsaw Poland.

(8) D. Micallef et al. Validating BEM, direct and inverse free wake models with the Mexico experiment. 48th AIAA Aerospace Sciences meeting, January 2010.

(9) A. Bechmann and N. Sørensen CFD simulation of the Mexico rotor wake, European Wind Energy Conference, March 2009, Marseille France.

(10) S. Breton, C. Sibuet, and C. Masson. Using the Actuator Surface Method to Model the Three-Bladed MEXICO Wind Turbine 48th AIAA Aerospace Sciences meeting, January 2010.

(11) Wen Zhong Shen et al. Validation of the Actuator Line / Navier Stokes technique using Mexico measurements, 'The Science of Making Torque from the Wind', June 2010.

(12) Yang Hua et al. Determination of Aerofoil Data and Angle of Attack on the Mexico Rotor using Experimental Data, 'The Science of Making Torque from the Wind', June 2010.

(13) S. Schreck et al. Rotational Augmentation Disparities in the UAE Phase VI and MEXICO Experiments, 'The Science of Making Torque from the Wind', June 2010.

(14) S. Gomez-Irardi and X. Munduate. A CFD Investigation of the Influence of Trip-Tape on the MEXICO Wind Turbine Blade Sections, 'The

Science of Making Torque from the Wind', June 2010.

(15) B. Stoevesandt et al. OpenFOAM:RANS-Simulation of a wind turbine and verification 'The Science of Making Torque from the Wind', June 2010.

(16) S. Breton, C. Sibuet, C. Masson. Analysis of the inflow conditions of the MEXICO Rotor: comparison between measurements and numerical simulations, 'The Science of Making Torque from the Wind', June 2010.

(17) J.G. Schepers, K. Boorsma, H. Snel. IEA Task 29 Mexnext: Analysis of wind tunnel measurements from the EU project Mexico, 'The Science of Making Torque from the Wind', June 2010.

(18) T. Lutz, K. Meister, E. Krämer. Near Wake studies of the Mexico Rotor 'EWEA Annual Event', March 2011

(19) J.G. Schepers, K. Boorsma, C. Kim, T. Cho, Results from Mexnext: Analysis of detailed aerodynamic measurements on a 4.5 m diameter rotor placed in the large German Dutch Wind Tunnel DNW, 'EWEA Annual Event', March 2011

Author: J. Gerard Schepers, ECN, The Netherlands.

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



### 1.0 Introduction

The vast offshore wind resource represents a potential to use wind turbines installed offshore to power much of the world. Design standardization is difficult, however, because offshore sites vary significantly through differences in water depth, soil type, and wind and wave severity. To ensure that offshore wind turbine installations are cost effective, the use of a variety of support structure types is required. 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 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 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 the incident waves, sea current, hydrodynamics, and foundation dynamics of the support structure. The sophistication of these

aero-hydro-servo-elastic codes and the limited data available with which to validate them underscore 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, the IEA Wind Task 30 OC3 Continuation (OC4) project was established to continue the work. OC4 is led cooperatively by the National Renewable Energy Laboratory (NREL) and the Fraunhofer Institute for

Wind Energy and Energy Systems Technology (IWES).

Since the project began, 50 participants from 24 organizations in nine countries have participated in the task. Many more have followed the work via e-mail communication, but have not been able to attend any meetings.

### 2.0 Objectives and Strategy

The purpose of the project is to perform a benchmarking exercise of offshore wind turbine dynamics codes. To test the codes, the main activities of OC4 are to (a) discuss modeling strategies, (b) develop a suite of benchmark models and simulations, (c) run the simulations and process the simulation results, and (d) compare and discuss the results. These activities fall under broader objectives including:

- Assessing the accuracy and reliability of simulations to establish confidence in their predictive capabilities
- Training new analysts to run and apply the codes correctly
- Identifying and verifying the capabilities and limitations of implemented theories
- Investigating and refining applied analysis methodologies
- Identifying further research and development (R&D) needs.

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

Country		Institution(s)
1	Denmark	Risø DTU
2	Germany	Fraunhofer IWES, Germanischer Lloyd, LUH, Repower, University of Stuttgart, Garrad Hassan
3	Korea	POSTECH, University of Ulsan
4	The Netherlands	ECN, WMC
5	Norway	CeSOS/NTNU, FEDEM Technology, IFE, NTNU
6	Spain	Acciona Energia, ALSTOM Wind, CENER, SAMTECH
7	Sweden	GE Wind, Teknikgruppen
8	United States	ABS Consulting, National Renewable Energy Laboratory, Principle Power

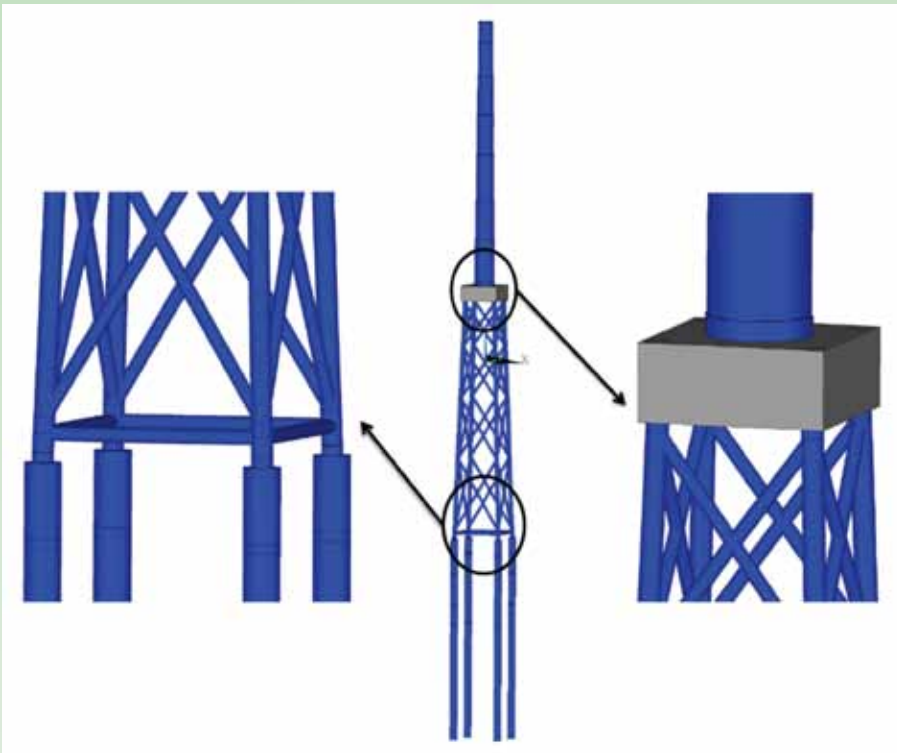


Figure 1 Fixed-Bottom Jacket Being Analyzed in OC4 Phase I (Wind Turbine Not Shown)

and lessons learned helped identify model deficiencies and needed improvements. These results are important because the advancement of the offshore wind industry is closely tied to the development and accuracy of system-dynamics models.

In OC3 and now again in OC4, 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. 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 semi-submersible. Additionally, an experts meeting on the topic of test methods, data availability, and code validation is planned as a stand-alone meeting.

The results of the OC3 project are summarized in its final report (1).

### 3.0 Progress in 2010

The project began with a kick-off meeting in Bremerhaven, Germany in June 2010. A second meeting was held in Hamburg, Germany in October 2010. In between physical meetings, progress is made through e-mail communication and Internet-meetings scheduled every one to two months.

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

- Many OC4 participants have contacted members of the IEA ExCo from their country to encourage them to join IEA Wind Task 30.
- An external website describing the work of the task has been published: [http://www.ieawind.org/Task\\_30/Task30\\_Public.html](http://www.ieawind.org/Task_30/Task30_Public.html). Work to establish an internal website for coordination of the task activities is ongoing.
- Many participants of OC4 who were also actively involved in the OC3 project under IEA Wind Task 23 Subtask 2 are working on a journal article summarizing the OC3 project's process and important results.

- The fixed-bottom jacket system design to be 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 (2). The jacket was designed to support the NREL 5-MW offshore baseline wind turbine (3).
- The load cases to be 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.
- Using the Phase I jacket system design and load cases, models were developed by 12 of the project organizations using 15 different codes, and initial simulation results were compared for the simplest load case



Figure 2 A Floating Semi-Submersible Will Be Analyzed in OC4 Phase II

## Task 30

involving the comparison of the component masses and overall system eigenfrequencies. With a few exceptions, the results compared well among the various models.

- Two floating semi-submersible platforms have been proposed for use in Phase II of OC4.

### 4.0 Plans for 2011 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. The topical experts meeting will be scheduled in late 2011 or early 2012. A report summarizing the results will be published at the conclusion of each phase, as well as on the results of the topical experts meeting. A final report encompassing the entire project will be published at the end of the task.

In the coming months, work will continue on (a) publishing the OC3 journal article, (b) modeling the OC4 Phase I jacket system, (c) assessing the options for the OC4 Phase II floating semi-submersible, and (d) planning the OC4 experts meeting on testing and model validation.

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 improve the accuracy of future predictions.

#### References:

(1) Jonkman, J. and Musial, M. Offshore Code Comparison Collaboration (OC3) for IEA Task 23 Offshore Wind Technology and Deployment. NREL/TP-500-48191. Golden, CO: National Renewable Energy Laboratory, December 2010.

(2) Vemula, N. K.; DeVries, W.; Fischer, T.; Cordle, A.; and Schmidt, B. Design Solution for the UpWind Reference Offshore Support Structure. UpWind

deliverable D4.2.6 (WP4: Offshore foundations and support structures), Esbjerg, DK: Rambøll Wind Energy, 2010.

(3) Jonkman, J.; Butterfield, S.; Musial, W.; and Scott, G. Definition of a 5-MW Reference Wind Turbine for Offshore System Development. NREL/TP-500-38060. Golden, CO: National Renewable Energy Laboratory, February 2009.

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



# Chapter 10

## TASK 3 | WAKEBENCH: Benchmarking of Wind Farm Flow Models

### 1.0 Introduction

Since the late 1980's with the appearance of the European Wind Atlas (1), the standard model for wind resource assessment has been Wind Atlas Analysis and Application Program (WAsP) with its Wind Atlas Methodology. The 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 since 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 there are currently a large variety of commercial and research models in the market. Yet, the transition from traditional linear models requires significant training and experience from the user due to the extended degrees of freedom of the CFD solver, compared with the linear model, which is more user-dependent. To overcome this difficulty, commercial CFD software developers are designing



user-friendly interfaces that can emulate to some extent the traditional way of working with linear models. Research CFD models in contrast are either based on generic commercial CFD solvers or on in-house or open-source codes and are used by researchers due to their flexibility to adapt to site-specific topographic and atmospheric conditions.

As with wind modeling, wake modeling for wind turbines originated in the 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, which results in unpredicted wake losses by 10% in many operational wind farms.

The turbine models embedded in an atmospheric model come in many different varieties and ranges of complexity and they are used for different scales of calculations. 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 simulations (DES) (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

computational time savings. Although, typically the more detail contained in the turbine model, the smaller the simulation due to constraints of computing resources.

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

Verification, validation and uncertainty quantification (VV&UQ) are fundamental problems in the development of any engineering model. This process allows a comprehensive transition from experience and test-based design to simulation-based design, producing more efficient and cost-effective design solutions (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: the domain size requires large wind tunnels and computer clusters, the wind conditions are the result of the interaction of a wide range of spatial and temporal scales, the simulation of open flow fields produces ill-defined boundary conditions.

As stated in the COST 732 Action (2009) report on microscale model evaluation (6), there is not a distinct definition of the requirements of a validation test case dataset and the procedure to use it in a consistent and systematic way. A basic requirement for any validation exercise is that the model and the validation dataset share the same or a very similar hypothesis. This basic rule is already difficult to fulfil since most of the microscale wind assessment models are based on steady-state simulations and field measurements are intrinsically transient and modulated by mesoscale effects. Intensive filtering of the field data and ensemble averaging is often necessary in order to match the desired flow conditions. A complementary solution to this “limitation” of the field data is to conduct wind tunnel measurements at a reduced scale. The controlled environment of the wind tunnel has been a fundamental tool for validation of CFD models even if, for atmospheric flows, all

the similarity criteria cannot be met at the same time.

A clever strategy for VV&UQ that combines field and laboratory measurements will be developed in this IEA 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 intercomparison 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 intercomparison 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 “WIND-BENCH” 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 2010

Task 31 was approved by the IEA Wind ExCo in October 2010. Since then, the OAs have been collecting expressions of interest from potential participants in the Task. In two months 30 organizations from 16 IEA Wind member countries, research institutes, and academia have declared interest. Negotiations are under way to consolidate the operational budget

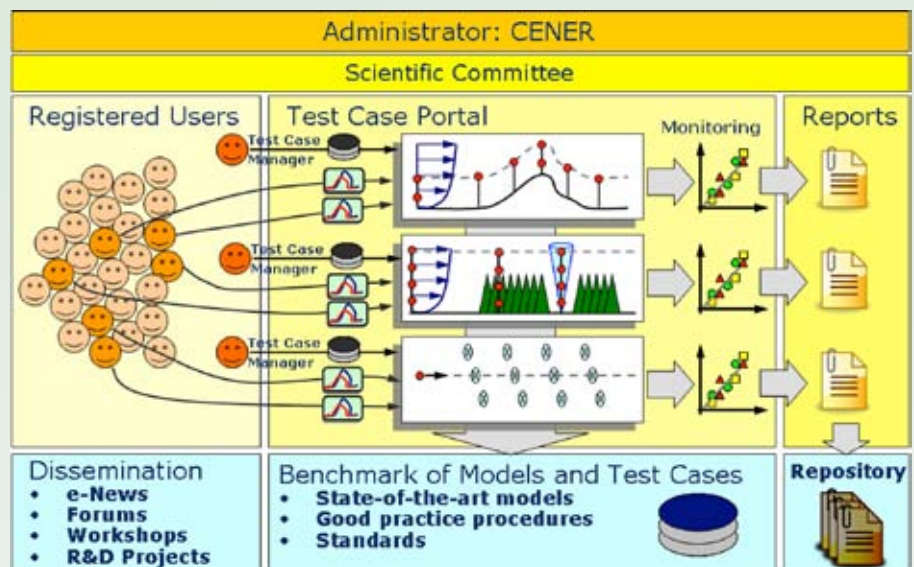


Figure 1 Sketch of the “WINDBENCH” web-portal for management of test cases

of the Task, which should start effectively in the second half of 2011.

#### 4.0 Plans for 2011 and Beyond

Besides the consolidation of the participants in the Task, 2011 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.

#### References:

- (1) Troen I., Petersen E.L., 1989, European Wind Atlas, Risø National Laboratory, Roskilde. ISBN 87-550-1482-8. 656 pp
- (2) Silva Lopes A., Palma J.M.L.M., Castro F.A., 2007, Simulation of the Askervein Flow. Part 2: Large-Eddy Simulations, Boundary-Layer Meteorol. 125: 85-108
- (3) Bechmann A., Sørensen N.N., 2010, Hybrid RANS/LES Applied to Complex Terrain, Wind Energy 13: 36-50

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

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

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

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



Source: Acciona Energy



### 1.0 Overview

Aided by world class resources, such as the Roaring Forties winds in the south of the continent, wind energy makes a significant contribution to Australia's clean energy mix and now supplies over 5,000 GWh annually - around 2% of the nation's overall electricity needs. Government support,

such as the Renewable Energy Target (RET), is crucial in supporting investment in the industry over the next decade and enabling wind to play a major role in helping Australia transition to a low carbon economy.

The RET scheme commenced on 1 January 2010, mandating that 20%

of Australia's electricity supply will be sourced from renewable energy by 2020. Its target is four times that of the previous mandatory renewable energy target (MRET) which was introduced in 2001.

The RET is expected to unlock more than 20 billion AUD (14.68 billion euro; 19.74 billion USD) in investment over the next decade, but has experienced teething problems over the last two years. Low prices for tradable renewable energy certificates (RECs) coupled with the global financial crisis and policy uncertainty around a price on carbon made it challenging for many developers to secure financing for new projects. Recent changes made to the implementation of the enhanced RET should go a long way toward returning some stability to the sector.

At the close of 2010 Australia had 54 wind farms with a total operating wind capacity of 1,880 MW. Three new projects

**Table 1 Key Statistics 2010: Australia**

Total installed wind generation	1,880 MW
New wind generation installed	167 MW
Total electrical output from wind	5.1 TWh
Wind generation as % of national electric demand	2%
Target:	The expanded Renewable Energy Target, (45 TWh from renewables by 2020) commenced in 2010.
<b><i>Bold italic</i></b> indicates estimates.	



were commissioned in 2010, adding 167 MW of capacity to the Australian electricity grid. Another eight projects were under construction by the end of 2010 and are expected to contribute an additional 1,047 MW within the next few years. A further 14,000 MW of projects currently proposed for Australia are either in the evaluation phase or undergoing the development approval process.

## 2.0 National Objectives and Progress

### 2.1 National targets

The expanded RET commenced on 1 January 2010 with an initial annual target of 12,500 GWh. This will be gradually increased until 2020. The purpose of the enhanced 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 RECs which must be surrendered each year by electricity retailers as prescribed by the RET legislation. An oversupply of these certificates in the REC market, as a consequence of other support measures for domestic small scale technologies, resulted in a low REC price during 2010. A reduced REC price makes it harder for wind developers to secure finance for projects.

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). This was designed to ensure a hot market for household technologies would not crowd out investment in industrial-scale investment. The new

scheme commenced on 1 January 2011. Combined, the new LRET and SRES are expected to deliver more than 45,000 GW-hours of renewable energy in 2020.

The Australian government is also re-examining placing a price on carbon following a decision in 2010 to delay the introduction of its Carbon Pollution Reduction Scheme (CPRS). The CPRS is an emissions trading scheme with medium and long-term emission reduction targets. The establishment of a multi-party Climate Change Committee in 2010 is exploring options for the implementation of a carbon price.

### 2.2 Progress

Since 2000, Australian cumulative installed wind capacity has greatly increased. The amount of installed capacity of wind power has increased by an average of 30%/yr over the past decade.

At the close of 2010, there were 54 wind farms (with two or more turbines) in Australia, with a total of 1,058 operating turbines. The total operating wind capacity was 1,880 MW. The estimated annual wind generation output in Australia from this 1,880 MW of installed capacity of wind energy is 5,100 GWh or 2.0% of national electrical demand.

Three new projects became fully operational throughout the year, adding capacity to the Australian electricity grid. All of these were in South Australia – Hallett 2 (AGL, 71.4 MW), Clements Gap, (Pacific Hydro, 56.7 MW) and Lake Bonney Stage 3 (Infigen Energy, 39 MW). Roaring 40s 111-MW Waterloo wind farm has also since been commissioned. An additional seven projects (Table 2) with a total of 936 MW are under construction and

expected to be 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 target of 33% by 2020, which provides an additional incentive for investment in the state.

In 2010 the federal government established The Australian Centre for Renewable Energy (ACRE). ACRE is a component of the government's 5.1 billion AUD (3.74 billion euro; 5.03 billion USD) Clean Energy Initiative. It aims to promote the development, commercialization, and deployment of renewable energy and hopes to enable technologies and to improve their competitiveness in Australia. The federal government is also planning to invest 1 billion AUD (.734 billion euro; .987 billion USD) over the next decade to bring more renewable energy into the national grid earlier.

GreenPower schemes also offer support to the deployment of renewables. Most major electricity retailers offer the option to purchase 10% to 100% of their electricity through the green power system. This allows customers to purchase electricity based on renewable energy from the electricity utility.

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 announced 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 (.734 million euro; .987 million USD) for wind farms. The scheme commenced in July 2010 and is valid for a period of four years.

### 2.4 Issues affecting growth

Although there are many wind farm projects currently proposed, including some very large projects, policy uncertainty around the introduction of a carbon price, the low price of RECs, and the financial crisis impacted upon the lending practices and risk appetites of banks. This combination of factors made it difficult for many developers to secure financing in 2010. The recent changes made to the

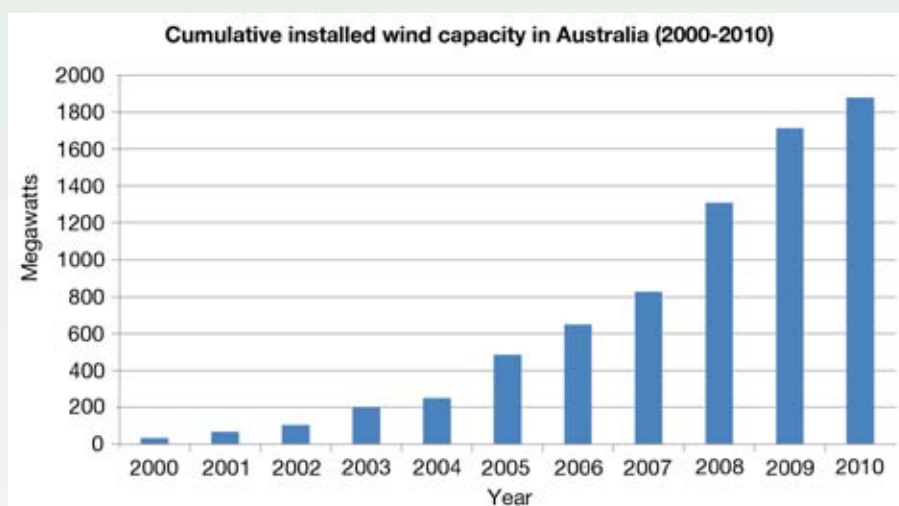


Figure 1 Cumulative installed wind capacity 2000-2010

Table 2 Wind farms under construction				
Owner	Location/Name	State	Expected Commission Year	Installed Capacity
AGL / Meridian Energy	Macarthur	Victoria	2013	420 MW
Roaring 40s	Musselroe	Tasmania	2013	168 MW
AGL	Hallett Stage 4 (Nth Brown Hill)	South Australia	2011	132 MW
Roaring 40s	Waterloo	South Australia	Commissioned Jan 2011	111 MW
Union Fenosa	Crookwell 2	New South Wales	2011	92 MW
AGL	Oaklands Hill	Victoria	2011	67 MW
AGL	Hallett Stage 5 (Bluff Wind Farm)	South Australia	2012	53 MW
Hepburn Community Wind Farm	Leonards Hill	Victoria	2011	4 MW

implementation of the enhanced RET should go a long way toward returning stability to the sector.

The ability to connect to the grid network impacts the placement of wind farms. In some parts of the existing electricity grid, upgrades and extensions may be required to support the expansion of the wind sector.

### 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. Nationally, wind power is spread over most states with South Australia having the highest capacity (Figure 2).

Around 2,000 people are employed in the wind sector and this figure is expected to grow as more wind farms are implemented. Bloomberg New Energy Finance estimated that new financial investment in wind power in the 2009-10 Australian financial year was almost 1.6 billion USD (2.15 billion euro).

Wind farm developers make an effort to source materials and labor from the local area wherever possible. An average-sized wind farm typically employs approximately 400 people during its construction. Wind turbines can also be an alternative source of income for farmers, who enter into leasing agreements to host them on their properties.

#### 3.2 Industry status

Many of the existing and proposed wind farms are owned by large electricity companies such as Acciona Energy, AGL, Origin Energy, Pacific Hydro, and Verve Energy. Other wind-specific companies include Infigen Energy and Roaring Forties. Investment and infrastructure funds such as Macquarie Capital Wind Fund 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 under development. These projects are small and

examples include the Denmark Community Wind Farm in Western Australia, the Hepburn Community Wind Park in Victoria, and the Mt Barker Wind Farm in South Australia.

Wind turbines are manufactured outside of Australia and imported as required. The majority of wind farm projects completed in the last few years have sourced wind turbines from companies such as Acciona, Enercon, REpower, Suzlon, and Vestas (Figure 3).

#### 3.3 Operational details

The size of Australian projects is increasing. The 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 proposal for a 1,000 MW wind farm at Silverton in New South Wales. In its current form, the Silverton Wind Farm would contain 598 turbines and produce 4.5% of the state's total power consumption.

Every Australian state generates wind power and South Australia provides more than 48% of the national total. Currently there are 8,638 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 4). Another 5,479 MW of projects are undergoing

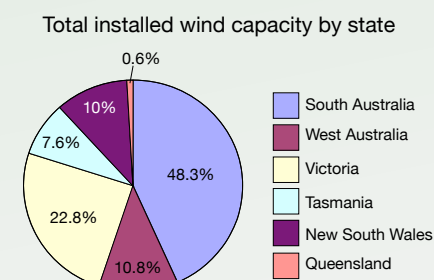


Figure 2 Installed wind capacity in Australia by state

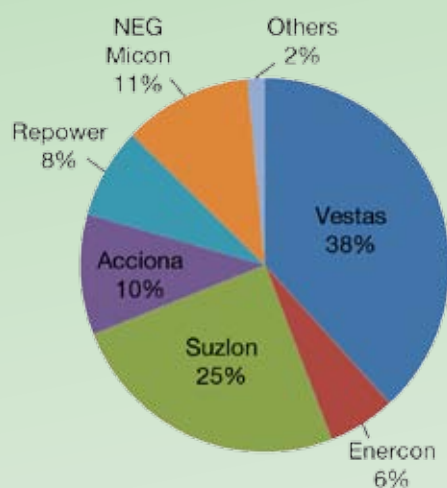


Figure 3 Installed wind capacity in Australia by turbine supplier

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

The Australian Centre for Renewable Energy (ACRE) is a one-stop shop for Australian renewable energy businesses and is responsible for the administration of programs such as the Renewable Energy Demonstration Program and the 14 million AUD (10.27 million euro; 13.82 million USD) Wind Energy Forecasting Capability Program which gave rise to the

Australian Wind Energy Forecasting System (AWEFS).

AWEFS is a centralized system that provides predictions of wind energy generation using weather forecasts from meteorological bureaus and operational data from wind energy generators. The system uses data such as site wind speed, wind direction, turbine availability, and output to forecast expected wind energy generation. The base system was launched in 2008 with additional Australian-specific functionality and enhancements implemented in 2010.

The Australian government announced a number of new initiatives in 2010. The government announced a commitment to set aside 1 billion AUD (.734 billion euro; .987 billion USD) over 10 years to connect Australia's renewables to Australian homes as part of the Connecting Renewables Initiative; a 40 million AUD (29.36 million euro; 39.5 million USD) investment in emerging energy technologies through the Emerging Renewables program; and a 100 million AUD (73.4 million euro; 98.7 million USD) investment to establish a Renewable Energy Venture Capital Fund to support emerging energy technologies. Part of the funding for these initiatives will come from the Renewable Energy Future Fund. As the latter two programs are directed toward emerging energy technologies, wind energy is not expected to be a recipient.

In 2010, the state of New South Wales established six renewable energy precincts across the state to streamline the planning and approval process for wind developers. Each precinct has a coordinator and an advisory committee that can provide advice on development issues

and enhance consultation with local government and communities.

### 5.0 The Next Term

In July 2010 the Environment Protection and Heritage Council released its draft National Wind Farm Development Guidelines for a period of 12 months to provide jurisdictions with the opportunity to assess how these guidelines would be incorporated within their existing planning and development processes. The guidelines aim to outline best practice for industry and planning authorities in areas including heritage, threatened species, and turbine noise.

The RET is expected to unlock an estimated 20 billion AUD (14.7 billion euro; 19.74 billion USD) of investment by 2020 and create more than 40,000 jobs. As wind power is the lowest cost form of large-scale renewable energy, much of the growth in renewable energy required to meet the targets is expected to come from this sector. With the right policy mix and increased demand for low emission energy, the wind industry can remain a major contributor to the multi-billion dollar challenge of decarbonizing Australia's energy supply.

Author: Felicity Sands, Policy Analyst, Clean Energy Council, Australia.

**Table 4 Indicative development costs for Australian wind farms**

Cost Item	Million AUD/ MW	Contribution to capital costs
Turbine works	1.50-2.00	60-75%
Civil & electrical work up to the point of connection	0.35-0.60	10-25%
Grid Connection	0.05-0.35	5-15%
Development & consultancy work, windspeed monitoring	0.15-0.42	5-15%
<b>Total</b>	<b>2.05-3.37</b>	<b>100%</b>

Source: Review of the Australian Wind Industry for the Clean Energy Council, Garrad Hassan, 2010





Source: Energiewerkstatt Verein

### 1.0 Overview

Wind power development has great potential in Austria again after four years of stagnation from 2006 to the beginning of 2010. Due to the new feed-in-tariff for 2010 and 2011 (0.097 €/kWh; 0.130 USD/kWh) eight wind turbines with a total capacity of 16 MW were built in 2010.

The feed-in-tariff for 2011 was fixed (0.097 €/kWh; 0.130 USD/kWh) for projects that apply for a purchase agreement by the end of 2011. The feed-in tariff is set by an ordinance of the Ministry for Economic Affairs and not fixed in the Green Electricity Act (GEA) itself. The tariff is applicable only for the year 2011, bringing some uncertainty for investors. The purchase obligation is limited to a specific amount of capacity (depending on the available funds for new projects).

At the beginning of 2011 there were 625 wind turbines in Austria with a total capacity of 1,011 MW. These turbines are producing 2.1 TWh of electricity, which

is a share of 3.9% of Austrian electricity production and energy for approximately 600,000 households. In 2011, we expect added installation of 120 MW. A total of 800 MW of capacity have already obtained all planning permits and have applied for a contract (granting the feed-in-tariff) at Ökostromabwicklungsstelle OeMAG and will be built in the next years.

### 2.0 National Objectives and Progress

#### 2.1 National targets

The GEA sets a target of 15% of renewable energy supply without large hydro and a specific target of additionally 700 MW of wind power capacity by 2015 (a rise to 1,700 MW). In its National Renewable Energy Action Plan (according to European Union directive 2009/28/EC), Austria sets a target of 1,951 MW by 2015 and 2,578 MW by 2020. 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 2010, 1,011 MW of wind capacity were installed in Austria (Figure 2), producing 2.1 TWh/yr. This is equivalent to 3% of the Austrian electricity consumption. This wind electricity avoids 1.3 million tonnes of CO<sub>2</sub> emissions every year.

### 2.3 National incentive programs

#### • Green Electricity Act (GEA)

The GEA (Ökostromgesetz) adopted in 2002 triggered investments in wind energy (Figure 2). An amendment in 2006 brought uncertainty to green electricity producers and new restrictions for projects. The purchase-obligation for new projects was limited to a certain annual budget. In addition to a low feed-in tariff, these new restrictions resulted in a dramatic reduction of new wind projects beginning in 2007. After three years of stagnation of the wind power market in Austria, an amendment to the GEA finally took effect in October 2009 that helps planners of wind parks and raises funds for new green electricity projects. Furthermore, a new feed-in-tariff was fixed in 2010 (0.097 €/kWh; 0/130 USD/kWh).

The GEA establishes a feed-in system for renewable energies. However, there are restrictions: 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 that is 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 (that is 21 million €/yr; 28.2 million USD/yr for new projects). Applicants have to submit all legal permissions in order to be able to get money from these funds.

#### • Green Electricity Regulation – Ökostromverordnung 2011

The feed-in tariffs for renewable energy sources are fixed in the Ökostromverordnung/Green

**Table 1 Key Statistics 2010: Austria**

Total installed wind generation	1,011 MW
New wind generation installed	16 MW
Total electrical output from wind	2.1 TWh
Wind generation as % of national electric demand	3%
NREAP-Target:	1,951 MW by 2015; 2,578 MW by 2020



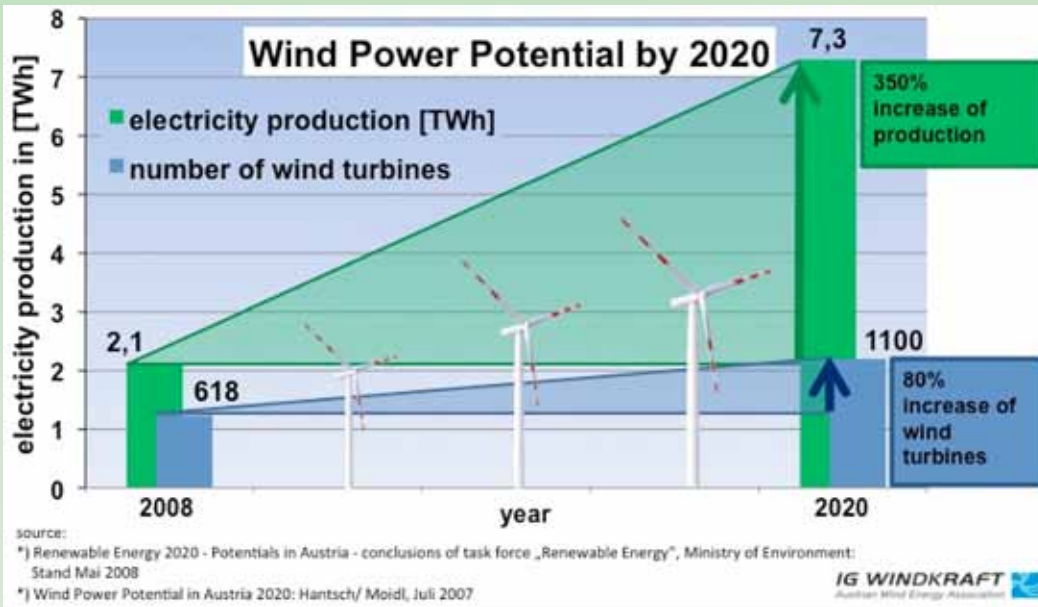


Figure 1 Wind power potential in Austria by 2020

Electricity Regulation by the Minister of Economy in accordance with the Minister of Environment. The tariffs are guaranteed for 13 years and applicable for projects that have obtained all planning permissions by 31 December 2011. The feed-in-tariff for wind energy is 0.097 €/kWh (0.130 USD/kWh). The tariff is applicable only for the year 2011, bringing some uncertainty for investors.

#### 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 program, and the annual amount of money for new projects (annual funds). Due to the problems mentioned above, wind power capacity growth stagnated from 2006 to 2009. In 2011 we expect the addition of 120 MW, mainly in the provinces of Lower Austria and Burgenland in the east of Austria. A total of 800 MW have obtained all planning permits and have applied for a contract (granting the feed-in-tariff) at Ökoabwicklungsstelle OeMAG and will be built within the next years.

One determining factor for wind power growth is that the already mentioned annual funds for new projects (21 million €; 28.2 million USD) is too low to give contracts to all 800 MW of projects that have applied for contracts. At the moment, negotiations with regard to an amendment of the GEA are taking place and there are good signals that there will be

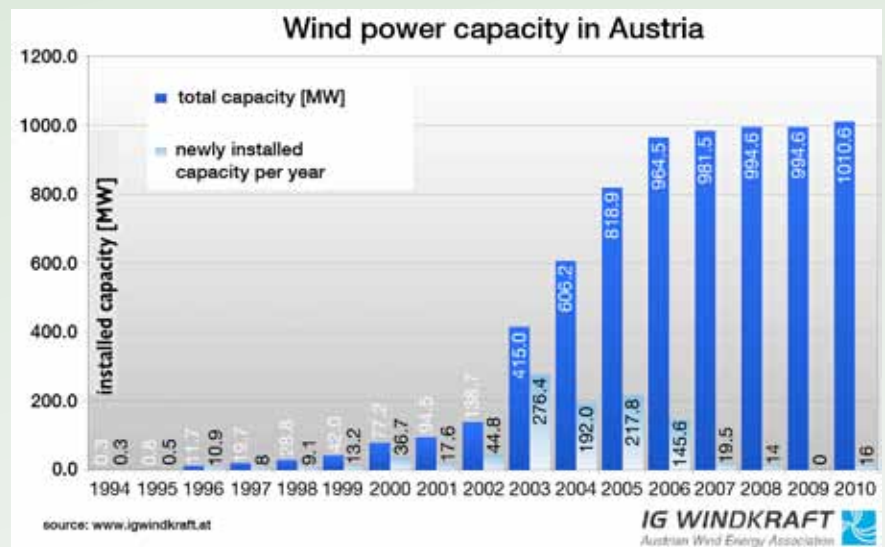


Figure 2 Total wind power capacity in Austria

an amendment by summer, removing this barrier and granting more annual funds.

### 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 € (201.6 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 470 million € (631.68 million USD). So far, 3,300 jobs have been created in the wind energy sector.

#### 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 were built in 1994 when

## Austria

cooperatives or single wind turbines built by farmers were most common. With a more stable framework in the support system since 2000, but especially since 2003, utilities and other companies entered the market. Today the most active operators planning new wind projects are cooperatives and traditional electricity utilities. The Austrian operators are very active in the neighboring countries of central and eastern Europe, and some independent companies have also started businesses outside Europe.

The one domestic manufacturer of large turbines, Leitwind, began the manufacture of wind turbines in Telfs in Tyrolia in 2008. Apart from Leitwind there are no major manufacturers of wind turbines (however there are manufacturers of small (micro) wind turbines).

Austrian component suppliers also serve the international wind turbine market. Bachmann electronic GmbH is a leading manufacturer of turbine control systems. Hexcel Composites GmbH develops and produces materials for blades. Elin EBG Motoren GmbH expanded its production of generators in 2009 and established a joint venture with Suzlon in India. AMSC Windtec GmbH is an engineering company that develops complete electrical and mechanical systems for wind turbine applications. Among its customers are Asian companies such as Hyundai and Sinovel. Windtec develops customized wind turbine concepts and helps its customers to set up their own production.

### 3.3 Operational details

Most of the turbines in Austria are 1.8 MW to 2 MW in capacity. Enercon and Vestas are the most important suppliers of turbines (Figure 3).

### 3.4 Wind energy costs

Table 2 shows estimated costs for wind project elements.

## 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 have focused on issues regarding complex terrain and cold climate solutions. Addressing the complex wind conditions in Austria, a two-year national research project (Project AuWiPot) aims to develop a high-resolution wind map of Austria. The new wind map combines numerical flow models with a

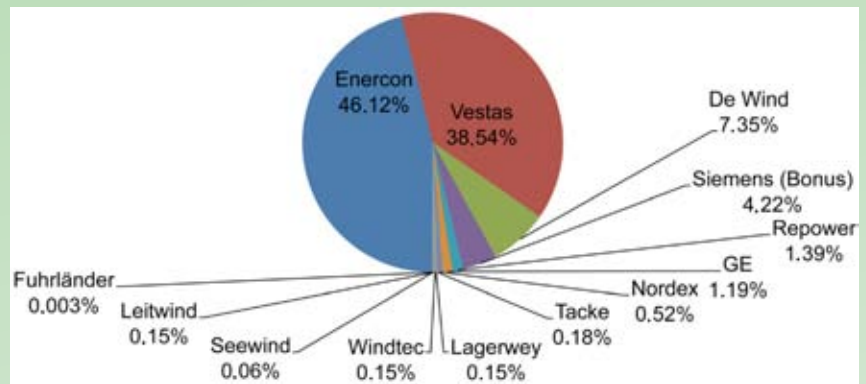


Figure 3 Market shares of wind turbine manufacturers in Austria

geo-statistical approach. This calculation of the theoretical wind potential strives to estimate the feasible wind energy potential of the country. An open WebGIS application will allow users to individually set the technical and economical parameters that are the basis for the subsequent wind potential calculation. The results of this project will be published in April 2011 ([www.windatlas.at](http://www.windatlas.at)).

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 economical 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.

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

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' ([http://windren.se/WW2011/62a\\_Energiewerkstatt\\_Krenn\\_Deicing\\_Enercon.pdf](http://windren.se/WW2011/62a_Energiewerkstatt_Krenn_Deicing_Enercon.pdf)).

The Austrian company 'Energiewerkstatt' ([energiewerkstatt.org](http://energiewerkstatt.org)) (opening photo) is the coordinator of SEEWIND, one of the largest Research and Demonstration Projects carried out under the Sixth Framework Programme (FP6) of the European Commission. The South Eastern European Wind Energy Project (SEEWIND) is a Research and Demonstration Project with ten partners from six European countries. SEEWIND has a total budget of 9.6 million € (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 four and a half years ([www.seewind.org](http://www.seewind.org)). The experiences of SEEWIND will be relevant for Austria because the three project sites have challenges similar to many locations in Austria.

#### **5.0 The Next Term**

Crucial for the growth of wind power capacity in Austria will be an amendment of the Green Electricity Act and the amount of the feed-in tariff in 2012.

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



# Chapter 13

## Canada

### 1.0 Overview

Canada is the sixth largest electricity producer in the world, and the fourth largest exporter – all of its exports go to the United States. With a huge landmass, lengthy coastlines, and quality wind resources, Canada has enormous potential to generate electricity from wind. In 2010, Canada installed more than 800 MW of new wind energy capacity, representing more than 1.7 billion CAD (1.27 billion euro; 1.69 billion USD) in new investment. By the end of 2010, Canada had more than 4,000 MW of installed wind energy capacity – enough to power over 1.4 million Canadian homes.

Canada has nearly 140 wind farms, spread across 10 provinces and the Yukon. Ontario currently leads in installed wind capacity, with over 1.3 GW (one-third) of the country's total capacity. Quebec and Alberta combined have one third, and the remaining provinces and Yukon account for the rest. The Ontario Power Authority (OPA) has awarded over 2 GW of wind power projects since the start of its landmark Feed-In Tariff (FIT) program in 2009. Ontario will also be home to two new manufacturing facilities – Ontario's first blade manufacturing plant and a tower manufacturing facility.

The government of Canada continues to accelerate the growth of Canada's wind power sector through the Clean Energy Fund and ecoENERGY for Renewable Power. Initiatives are also being employed in many provinces. Moreover, the province of Nova Scotia introduced a new FIT specifically for small wind – the first in the country; and British Columbia's Clean Energy Act received Royal Assent in the province's legislature.

The focus of Canada's wind energy R&D continues to be the advancement, development, and demonstration of safe, reliable, and economic wind turbine technology to exploit Canada's large wind potential. Canada's federal departments and research organizations are working together in R&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



Source: Jimmy Royer/NRCan

**Table 1 Key Statistics 2010: Canada**

Total installed wind generation	<b>4,124 MW</b>
New wind generation installed	<b>836 MW</b>
Total electrical output from wind*	<b>9.98 TWh</b>
Wind generation as % of national electric demand*	<b>1.8%</b>
Target:	N/A

\* Value from 2009 **Bold Italic** indicates estimate



large wind turbines, and improving the performance and reliability of turbines in Canada's North.

## 2.0 National Objectives and Progress

By the end of 2010, Canada had more than 4,000 MW of wind energy capacity – enough to power over 1.4 million Canadian homes. According to the Canadian Wind Energy Association (CanWEA), over 800 MW of new wind capacity were installed across the country, representing 1.7 billion CAD (1.27 billion euro; 1.69 billion USD) in new investment.

### 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. Most recently, the government of Nova Scotia released its 2010 Renewable Electricity Plan (REP) for the province (<http://www.gov.ns.ca/energy/resources/EM/renewable/renewable-electricity-plan.pdf>). The REP for Nova Scotia sets out a detailed program to move the province away from carbon-based electricity towards greener, more local sources. Today, nearly 90% of the province's electricity supply comes from fossil fuels, most of it from imported coal. But under the new law, the province has committed to change and by 2015, 25% of Nova Scotia's electricity will be supplied by renewable energy sources. Moreover, the province has established a new goal of 40% electricity from renewable sources by 2020.

In British Columbia (BC), the Clean Energy Act (CEA) received Royal Assent in the BC Legislature. The province now has a dedicated piece of renewable energy legislation. According to the CEA (<http://www.gov.bc.ca/cleanenergyact>), BC is to achieve electricity self-sufficiency by 2016. The CEA also sets a clean and renewable energy target of 93%, and commits the province to becoming a net exporter of electricity from clean and renewable resources. Furthermore, the CEA mandates reductions of BC's greenhouse gases for prescribed periods to 2050.

In Ontario, the Ministry of Energy released a Long-Term Energy Plan (LTEP) for the province in November 2010 ([http://www.mei.gov.on.ca/en/energy/html/LTEP\\_en.html](http://www.mei.gov.on.ca/en/energy/html/LTEP_en.html)). The LTEP is a

20-year plan to guide the province's electricity system. The Plan forecasts moderate growth in electricity demand (about 15%) between 2010 and 2030. Key features of the LTEP include a continuation of FIT and microFIT programs, 10,700 MW of renewable energy in Ontario by 2018, and a 2 billion CAD (1.5 billion euro; 1.99 billion USD) commitment to proceed with five priority transmission projects.

### 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. Although hydroelectric, nuclear, and natural gas capacities are expected to increase in the future, large changes are also projected in renewable energy such as wind generation capacity.

Ontario currently leads in installed wind capacity, with over 1.3 GW (one-third) of the country's total capacity. The opening photo shows the Front Line Wind Farm in southwest Ontario by Boralex Inc., a 10-MW project using five Enercon E82 turbines. Quebec and Alberta combined have one third, and the remaining provinces and Yukon account for the rest.

Wind energy in Ontario hit a new all-time record high for hourly electricity output on October 26, 2010, producing 1,056 MW of power. According to Independent Electricity System Operator (IESO), wind energy supplied more than 5% of Ontario's total electricity demand, over the course of the entire day. Ontario also celebrated the arrival and installation of the first domestic content compliant turbines under the provincial FIT program, at the Pointe-Aux-Roches wind project. The project in southwestern Ontario is the first wind power project to be constructed under the FIT that utilizes 100% Ontario steel in its towers. The turbine towers were manufactured from steel that was processed and fabricated at Essar Algoma Steel, in Sault Ste. Marie. In the spring of 2010, the Ontario Power Authority awarded the first contracts under the province's FIT program for projects between 10 kW and 500 kW. The 510 projects are to be built in 120 communities across Ontario and will have a total generating capacity of 112 MW. Three of the projects will use onshore wind, with nearly 95% of the remaining projects using solar. A month following, the OPA awarded another set of contracts – this time for large-scale projects (those exceeding 500

kW). These projects will generate a total of nearly 2,500 MW. Of the 184 projects approved, 47 are onshore wind projects and one is an offshore wind project.

In Saskatchewan, the province's power utility SaskPower announced that 21 companies had been selected to participate in the next phase of its Green Options (GO) Plan. The pre-qualifying projects will add 175 MW of wind power to Saskatchewan's electricity system. The proponents of the projects will be asked to submit proposals to SaskPower. Final projects selected are expected to be in service between 2013 and 2015.

SaskPower subsequently announced the addition of more wind generation through its GO Partners Program. Six projects from five power producers were chosen through a lottery process – three 10-MW wind projects and three others. In total, these projects would add 33 MW to the provincial grid. Once formal power purchase agreements are signed, the proponents of wind projects will have up to three years to start providing electricity to the grid. When all new wind projects are brought into service, wind power will make up about 8.5% of SaskPower's total generating capacity – among the highest percentages in Canada. The expansion of wind power will reduce SaskPower's CO<sub>2</sub> emissions by approximately 225,000 tonnes a year.

Manitoba powered up the first group of turbines at the province's largest wind farm. Construction of the 138 MW wind farm at St. Joseph is nearly complete, following the successful negotiation of a 27-year power purchase agreement between Manitoba Hydro and Pattern Energy. The St. Joseph wind farm was Canada's largest project under construction in 2010, costing an estimated 345 million CAD (256.7 billion euro; 344.7 billion USD). When fully operational, the 60 turbines at St. Joseph will generate enough power to meet the needs of 50,000 homes. Furthermore, Pattern Energy will pay local landowners a total of 38 million CAD (28.3 million euro; 37.9 million USD) over the life of the project, for the use of their land.

In Quebec, Hydro-Quebec Distribution announced that it accepted twelve bids totaling 291 MW in response to the call for tenders issued in 2009. The bids were 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. One bid totaling 24 MW was accepted for the Aboriginal block, and 11 bids totaling

267 MW were accepted for the community block. The average price of the accepted bids is 0.13 CAD/kWh (0.09 euro/kWh; 0.12 USD/kWh), including 0.02 CAD/kWh (0.01 euro/kWh; 0.019 USD) to transmit the electricity generated. The projects will generate nearly 1 billion CAD (0.744 billion euro; 0.999 billion USD) of investment in the region – about 730 million CAD (543.12 million euro; 729.27 million USD) for wind farm development and another 260 million CAD (193.44 million euro; 259.74 million USD) for power transmission.

### 2.3 National incentive programs

The government of Canada has been instrumental in the significant growth witnessed by the country's wind energy sector over the past ten years through the 325 million CAD (241.8 million euro; 324.67 million USD) Wind Power Production incentive, launched in 2002, and the 1.48 billion CAD (1.1 billion euro; 1.47 million USD) ecoENERGY for Renewable Power program, launched in 2007. As of December 2010, through the ecoENERGY for Renewable Power program alone, the government has committed close to 980 million CAD (729.1 million euro; 970.2 million USD) for 65 wind energy projects, representing 3,400 MW. Payments to these qualifying projects will continue to be made over the next ten-year period, ending in 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.

Provinces across Canada offer a range of incentives for renewable power, including wind. Examples of incentives were reported in Canada's country report in the 2009 *IEA Wind Annual Report*. Furthermore, some provinces have introduced new programs. For example, Nova Scotia is the first province in Canada to adopt a specific FIT for small wind. The Nova Scotia government included a FIT for small wind systems with a rated capacity of less than 50 kW, in the province's new Renewable Electricity Plan.

Ontario introduced North America's first comprehensive FIT Program in 2009. Since the start of the program, 54 contracts (totaling 1,530 MW) for wind energy projects have been signed and are under development. OPA's FIT website (<http://fit.powerauthority.on.ca/>)

provides bi-monthly reports on the progress of all applications to the program.

In British Columbia, the Ministry of Energy is considering a FIT Regulation under the province's new Clean Energy Act. The Regulation would require BC Hydro to establish a FIT program, and would set out key aspects of the program, including eligibility criteria. In August 2010, the Ministry released a Consultation Paper on the FIT to inform stakeholders and the general public of the government's intentions to develop the regulation and to solicit comments for consideration. BC Hydro is currently working collaboratively with the Ministry of Energy to scope out the initial elements of a FIT program. The province has also recently completed a two-year review of its Standing Offer Program (SOP) for clean or renewable energy projects. As a result, changes have been made to the maximum allowable project size (now 15 MW) and the price paid for energy.

### 3.0 Implementation

Wind energy capacity in Canada has increased ten-fold since 2003, thrusting wind power into the mainstream as a significant future energy source and emerging green industry. According to CanWEA, every 1,000 MW of new installed wind generation capacity represents approximately 2.75 billion CAD (2.05 billion euro; 2.74 billion USD) in private sector investment, 1,000 new jobs, and enough electricity to power 300,000 Canadian homes. It also provides a minimum of 3 million CAD (2.23 million euro; 2.99 million USD) in annual lease payments for farmers and other rural landowners as well as a similar amount in new taxes for rural municipalities.

### 3.2 Industry status

CanWEA is the voice of Canada's wind energy industry, representing well over 400 companies. CanWEA estimates that the industry supports more than 4,000 jobs. The wind industry is present throughout Canada, with manufacturing centers located primarily in Ontario and Quebec. In fact, Canadian small wind manufacturing capacity is growing, with Canadian firms now representing over half of the world's manufacturers of small wind turbines in the 30–100 kW range. According to a recent market study conducted for CanWEA, annual sales for small wind energy systems in Canada have grown by 55% over 2008 to 2009 (<http://www.canwea.ca/pdf/Small-Wind/canwea-smallwindmarketsurvey-e-web.pdf>).

### Manufacturing

The Canadian Manufacturers & Exporters (CME), in partnership with CanWEA, has been exploring Canadian manufacturing opportunities in the growing global wind energy industry. CanWEA and CME have published a joint report titled "Wind Industry Supply Chain Opportunities for Canadian Manufacturers" ([http://www.canwea.ca/wind-energy/supplychain\\_e.php](http://www.canwea.ca/wind-energy/supplychain_e.php)). The report, published in April 2010, outlines the "significant opportunity" that North America's growing wind energy market represents for Canadian manufacturers. The CanWEA–CME report lists action items required to ensure a globally competitive wind energy supply industry in Canada, including the need for Canadian companies to find new ways to leverage existing capabilities and transform operations, and for enhanced collaboration between industry and government.

For example, Canada's second largest automobile parts producer Linamar has formed a strategic alliance with German-based NCB Lohmann, to build and develop wind turbine components for customers in North America. The deal broadens Linamar's business beyond its traditional auto industry business, by complementing Linamar's advanced machining capabilities with Lohmann's long-time experience in manufacturing high-precision components for wind turbines. Linamar plans to make the wind turbine components such as gearbox housings, planetary carriers, bearing housings and torque arms for large turbines at its Guelph manufacturing plant.

In a separate deal, also in Ontario, the provincial government signed an agreement with a consortium comprised of Samsung C&T Corporation and the Korea Power Electric Corporation, which will triple Ontario's wind and solar energy generation capacity (add 2,500 MW). Under the agreement, the Consortium would qualify for FIT prices available to all eligible projects, and in addition the Consortium would be eligible for an economic development adder. The adder is contingent upon the Consortium manufacturing partners operating four manufacturing plants in Ontario, and is expected to add 1.60 CAD (1.19 euro; 1.59 USD) annually, to the cost of an Ontario resident's electricity bill.

Since the signing of the agreement, two new manufacturing facilities have been announced. Ontario's first wind turbine blade manufacturing plant is to be located in Tillsonburg. The plant will be built and operated by Siemens, and is expected



to create up to 300 manufacturing jobs, as well as up to 600 related construction and indirect service jobs. The facility will be the company's first manufacturing plant for wind turbine components in Canada, and represents an investment in excess of 20 million CAD (14.88 million euro; 19.98 million USD). In addition, Korea-based CS Wind will open a new turbine tower factory in Windsor. The facility is expected to create 300 full-time manufacturing jobs and another 400 indirect construction and service jobs for the city of Windsor. CS Wind has pledged to use 100% Ontario steel in the manufacturing of the towers – an estimated 200,000 tonnes a year. The plant should be in operation by early 2012, and will turn out 200-300 towers a year for not just the Canadian market but also for all of North America.

In Nova Scotia, the provincial government and Daewoo Shipbuilding & Marine Engineering (DSME) signed legal documents, closing the transaction on a joint venture. The DSME Trenton Joint Venture, between the province and DSME will establish a wind turbine tower and blade manufacturing facility at a former railcar plant – TrentonWorks. DSME is contributing 20.4 million CAD (15.2 million euro; 20.38 million USD) (or 51%) in equity into the new joint venture, and the province is contributing 19.6 million CAD (14.6 million euro; 19.58 million USD) (or 49%). It is expected that the venture will create 120 jobs within the first year of plant opening, growing to almost 500 jobs over three years.

Subsequently, Nova Scotia Power and DSME Trenton have agreed to work together to deploy made-in Nova Scotia wind towers and blades across the province. A letter of intent signed between Nova Scotia Power and DSME Trenton provides the opportunity for the joint

venture to supply wind turbine components for up to 100 MW of capacity expected over the next four years.

### 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, [www.canwea.ca](http://www.canwea.ca)). That said, the province of Ontario is spurring community power in Canada through its landmark FIT program. The OPA has signed contracts for 384 MW of community-owned renewable energy projects in the province. When completed, Ontario is expected to have the largest installed base of community-owned renewable generation in Canada.

The Pukwis Community Wind Park (<http://www.pukwis.ca/>) on Georgina Island in Lake Simcoe, Ontario, is an example of a community project made possible by the provincial FIT program. The program provides a bonus payment for projects owned by Ontario's First Nations and Métis, and another bonus for community-owned projects. The first phase of the Pukwis Community Wind Park consists of 10 utility-scale wind turbines with capacity of 2 MW each. The turbines will be grid-connected and produce enough electricity to power 7,500 homes and displace 15,000 tonnes of greenhouse gases annually.

### 3.3 Operational details

Twenty-seven wind farms were commissioned across seven provinces in 2010. Summary data follows in Table 2.

### 4.0 R, D&D Activities

The focus of Canada's wind energy R&D activities continues to be the advancement and development of safe, reliable, and economic wind turbine technology. Several

departments of the federal government are active in wind energy R&D:

- Natural Resources Canada's (NRCan's) R&D priority areas include: 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 conducts research on wind resource assessment, and wind and icing forecasting.
- Health Canada is coordinating federal – provincial – 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 noise.
- 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 and multi-disciplinary research network. With the network crossing the mid-point of its five year mandate in 2010-2011, a number of network researchers have achieved advanced research results, which are ready for technology transfer to industry. The Outreach

**Table 2 Wind farm statistics 2010: Canada**

Installed capacity per wind farm	0.3-101 MW
Smallest wind farm	Addition to Ramea Project, Newfoundland = 0.3 MW
Largest wind farm	Kruger Energy Chatham Wind Project, Ontario = 101 MW
Wind farm locations (provinces)	Alberta, British Columbia, New Brunswick, Newfoundland, Nova Scotia, Ontario, Quebec
Turbine manufacturers	Enercon, GE, Leitwind, Northwind, REPower, Siemens, Vensys, Vestas
Turbine sizes (range)	0.1-3 MW
Average turbine size	2.1 MW
Average estimated capacity factor	33%

Committee and Scientific Committee of WESNet are taking the lead in working with Canadian wind industry for technology transfer opportunities (<http://www.wesnet.ca>).

- TechnoCentre éolien (TCE) is a not-for profit organization whose mission is to contribute to the development of an industrial wind energy network in Quebec. TCE (<http://www.eolien.qc.ca>) continues research in cold climate adaptation with German turbine manufacturer REpower Systems AG. The Centre owns an experimental northern wind energy site: Site nordique expérimental en éolien CORUS (SNEEC) has two REpower MM92 CCV wind turbines with a capacity of 2.05 MW each (Figure 1). TCE also works with other businesses such as Éocycle Technologies on a technical validation of a 25-kW wind turbine, and with Technostrobe on a technical validation of a new generation of red flashing beacons in cold climate.

- Wind Energy Institute of Canada (WEICan) is a wind energy research, testing and training facility, located in the province of Prince Edward Island. In addition to conducting testing on the Zephyr AirDolphin 1-kW turbine, WEICan ([www.weican.ca](http://www.weican.ca)) has signed contracts with three small wind turbine manufacturers for type testing leading to certification: Raum Energy's 3.5-kW, BRI Energy Solutions Ltd. VBine 5-kW, and BerMc Controls Inc. 30-kW turbines. In June of 2010, WEICan began a testing and research project in collaboration with SûGen Research Inc. (SûGen). The Institute provided technical, engineering, and project management services to assist in the design, installation, and performance testing of the Gual Industries GSE4 vertical axis wind turbine – a turbine designed to withstand and generate power at high wind speeds. Furthermore, WEICan has been awarded funding from the government of Canada to develop a 10-MW Wind Energy R&D Park with an energy storage system.

#### 4.1 National R, D&D efforts

The government of Canada announced the Clean Energy Fund (CEF) in Budget 2009. The CEF is providing nearly 795 million CAD (591.5 million euro; 794.2 million USD) over five years to advance

Canadian leadership in both carbon capture and storage, and renewable and clean energy systems.

Up to 146 million CAD (108.6 million euro; 145.8 million USD) will be invested in small-scale renewable and clean energy demonstration projects. As of January 2011, 17 projects have signed agreements and are underway; two of which are wind projects:

- With 12 million CAD (8.9 million euro; 11.9 million USD) from the CEF and a loan from the Government of Prince Edward Island, the Wind Institute of Canada (WEICan) is developing a 10-MW Wind Energy R&D Park with an energy storage system. It will demonstrate how energy storage can be utilized

to maximize renewable energy production and to stabilize the grid. The Wind Park will also be made available for purposes of wind technology R&D, such as testing of auxiliary technology concepts.

- With 2.8 million CAD (2.08 million euro; 2.79 million USD) from the CEF and support from the Government of Saskatchewan, the Cowesses First Nation (CFN), in partnership with Saskatchewan Research Council, is developing a wind turbine and battery storage system. The turbines will harness wind between 70 to 80 m above ground heights (exceeding the turbines currently installed in the province of Saskatchewan), in order to capture wind that is stronger and



Figure 1 One of two REpower 2.05-MW turbines operating at the TechnoCentre éolien's Site nordique expérimental en éolien CORUS (SNEEC) in Quebec. Photo credit: Marc Petsche / Repower



more consistent. The CFN will host the project, and the system will be installed on their land. The project could serve as a model for other like communities across Canada.

The CEF is also investing in renewable and clean energy R&D projects within the government of Canada. Over the next two years, up to 918,000 CAD (682,992 euro; 917,082 USD) will be invested in three wind projects to:

- Expedite wind energy development through improved and more efficient environmental assessments – develop standards, guidelines, tools and technologies, based on remote sensing using marine radars, infrared and thermal imaging cameras, and acoustic sensors.
- Develop a short term wind forecasting system (to support a CEF funded demonstration project) – use Environment Canada’s existing Wind Energy Forecasting System to develop an innovative modeling strategy for local applications of short-term wind forecasting in the Maritimes.
- Forecast and estimate atmospheric icing on wind turbines – investigate the use of NWP (numerical weather prediction) meso-scale models, along with rime icing models to simulate and forecast the occurrence and

amount of rime ice accretion on structures such as wind turbines at specific locations.

#### 4.2 Collaborative research

Canada participates in IEA Wind Tasks 11 Base Technology Information Exchange, 19 Wind Energy in Cold Climates, 25 Power Systems With Large Amounts of Wind Power, and 28 Social Acceptance of Wind Energy Projects, as well as, in Technical Committee-88 (TC-88) of the International Electrotechnical Commission (IEC).

#### 5.0 The Next Term

It is expected that 2011 will be a record year for wind in Canada, with more than 1,000 MW likely to be installed. Already, several provinces such as Saskatchewan, Ontario, and Quebec have signed power

purchase agreements. According to CanWEA, wind energy will continue to grow in Canada, with production tripling in the next five years. If provincial governments meet their stated targets and objectives for new wind energy development, Canada will have a minimum of 12,000 MW of installed capacity by 2015.

Author: Melinda Tan, Natural Resources Canada, Canada.



3-MW wind turbines that have passed the acceptance appraisal. In addition, there are plans for eight, 10-GW-class wind farms in China's Inner Mongolia, Gansu, Xinjiang, Jilin, Hebei, Shandong, and Jiangsu provinces. The first 10-GW-class wind power project (Term-1) in Gansu Jiuquan was 4.72 GW.

In 2010, the China National Energy Bureau actively pushed for the formulation of wind power industry standards and the construction of a wind power public technology service platform. It started the wind power equipment quality investigation to control manufacturing quality and to improve operational reliability of wind farms. In addition, fundamental research for new wind power applications received high priority. The Chinese national science and technology department set up special research projects in the national key basic research and development program (973 Program) and the national high technology development program (863 Program) on problems in wind resource evaluation, wind machine aerodynamics, wind power systems, sea wind access, and wind power applications.

To maintain sustainable wind power development in China, a wind energy technology road map is being formulated. Wind energy development is currently mainly onshore with moderate development of offshore wind power. According to the situation in different regions, China will develop distributed off-grid and on-grid systems when developing the centralized power integration system.

## 2.0 National Objectives and Progress

### 2.1 National targets

According to The Renewable Energy Development 11th Five-Year Plan, the accumulated installed capacity of wind power would reach 10 GW in 2010. By the end of 2008, installed capacity had already exceeded 12 GW, with the newly installed capacity of 6,245 MW, fulfilling the target ahead of schedule.

In line with the commitment of the Chinese government at the COP 15, in 2020 non-fossil energy should fulfill 15% of primary energy demand in China. This has raised expectations and requirements

### 1.0 Overview

China occupies a huge landmass, has lengthy coastlines, and enjoys abundant wind resources. According to preliminary estimates, exploitable wind energy resources amount to between 70 GW to 120 GW, therefore, there is great potential for wind energy development and utilization.

In order to cope with climate change and reduce GHG emissions, the Chinese government put forward the strategic objective that "Non-fossil energy will represent 15% of the energy mix by 2020." The government also has the target to reduce carbon emissions "40% to 45% by 2020 per GDP compared to 2005 levels."

To achieve these goals, the Chinese government began implementing The

Renewable Energy Law of the People's Republic of China (amendment) in 2010. This law established the full indemnificatory acquisition system for renewable energy and the renewable energy development fund. It will include "new energy" to foster and develop as one of the seven strategic emerging industries during The 12th Five-year Plan and further push wind power development in China.

In 2010, 18.9 GW of new wind generating capacity was installed bringing the total installed capacity to 44.7 GW. This made China the country with the most wind generating capacity in the world. In 2010, the first offshore demonstration wind farm near Shanghai Donghai Bridge began operation and feeding power to the grid. This 102-MW wind farm has 34,

**Table 1 Key Statistics 2010: Chinese Wind Energy Association**

Total installed wind generation	44,773 MW
New wind generation installed	18,928 MW
Total electrical output from wind	50.1 TWh
Wind generation as % of national electric demand	1.2%
Target:	90 GW (including 5 GW offshore) in 2015, 150 GW (including 30 GW offshore) by 2020.
<b><i>Bold italic</i></b> indicates estimates	

for the scale and speed of clean energy development in general and for wind energy in particular. According to the new development plan, wind power installed capacity will reach 90 GW (including 5 GW offshore) in 2015, and by 2020, the accumulated installed capacity will be 150 GW (including 30 GW offshore).

To achieve the goal of constructing large power plants integrated into the larger power grid, China will construct eight 10-GW-class wind power plants in the north, northwest, northeast, and coastal areas. These will include Hebei, the east and west of Inner Mongolia, the Jiuquan area in Gansu, the Hami area in Xinjiang, Jilin, and the coastal areas in Jiangsu and Shandong (Figure 1). In the areas with rich wind resources, such as mountainous regions, river valleys and lakes, wind power will be developed appropriate to the local conditions. During The 12th Five-Year Plan, more emphasis will be placed on offshore wind power development. Several offshore wind power projects will be constructed in coastal areas including Jiangsu, Shandong, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi, and Hainan. The accumulated installed capacity of offshore wind power will reach 5 GW by 2015 and 30 GW in 2020.

## 2.2 Progress

According to the statistic of the Chinese Wind Energy Association, at the close of 2010 the newly installed capacity in China (Taiwan excluded) was 18.9 GW and about 12,904 new wind turbines were installed (Figure 2). The accumulated installed capacity reached 44.7 GW, moving China to the top of the world in wind generation capacity. Compared with 2009, capacity grew by 73.3%. Wind power generated 50.1 TWh of electricity which reduced CO<sub>2</sub> and other green house gases by 43.1 million tons. At the end of 2010, more than 700 wind farms had been constructed in 29 provinces, municipalities, and autonomous regions (Hongkong, Macau, and Taiwan excluded). Among these, 10 provinces have over 1 GW of wind power installed capacity.

The first national offshore wind power demonstration project, Shanghai Donghai Bridge offshore wind power project, was completed at the beginning of 2010 (Figure 3). With total capacity of 102 MW, it was connected to the grid and began operation in July 2010. In January 2010, the Interim Measurement for Management of Offshore Wind Power Development and Construction was

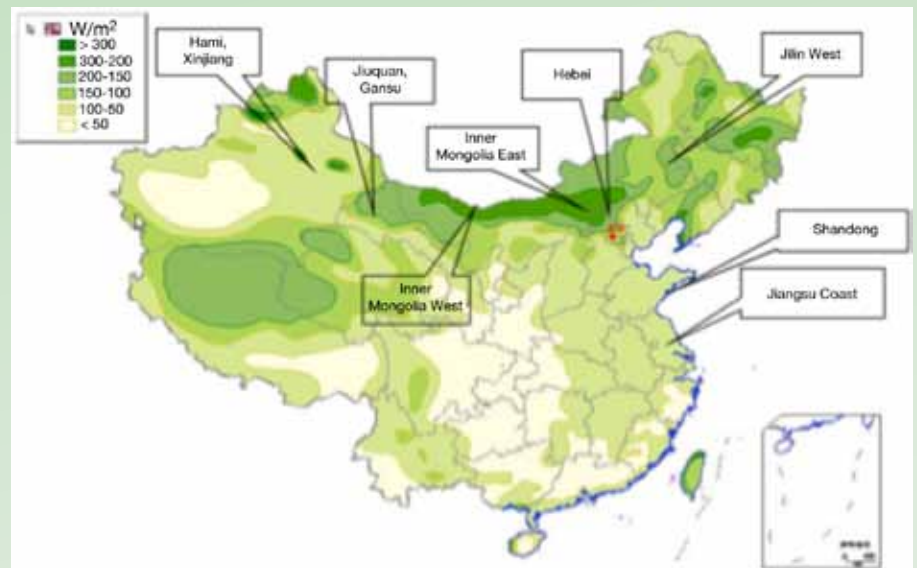


Figure 1 Eight 10-GW-class wind power plants are planned

created to develop offshore wind power concession projects in 11 provinces. With this action, offshore wind power moved from the demonstration phase into the mass commercial usage stage. In May 2010, the first round of offshore wind power concession projects with four wind farms and 1 GW of installed capacity was started in Jiangsu Province.

## 2.3 National incentive programs

Wind power development in China is being supported by a series of policies and regulations, among which the most important is the Renewable Energy Law of People's Republic of China (hereinafter Renewable Energy Law). It includes

a series of systems, including establishing national targets, setting grid connection priorities, classifying tariffs for renewable electricity, and sharing cost at the national level. It also includes a special renewable energy fund, to guarantee and promote the development of renewable energy in China. The Renewable Energy Law was revised in 2009. During the 10th National People's Congress (NPC) Standing Committee Meeting, the draft revised Renewable Energy Law was reviewed and the governmental renewable energy development fund was approved to be established.

Concerning tax incentives, according to the Tentative Provisions on Import Tax Policy for Important Technological

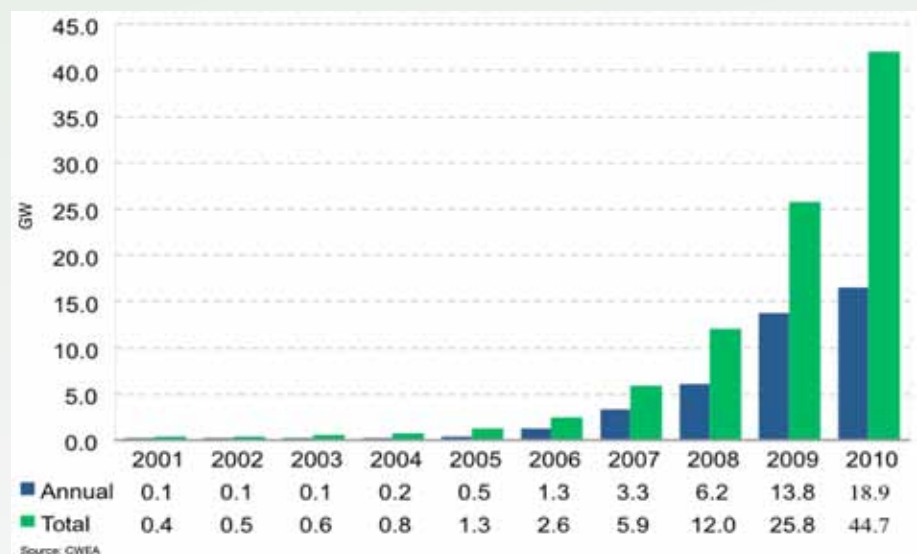


Figure 2 Wind power new and accumulated installed capacity from 2001 to 2010





Figure 3 The first offshore wind farm in China began operation in 2010. It is 102 MW and located near Shanghai Donghai Bridge.

Equipment, the list of important technological equipment and products supported by the nation was revised in 2010. The new list includes high-output wind power generating systems and related components for which normal fees for customs and import VAT are not charged.

Regarding wind power technology research and development, China has included wind power in its National Mid- and Long-Term Science and Technology Development Plan. It has also provided support in national programs such as the National Key Technology R&D Program, the Chinese National Programs for High Technology and Development (863 Program), and the Key Project of Chinese National Programs for Fundamental Research and Development (973 Program).

In 2003, a concession bidding mechanism was introduced for key wind power projects construction, which accelerated the development of wind power. In July 2009, in order to regulate wind power price management and promote the healthy and sustainable development of wind power, the National Development and Reform Committee issued the Notice on Policy to Improve Grid-connected Power Pricing for Wind Power. This changed the price policies from bidding tariffs to benchmarking feed-in tariffs. According to the notice, there are four kinds of wind resource areas with different feed-in tariffs of 0.51 yuan/kWh (0.058 euro/kWh; 0.078 USD/kWh), 0.54 yuan/kWh (0.061 euro/kWh; 0.082 USD/kWh),

0.58 yuan/kWh (0.066 euro/kWh; 0.088 USD/kWh), and 0.61 yuan/kWh (0.069 euro/kWh; 0.093 USD/kWh).

#### 2.4 Issues affecting growth

Due to the rapid development of the Chinese wind power industry and the continuous increase of installed capacity, several issues have arisen that are restricting wind power development. The first issue is the grid-connection problem. Because wind power is an intermittent and unstable power supply, large-scale wind power development must deal with the problem of how to be connected smoothly into the grid. The rich wind energy resource areas are in the western and northern part of the country where the local power network facilities are relatively weak. The load center is in the eastern part of China, so the wind generating areas and load center are far apart. The current power grid design is a restricting factor for wind power development. The large-scale construction of wind power plants will demand a solution to the transmission problem of a long-distance and high-voltage connection system.

The second issue limiting growth is the shortage of qualified wind industry personnel. In China, wind power is a rising industry. Although some domestic universities offer degrees in wind power, the number of graduates is not enough to meet the needs of the industry. In addition, the research and development capacity should also be enhanced.

The third issue limiting wind power development is the lack of wind power standards, testing, and certification systems. A better wind power standard, testing, and certification system is needed to regulate the market, guarantee the reliability of wind power generating system, and promote the development of wind power technology. A related issue is the need to improve quality control technology and key components in manufacturing technology of wind power generating system.

### 3.0 Implementation

#### 3.1 Economic impact

In 2010, more than 18.9 GW of wind turbines were newly installed in China, making the total wind power installed capacity 44.7 GW of which 31.1 GW was connected to the grid, generating 50.1 TWh for the year. Wind power generation can supply the power needs of more than 33.4 million families in China. Thanks to the rapid development of wind power, 28,000 new jobs were created. So far, more than 297,000 people are working in the Chinese wind power industry.

#### 3.2 Industry status

##### 3.2.1 Ownership

Wind power has moved into large-scale development. State-owned enterprises have played an important role in promoting the development of wind power and the market competitive landscape is relatively clearly mapped. The key state-owned enterprises, represented by Guodian, Dtang, Huaneng, Huadian, and China Power Investment represent around 56.2% of the newly installed wind power capacity in China. The local power and energy investing enterprises such as Beijing Energy Investment and Hebei Construction & Investment have a market share of 15%. The accumulated installed capacity of the central energy enterprises such as Guohua, CNOOC, CGN, CE-CIC, and Three Gorges represents about 13.8% of the market. Private enterprises such as Hongkong enterprises and foreign capital enterprises such as China Wind Power Group, etc., have a relatively small share of the market and fewer projects compared to the first three kinds of enterprises. Other enterprises have formed joint development agreements with central enterprises or local enterprises to invest in wind power.

##### 3.2.2 Manufacturing

In 2010, 60 Chinese wind turbine manufacturers had prototypes. Of these, 25 had



No.	Name	Annual MW	Total MW
1	Guodian Group (incl. Longyuan)	3,490	8,941
2	Huaneng Group	3,171	6,331
3	Datang Group	2,268	5,620
4	CGN Wind	1,017	2,364
5	Huadian Group	925	2,557
6	Guohua	897	2,346
7	China Power Investment	772	1,708
8	China Resource Power	586	97
9	China Suntien Green Energy	528	935
10	Three Gorges New Energy	430	731
11	Tianrun	403	726
12	China Wind Power Group	381	767
13	CNOOC	271	350
14	Hydro China	251	350
15	Sino Hydro	215	407

started batch production. Four of these manufacturers had annual production of more than 1,000 units of MW-class turbines; another three produced 500 units per year; 13 manufacturers produced 100 units per year; and the other five manufacturers have annual production between 50 to 100 units.

In China, the top 10 manufacturers represented a market share of 84% of the new installations in 2010. The top five were Sinovel (4,386 MW, 23.2%), Goldwind (3,735 MW, 19.7%), Dongfang (2,623.5 MW, 13.9%), United Power (1,643 MW, 8.7%), and Mingyang (1,050 MW, 5.5%).

International players have increased their investments in the Chinese market. For instance, Vestas expanded its factory's capacity in Tianjin and built a new wind turbine assembly factory in Hohhot. Gamesa also added to its capacity with new facilities in Jilin province and in the Inner Mongolia Autonomous Region (IMAR). Gamesa will begin batch production of its G8X product and expects to introduce its G10X-4.5MW to the Chinese market in 2011. Suzlon's CEO announced new investment in China. More importantly, those international giants like Vestas and Suzlon are setting up new R&D centers in China to support technology R&D for Chinese market.

In addition, much improvement can be seen in China's wind power equipment supply chain. More than five manufacturers can now make blades for 3-MW turbines. SINOI in Lianyungang, Jiangsu province has made new 62-m blades for 5-MW turbines, the longest blade so far in the world. More than 10 manufacturers have started batch production of generators, and XEMC motors has made 5-MW permanent magnet generators, the biggest in China and the world. Even more important, components like the main shaft bearing, gearbox bearing, and converter which were mostly dependent on imports now have local production and supply.

### 3.3 Operational details

At the close of 2010, China (Taiwan excluded) had more than 700 wind power projects with more than 40 GW capacity. The top three provinces (IMAR, Hebei, and Liaoning) have 13,858 MW, 4,944 MW, and 4,922 MW each. In addition, some inland regions have started wind farm development like Shaanxi, Qinghai, Anhui, and Sichuan. The largest wind farm, Gansu Jiuquan wind plant, has accelerated its construction process which had a total capacity of more than 5 GW by the end of 2010. The transmission line for the Gansu wind plant is a 750-kV UHV line that is under construction.

### 3.4 Wind energy costs

The cost of wind farm development in China decreased in 2010 due to the 15% decline in wind turbine price from 5,300 yuan/kW (599 euro/kW; 806 USD/kW) in 2009 to 4,500 yuan/kW (509 euro/kW; 684 USD/kW) in 2010. In the 3.5 GW of state-run bidding projects, the tender price became 3,850 yuan/kW (435 euro/kW; 585 USD/kW) for 1.5-MW wind turbines, the lowest price in three years.

At the close of 2010, the average cost for wind farm construction would be 8,600-9,000 yuan/kW (972-1,017 euro/kW; 1,307-1,368 USD/kW), of which 50%-60% is the cost of equipment, nearly 20% is transmission line cost, and the other costs (land expense, financing, and labor cost) represent 25%-30%.

No.	Name	Installed Capacity MW
1	Sinovel	4,386
2	Goldwind	3,735
3	DONGFANG	2,624
4	United Power	1,643
5	Mingyang	1,050
6	Vestas	892
7	Sewind	598
8	Gamesa	596
9	XEMC Wind	507
10	CCWE	486
11	CSIC Haizhuang	383
12	CSR	335
13	Envision	251
14	GE	210
15	Suzlon	200
Other		1,034
<b>Total</b>		<b>18,928</b>

## 4.0 R, D&D Activities

### 4.1 National R, D&D efforts

During The 11th Five-Year Plan, the Chinese government increased investment in scientific and technical research in wind

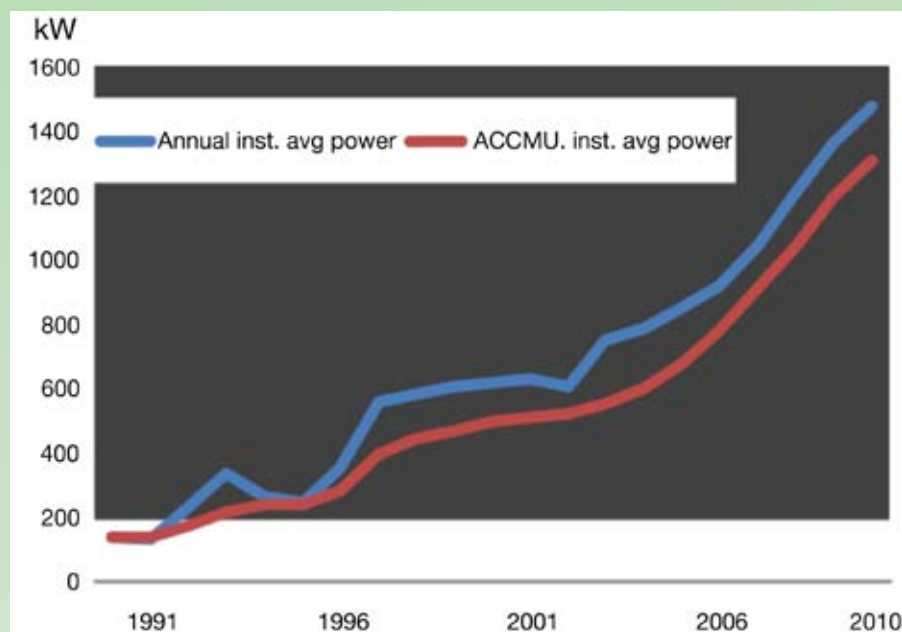


Figure 4 Average size of wind turbines installed from 1991 to 2010

energy. It strengthened basic research on developing wind power, on constructing a wind power public technology service platform, on enhancing wind power equipment R&D capabilities, and on manufacturing standards to reduce costs, improve equipment performance, and increase reliability.

About 40 research tasks addressing key technological problems are included in the 863 Program of the Ministry of Science and Technology, with total investment of around 50 million yuan (5.65 million euro; 7.6 million USD). Two projects mainly for basic research were set up in 973 Program by the Ministry of Science and Technology: 1) Aerodynamic Basic Research for Large-Scale Wind Turbine Generating Systems with a fund of 3.15 million yuan (356,000 euro; 479,000 USD) and 2) Basic Research for Large-Scale, Off-grid Wind Power Systems with a fund of and 2.64 million yuan (296,000 euro; 401,000 USD). During this period, the National Development and Reform Commission and the Ministry of Science and Technology set up nine key laboratories and research centers related to wind energy among enterprises and research institutes, mainly for capacity building.

#### 4.1.1 Wind energy resource assessment technology

From the 1970s to the beginning of this century, three different wind resource surveys and evaluations were carried

out using statistical methods and meteorological observation data. Along with the development of numerical simulation techniques for wind energy resource assessment in the world, the Canadian Wind Energy Simulating Toolkit (WEST) was used by the China Meteorological Administration (CMA). A wind map of China with resolution of 5 km×5 km was completed.

In 2009, the Wind Energy Resource Assessment System of the CMA (WERAS/CMA) was also set up. It includes a weather classification scheme, a modeling system combining a meso-scale model and a micro-scale model of dynamical diagnosis for complex terrain, and a wind power potential analysis system based on GIS. In 2010, a wind energy resource assessment for the Chinese mainland and offshore was completed with a resolution of 1 km×1 km. The new wind map shows 30 years averaged and wind power potential obtained at heights of 50 m, 70 m, and 100 m above ground level. This China wind power resource assessment report has now been published.

A professional wind resource observation network has been set up that includes more than 400 meteorological towers with height of 70 m and 100 m. The observation network feeds into the operational observation system of CMA and provides wind energy resource assessment, prediction, and study of wind characteristics in different regions as well.

#### 4.1.2 WTGS design and manufacturing technology

R&D in China on large-scale wind turbines started in the 1990s and evolved from technology introduction, digestion and absorption, and joint R&D to independent R&D in the last ten years. In 2010, domestically manufactured wind turbines represented 89.5% of installed capacity. Turbines of the 1.5–2.0-MW size represented 87.9% of the Chinese turbines. A few 3.0-MW turbines have been manufactured; some 3.6-MW turbines have been put into operation; prototype 5-MW turbines have been fabricated, and a 6.0-MW wind turbine is being developed.

In China double-fed turbines account for 78% of the newly installed systems and direct drive turbines are showing a growth trend. In addition, semi-direct drive wind turbines have also been put into operation.

Wind turbine designs must tolerate the specific conditions of the Chinese climate and environment. Research is being conducted on the meteorological disasters of typhoon, lightning, cold, ice coating, sand storms, etc. In addition, the characteristics of high altitude, sea islands, and low wind speed regions have been explored with some research results applied directly to the industry.

#### 4.1.3 Wind farm construction technology

In 2010 more than 400 wind farms had been constructed in China. The installed capacity of the largest wind farm was 300 MW. The capacity coefficients of some wind farms were lower than expected after construction, and the number of the equivalent full load operating hours was below 2,000 hours. The reasons, besides problems with wind turbine type selection, were linked to poor micro-siting and wind farm layout.

In recent years, in addition to widely used commercial software, special Chinese software systems were also developed. Research is now being conducted to support building 10-GW-class, large-scale wind power bases (wind farms).

Offshore wind farm construction in China is still in the demonstration phase and considered small-scale development. A 102-MW offshore wind farm was put into operation near Shanghai Donghai Bridge in July of 2010. Then, the tender process for four more offshore wind farms with total capacity of 1 GW in Jiangsu province was completed in September 2010. One feature of developing offshore wind farms in China is construction in the intertidal

zone, which requires R&D on the special equipment needed to transport and install wind turbines. In 2010, the first 30-MW intertidal wind farm in Jiangsu Rudong was put into operation.

#### 4.1.4 Wind power integration technology

At present, wind power integration is becoming a bottleneck of wind power deployment in China. The wind farms in operation sometimes have to curtail production to the grid during the minimum load period. More attention has been paid to the problem of how to coordinate wind power production with the management of the power grid. Work to resolve wind power integration issues in China is described here.

- Support large-scale wind power development by enhancing power grid construction. In 2010, work was completed on the 750-kV interconnect grid transmission line between Xinjiang and the northwest area and the first phase of the 750-kV transmission line between Anxi and Yongdeng of Gansu 10-GW wind farm to guarantee timely wind power integration.

- Build one-body research model to analyze and optimize the power source structure (including wind power). Based on the principles of safety, economy and clean energy, the work will provide analysis methods for researching ways to coordinate wind power with the grid and to confirm reasonable development scales, consumption areas, and developing costs.

- Strengthen wind power dispatching and operation management and upgrade the ability to accept wind power production. So far, wind farms have been supervised by different levels of dispatching centers. The centers can dispatch about 86% of the wind installed capacity. Wind power prediction systems have been installed in the provincial power grid companies among north China, northeast China, northwest China, Shanghai, Jiangsu, Fujian, Liaoning, Jilin, Heilongjiang, Ningxia, Gansu, Xinjiang, etc. The total covered wind power installed capacity is above 12 GW. These wind power prediction systems, based on international systems, have reached a similar level of precision for wind power dispatching and operation in China.

- Develop standards for wind power integration and enhance wind power testing capability. In 2010, the national standard Technical Rule for Wind Farm Connecting to Power System (revised version) was officially issued. The National Wind Power Research and Testing Center was completed at the China Electric Power Research Institute. A test wind farm that can accept up to 30 wind turbines was built in Zhangbei County of Hebei province. This facility features testing capabilities for wind turbine power performance, low voltage ride through (LVRT), anti-jamming, and more.

- Explore market mechanisms for pumped storage power stations. Pumped storage power stations have been shown to be good at balancing electrical loads in China. This mature technology only needs research to determine the best price mechanism and selling mode.

#### 4.1.5 Wind energy application technology

Currently, the main application of wind energy in China is power transmission from wind farms integrated with the grid. The second most used application is small, distributed power systems rated at less than 100 kW that are used for homes, communication, and factories. While most are used in off-grid applications, some are connected with a local grid. Another application is mid-size wind turbines that can provide supplementary power for oil drilling. Some research focuses on key scientific and technical issues with applications such as wind energy for seawater desalination and wind-hydrogen production. Other work is exploring the feasibility of using wind power in some high energy-consuming industries where power quality is not critical.

#### 4.1.6 Fundamental research on wind power

In recent years, fundamental research on the aerodynamics of large-scale wind turbines has been supported as part of the national key basic research and development program (973 Program). The research addressed complex flow structures, unsteady aerodynamics, aero-noise, and aero-elastics related to the blades of large-scale wind turbines. The increased understanding of aerodynamics, aero-elastics, and aero-acoustics will improve the optimization method used to design blades.

The design and utility of advanced airfoil families of wind turbine blades is

supported as part of the national high technology development program (863 Program). A series of accomplishments on airfoil design have been obtained. Software has been developed for design and performance analyses on the airfoil. Two airfoil families have been designed specifically for large-scale wind turbines, and have been tested in low-speed wind tunnels. The shape and aerodynamic property database of the airfoils has been established and is ready to be applied in the research and development for MW-class wind turbine blades.

In the National Scientific Support Project, special research projects are working on the critical technology of integrating wind farms with the power system. This includes mathematical models of the turbine and wind farm performance, the stability and reliability of wind farm integrating with the power system, the prediction of wind farm power output, and the control system of the wind farm. In addition, the Chinese government has paid much attention to fundamental research on the technologies of offshore wind power, such as research on the structural dynamics features of offshore wind systems.

## 4.2 Collaborative research

In 2010, IEA Wind provided an attractive platform for China to participate in exchanges and cooperation with other member countries. In November 2010, the Chinese Wind Energy Association (CWEA) joined IEA Wind as sponsor member. CWEA has organized researchers from enterprises, research institutes, and universities to participate in five IEA Wind research tasks: Task 11: Base Technology Information Exchange; Task 19: Wind Energy in Cold Climates; Task 26: Cost of Wind Energy; Task 27: Consumer Labeling of Small Wind Turbines; Task 30: Comparison of Dynamic Computer Codes and Models for Offshore Wind Energy (OC4).

Furthermore, the National Standardization Technical Committee of Wind Power Machinery also actively participated in the IEC standards formulating work. China hosted the compilation of IEC 61400-5: Wind Turbine Generator Systems—Part 5: Wind Turbine Blades. The Chinese government also signed cooperation agreements on wind energy with other countries, including Denmark, Germany, and the United States.



## 5.0 The Next Term

In 2011, the Chinese government will pursue the target of “total wind power installed capacity of 150-200 GW by 2020.”

It will continue to foster the wind power market, develop the wind power industry, upgrade wind power technology, and expand wind power applications. The 2-GW onshore wind power franchise project and the 1-GW offshore wind power franchise project will be put into effect in 2011. In addition, the Chinese government will increase investment for wind power capacity construction; establish national-class wind power research centers; construct national-class large-scale wind turbine testing platforms and a wind farm for testing services; improve wind turbine standards, testing, and certification systems; accelerate education and training

in the wind power technology field; and strengthen international communication and cooperation.

### References

China Energy Mid and Long Development Strategy Research, Renewable Energy Sector (ISBN 976-7-03-029944-4), published by Science Press, 2011

“Chinese Wind Power Installed Capacity Statistics 2009,” published in Wind Energy (CN 11-5942/TK) in March, 2010

“Analysis on Chinese Wind Power Market Share in 2009 and Development Trend,” published in Wind Energy (CN 11-5942/TK) in March, 2010

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

# Chapter 15

## Denmark

### 1.0 Overview

Approximately 19.3% of Denmark's energy consumption came from renewable sources in 2010, 38.7% from oil, 21.8% from natural gas, and 13.3% from coal. The production from wind turbines alone corresponded to 21.9% of the domestic electricity supply, compared to 19.3% in 2009.

Wind power capacity in Denmark has increased by 320 MW in 2010, bringing the total to 3,802 MW (Table 1). From the total installed capacity, 868 MW is offshore. The only offshore farm completed in 2010 was Rødsand, (opening photo) with a total of 207 MW rated capacity (90 turbines rated at 2.3-MW each).

The Danish government continues to promote the use of renewable energy in Denmark, in order to meet national and international targets, with an act passed at the end of December 2008 (Law No. 1392 of 27/12/2008). This is essentially an implementation of the February 2008 Agreement, defining among other things, subsidies for renewable energy plants and access to offshore sites. This is the most recent agreement, but will be renegotiated in the beginning of 2011.

### 2.0 National Objectives and Progress

#### 2.1 National targets

The figures from the Danish Energy Agency show that the national target of 20% of gross energy consumption from renewable energy sources by 2011 was fulfilled in 2010. There is furthermore a commitment to an EU target of 30% from renewable energy by 2020 calculated on the basis of final energy consumption. The former target was defined in the Danish energy agreement from 2008 and the latter in the EU's climate and energy package (the RE-Directive) in December 2008.

#### 2.2 Progress

The wind generation capacity in Denmark increased by 320 MW in 2010, bringing the total to 3,802 MW. Although the total capacity increased, the number of turbines decreased in 2010 to 5,033 from 5,110 in 2009. This is because 241 turbines were decommissioned with a total



capacity of 44 MW, while 164 wind turbines were commissioned with a total capacity of 364 MW. The average capacity of those installed in 2010 was thus 2.2 MW. Included in these numbers are 90 Siemens 2.3-MW turbines were installed offshore at Rødsand II, by Lolland. A detailed history of installed capacity and production in Denmark can be downloaded at the Danish Energy Agency Web site (1).

As shown in Table 1 and Figure 1, electricity from wind energy covered 21.9% (26% corrected to normal wind index) of the electricity consumption in Denmark in 2010. The total electricity production from wind energy in 2010 was 7,818 GWh, compared to 6,716 GWh in 2009.

The environmental benefits due to the 2010 wind energy production, assuming coal is being substituted, results in 61.2% of Denmark's yearly CO<sub>2</sub> reduction obligation (1990-2010). More specifically (2): Saved coal: 2,841,452 tons (364 g/kWh); CO<sub>2</sub>: 6,682,096 tons (856 g/kWh); SO<sub>2</sub>: 2,108 tons (0.27 g/kWh); NO<sub>x</sub>: 8,118 tons (1.04 g/kWh); Particles 234 (0.03 g/kWh); Cinder/Ash 421,534 tons (54 g/kWh) (2).

#### 2.3 National incentive programs

The act passed at the end of December 2008 (Law No. 1392 of 27/12/2008), included subsidies for wind turbines and other renewable energy generating plants, schemes to foster the development of

**Table 1 Key Statistics 2010: Denmark**

Total installed wind generation	3,802 MW
New wind generation installed	320 MW
Total electrical output from wind	7.81 TWh
Wind generation as % of national electric demand*	21.9%
Target**	Not specified for wind
* In 2010 the wind index was 89%, thus wind generation as % of national electric demand is 26% corrected to normal wind index, corresponding to 9,263 GWh	
** Target for renewable energy is 20% of gross energy consumption in 2011 and 30% in 2020	

wind turbines, connection and safety requirements for wind turbines, and regulation of electricity from proposed offshore wind turbines. In addition to this law, which took effect 1 January 2009, one new support scheme has been introduced in 2010 for Mikro VE.

**Mikro VE:** Small renewable energy support scheme (3): As of June 2010, an obligation was passed to Energinet.dk to offset the electricity bill of users that produce their own ‘environmentally-friendly’ electricity. The support scheme regulations depend on the type of grid connection, the size of the generating units, electricity use, the existing settlement agreement, electricity taxes, and taxation scheme. Detailed information can be obtained from the Danish Energy Agency (1) and (3).

**2.4 Issues affecting growth**

In December 2009, the EU approved 15 energy projects, with a total of 565 million euro (759 million USD) to offshore wind energy, in the context of the European Energy Programme for Recovery (EEPR Regulation). Two of these projects will build large capacity grid interconnections between Denmark and other EU member states (Table 2).

**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 Danish Wind Industry Annual Statistics 2010 (4) is for 2010.

**3.1 Economic impact**

The turnover of the industry located in Denmark in 2010 was 55.3 billion DKK

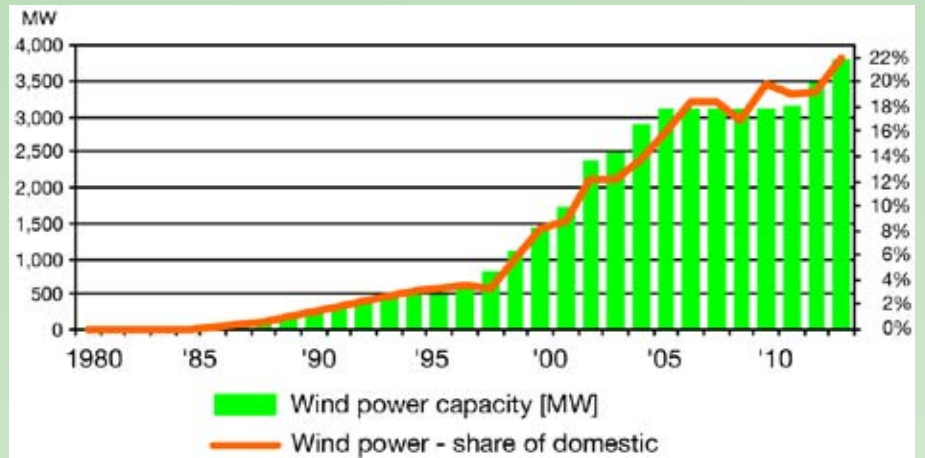


Figure 1 Danish wind power capacity and its share of domestic electricity supply (1)

(7.4 billion euro; 9.9 billion USD), which is a decrease of 8.3% compared to 2009. The turnover of the Danish wind industry worldwide was 98.8 billion DKK (13.2 billion euro; 17.8 billion USD) in 2010, an increase of 9.1% compared to 2008. The industry has continued its globalization during the financial crisis with foreign production facilities increasingly supplying the markets in primarily Asia and North America. The Danish wind industry’s total export amounted 46.2 billion DKK (6.2 billion euro, 8.3 billion USD) in 2010, an increase of 11% from 2009, maintaining the high level of exports.

The number of people employed within the wind energy sector in Denmark decreased by 1.2% in 2010 compared to 2009, with about 25,000 employees at the end of 2010. This increase came after the drop in 2009 affected by the cutbacks (Figure 2).

**3.2 Industry status**

The Danish Wind Industry Association’s publication of its membership directory, ‘Wind Power Hub – The Green Pages 2011 (10), lists Denmark-based companies alphabetically and by type e.g., wind turbine, tower, blades, control systems manufacturer, consultancies, project development, etc. Today, the major Denmark-based manufacturers of large commercial wind turbines of one megawatt or larger are Siemens Wind Power (formerly Bonus Energy A/S) with around 5.9% of the 2010 world market and Vestas Wind Systems A/S, the leading manufacturer with around 14.8% of the 2010 world market.

**3.3 Operational details**

In 2010, 113 MW of wind power was installed onshore (including decommissioning), and 207 MW offshore. The average capacity of turbines installed in 2010 was 2.1 MW. The largest onshore turbine installed in Denmark by the end of 2010 was the Siemens 3.6-MW turbine and the largest offshore wind farm is Horns Rev II with 91 turbines and an installed capacity of 209 MW. Existing and planned offshore wind farm locations in Denmark and a list of these with year of connection and size can be seen in Figure 3 (5).

Rødsand II (opening photo) is located in the Baltic Sea off the Danish island of Lolland and is situated just 3 km to the east of the existing 166-MW Rødsand I (or Nysted). Rødsand II was inaugurated in October 2010, with all turbines producing by August of 2010. The wind farm consists of 90 Siemens 2.3-MW wind turbines, with a hub height of 68.5 m and a rotor blade diameter of 93 m. They

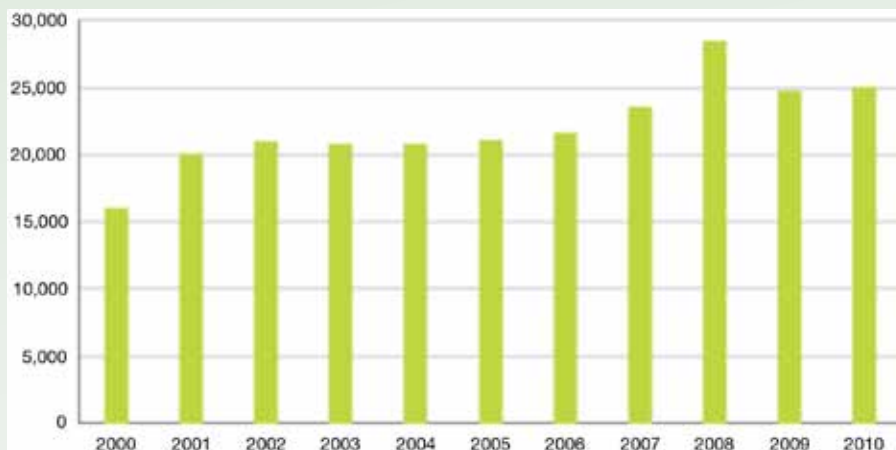


Figure 2 Employment in Danish wind industry from 2000 to 2010 (4)





Figure 3 Existing and planned offshore wind parks in Denmark

are arranged in five curved rows consisting of 18 turbines each. The developer of the wind farm is E.ON Wind Sweden AB who won the tender at 0.629 DKK/kWh (0.084 euro/kWh; 0.113 USD/kWh).

The Anholt project (400 MW) was proposed in February 2008, as part of the Danish government's Energy Policy Agreement. In June 2010 the contract was awarded to DONG energy, the only bidder for the project. The wind farm will cost an estimated 10 billion DKK (1.34 billion euro; 1.8 billion USD). According to the tender specifications, the wind farm must supply its first power by the end of 2012, and the entire wind farm must be commissioned by the end of 2013. When fully operational, it will provide clean energy for approximately 400,000 households, or 4% of Denmark's power consumption. DONG Energy will get a feed-in tariff of 1.051 DKK/kWh (0.141 euro/kWh; 0.189 USD/kWh) for the first 20 TWh. 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.

### 3.4 Wind energy costs

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

costs in Denmark as of end of 2009 has been published under the EUDP 33033-0196 project (7), and summarized in the IEA Wind 2009 Annual Report. A very brief overview of this is included.

#### 3.4.1 Installed costs

Costs for installing an onshore wind energy project are around 10 million DKK/MW (1.34 million euro/MW; 1.8 million USD/MW). Cost depends on the size of the rotor area per megawatt of rating and its hub height i.e. energy production per installed MW. Offshore, the cost is approximately twice the price of onshore: 20 million DKK/MW (2.68 million euro/MW; 3.6 million USD).

#### 3.4.2 Operation and maintenance costs

The expected lifetime average cost for an on-shore wind turbine is 0.08–0.10 DKK/kWh (0.0107–0.0134 euro/kWh; 0.0144–0.018 USD/kWh). O&M for an offshore turbine is up to 50% higher, but very dependent on the project.

#### 3.4.3 Cost of energy

The cost of wind electricity on shore, excluding risk factors and profit, was calculated to be 0.03–0.05 euro/kWh (0.04–0.06 USD/kWh). The actual cost depends on the wind profile at the location and also on the type of investor. Private investors will expect a shorter payback period than

Existing Offshore Wind Farms	
1. Vindeby (1991)	11 wind turbines, 5 MW
2. Tunø Knob (1995)	10 wind turbines, 5 MW
3. Middelgrunden (2000)	20 wind turbines, 40 MW
4. Horns Rev I (2002)	80 wind turbines, 160 MW
5. Rønland (2003)	8 wind turbines, 17 MW
6. Nysted (2003)	72 wind turbines, 165 MW
7. Samsø (2003)	10 wind turbines, 23 MW
8. Frederikshavn (2003)	3 wind turbines, 7 MW
9. Horns Rev II (2009)	91 wind turbines, 209 MW
10. Avedøre Holme (2009/2010)	3 wind turbines, 10–13 MW
11. Sprogø (2009)	7 wind turbines, 21 MW
12. Rødsand II (2010)	90 wind turbines, 207 MW
Planned Offshore Wind Farms	
13. Anholt (2012)	400 MW

a large investor, like utilities. Private investors require 0.04–0.08 euro/kWh (0.05–0.10 USD/kWh) on top of the raw cost (includes profit and risk factor) to invest in wind production, depending on the local wind conditions. At present an investor receives approximately 0.07 euro/kWh (0.09 USD/kWh) half of which is subsidy, which is time limited to approximately 10 years (22,000 full load hours), and the other half is the free market price.

## 4.0 R, D&D Activities

### 4.1 Priorities

Energinet.dk has prepared a Strategy 2010+, for R&D activities within electricity and gas, in dialogue with the Danish Energy Agency and following a request from the Danish Minister for Climate and Energy on 26 June 2008. This strategy includes a description of partnerships with universities in Denmark and abroad, the extensive hosting of PhDs, Energinet.dk's own research projects as well as other joint research activities in Denmark and

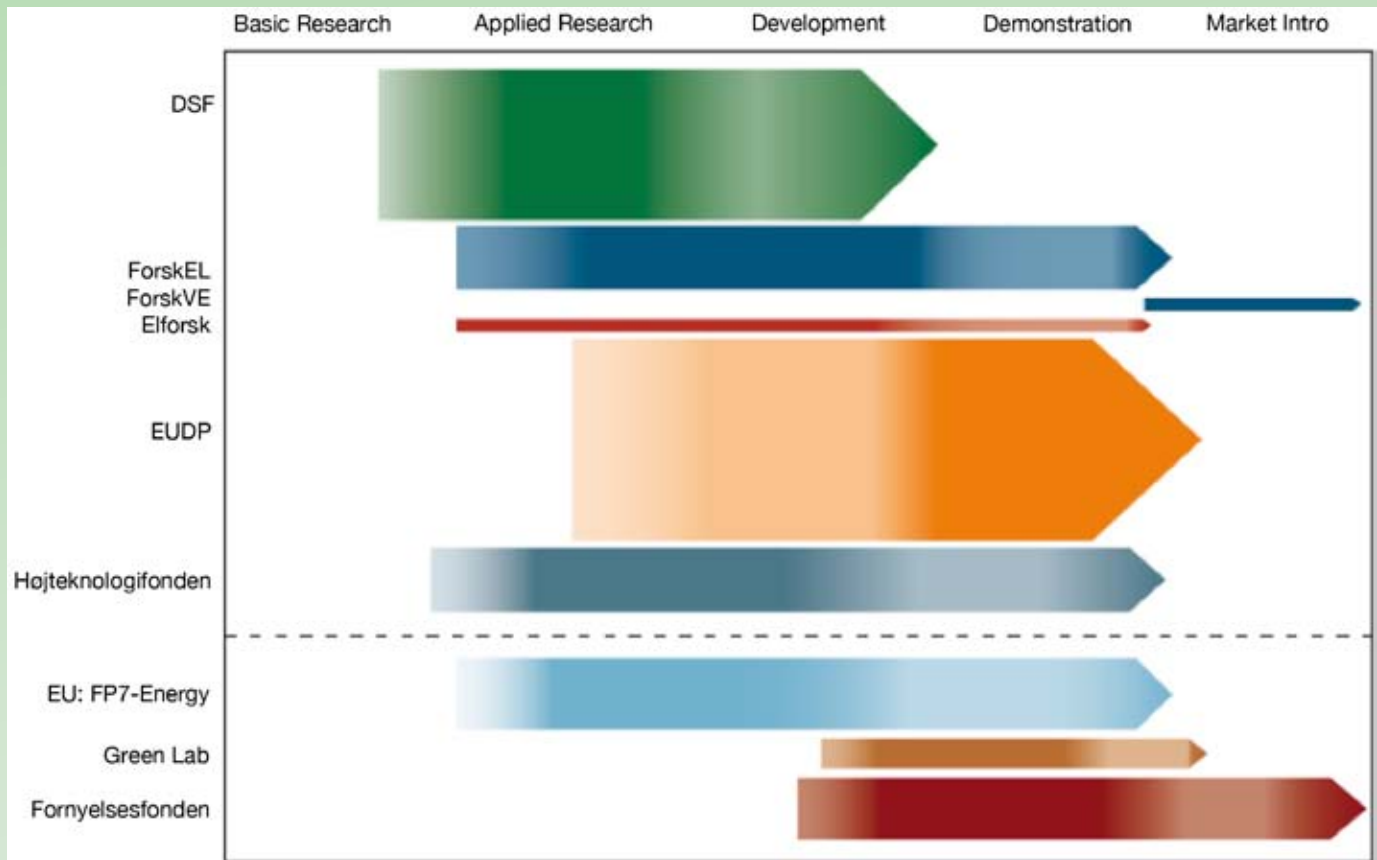


Figure 4 The different Energy Research Programmes (2010) in the technology development chain.

internationally (Figure 4). The report was available in Danish in December 2009, and an English version was available in early 2010 (10).

Green Lab DK is a new support scheme for the construction of large-scale test facilities in Denmark to demonstrate new climate-friendly technologies. The program supports test facilities in types of technology that can help to make Denmark fossil fuel free, primarily energy efficiency and renewable energy technologies. Green Labs DK was launched in connection with the government's Business Climate Strategy (Erhvervsklimastrategi), with which the government allocated about 600 million DKK (80.4 million euro; 108.1 million USD) for a better framework for Danish enterprises to exploit new growth opportunities that arise in the wake of climate challenges. The first call for applications had a deadline on 20 October 2010 and expected to award 130 million DKK (17.42 million euro; 23.41 million USD).

Fornyelsesfonden (Renewal Fund) arises from the agreement between the government and the parliamentary

political parties on the distribution of globalization funds for innovation and entrepreneurship for the years 2010–2012. The fund is the largest initiative in this agreement, assigning 760 million DKK (101.8 million euro; 136.8 million USD) in order to support the green transition and economic renewal, especially in small and medium enterprises.

Megavind published a 'Strategy for Offshore Wind Research, Development and Demonstration' in December 2010 (11). Three main achievements must be realised by industry and research between 2010 and 2020. Firstly, newly built offshore wind farms must be able to produce roughly 25% more electricity per installed MW. Secondly, the capital expenditure including costs per installed MW must be reduced by approximately 40%. And thirdly, the cost of operation and maintenance per installed MW must be reduced to about half.

#### 4.2. Yearly budgets

The yearly report Energy 2010 (8) publishes a summary of the research, demonstration, and new energy technology

projects that receive funding (Figure 5). The report also contains an overview of 2009 results in the different technology areas. The report contains projects supported from the following programs:

- The Energy Development and Demonstration Program (EUDP) including the Energy Agency's Energy Research Program (ERP) and Nordic Energy Research (NEF)
- Energinet.dk's ForskEL program and ForskNG program (PSO)
- The Danish Council for Strategic Research's (DCSR) Programme Committee on Energy and Environment
- The Danish National Advanced Technology Foundation (HTF).

Grants to wind energy projects supported in 2010 totaled 134.5 million DKK (18 million euro; 24.2 million USD). The most important projects are listed in Table 3. The total funding was increased to about 1 billion DKK (134 million euro; 180 million USD) in 2010, substantially higher than the 700 million DKK (93.8 million euro; 126.1 million USD) in 2009

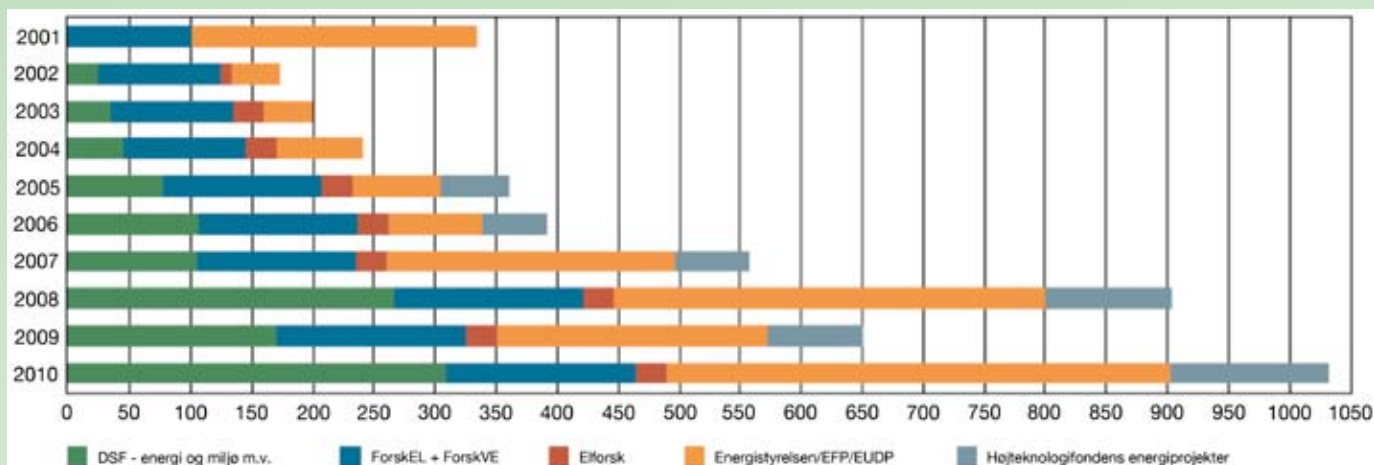


Figure 5 Support to new energy technologies from 2001 to 2010, million DKK (0.134 million euro; 0.18 million USD).

and highest since 2001. Funds are available under the annual Finance Act and Public Service Obligation funds (PSO), which Energinet.dk is entitled to collect from the electricity users under the Danish Electricity Supply Act and apply toward research in environmentally friendly electricity generation and efficient energy use.

#### Test-facilities (on-shore and offshore):

Two offshore demonstration wind farms are planned, one at Nissum Bredning, just off Rønland (opening photo), with a space for up to 10 turbines, and one in the area near Frederikshavn with a view to build six demonstration turbines. One onshore national test center at Østerild is planned. The government's focus on the construction of large scale test facilities has seen the establishment of a large offshore test center at the former Ship Yard Lindoe (LORC).

Frederikshavn demonstration wind farm (6): The project proposal includes the establishment of six major demonstration wind turbines for tests of foundations and other technologies for offshore wind turbines. Testing of foundations is planned to take place in 2012 and the installation of wind turbines in 2013–2016.

To supplement Høvsøre, the Danish government, in September 2009, designated the area of Østerild Klitplantage, in the north-west of Jutland, as the location for testing up to seven wind turbines up to 250 m total height. The EIA for the project and a parliament bill was under consultation until 5 March 2010. The bill was passed in Parliament on 4 June 2010 and came into force on 1 October 2010. More information on the test center (vision, site

selection, project updates, implementation plan) can be found under (12).

Lindoe Offshore Renewables Center (LORC) has been established in north Fyn, aiming to be a European center for 1:1 testing, demonstrations and research into offshore renewable energy. A facility for testing wind turbine drive-train components of 10 MW/20 MW rated/peak power is underway.

Furthermore an R&D Centre for Wind Turbine Components, at Risø DTU, is in the construction phase. Initially, a test bed for a 200–300 kW drive train is being established.

#### 4.3 Funded projects 2010

Table 3 presents the funded wind energy projects in Denmark for 2010.

#### 4.4 Collaborative research

Denmark participates in international collaboration through IEA Wind, the Nordic Top-level Research Initiative, and the EU research projects.

Denmark participates in the following IEA Wind research tasks:

- Task 30: Offshore Code Comparison Collaboration Continuation (OC4)
- Task 29: MexNet: Analysis of Wind Tunnel Measurements; Participant: Risø DTU, DTU-Mech
- Task 28: Social Acceptance of Wind Energy Projects; Participant: Danish Energy Agency
- Task 26: Cost of Wind Energy; Participants: Danish Energy Agency, Risø-DTU, EA Energy Analysis.

- Task 25: Power Systems with Large Amounts of Wind Power. Participants: Risø-DTU and energinet.dk (through 2011)
- Task 11: Base Technology Information Exchange; Organized workshops, participants vary.

Risø DTU plays a leading role in the large EU project called UpWind, which will be completed in February 2011.

#### 5.0 The Next Term

The next offshore project planned is the Anholt farm at 400 MW in Kattegat. The tendering period ended 7 April 2010 and the wind farm must be finished by December 2012. Also, discussions have started on Krieger Flak in the Baltic Sea, which is on the border between Denmark, Sweden, and Germany and to which EU has awarded 150 million euro (201.6 million USD) for the grid connections to land.



**Table 3 Wind Energy Projects that received funding by Danish R&D Programs in 2010**

Project Title; Project Manager	Support Total budget , Start/Completion date	Purpose/Project description
Industrial implementation of prototype flaps systems for wind turbines; Department of Wind Energy (DWE)/ Risø DTU	EUDP: 9,908,000 DKK; 1,327,672 euro; 1,783,440 USD Total: 14,688,000 DKK; 1,968,192 euro; 2,643,840 USD 2011-2013	To develop controllable flaps for wind turbine blades. A prototype was tested under laboratory conditions. The flaps for full-scale wind turbines, ready for prototype testing will be developed.
Influence of atmospheric stability on loads and power generation in wind farms; DWE/Risø DTU	EUDP: 4,729,000 DKK; 633,686 euro; 851,220 USD Total: 6,911,000 DKK; 926,074 euro; 1,234,980 USD 2011-2013	To model and explore the influence of stability conditions in the atmospheric boundary layer on the power output and the load of turbines in wind parks, and to exploit the developed models for design of load limiting control. Demonstrate the potential of the models by comparison with full-scale wind farm data.
Experimental blade experiments – Phase 2; DWE/Risø DTU	EUDP: 10,000,000 DKK; 1,340,000 euro; 1,800,000 USD Total: 17,194,000 DKK; 2,303,996 euro; 3,094,920 USD 2011-2013	To develop an experimental platform necessary to design stronger and more reliable turbine blades. Will develop new tests and measurement methods and provide a design framework to achieve an optimal design for a given level of reliability.
FastWind-Accelerating wind turbine development and precise wind farm monitoring using dynamic data analysis; DWE/Risø DTU	EUDP: 1,260,000 DKK; 168,840 euro; 226,800 USD Total: 1,942,000 DKK; 260,228 euro; 349,560 USD 2011-2013	To implement a new dynamic data analysis method in the Danish wind industry based on rapidly sampled time series, rather than on traditionally measured data based on 10-min mean values. Dynamic data analysis can reduce the influence of noise in measurement data and can reduce time needed for performance and load measurements.
IEA Wind Task 30 OC4; DHI. Ports and Offshore Technology	EUDP: 608,000 DKK; 81,472 euro; 109,440 USD Total: 935,000 DKK; 125,290 euro; 168,300 USD 2011-2012	To strengthen the Danish contribution to the international project IEA Wind Task 30: OC4, with innovative marine model technology, which will develop and validate existing aero-elastic models for offshore wind turbines located on two substructures in more than 30 m of water.
Less noise and better operation in new wind turbine technology; Svendborg Brakes A/S.	HTF: 10,000,000 DKK; 1,340,000 euro; 1,800,000 USD Total: 18,000,000 DKK; 2,412,000 euro; 3,240,000 USD 2010-2012	
Controlling the flow of wind turbines; Vestas Wind Systems A/S.	HTF: 15,000,000 DKK; 2,010,000 euro; 2,700,000 USD Total: 30,000,000 DKK; 4,020,000 euro; 5,400,000 USD 2010-2012	
Offshore wind turbines to new depths; Vestas Wind Systems A/S	HTF: 40,000,000 DKK; 5,360,000 euro; 7,200,000 USD Total: 80,000,000 DKK; 10,720,000 euro; 14,400,000 USD 2010-2013	

Project Title; Project Manager	Support Total budget , Start/Completion date	Purpose/Project description
Cost effective monopiles through joint applied research; Vestas Wind Systems A/S. Tower & Structure Inc. R&D	EUDP: 15,000,000 DKK; 2,010,000 euro; 2,700,000 USD Total: 28,903,000 DKK; 3,873,002 euro; 5,202,540 USD 2010-2014	To reduce the total cost for an offshore wind turbine system including the foundations by 10%.
Offshore wind turbine reliability through complete loads measurements; DWE/Risø DTU	EUDP: 7,368,000 DKK; 987,312 euro; 1,326,240 USD Total: 16,878,000 DKK; 2,261,652 euro; 3,038,040 USD 2011-2014	To improve the data base for Danish wind turbine design through a measurement campaign on the Siemens/DONG Energy Walney wind farm off the British east coast.
Light rotor; DWE/Risø DTU	EUDP: 7,732,000 DKK; 1,036,088 euro; 1,391,760 USD Total: 11,567,000 DKK; 1,548,978 euro; 2,082,060 USD 2010-2013	To design blades for machines up to 10 MW with lower weight, adapted aeroelastic response, and optimized aerodynamic efficiency.
Tower - the foundation and yaw loads on offshore turbines; DWE/Risø DTU	PSO: 2,202,000 DKK; 295,068 euro; 396,360 USD Total: 5,404,000 DKK; 724,136 euro; 972,720 USD 2010-2012	
Wave loads on offshore wind turbines; DTU Mechanical Engineering	PSO: 5,246,000 DKK; 702,964 euro; 944,280 USD Total: 10,491,000 DKK; 1,405,794 euro; 1,888,380 USD 2010-2013	
Integrated planning tool – wind power	PSO: Total: 4,594,000 DKK; 615,596 euro; 826,920 USD 2010-2012	
Participation in IEA Wind Task 30: OC4	EUDP: 836,000 DKK; 112,024 euro; 150,480 USD Total: 984,000 DKK; 131,856 euro; 177,120 USD 2010-2013	To develop and validate the existing aeroelastic computational tools for offshore wind turbines located at two selected substructures for water depths over 20 m. The project is an international collaboration between industry and university experts in wind energy and from the oil and gas industry.

## References

- (1) The Danish Energy Agency Web site ([www.ens.dk](http://www.ens.dk))
- (2) <http://www.vindstat.dk/>
- (3) <https://www.retsinformation.dk/>
- (4) Danish Wind Industri Annual Statistics 2011, Vindmølleindustrien, Language: English
- (5) Wind Power Hub – The Green Pages 2011, Danish Wind Industry, November 2010
- (6) Vindmøllers Økonomi, Nielsen, P. et al., UEDP projekt 33033-0196, February 2010

- (7) Frederikshavn Demonstrationsvindmøller, Dong Energy, August 2008
- (8) Energi 2010: Forskning, Udvikling, Demonstration, Language: Danish, June 2010, <http://www.energinet.dk/SiteCollectionDocuments/Danske%20dokumenter/Forskning/Energi2010.pdf>
- (9) [http://www.aturstyrelsen.dk/Planlaegning/Planlaegning\\_i\\_det\\_aabne\\_land/Testcenter](http://www.aturstyrelsen.dk/Planlaegning/Planlaegning_i_det_aabne_land/Testcenter)
- (10) The PSO programmes and the energy agreement: Strategy 2010+ for the ForskEL and ForskVE programmes - Contribution towards fulfilling the energy

agreement and the climate goals, Energinet.dk

- (11) Denmark – supplier of competitive offshore wind solutions: Megavind's Strategy for Offshore Wind Research, Development and Demonstration, Magavind, Dec 2010, Language: English

Authors: Jørgen Lemming and Helen Markou, Risø DTU, Denmark; Hanne Thomassen, Danish Energy Agency, Denmark.

## The European Commission\* EWEA (European Wind Energy Association)

### 1.0 Introduction

Europe continues to be one of the world's strongest markets for wind energy development. In 2010, the European Union (EU) saw reasonable growth in light of the economic crisis with installations of 9,295 MW, thereby reaffirming its status as a leading wind energy market (1). Industry statistics released by the European Wind Energy Association (EWEA) show that in 2010, cumulative wind capacity increased by 12.3% to reach a level of 84,278 MW; this was up from 75,092 MW at the end 2009 (Figure 1). This 9.3 GW of new wind power capacity represents a wind turbine manufacturing turnover of some 12.7 billion euro (17.07 billion USD), of which 2.6 billion euro (3.5 million USD) is from offshore wind investments.

#### 1.1 Overall capacity increases

Over the last 15 years, cumulative wind energy installations in the EU have increased steadily from 814 MW in 1995 to 9,295 MW, an average annual growth rate of 17.6%. Looking beyond Europe, the global market for wind turbines grew by 22.5% last year to a total of 194.4 GW.

In the EU, wind power continues to be one of the most popular electricity generating technologies for expanding capacity. Since 2000, 271 GW of new electricity generating capacity of all types has been installed in the EU. And 2010 was a record year with 55.4 GW of new capacity installed. Since 2000, installed wind capacity has increased almost seven times from 12.9 GW to 84.3 GW. Over the last ten years, according to figures from Platts PowerVision and EWEA, new gas installations totaled 131.3 GW, while wind energy installations totaled more than 75 GW. Wind represented 27.7% of the total new generation installations over the period (Figure 2).

In 2010, wind power installations accounted for 17% of new power installations in Europe and renewables together represented 41% of total new installed capacity – the fifth consecutive year that renewable represent over 40% of total installations. Wind energy now represents 10% of the total EU installed power capacity (Figure 3). Total wind power capacity installed by the end of 2010 will

produce 181 TWh, meeting 5.3 % of gross EU final power consumption in an average wind year, avoiding about 115 million tons of CO<sub>2</sub> annually. By comparison, in 2000, less than 0.9% of EU electricity demand was met by wind power. The countries with the highest penetration of wind energy were, in 2010, Denmark (24%), Portugal (14.8%), Spain (14%), Ireland (10.1%) and Germany (9.4%).

Capacity increase in 2010 was driven by Spain, Germany, and France, together representing 44% of EU total. Spain added 1,516 MW to reach 20,676 MW; Germany added 1,493 MW to reach 27,214 MW; France installed 1,086 MW for a total of 5,660 MW; and the UK added 966 MW reaching 5,204 MW. The new Member States of the EU performed remarkably well and increased their installed wind capacity by 82.5%, with Romania, installing 448 MW on top of a cumulative capacity at the end 2009 of just 14 MW. Poland (382 MW) and Bulgaria (198 MW) follow.

During 2010 all EU Member States were required to submit to the European Commission a National Renewable Energy Action Plan (NREAP) detailing sectoral and technology-specific targets and all policy measures implemented to reach their binding 2020 RES target as set out in EU directive 2009/28/EC – or “RES directive.” Summing the 27 NREAPs, it is expected that over 34% of EU electricity demand be covered by RES, almost half of that (14%) by wind energy alone.

The correct implementation of the NREAPs should ensure an increased build-out of wind and other RES energy projects up to 2020. However, slow administrative processes, problems with grid access, and legislative uncertainty are still creating bottlenecks (see section 2).

#### 1.2 Offshore wind

Offshore wind, seen as a key market for European expansion, had a record year in 2010. Installing 883 MW during 2010 brought cumulative installations to 2,946 MW in 45 wind farms spread across nine countries (Figure 4). In 2010, Thanet in the UK became the biggest offshore wind farm in the world with a capacity of 300 MW installed. Offshore wind

installations represent, at the end of 2010, 3.5% of the total installed wind power capacity in the EU.

The short-term prospects for offshore wind are promising, with several projects planned to be connected to the grid in 2011. EWEA expects another 1 GW of offshore capacity to be fully grid connected during 2011, part of 3.3 GW currently under construction in 10 wind farms. Therefore, 2011 could see a 75% growth in the offshore market compared to the previous year. When the latter 10 wind farms are completed, Europe's installed offshore capacity will increase to 6.2 GW as shown in Figure 5. At the end of 2010, EWEA identified 19 GW of consented offshore projects and a further proposed pipeline of over 100 GW.

### 2.0 The EU Legislative Framework for Wind Energy

#### 2.1 EU legislative framework

Up until now, an important factor behind the growth of the European wind market has been strong policy support both at the EU and at the national level. The EU's Renewable Electricity Directive (77/2001/EC) had been in place since 2001. The aim was to increase the share of electricity produced from RES in the EU to 21% by 2010, up from 15.2% in 2001. This target was established by the EU Renewable Electricity (RES-E) Directive, which set out differentiated national indicative targets. The RES-E Directive was a historical step in the delivery of renewable electricity and constituted one of the main driving forces behind recent policies being implemented.

In December 2008, the EU agreed to a new Renewable Energy Directive to implement the pledge made in March 2007 by the EU Heads of State for a binding 20% renewable energy target by 2020. The EU's overall 20% renewable energy target for 2020 has been divided into legally binding targets for the 27 member states, averaging out at 20%. The member states are given an 'indicative trajectory' to follow in the run-up to 2020. By 2011-12, they should be 20% of the way toward the target (compared to 2005); 30% by 2013-14; 45% by 2015-2016; and 65% by 2017-18. The directive also provides that each



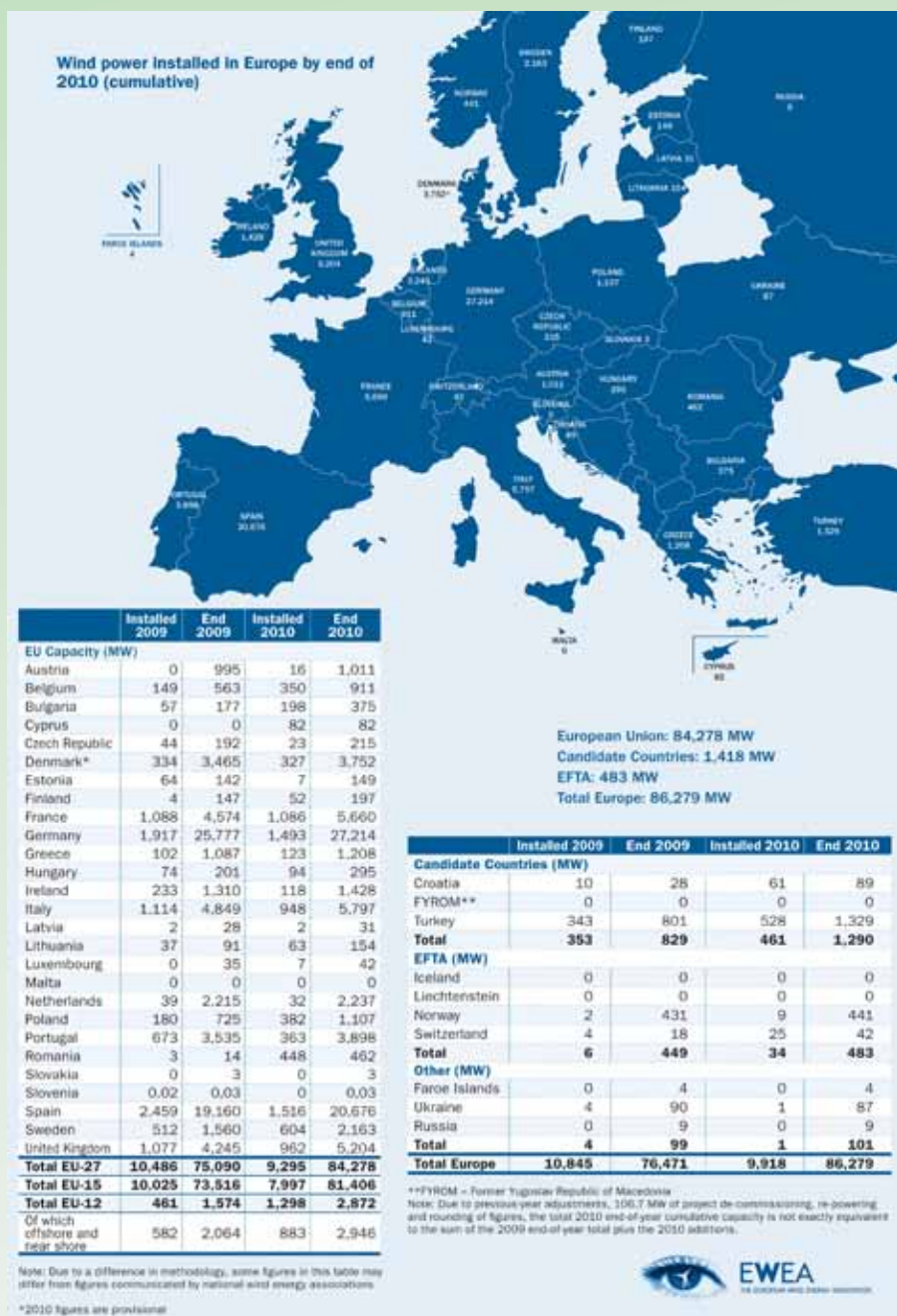


Figure 1 Wind power installed in Europe by end of 2010 Source: EWEA

a progress report to the EC, containing information on their share of renewable energy, support schemes, and progress on tackling administrative and grid barriers. Based on these reports from the member states, the EC will publish its own report the following year.

Certain measures to promote flexibility have been built into the Renewable Energy Directive in order to help countries achieve their targets in a cost-effective way without undermining market stability. For example, member states may agree on the statistical transfer of a specified amount of renewable energy between themselves. They can also co-operate on any type of joint project relating to the production of renewable energy, including projects involving private operators if relevant. Thirdly, two or more member states may decide, on a voluntary basis, to join or partly coordinate their national support schemes in order to help achieve their targets. Moreover, under certain conditions, member states can help meet their national electricity sector target with imports from non-EU countries. Some of the 16 Member States that indicate in their NREAP that they will exceed their target have indicated their interest in participating in such flexibility mechanisms.

Regarding administrative procedures, the member states will have to make sure that the authorization process for renewable energy projects is proportionate, necessary, and transparent. This should reduce the time a new project takes to become operational and help the 2020 targets be met more easily.

For integration to the electricity system, the NREAP agreement requires EU countries to take “the appropriate steps to develop transmission and distribution grid infrastructure, intelligent networks, storage facilities, and the electricity system” to help develop renewable electricity. They must also speed up authorization procedures for grid infrastructure. EU countries must ensure that transmission system operators and distribution system operators guarantee the transmission and distribution of renewable electricity and provide for either priority access to the grid system (meaning connected generators of renewable electricity are sure that they will be able to sell and transmit their electricity) or guaranteed access, ensuring that all electricity from renewable sources sold and supported gets access to the grid.

The NREAPs are required to indicate all the measures taken in these fields. If member states fail to demonstrate

Member State draft a NREAP detailing sectoral and technology-specific targets as well as all policy measures envisaged to achieve them.

Analyzing the 27 NREAPs, renewable sources should provide over 34% of the EU’s electricity by 2020, and wind energy is set to contribute the most – 14% of EU’s total electricity demand up from 5.3% in 2010. Moreover, the analysis confirms that the EU Member States should exceed the overall 20% RES target by 0.7 percentage points. Only two Member

States, Luxembourg and Italy, stated that they will not be able to meet their binding national targets domestically.

Ireland is expected to be the Member State with the highest wind energy penetration in 2020 meeting 36.4% of its total electricity demand, followed by Denmark at 31%. According to the NREAPs cumulative installed wind capacity will increase from 843 GW at the end of 2010 to reach 213.4 GW in 2020 with 170.1 GW onshore and 43.3 GW offshore. Every two years member states are required to submit

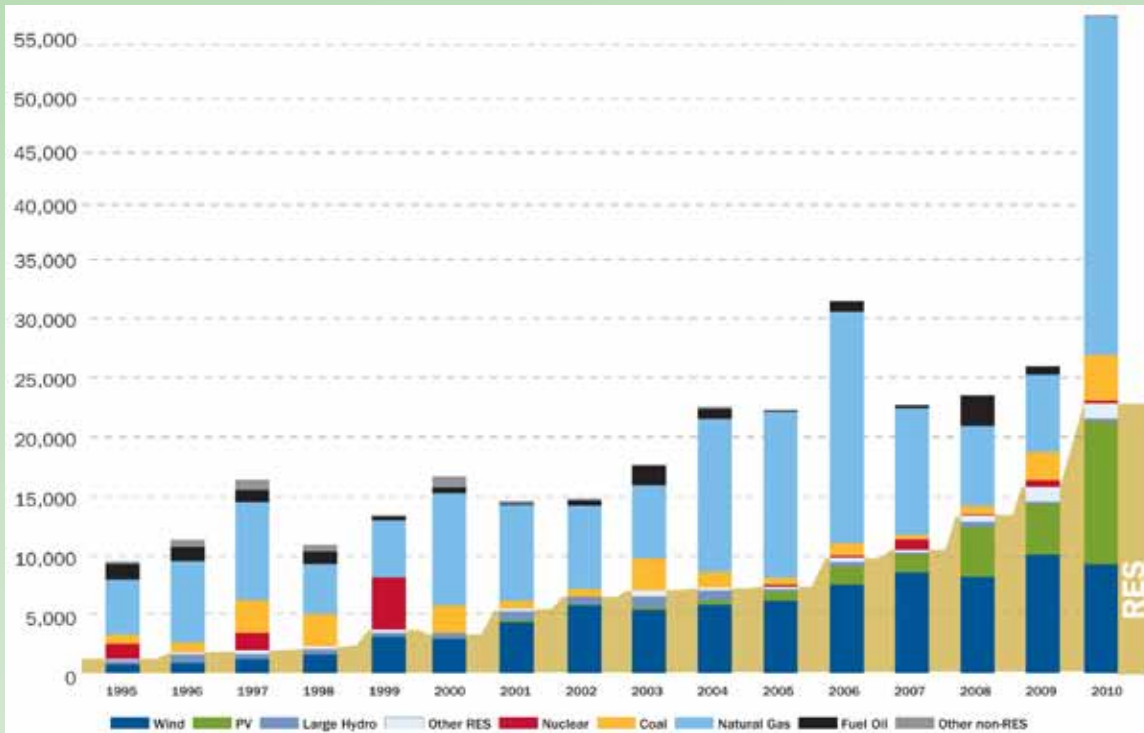


Figure 2 New electricity generating capacity in the EU from 1995 to 2010  
Source: EWEA

adequate progress towards meeting their targets, they are required to submit an update NREAP detailing new measures.

The EC will publish, by 2018, a Renewable Energy Roadmap for the post-2020 period. This is a very welcome development that will allow the wind power sector to ensure that a stable regulatory framework replaces the Renewable Energy Directive of 2009 when it expires at the end of 2020.

### 3.0 R, D&D Wind Energy Projects

In 2010, 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 (DG Research) for projects with medium- to long-term impact and the Directorate-General for Transport and Energy (formerly DG TREN, now 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 2009.

### 3.1 DG Research activities

In 2010, one FP6 projects UPWIND, as well as four FP7 projects, RELIAWIND, SAFEWIND, ORECCA, and Marina Platform continued their activities while three new projects HAWE, Deep-Wind, and HiPRwind started at the end of the year. PROTEST was the first FP7 wind project to finish in August 2010. The following gives some details about those projects:

UPWIND, which stands for Integrated Wind Turbine Design ([www.upwind.eu](http://www.upwind.eu)), 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, aero-elastic, 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 is 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 will go for 36 months. The objectives of this research project are:

- 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



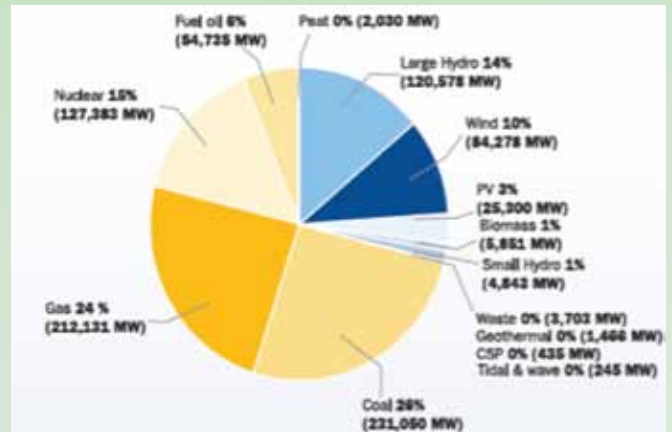
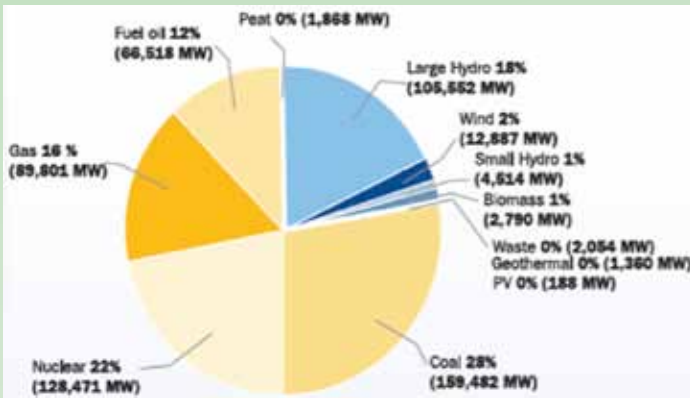


Figure 3 EU power capacity mix in 2000 and 2010 Source: EWEA

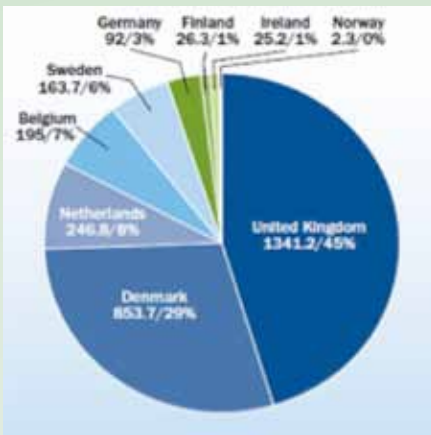


Figure 4 Offshore wind power installed by the end of 2010 by Member States of the EU Source: EWEA

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).

**PROTEST:** One of the major causes of failures of mechanical systems (e.g. drive trains, pitch systems, and yaw systems) in wind turbines is insufficient knowledge of the loads acting on these components. The objective of this pre-normative (before standards development) (2) project is to set up a methodology that enables better specification of design loads for the mechanical components. The design loads will be specified at the interconnection points where the component can be “isolated” from the entire wind turbine structure (in gearboxes for instance, the interconnection points are the shafts and the attachments to the nacelle frame). The focus of this activity will be on developing guidelines for measuring load spectra at

the interconnection points during prototype measurements and to compare them with the initial design loads.

Ultimately, these new procedures will be brought to the same high level as the state-of-the-art procedures for designing and testing rotor blades and towers, which are critical to safety. A well-balanced group consisting of a turbine manufacturer, component manufacturer, certification institute, and R&D institutes will describe the current practice for designing and developing mechanical components. Based on this starting point, the project team will draft improved procedures for determining loads at the interconnection points. The draft procedures will then be applied to three case studies, each with a different focus. They will determine loads at the drive train, pitch system, and yaw system. The yaw system procedures will take into account complex terrain. The project team will assess the procedures, and (depending on the outcome) the procedures will be updated accordingly and disseminated. All partners will incorporate the new procedures in their daily practices for designing turbines and components, certifying them, and carrying out prototype measurements. Project results will be submitted to relevant standardization committees. PROTEST started in March 2008 and will end in August 2010.

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



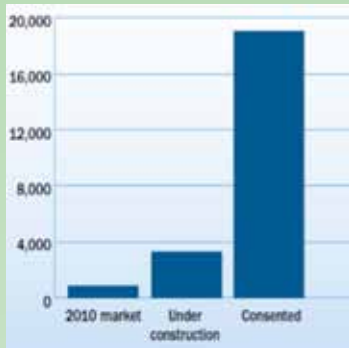
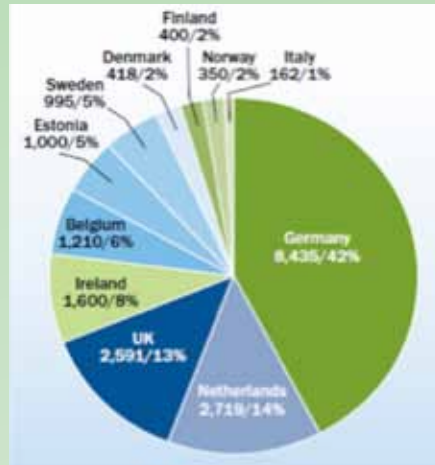


Figure 5 Consented and under construction offshore wind capacity, representing respectively 19 GW and 3.3 GW Source: EWEA



ORECCA: the objectives of the Offshore Renewable Energy 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 will stimulate 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 will overcome the knowledge fragmentation existing in Europe and 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 will be given to respect the strategies developed towards an integrated European maritime policy. The project will define the technological state of the art, describe the existing economical and legislative framework and identify barriers, constraints and needs within.

ORECCA will enable collaboration of the stakeholders and will define 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 will finally develop a vision including different technical options for deployment of offshore energy conversion platforms for different target areas in the European seas and deliver integrated roadmaps for the stakeholders. These will

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 multi-purpose 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, 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: the acronym stands for 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 (below 200 m of height). 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:

- i) 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,
- ii) to develop calculation and design tools for development and evaluation of very large wind turbines based on this concept, and
- iii) evaluation of the overall concept with floating offshore horizontal axis wind turbines. Up scaling 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:

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

**HiPR wind:** The aim of the HiPR wind 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 MultiWM 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.

### 3.2 DG ENER activities

The two projects discussed below represent demonstration actions funded within the Seventh Framework Programme (FP7- 2009 Call) of the EU and managed by the DG ENER.

**TWENTIES :** This is the largest renewable energy research project ever funded by the EU. Its objective is to significantly advance the development and implementation of new technologies, which allow the consolidation of wind power generation into the European electricity system. By means of six demonstrations, ways to remove the barriers to incorporate more wind energy (both onshore and offshore) into the electricity system will be explored. The full scale demonstrations aim at proving the benefits of novel technologies, the majority coupled with innovative system management approaches. The consortium consists of 26 companies and institutions of the electricity sector in 10 member states and one associated country. Through its size, scope, and ambition to enable the integration of large volumes of wind electricity in the European grid system, TWENTIES is already fully aligned with the logic and the priorities of the SET plan.

**TOP WIND:** The main aim of this project is to ensure the proper functioning of the European Wind Energy Technology

Platform over the 2010-2013 period, as well as to increase its effectiveness, impact, visibility and network (especially by reinforcing existing relationships, and developing new ones, with oil and gas, ocean, and grid operators, who can cooperate with wind energy players to reduce fragmentation of EU R&D activities).

Several actions funded under the sub-programme Offshore Wind Energy of the European Energy Programme for Recovery (EEPR) have been built on the innovative demonstration projects funded under the FP6 and FP7. The EEPR is a 565 million euro (759 million USD) spending programme, that, besides stimulating economic growth, aims at enhancing innovation with forerunner technologies in the offshore wind energy sector: multi-MW turbines, offshore structures, and HVDC technology for integrated connection of multiple wind farms.

### 3.3 Future R&D projects

New FP7 projects to start in 2011 will address the topic of design tools for offshore wind farm clusters (EC Call FP7-ENERGY-2011-1) and demonstration of innovative off-shore wind energy electricity generation structures (FP7-ENERGY-2011-2.3-1).

### 3.4 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 most cost effective 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 5-6 MW to 10-20 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 euro (8.06 billion USD) (public and private resources) for the 2010 – 2020 period, will integrate the following elements:

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

### 3.5 European Commission contacts

DG RESEARCH

Thierry LANGLOIS d'ESTAINOT  
European Commission  
Office CDMA 5/138  
B-1049 Brussels Belgium  
Tel. direct: +32-2-295.07.65  
Fax: +32-2-299.49.91  
Email: thierry.d'estaintot@ec.europa.eu

DG ENER

Roberto GAMBÌ  
European Commission  
Office DM24 3/126  
B-1049 Brussels Belgium  
Tel. direct: +32-2-299.81.75  
Fax: +32-2-296.62.61  
Email: roberto.gambi@ec.europa.eu

## 4.0 The European Wind Energy Technology Platform

### 4.1 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 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 and 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 27 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.

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

### 4.2 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 Programme 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 euro (8.06 billion USD), including public and private resources.

TPWind Secretariat contact

TPWind Secretariat

Rue D'Arlon 80

B-1040 Brussels, Belgium

Tel.: +32-2-213.18.13

Fax: +32-2-213.18.90

Email: secretariat@windplatform.eu

www.windplatform.eu

### References and notes

(1) Note that due to differences in statistical methodology, there may be slight differences between the figures quoted in this section and those in other sections of the IEA Wind Annual Report.

(2) Pre-normative research is R&D likely to generate new matters for standardization, usually in advance of these activities, (i.e. work anticipating future standards).

(3) Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions – A European strategic energy technology plan (SET-plan) – 'Towards a low carbon future', COM/2007/0723 final.

(4) COM(2009) 519 final.

Authors: Thierry Langlois d'Estaintot, European Commission, DG Research; Roberto Gambi, European Commission, DG ENER; Glória Rodrigues, Angeliki Koulouri and Filippo Gagliardi, EWEA.

---

\*LEGAL NOTICE: Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use that might be made of the following information. The views expressed in this document are the sole responsibility of the authors and do not necessarily reflect the views of the European Commission.



# Chapter 17

## Finland

### 1.0 Introduction

In Finland, 31% of electricity generation was by renewables in 2010. Finland's generating capacity is diverse. In 2010, 25% of gross demand was produced by nuclear, 15% by hydropower, 33% from combined heat and power (coal, gas, biomass, and peat), and 15% from direct power production from mainly coal and gas. Biomass is used intensively by the pulp and paper industry, raising the share of biomass-produced electricity to 12% in Finland. About 12% of electricity was imported, mainly from Russia, so the renewable share of gross electricity demand in Finland was 27%. The electricity demand, which is dominated by energy-intensive industry, grew by 8% to 87 TWh, after a decrease of 7% in 2009 due to economic recession.

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 a new 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 2010, a total of 197 MW were installed, producing about 0.3 TWh, or 0.3% of gross demand in Finland. At the beginning of 2011, there were 2,900 MW of wind power projects in various phases of planning onshore and 3,000 MW of announced projects offshore.

A market based feed-in system with a guaranteed price of 83.5 euro/MWh (112.2 USD/MWh) entered into force on 25 March 2011 in Finland. There will be an increased tariff of 105.3 euro/MWh (141.5 USD/MWh) through the end of 2015 (maximum three years). The difference between the guaranteed price and spot price of electricity will be paid to the producers as a premium.

Wind power technology exports from Finland amount to about 0.8 billion euro (1.08 billion USD). The wind turbine



Photo: Suomen Hyötytuuli Oy

manufacturer WinWinD has developed an ice prevention system for its 3-MW turbines in collaboration with VTT Technical Research Centre of Finland. Moventas is developing its gearboxes for larger turbines, and ABB and The Switch are developing generator and frequency converter solutions for wind power.

### 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 2010, there were 17 new turbines installed with the total capacity of 52 MW. These turbines are sited in Pori (1 at 2.3 MW), Raahe (4 at 2.3 MW) and Tornio (8 at 3.6 MW). The single turbine in Pori is a pilot offshore turbine for a larger planned offshore wind farm (opening photo). The wind turbine manufacturer Siemens has the largest part of new installations in Finland - 13 turbines are from Siemens (40 MW). The remaining four turbines are WinWinD machines (4 at 3 MW) and they are installed in Hamina. Five turbines were decommissioned in 2010, with a total capacity of about 2 MW. The net increase was 50 MW, bringing the total capacity to 197 MW at the end of 2010, which is a 35% increase from the previous year.

Table 1 Key Statistics 2010: Finland

Total installed wind generation	197 MW
New wind generation installed	52 MW
Total electrical output from wind	0.29 TWh
Wind generation as a percentage of national electric demand	0.3%
Target:	6 TWh/yr (2,500 MW) in 2020

Although the wind resource was lower than average during 2010, the total wind energy production in 2010 increased by 6% compared to 2009. The production of 292 GWh corresponds to 0.3% of the annual gross electricity consumption of Finland (Table 1). The environmental benefit of wind power production in Finland is about 0.2 million tons of CO<sub>2</sub> savings per year.

At the end of 2010, 130 wind turbines were in operation in Finland (Figure 2). The average wind turbine size is 1,520 kW. 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. The 17 turbines installed in 2010 were from 2.3 MW to 3.6 MW.

In early 2011, there were 10–50 MW worth of wind power projects preparing for construction, with most sited in the Åland islands. Other places of interest for wind power projects are Raahe and Merijärvi.

The Åland islands between Finland and Sweden constitute an autonomous region with its own legislation, budget, and energy policy. How the feed-in tariff system will be implemented to this autonomous region is still unclear. Wind energy covered 18% of electricity consumption in 2010 with 22 MW installed capacity. A transmission line to mainland Finland is planned and this will help further deployment of wind power in this wind rich region.

**2.3 National incentive programs**

Up until 2010, the main incentive to promote wind investments has been an investment subsidy of up to 40% depending on the level of novelty of a wind energy installation. In addition to the investment subsidy, a tax refund of 6.9 euro/MWh (9.3 USD/MWh) has been awarded. Projects that applied for a subsidy between 2001 and 2006 received an average investment subsidy of 35%, but the number of projects and MW installed has been low (3 to 30 MW/yr, 2 to 14 million euro/yr or 2.7 to 18.8 USD/yr in subsidies). In 2009, additional funds for investment subsidies were made available and about 60 MW of wind power projects received an investment subsidy decision.

A feed-in premium entered into force on 25 March 2011 in Finland. A guaranteed price of 83.5 euro/MWh (9.3 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. The initial proposal of collecting the costs from consumers in an electricity tariff proved to violate the constitutional law and so the cost will be recovered by electricity taxes. There is an increased level of 105.3 euro/MWh (141.5 USD/MWh) until the end of 2015 (maximum 3 years) to encourage early projects. A three-month average spot price will be the comparison price to determine the payments to the producers (the guaranteed price minus the average spot price). 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. If the impacts of emission trading continue to raise electricity market prices, this will reduce the payments for this subsidy. A special subsidy for offshore wind power will still be considered.

To help reduce uncertainty when estimating the production potential of the taller multi-megawatt machines in the forested coastal areas of Finland, a new wind atlas was made by FMI with government funding. The first part (2.5-km grid) was published in November, 2009 and the second part (coastal area with a 250-m grid) was launched at the end of March 2010.

An addition to the Electricity Market

Act set a ceiling to the distribution network charges for distributed generation, including wind. The act also stated that grid reinforcement payments must be borne by the consumers, not by the producer. However, project size for the grid reinforcement exemption was limited to 2 MW, limiting the promoting effect of the grid reinforcement exemption for wind power.

To overcome planning and permitting problems, the Ministry of Environment published guidelines for planning and building permission procedures for wind power plants. Sites for wind power have been added to regional plans by the authorities. This will help future wind power projects.

**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 have been 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 anticipated feed-in tariff system has led to a rush for the best sites. At the beginning of 2011, there were 2,900 MW of wind power projects in various phases of planning onshore, and 3,000 MW of announced projects offshore.

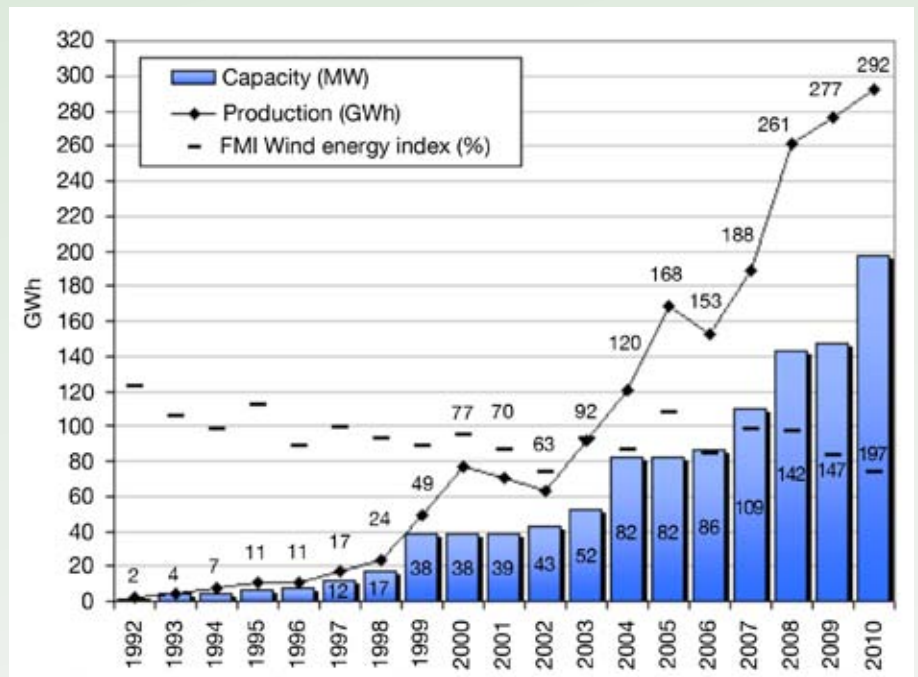


Figure 1 Wind power capacity and production. FMI Wind energy index is calculated from Finnish Meteorological Institute (FMI) wind-speed measurements converted to wind power production, 100% is average production from 1987 to 2001.



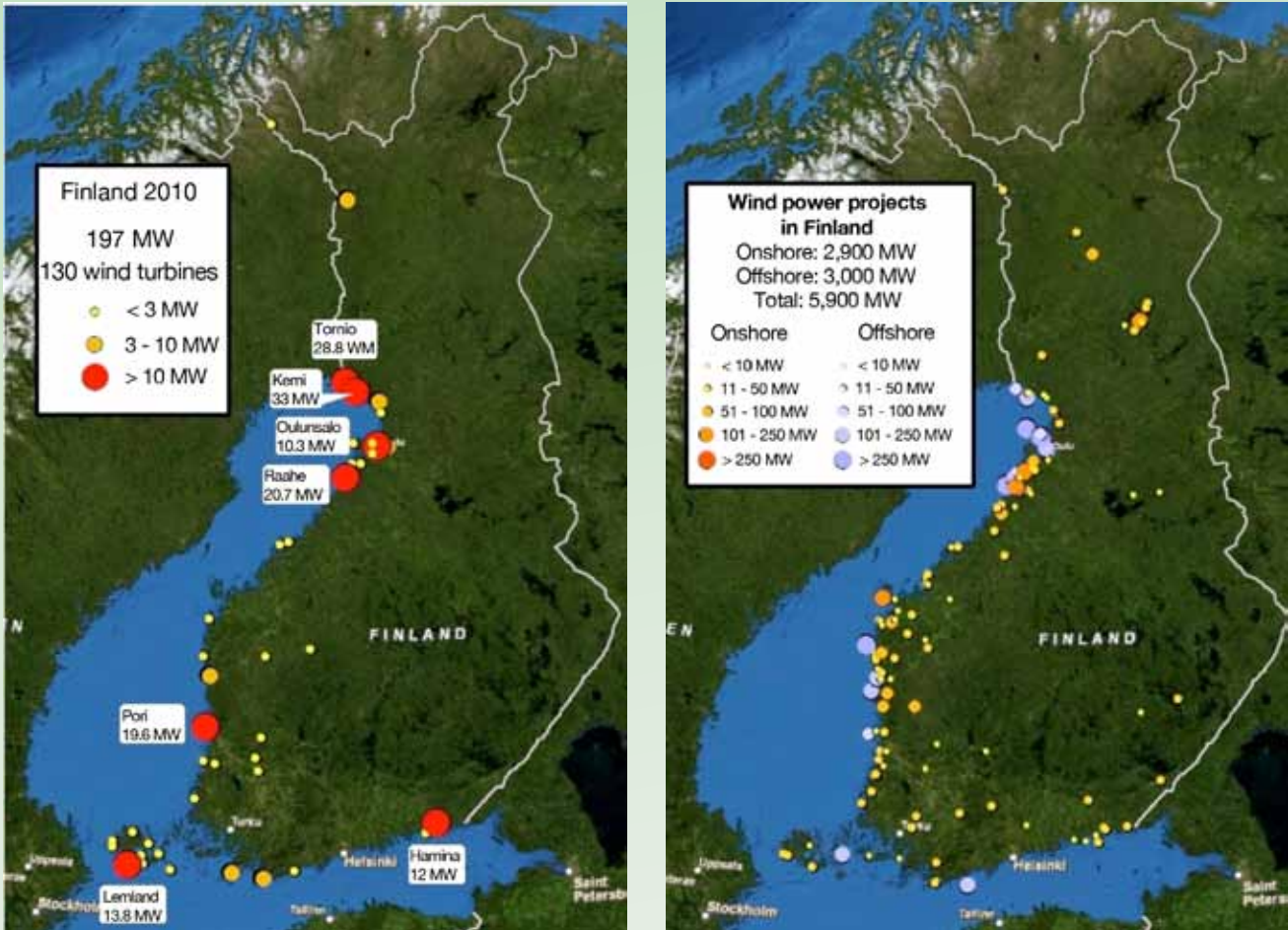


Figure 2 Wind turbines operating in Finland by the end of 2010 (left); Wind power projects published at the beginning of 2011 (right).

The proposed feed-in tariff is not sufficient to start offshore projects, and the ministry will come up with a proposal for offshore project subsidies later (the projects are anticipated to start after 2012).

Permitting will probably be a challenge for many of the planned projects. Radar influence has become an issue and a study is currently being carried out to estimate the impacts in order to give green light to wind power projects that will not cause problems. There is also growing concern about eagles (*Haliaeetus albicilla*). A study of wind turbine impacts on nesting and behavior of eagles has been proposed by the World Wildlife Fund.

### 3.0 Implementation

#### 3.1 Economic benefits

The estimated value of all business activity related to wind energy development in Finland is presented in Figure 3. 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 about 20 technology and manufacturing companies involved in wind power in Finland, employing more than 4,000 people, with an economic turnover of about 0.8 billion euro/yr (1.08 billion USD). Maintaining current market share in global wind power markets would mean increasing economic turnover to a level of 3 billion euro/yr (4.03 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 euro/yr (16.1 to 18.8 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.

#### 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 2010, 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 4). In 2010, the number of employees was about 800 (311 in Finland). In 2009, WinWinD opened a new manufacturing facility for 3-MW turbines in Hamina, Finland and started an assembly and blade manufacturing plant for 1-MW turbines in Chennai, India. The main owner of WinWinD since 2006 is Siva Group (previously Sterling Group, India) and in 2008 Masdar (Abu Dhabi) became a major shareholder, too.

In 2009, a new turbine manufacturer, Mervento, started to develop its first prototype that is especially designed for offshore applications. The plan is to erect it in 2011. Mervento is planning an assembly line in Vaasa with annual capacity



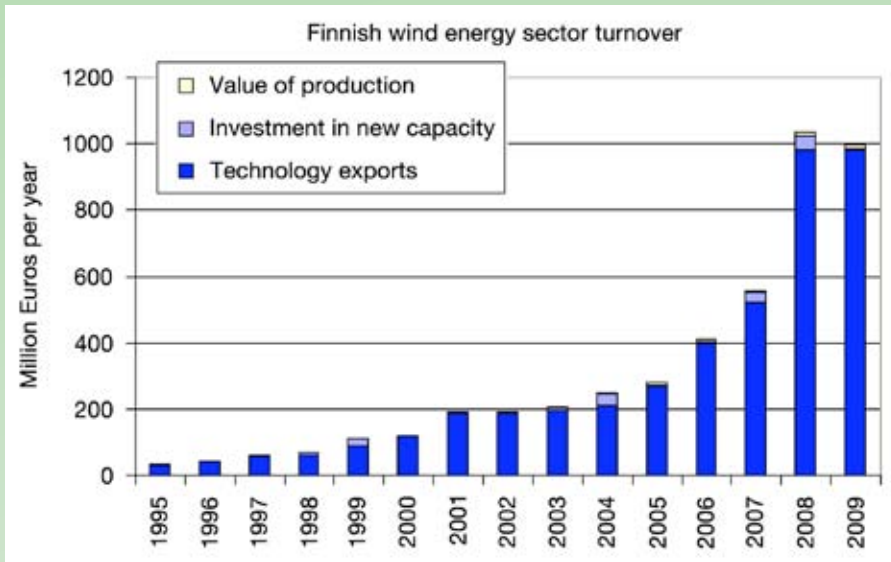


Figure 3 Finnish wind sector turnover: wind power technology exports, investments, and production turnover (year 2010 figure for technology exports was not available so 2009 figure was used). Turnover from electricity production sales was estimated from the average spot market price.

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 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 world-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, Labkotec, and Hoxville.

**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 farmers are located inland where the wind resource is limited at heights below 60 m.

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 Båtskäär. 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 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 (Suurhiekkä, 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 analyses. An offshore demonstration will need funding to be realized.

**3.3 Operational details**

The average capacity factor of wind turbines operating in Finland was 19% in 2010 due to the less than average wind index (production index was 73- 91% in different coastal areas in Finland). In the 2000’s, the average capacity factor has been 17- 24%. As reported in the wind energy statistics of Finland yearly reports, the capacity factor of the MW size turbines is considerably higher than for turbines less than 50 m high. More large turbines are being installed (Figure 5).

The average availability of wind turbines operating in Finland was 90% in 2010 (91 to 96% in 2001 to 2009). Of the 81 turbines reporting, there were five turbines with less than 70% availability in 2010 due to a failure in the gear and problems in the hydraulic and pitch system.

**3.4 Wind energy costs**

On coastal sites in Finland, the cost of wind energy production is estimated to be about 60 to 80 euro/MWh (80.6 to 107.5 USD/MWh) without subsidies (2,100 to 2,400 h/a, 1,300 to 1,400 euro/

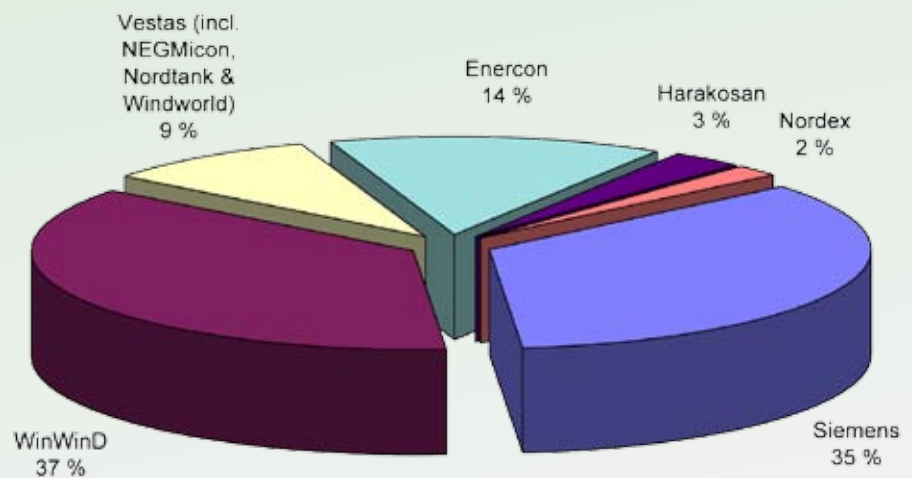


Figure 4 Market shares of turbine manufacturers in Finland as a percentage of total capacity at the end of 2010 (197 MW)

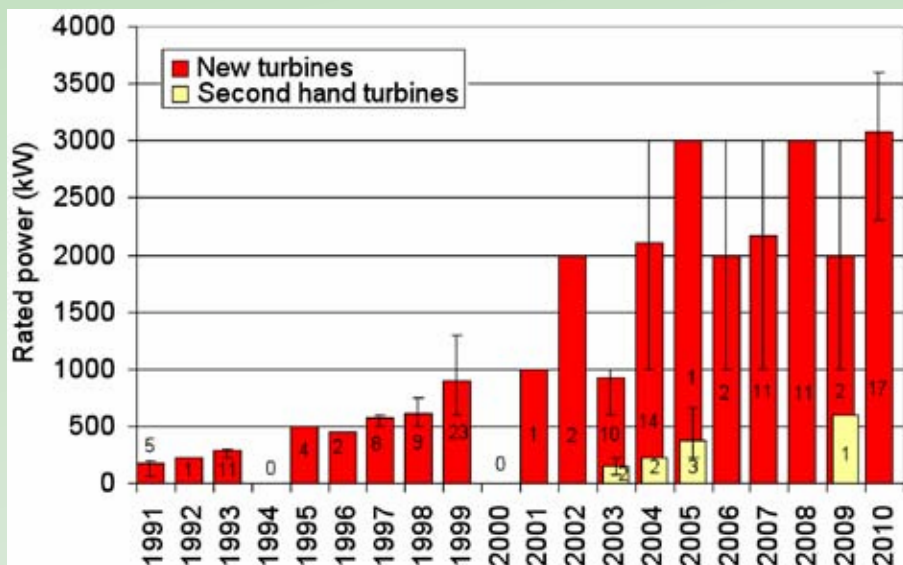


Figure 5 Average size of installed capacity (the vertical line represents minimum and maximum capacity of turbines installed)

kW [1747.20 to 1881.6 USD/kW] investment cost, 20 years, 7% internal rate of return, 26 to 28 euro/kW/yr [34.90 to 37.60 USD/kW/yr] O&M cost, and 2 euro/MWh [2.70 USD/MWh] balancing cost). The estimated cost of offshore production could exceed 100 euro/MWh (134.40 USD/MWh). The average spot price in the electricity market Nordpool was 57 euro/MWh (76.60 USD/MWh) in 2010 (37 euro/MWh or 49.73 USD in 2009). Wind power still needs subsidies to compete even on the best available sites. The planned feed-in guaranteed price of 83.5 euro/MWh (112.22 USD/MWh) for 12 years (105.3 euro/MWh [141.52 USD/MWh] for the first three years but only until the end of 2015) is expected to open the onshore market in 2011.

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.

#### 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 633 million euro (850.8 million USD) in R&D projects in 2010. 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. Benefit to industry is stressed, as is the industry's direct financial contribution to individual research projects. A

new research program for wind (CLEEN WIPO program) was proposed, stressing a strong industry involvement, with 50% of the R&D work to be carried out in industries. However, it was not approved by Tekes. Instead, the role of wind power is increasing in other R&D programs, like the new GROOVE program for renewable energy commercialization.

Tekes funding for wind power in the last six years is presented in Figure 6. Tekes invested over 4 million euro (5.4 million USD) in wind power R&D projects in 2010. There were 36 ongoing wind power R&D projects in 2010; most of them 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. WinWinD developed an ice prevention system for its 3-MW turbines in 2009, in collaboration with VTT. The first four turbines were erected in Swedish Lapland, Ullabouda in September 2009 and another six in 2010.

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

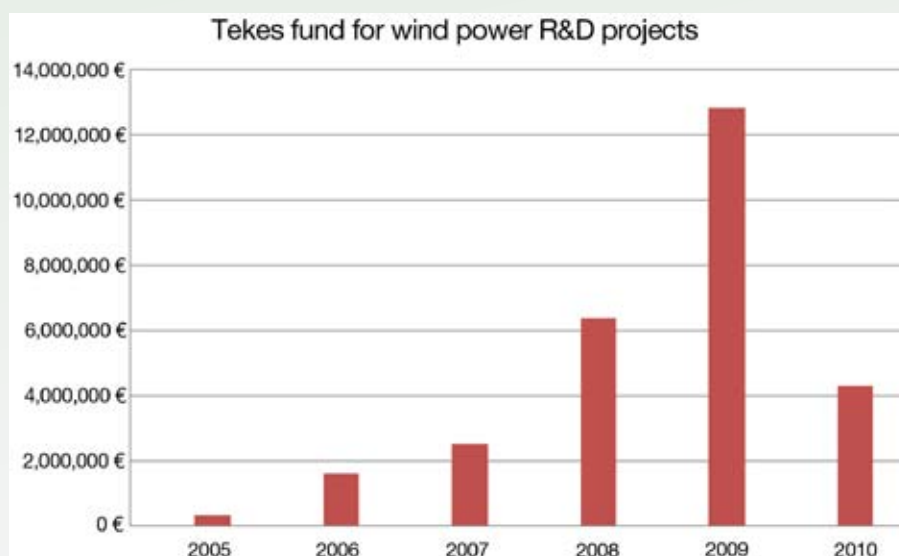


Figure 6 Tekes funding for wind power R&D projects in the last five years

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 Tradewind (2006–2009), VTT estimated the impact of wind power on cross border flows in the European power system. As part of the EU project UPWIND, technologies to control the shape of composite structures were developed at laboratory scale.

The Finnish Meteorological Institute (FMI) has been active in EU collaboration for wind and ice measurement technology. FMI has been coordinating the COST collaboration “Measuring and Forecasting Atmospheric Icing of Structures.”

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

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

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

### 5.0 The Next Term

Approximately 10 to 50 MW of new capacity is anticipated for 2011. A huge number of projects are planned, under feasibility studies, or have just been proposed: 2,900 MW onshore and 3,000 MW offshore. A list of wind turbine projects in Finland can be found at <http://www.vtt.fi/windenergystatistics>.

A radar study needs to give first results for some projects to get building permits.

A next-generation blade heating system has been developed in Finland, and further development is ongoing. This will enable the use of the wind resource potential in arctic fell areas of Finland. Increasing global demand for ice-free turbines is foreseen.

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



# Chapter 18

## Germany



### 1.0 Overview

At the end of 2010, Germany had 21,585 wind turbines (2009: 21,164) installed with a capacity of 27,204 MW (2009: 25,777 MW). The new installed capacity in 2010 is 1,551 MW (2009: 1,880 MW) (1). In the German offshore market's second year, 108 MW of new capacity was installed in the Baltic 1 (Baltic Sea) and BARD Offshore 1 (opening photo) (North Sea) offshore projects (2). So about 180 MW (2009: 60 MW) was installed offshore.

After construction in 2009, the alpha ventus offshore test site began public operation in April 2010. At the end of 2010, the European Commission authorized a grant of 30 million euro (40.3 million USD) from the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) to alpha ventus. The accompanying research initiative at alpha ventus (RAVE) is funded by BMU with another 43 million euro (57.8 million USD). After near 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 at the end of 2010.

### 2.0 National Objectives

#### 2.1 National Targets

In September 2010, the German federal government decided on a new energy concept. The scenarios used as the basis for the Energy Concept showed that in 2050 wind energy will play a key role in electricity generation (4). The energy concept therefore consequently emphasizes the extension of onshore and offshore wind energy. The energy concept formulates an explicit 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% in 2050 (4).

For a better understanding of the technical risks entailed in offshore wind farming, and hence to facilitate financing of offshore wind farms, funding for construction of 10 of the first wind farm

projects is planned. This shall allow essential technical and financial experience to be gained for further extension. To this end, the KfW Bankengruppe will initiate a special program in 2011 with a total credit volume of 5 billion euro (6.7 billion USD) at market rates of interest (4).

One of the measures for onshore wind energy is to enhance the compatibility of military radar installations and wind energy deployment. Technical conditions shall be created to prevent interference from wind turbines on radar. The German government will undertake corresponding research and development measures to improve radar installations and modifications of wind turbines accordingly (4).

#### 2.2 Progress

The contribution of renewable energies to total electrical energy consumption 2010 was 16.8% (2009: 16.3%). Electrical energy production from renewables was 102 TWh. This is equivalent to avoiding emission of 76 million tons of greenhouse

gases (3). Wind energy generated 36% of the electrical energy production from renewable energies, followed by hydropower (19%) and photovoltaic power (12%). The electrical energy produced from wind decreased to 36.5 TWh in 2010 (2009: 38.6 TWh, 2008: 40.6 TWh) because of lower wind conditions. If 2010 had been an average wind year, about 6 TWh more energy production could have been expected (3).

#### 2.3 National incentive programs

The Renewable Energy Sources Act (EEG) is the main incentive for Germany's onshore, offshore, and repowering market. The energy produced is sold under a fixed feed-in tariff. A project built in 2010 had a premium tariff of 91 euro/MWh (122.3 USD/MWh). The tariff will decrease annually using a regression rate of 1% based on the year the wind farm was constructed. For repowering projects, an additional bonus of 5 euro/MWh (6.7 USD/MWh) is allowed. In certain

**Table 1 Key Statistics 2010: Germany (3)**

Total installed generation	27,204 MW
New wind generation installed	1,551 MW
Total electrical output from wind	36.5 TWh
Wind generation as % of national electric demand	6%
Targets	35% of electrical energy consumption by renewables and 10 GW offshore wind by 2020.

instances, wind turbines, which are able to support electricity grids in critical conditions (e.g. low frequency), receive a bonus of 5 euro/MWh (6.7 USD/MWh) as will new projects installed before 2014 (7 euro/MWh or 9.4 USD/MWh for optimization of existing projects until 2010) (7).

Offshore wind farms benefit from a premium tariff of 150 euro/MWh (201.60 USD/MWh) which is paid for 12 years. After that period, the basic tariff decreases to 35 euro/MWh (47.1 USD/MWh). If a project is constructed before 2016, an additional bonus of 20 euro/MWh (27 USD/MWh) will be paid. The extension of the premium tariff follows the general EEG mechanism. For a more detailed description see (8). The next amendment of the EEG based on an analysis of the practical development is planned for 2012.

In order to give wind turbine manufacturers sufficient time to prove their turbines' ability to deliver system services, the federal government has prolonged the transition periods within the Ordinance on System Services by Wind Energy Plants (System Service Ordinance – SDL-WindV) (7) in June 2010.

### 2.4 Issues affecting growth

In 2010, 1,551 MW (754 wind turbines) were added to Germany's wind energy capacity of 27,204 MW (21,585 wind turbines) (1). This is 19.1% less than the capacity installed in 2009, as shown in Figure 1.

The worldwide financial crises hampered the acquisition of debt capital and slowed the growth of the German market, especially offshore. A survey by KPMG (8) revealed the acquisition of debt capital to

be the number one obstruction to increasing wind energy capacity.

Onshore, 11.8% of the newly installed capacity is based on repowering. One hundred sixteen wind turbines (55.7 MW) were decommissioned in 2010. In their places 80 wind turbines with a total capacity of 183.4 MW have been installed (1).

### 3.0 Implementation

With its turbine manufacturers, sub-suppliers, and service providers the German wind energy sector is an important and innovative industry. Although being a very attractive job market, the lack of highly qualified people is imminent and became a limiting factor of industrial growth. Therefore – partly supported by the industry – several universities and universities of applied sciences opened new positions for wind energy professorships.

### 3.1 Economic impact

Investment in wind energy amounted to 2.5 billion euro (3.4 billion USD) (3). With approximately 96,000 people being employed in the business in comparison to 102,000 in 2009 employment decreased slightly but wind energy remains an attractive job market (2007: 86,000). Of the people working in wind, 6,900 are employed for offshore wind energy (Table 2). Another 7,500 people are employed in R&D and public administration for all renewable energies (3). Experience from the first offshore projects reveal the demand for highly qualified staff with expertise in wind energy and maritime technology. New companies entered the market, such as those building specialized jack-up

installation vessels and other marine technologies and services or new turbine manufacturers, focusing on the development of onshore wind power plants.

### 3.2 Industry status

Several key changes occurred in 2010. After having bought ScanWind, GE announced in March 2010 its decision to open an Offshore Wind Technologie Center in Hamburg, Germany in addition to its locations in Salzbergen (GE Wind Energy) and Munich (GE Global Research). In June 2010 AREVA, having already held 51% share of Multibrud, bought the remaining 49% share. Since then Multibrud is operating under the name of AREVA Wind GmbH.

With respect to newly installed capacity (1,551.03 MW, 754 wind turbines) the biggest shares of the German wind market are still held by Enercon (59.2%), Vestas (14.6%), and REpower Systems (10.3%). However, the largest growth in market share in 2010 was achieved by Siemens (+3.9 percentage points), BARD (+3.9 percentage points), and Nordex (+2.6 percentage points) (1). German manufacturers in general worked hard on the home market. Nevertheless export of wind turbines and components remained the main business of German manufacturers. A new manufacturer, PowerWind GmbH, commissioned its first 2.5-MW turbine in Bremerhaven with a special conception to prevent the gear train components from overloading.

### 3.3 Operational details

In 2010, the two first commercial offshore wind farms were (partially)

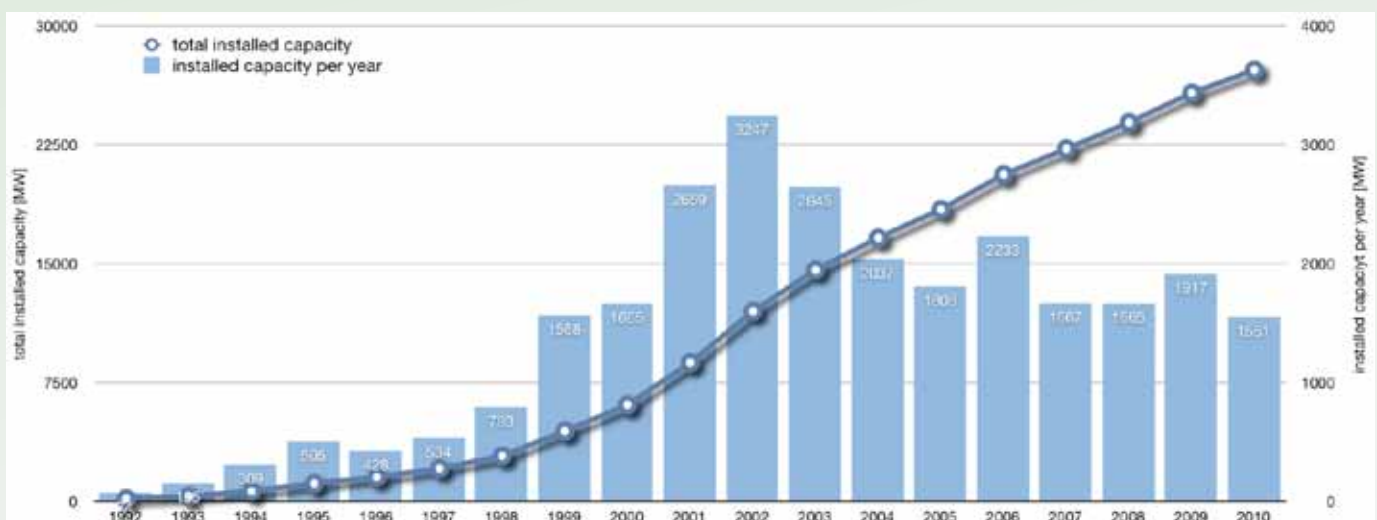


Figure 1 Total and annually installed capacity of wind power in Germany 1992-2010

**Table 2 Number of employees for different branches of wind energy in 2010 (3)**

	Investment including export	Operation and maintenance	Total employment
Onshore Wind	71,300	17,900	89,200
Offshore Wind	6,400	500	6,900

installed. In September 2010, the last of the 21 Siemens SWT-2.3-93 turbines were installed by EnBW at Baltic 1. With its capacity of 48.3 MW, Baltic 1 is expected to feed 185 GWh/yr into the grid. Due to moderate water depths of 16-19 m, the turbines could be installed on monopile foundations.

In December 2010, the BARD company had 15 of the 80 planned BARD VM turbines installed at BARD Offshore 1. A part of those turbines were connected to the HVDC transformer station BorWin1 and fed the first MWh of electricity into the grid. With a total capacity of 400 MW, BARD Offshore 1 is expected to feed 1,600 GWh/yr into the grid. All wind turbines will be installed on BARD's in-house developed tripile foundations. With more than 100 km distance to shore and water depth of 40 m, the site was the most remote offshore wind farm under construction. The project is being supported by the European Commission within the European Energy Programme for Recovery (EPR) and received a grant of 53.1 million euro (71.4 million USD).

Germany's first offshore wind farm alpha ventus completed its first year of operation in November 2010. By the end of January 2011, the wind farm had fed 230 GWh of electricity into the grid (9). Also during the first year of operation all nacelles of the AREVA Wind M5000 turbines had to be replaced. This was necessary due to increases of temperatures of sliding bearings, which were noticed in spring 2010. The replacement of the nacelles took only few hours per wind turbine and barely affected the power production. Necessary reinstallation costs of RAVE measuring equipment were fully covered by AREVA.

### 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. Basic figures and a comprehensive overview are given in the contribution of Deutsche

WindGuard GmbH to the Multi-national Case Study of the Financial Cost of Wind Energy, in the frame of IEA Wind Task 28 (10). The German Wind Energy Association (BWE) mentions investment costs for offshore wind energy far from the coast as 4.3 million euro/MW (5.8 million USD/MW) in comparison to 1.4 million euro/MW (1.9 million USD/MW) onshore (11). The KPMG 2010 Market Report calculated costs of 3.7 million euro/MW (5 million USD/MW) for a typical future German offshore wind farm (8). On the other hand, offshore wind farms can produce electricity during about 4,000 hr/yr with their maximum capacity as the FINO data show. This is about double the mean yearly full load hours for onshore wind farms. Because the extension of offshore wind energy is essential if the governmental targets shall be reached, it is further a major topic for R&D to develop technology with lower costs and to ensure high availability of offshore wind farms.

## 4.0 R, D&D Activities

### 4.1 National R, D&D efforts

The BMU is in charge of funding practically oriented research. Thirty seven new projects (including thematic and financial extension of ongoing projects) were funded by 54.1 million euro (72.7 million USD) in 2010 (2009: 28.1 million euro, 37.7 million USD). Most projects run for three years. Figure 2 shows the development of R&D funds for new projects and

the number of yearly new projects since 2004. The dark blue bar represents the grant for alpha ventus to the operator DOTI GmbH & Co. KG. Funds consumed by all running projects (i.e. including those started the years before) amounted to 36.7 million euro (49.3 million USD). Table 3 shows how these project funds were used for different general topics.

### Alpha ventus

The research initiative at the test site alpha ventus - RAVE - was a major 2010 activity in wind energy research. By the end of 2010, 43.1 million euro (58 million USD) had been funded for RAVE, which involves 45 institutes and companies. The RAVE research data bank contains about 3.5 TByte of information gained from the test site after five months of full operation. A more detailed description of RAVE was given in (13). A 50-page brochure describing all RAVE projects can be ordered at Fraunhofer IWES: info@rave-offshore.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" which contains a chapter on RAVE (14).

The GIGAWIND alpha ventus project is an example of a RAVE research compound, which received data from alpha ventus since spring 2010. An objective of this project is to reduce the cost of offshore wind turbine support structures: towers, substructures, and foundations. This can be accomplished by designing lighter support structures on the one hand (reducing material cost) and by optimizing the design process on the other hand (reducing personnel cost). This is reflected in several work packages and main topics (see Figure 3): loads, durability, foundation, general structural models, and holistic design.

**Table 3 Funds invested in ongoing projects 2010 (12)**

General Topic	Funds million euro/million USD
Accompanying ecological research (mainly offshore)	2.8/3.7
Offshore research platforms and data acquisition	2.6/3.5
Alpha ventus and research at alpha ventus	15.2/20.4
Other technological research	16.1/21.6



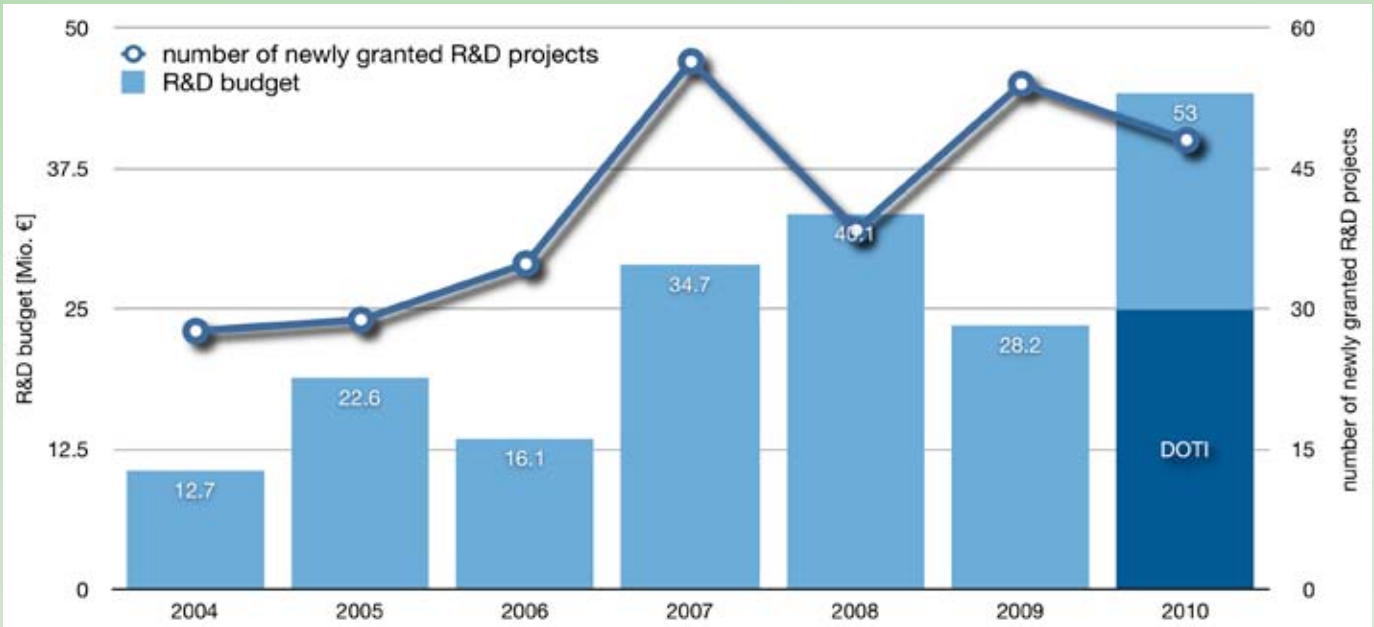


Figure 2 Development of R&D funds and number of yearly new projects of BMU for wind energy research

Algorithms, new methods, and software-tools will be developed and validated using measurement data from the test site. With a more efficient design process and by utilization of design reserves, the support structures can be provided

more economically. With the integration of separate computational tools into an easy operable simulation and design package with common interfaces, the effort of the design process will be minimized. The holistic design concept for offshore wind turbine support structures is built up in a modular way, so that further extensions can easily be implemented. The consortium consists of ForWind – University of Hannover and Fraunhofer IWES. The AREVA Wind GmbH and REpower Systems AG support this research practically in the frame of the RAVE declaration for cooperation (15, 12).

data to work on aspects of offshore logistics (12).

FINO 2 in the Baltic Sea was taken over in 2010 from the federal government. GL Garrad Hassan Deutschland GmbH was contracted to operate FINO 2 after a European-wide tender. FINO 3 in the North Sea continued its measurement for the second year. A co-operation with the University of Bergen, Norway was started. The University of Bergen intends to install a floating platform with a similar measuring regime to FINO 3 in Norwegian waters.



Figure 3 Contents and structure of the GIGAWIND alpha ventus research compound in the frame of RAVE (15), source of graph: ForWind - University of Hannover

The three FINO offshore research platforms continued their measurements in 2010. FINO 1 is located only 400 m to the west of alpha ventus and delivers important reference data such as wind profiles and wave heights, as well as sea currents and ecological findings. These data are also part of the RAVE research data bank. The Federal Maritime and Hydrographic Agency (BSH) carried out an inquiry among more than 360 users of FINO data. Of these, 58% of them are research institutes, 28% companies, 9% public authorities, and 5% other facilities. The inquiry confirmed the benefit of the FINO offshore measurements. Research institutes use these data mainly to develop energy output prognosis tools, mechanical load prognosis methods, wind physical investigations as for instance turbulence research, and development of meteorological models. Companies also used FINO

**Project highlights**

A high-performance computer cluster for calculation of highly complex aerodynamic flow processes or modeling of large entities of wind turbines was established at ForWind - University of Oldenburg. The computer cluster allows very precise calculations of flow processes around the surface of rotor blades as well as computation of flow processes within a whole wind farm area. For both applications, flow data with high resolution are necessary which are impossible to be gained by experimental methods. The computer cluster allows investigating the influence of small design changes at a rotor blade on the whole flow process through the rotor. It allows calculation of details needed for turbine construction as well as for assessing the influence of the turbine arrangement in a wind farm on the electrical output and on mechanical loads. The



Figure 4 The 90 m test rig for rotor blades next to the 70 m test rig at IWES

computer cluster is funded with 3 million euro (4.1 million USD) and makes the German wind energy research independent from the availability of other super computer centers.

The availability of test facilities for large components is important for the development of new more effective and powerful turbines. The rotor blade test center at Fraunhofer IWES in Bremerhaven for blades up to 70 m was described in the German report 2009 (13). Cyclic biaxial fatigue test methods, which are developed in the InnoBladeTeC project will simulate 20 years of operation in four months. In 2010 the construction of a second 90 m test rig (Fig.4) started at IWES and will begin operation in spring 2011.

Full-scale tests of the mechanical behavior of new offshore foundations have been carried out onshore in Bremerhaven for a jacket foundation with iron cast nodes and for the tripod foundation used later on in *alpha ventus*. In 2010, Ed. Züblin AG started a unique full-scale onshore test of a gravity foundation. It will provide fundamental knowledge on the long-term stability of such foundations. To create conditions near to reality, a 7-m deep hole was excavated near the coast line, so that the foundation stands

on water-saturated sediment very similar to the open sea bottom. Wave forces are simulated by means of hydraulic devices. Up to 170 sensors measure the displacements of the foundation and of the sediment as well as other physical parameters. The technical expertise and data gained will be used to plan the foundation design of future wind farms in the North Sea and for the development and validation of numerical models. The measurement aspects of this project are funded by BMU with 1.2 million euro (1.6 million USD).

The basic design of a test centre for offshore foundation components and large-scale foundation models was developed in 2010 at ForWind – University of Hannover in cooperation with the relevant industry.

The interference of wind turbines with radar can be an obstacle for the approval of wind farm projects. A project of EADS Deutschland GmbH, partly funded by BMU, investigated the interference of wind turbines with Air Traffic Control Radars (ATC) and appropriate measures on radar and turbine design for mitigation of these impacts. The radars being investigated are the Raytheon ASR-910 and the Cassidian ASR-S. Methods for assessing the impact of turbine – radar interference on ATC tasks are developed in addition to the existing Euro Control guidelines and recommendations. With respect to the ASR-S, a “Turbine-Modkit” was tested to track vehicles overflying extended wind farm areas, while the radar is using the primary radar information only. The increased compatibility achieved by using the “Turbine-Modkit” was tested in several measurement campaigns and in comparison with the unmodified radars. The effects of wind turbine design, size, and operation parameters on the compatibility for interference to these radars were

determined in qualitative and quantitative manner and evaluated in terms of statistics. Recommendations will be given for a radar optimized turbine design and siting as well as for retrofit measures on the radar. Preliminary results: the compatibility problems can be solved for ATC radars using a “Turbine-Modkit.” In addition or at least for larger wind turbine groups and types, moderate optimization and absorption measures will be necessary in order to ensure full compatibility (16).

A new 6.5-MW prototype wind turbine was developed by the BARD-group. The BARD 6.5 offshore wind converter has one main gearbox equipped with two drive shafts that each power its own synchronized generator with a 3.4-MW capacity. BARD equips its new 6.5-MW turbines with fully rated converters, enabling them to fulfill the needs and demands of an intelligent future European super grid. An onshore test program started in February 2011 (17).

#### 4.2 Collaborative Research

The “Berlin Declaration” of the European Policy Workshop on Offshore Wind Power Deployment held in February 2007 in Berlin extended the existing Joint Declaration on Cooperation in Offshore Wind Energy Research between Denmark, Germany, Sweden (2007), and Norway (2009). The meeting of the joint committee of this cooperation in October 2010 stated the following activities so far.

##### Germany – Denmark

Common research projects on

- Bird and porpoise behavior at Horns Rev I and Nysted,
- Acoustic detection methods for porpoises,
- Heat development of marine cables,
- Tracking routes of seals,
- Hearing sensitivity of porpoises,
- Effectiveness of chasing away seals during offshore pile driving activities.

The results of this collaborative research are publically available and have been presented at the relevant conferences.

##### Germany – Sweden

- Exchange of wind data of FINO 2 to Vattenfall/Kriegers Flak Sweden,
- Integration of Vattenfall’s marine data at Kriegers Flak to the FINO-data base



Figure 5 The gravity test foundation of Ed. Züblin AG in Cuxhaven

### Germany – Norway

- Two joint research workshops in 2010 in Hannover and Bergen,
- Visit at FINO 3 research platform,
- Proposal on FINO cooperation.

It was stated that the declaration on Cooperation in the Field of Research on Offshore Wind Energy Deployment (17) is a beneficial network for common activities and exchange of information between countries with similar conditions for the development of wind energy technologies at their adjacent seas.

### 5.0 The Next Term

In order to industrialize the wind energy sector further efforts are needed. Supply and process chains have to be optimized with respect to standards and production efficiency. To tackle this task, research institutes and industry will converge even more. In accordance with the task formulated in the Energy Conception, the R&D budget for wind energy research of BMU will increase significantly in 2011. The 5 billion euro (6.7 billion USD) from the KfW Bankengruppe credit program will relieve financial tension for the first offshore wind farms. This will enable small and medium-sized enterprises as well as municipal utilities to enter the offshore market.

### References

- (1) DEWI Magazine No. 38, Wind Energy Use in Germany - Status 31.12.2010, p. 36-48 <http://www.dewi.de/dewi>
- (2) Bundesverband Windenergie, Annual balance for wind energy generated in 2010, 27.01.2011, <http://www.wind-energie.de>
- (3) Erneuerbare Energien 2010, Daten des Bundesumweltministeriums zur Entwicklung der erneuerbaren Energien in Deutschland im Jahr 2010 auf der Grundlage der Angaben der Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat), Vorläufige Angaben Stand: 14. März 2011, [www.erneuerbare-energien.de](http://www.erneuerbare-energien.de)
- (4) Energy Concept for an Environmentally Sound, Reliable and Affordable Energy Supply, <http://www.bmu.de/english/energyefficiency/doc/46516.php>
- (5) IEA Wind Task 26, Work Package 1 Final Report, Multi-national Case Study of the Financial Cost of Wind Energy, p. 42 <http://www.ieawind.org>
- (6) Chapter 17 Germany, IEA Wind Annual Report 2008, p. 145
- (7) Ordinance on System Services by Wind Energy Plants (System Service Ordinance – SDLWindV), Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, <http://www.erneuerbare-energien.de/inhalt/44629/4596/>
- (8) Offshore Wind in Europe - 2010 Market Report, KPMG AG, <http://www.kpmg.de/Themen/21649.htm>
- (9) <http://www.alpha-ventus.de/index.php?id=22>
- (10) IEA Wind Task 26, Work Package 1 Final Report, Multi-national Case Study of the Financial Cost of Wind Energy, p. 40-42
- (11) Der Turbo Ausstieg, Berliner Zeitung, No. 66, 19./20. March 2010, p. 11
- (12) Innovation through Research, Yearly report 2010 on Funding of Research in the Field of Renewable Energies, Bundesministerium für Umwelt Naturschutz und Reaktorsicherheit (in press)
- (13) Chapter 17 Germany, IEA Wind Annual Report 2009, p. 89
- (14) ALPHA VENTUS – Operation offshore, Editor Stiftung Offshore-Windenergie, Publisher BVA Bielefelder Verlag GmbH & Co. KG, 1st ed. 2010, ISBN 978-3-87073-479-4
- (15) [http://www.gigawind.de/gigawind\\_av.html?&L=0](http://www.gigawind.de/gigawind_av.html?&L=0)
- (16) Fortführung von Messkampagnen zur Verifizierung von WEA-Radar-Verträglichkeiten unter Einbezug von neuen Radaroptionen sowie Untersuchung eines reflektionsarmen WEA-Prototypen auf Radarverträglichkeit, project abstract by EADS, 2011
- (17) <http://www.bard-offshore.de/de/mehr-nachrichten/123-ersterstrom>
- (18) Joint Declaration on Cooperation in Offshore Wind Energy Research between Denmark, Germany, Norway and Sweden, THIRD SCIENCE DAYS ON THE UTILIZATION OF OFFSHORE WIND ENERGY by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, November 17th and 18th, 2009 in Oldenburg (Oldb), Germany (in press), [www.forwind.de/wissenschaftstage](http://www.forwind.de/wissenschaftstage)

Authors: Joachim Kutscher, Forschungszentrum Juelich GmbH, PtJ and Stephan Barth, ForWind-Center for Wind Energy Research, Germany.



# Chapter 19

## Greece

### 1.0 Overview

During 2010, 88 wind turbines were installed, increasing the total installed power from 1,109 MW in 2009 to 1,210 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. New projects regarding green energy, such as green islands, green villages, etc. are under preparation and will be announced in the first half of 2011.

### 2.0 National Objectives and Progress

In 2010, the installed capacity of the wind turbines reached 1,210 MW, an increase of about 9%. In 13 separate projects, a total of 88 wind turbines with an installed capacity of approximately 101 MW were connected to the electricity supply network. The development of wind energy within the last 10 years is shown in Figure 1, which depicts the total installed capacity per year.

#### 2.1 National targets

The Greek government sets a binding national target of 20% RES contribution to the gross electricity consumption by 2020. The law 3851/2010 aims to accelerate the licensing procedures and to reduce administrative burdens on the renewable energy sector. The law promotes the development of offshore wind parks and provides priorities, regarding the license procedure, of RES projects combined



with desalination for the production of potable water or other water use. During the production license granting, RES plants are exempt from the obligation to attain such a license for RES plants in islands, the applications for the installation of RES plants which are combined with the installation of water desalination plants, are examined with absolute priority under conditions. These conditions are: the installed capacity of RES should not exceed the 25% of the installed capacity of the desalination unit, as well as, the contracts for the distribution of the produced water should have already been signed, between

the applicant and the General Secretariat for the Aegean and island policy or with the relevant local authorities. The electricity produced from the RES plant is recompensed, on an hourly basis, according to the consumption of the desalination plant. The surplus electricity may be committed to the network up to 20% of the produced power, in accordance to the rules applicable for self-producers.

Regarding the development of offshore wind parks, the law states that with special plans which are subject to undergoing the process of Strategic Environmental Assessment, according to provisions

**Table 1 Key Statistics 2010: Greece**

Total installed wind generation	1,210 MW
New wind generation installed	101 MW
Total electrical output from wind	2.714 TWh
Wind generation as % of national electric demand	4.0%
Target:	10.7%

of Ministerial Decision MD IPEXODE/EIPE/οικ.107017/2006 (FEK B' 1225), the exact location of offshore wind farms, the sea area they occupy, and their maximum installed electrical capacity will be determined. The strategic environmental assessment conducted for this procedure evaluates in particular issues concerning the protection of the marine natural and cultural environment and in general of its ecosystems. It emphasizes the sustainability of the marine flora, fauna, and birds; the national security; the secure energy supply of the islands; and the safety of shipping. The procedure for the installation of the wind farms within the national sea territory is described analytically in Article 6A of the law 3851/2010.

Moreover, the law introduces discounts in the electricity bills of local communities and a different tariff regime for the new RES installations (except for photovoltaic and solar thermal plants). A 20% higher tariff will be provided to those investors that will consider not using state subsidies for the development of the RES system. Additionally, an important issue in this law is the implementation of a strategic plan for island interconnections, by ceasing the operation of the

local conventional plants and minimizing the local pollution. Based on the law, an individual entity has been developed for the service of investors on RES projects under the standards of "one-stop service."

Finally, law 3851 sets more beneficial feed-in-tariffs for wind energy. For wind projects of more than 50 kW it provides a feed-in tariff of 87.85 euro/MWh (108.07 USD/MWh) for the interconnected areas and 99.45 euro/MWh (133.67 USD/MWh) for the non-interconnected islands. For wind projects of less than 50 kW, it sets a feed-in-tariff of 250 euro/MWh (336 USD/MWh).

## 2.2 Progress

The energy produced from wind turbines during 2010 was approximately 2,714 GWh, and corresponds to 4% of the national electric demand. Figure 2 shows the electricity produced from wind turbines during the last ten years.

## 2.3 National incentive programs

Financial support for RES projects are provided by the state in the framework of the program entitled National Strategic Development Plan (NSDP), 2007–2013, which is the continuation of the

Operational Program for Competitive-ness (OPC), 2000–2006, and the Law for Development 3299/04 as amended with Article 37 of Law 3522/2006. The NSDP raises resources from the Fourth Framework Programme to reinforce the investment activities of the private sector and strengthening the productive potential of the country. The Law for Development 3299/2004, as amended with Article 37 of Law 3522/2006 provides grants of up to 40% of the total investment. A new Law for Development, the Investment Incentives Law, will come into force the first semester of 2011. Greece's new Investment Incentives Law will respond to the diverse needs of today's investor and, in parallel, will create a forward-looking investment environment. The purpose of the new law is to promote economic growth in Greece by introducing investment aid schemes to improve entrepreneurship, technological development, the competitiveness of enterprises and regional cohesion and promote green economy, the efficient function of existing infrastructures and the deployment of the country's human resources.

## 3.0 Implementation

### 3.1 Economic impact

In the last decade, interest in wind energy projects has increased, mainly among construction companies and individual investors. Wind energy deployment has become a challenging area for development all over the country - especially in areas having poor infrastructure, in which some of the most promising sites for wind energy development can be found. Although manufacturing of wind turbines has not been established in Greece, there is considerable domestic added value in connection with infrastructure works, for example, grid strengthening, tower manufacturing, road and foundation construction, civil engineering works, and so on. In addition, new jobs are created related to maintenance and operation of the wind farms mainly in underdeveloped areas. The distribution of installed wind farms throughout Greece is depicted in Figure 3.

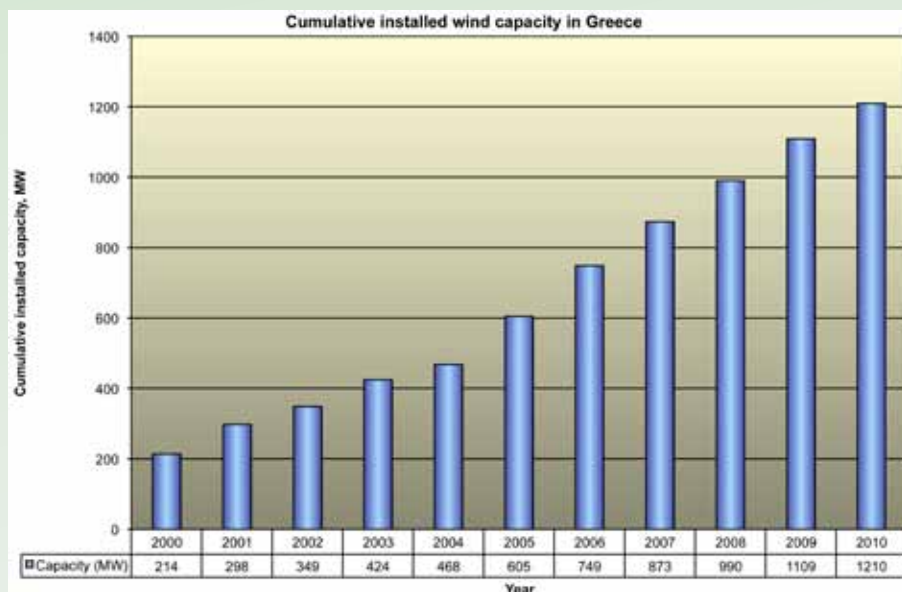


Figure 1 Cumulative installed wind capacity in Greece

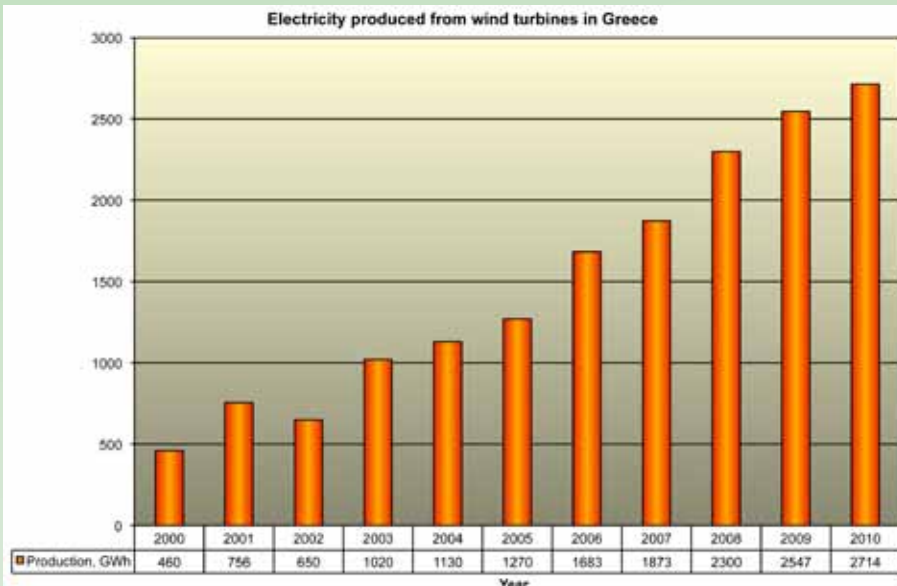


Figure 2 Electricity produced from wind turbines in Greece

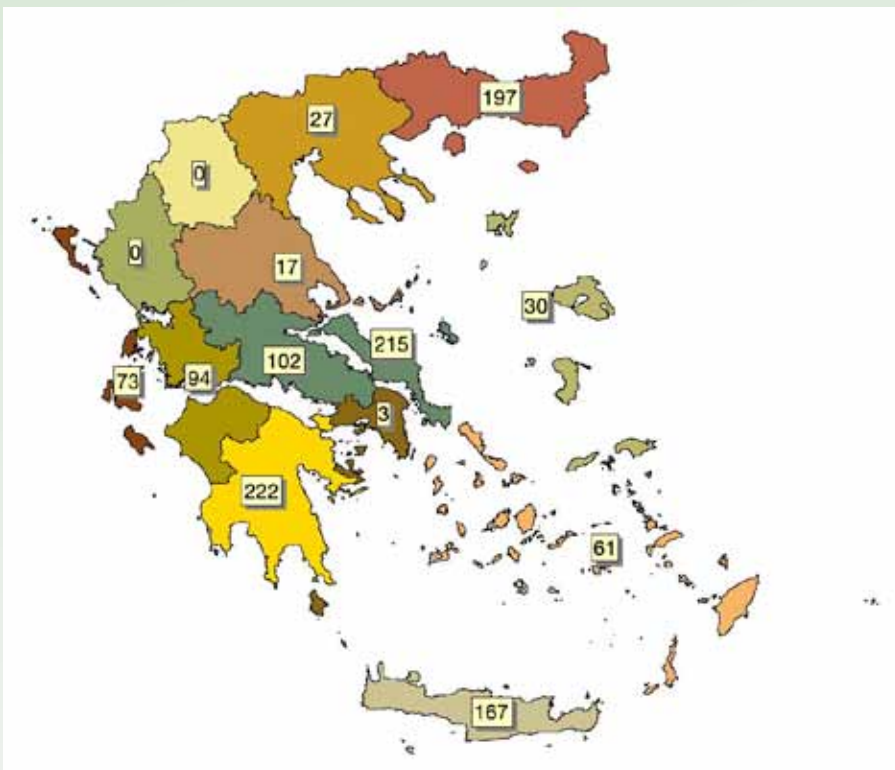


Figure 3 Installed wind farms distribution in Greece

### 3.2 Industry status

A significant share of the wind projects is owned by six important companies from the field of construction. There are also a significant number of small investors, where the ownership structure is unknown. No significant domestic manufacturing developments occurred in 2010 apart from the continuing involvement of the Greek steel industry in wind turbine tower manufacturing. The Greek market share of wind turbine manufacturers is depicted in Figures 4 and 5.

### 3.3 Operational details

The average capacity of the wind turbines installed in 2010 was 1,145 kW, while the average capacity of all the wind turbines operating in the country was 891 kW. Wind farm malfunctions that have been reported up to now are mainly related to gearbox failure and lightning strike events. No major events leading to extensive wind farm outages have been reported.

### 3.4 Wind energy costs

The total cost of wind-power projects depends on the wind turbine type, size, and accessibility. This cost ranges from 1,100 to 1,400 euro/kW (1,478 to 1,881 USD/kW) and is mainly influenced by international market prices and interconnection costs. The cost of generated wind power could be assumed to be between 0.026 and 0.047 euro/kWh (0.035 and 0.063 USD/kWh), depending on the site and project cost. The typical interest rate for financing wind energy projects is 7% to 8%.

### 4.0 R,D&D Activities

Key areas of R&D are wind assessment and characterization, standards and certification, wind turbine development, aerodynamics, structural loads, blade development, noise, power quality, wind desalination, and autonomous power system integration. The main actors in this field is the Centre for Renewable Energy Sources and Saving (CRESS), the National Technical University of Athens (NTUA), and University of Patras. Among the above mentioned organizations collaboration is



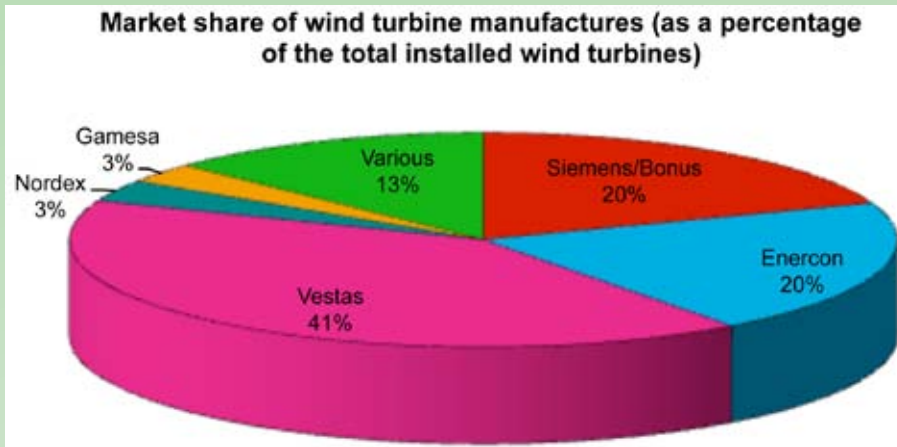


Figure 4 Market-share of wind turbine manufacturers (as a percentage of total installed wind turbines)

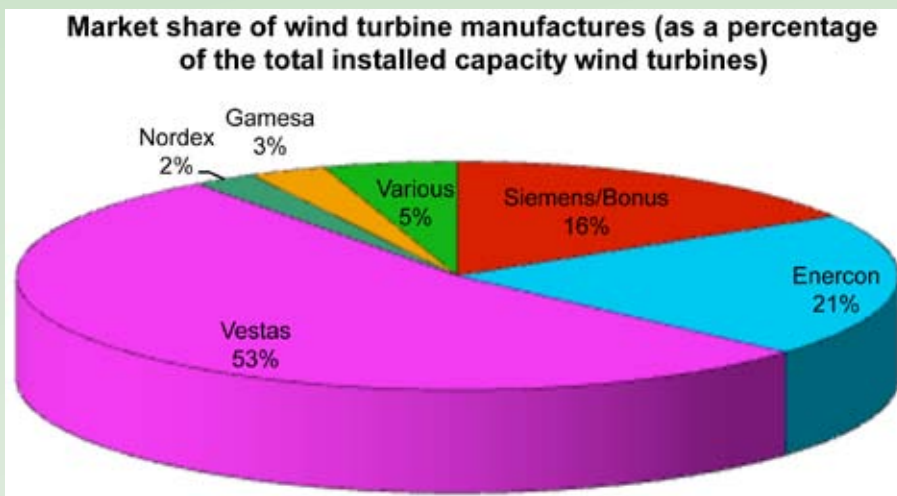


Figure 5 Market-share of wind turbine manufacturers (as a percentage of total installed capacity of wind turbines)

strong and of long duration on national and EU projects for the development and optimization of wind energy technology.

### 5.0 The Next Term

The new law of RES deployment will accelerate the license procedure and will allow the development of new wind farms. It is expected that focus on wind energy and other RES will continue with emphasis on the projected new offshore wind projects. The provision of available sites for the development of offshore wind farms will be the beginning for a new opening of the wind energy market. With the implementation of the new law for the acceleration of RES as well as with the coming financial support programs, the government will set the base for the fulfillment of the RES objectives of the country.

Authors: Kyriakos Rossis and Eftihia Tzen, CRES, Greece.

# Chapter 20

## Ireland



Photo Credit: T.J. Hunter, SWS Energy

### 1.0 Overview

The strong growth trend in Ireland's installed wind power capacity continued in 2010 with an annual increase of 9%. The additional capacity also leads to new records in wind power production. On the afternoon of 26 December 2010, 1,228 MW was generating. Instantaneous wind power penetration levels in the Irish electricity system have exceeded 45% at times during 2010. This is remarkable given the small isolated nature of Ireland's electricity grid. Exceptionally cold periods at the start and the close of the year and prolonged still periods during the summer months made 2010 an historically low wind year.

Much innovative work is ongoing to facilitate the de-carbonizing of Ireland's energy supply and with a planned trebling of wind capacity. The next decade will pose significant challenges particularly in permitting and grid expansion. Where grid access is available the details of conditions of access have yet to be finalized.

Ireland's dependence on imported fossil fuels remains at 89% of total primary energy (3). Between 1990 and 2009, gas-fired electricity generation increased by 227%. Wind capacity increased from less than 1 MW to 1,311 MW over the same period. These were the primary factors that reduced the carbon intensity of electricity from 896 g CO<sub>2</sub> /kWh to 533 g CO<sub>2</sub>/kWh in that period. Renewable energy in Ireland, which accounts for 4.9%

of energy consumed, avoids approximately 3 million tonnes of CO<sub>2</sub> emissions per year. In 2009, wind energy accounted for 38% of renewable energy or 1.9% of national gross final energy consumption.

### 2.0 National Objectives and Progress

#### 2.1 National targets

Ireland's binding EU target was to supply 13.2% of electricity demand from renewable resources by 2010. In July 2010, Ireland, along with the other EU member states, submitted a National Renewable Energy Action Plan (NREAP) describing the trajectory towards meeting national 2020 renewable energy targets. The NREAP was prepared by the Department of Communications Energy and Natural Resources with modeling support from SEAI and took account of the impact of existing strategies, measures, and interventions (4). A strictly prescriptive template was provided by the EC to enable comparison of individual plans. The NREAP

concluded that the support mechanisms and policy already in place in Ireland should be sufficient to enable the achievement of the RES-E target (40%) with the potential for more.

#### 2.2 Progress

Renewable energy supplied 14.4% of demand in 2009 (3). However, because 2010 proved to be a poor wind year the contribution from wind to the energy mix dropped. A provisional figure of 12.5% indicates that the EU 2010 target of 13.2% was not achieved during 2010. Partly due to the impacts of prolonged adverse weather, new wind power connections dropped significantly from the record high of 2009. In 2010, 115 MW were connected, as shown in Figure 1 (1). However, additional wind power grid export capacities of 130.76 MW were enabled in 2010 by a combination of the new and previous installations with grid improvements.

**Table 1 Key Statistics 2010: Ireland**

Total installed wind generation (1)	1,415 MW
New wind generation installed	115 MW
Total electrical output from wind	2.888 TWh
Wind generation as % of national electric demand	10.5 %
RES-E Target:	2010: 15% 2020: 40%

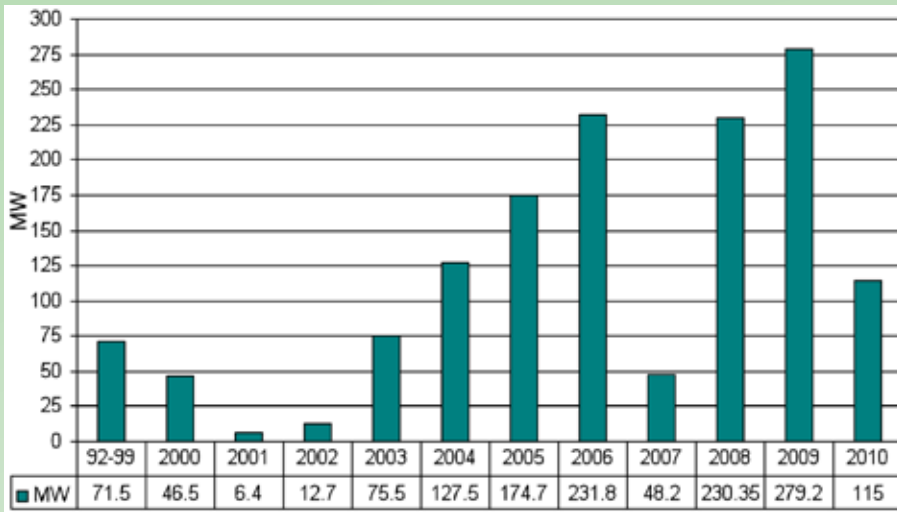


Figure 1 Wind generation added from 1992-2010

The system operators have published indicative firm access quantities and dates for contracted and soon-to-be contracted generator connections (Figure 2) (5). Additional capacity of 115 MW in 2010 falls well short of the indicative time-table. A 'Gate' is a batch or round of connection offers in a group processing approach. Please refer to previous IEA Wind reports for more details.

The 2010 publications of the Commission for Energy Regulation (CER) and the system operators made significant progress towards addressing gaps in regulations and arrangements for wind power plants (6). They included:

- Rules for Relocation of Generation Capacity (CER/10/211)
- Connection Offer Policy Principles Paper (CER/10/237)
- Contestability for Grid Connections (CER/10/056)
- Charter for Connection of Renewable Generators (CER/10/168)

In September, the Single Electricity Market Committee (SEMC) published a position paper on the principles of dispatch and market schedule design (SEM-10-060) (7). It recognizes that the current SEM design will be severely strained by high wind penetrations. No major redesign of the schedule or dispatch rules will take place until wind has a, yet to be defined, 'material effect' on final customers.

### 2.3 National incentive programs

The government-mandated Renewable Energy Feed in Tariff (REFIT) support

mechanism for wind is funded through an EC state-aid sanctioned, public service obligation (PSO) on final customers. Under the REFIT scheme, generators enter into 15-year power purchase agreements (PPA) with electricity suppliers at a negotiated price per unit of electricity. The supplier then sells the electricity into the SEM pool. If the aggregate revenue a supplier receives from each trading period throughout the year is less than the REFIT tariff, then the difference is paid through the PSO. Under REFIT, suppliers also receive a balancing payment – 15% of the large wind category tariff – to cover the cost of managing the short term variable production of wind energy. Each year, all suppliers submit estimates for the next year's PSO costs as well as any corrections for previous forecasts. Wind PSO costs are

then accounted for along with other PSO supported renewable and non-renewable (some gas and peat) generation.

The cost of the PSO fund is allocated to and collected from all customer categories as a separate item on all bills. For a number of years due to negative wind costs reducing the net PSO funding cost to negligible amounts PSO cost has to justify the costs of collection. At times in those previous four years the effect of wind has therefore been to cancel out the costs generated by other PSO contracts. However, the forecast for 2010/11 saw the net PSO figure rise significantly to 156.6 million euro (210.5 million USD) (CER/10/131) (6). Approximately 43 million euro (57.8 million USD) of this is attributed to wind.

The high visibility of the now non-zero PSO levy on customers' bills has caused concern among domestic and commercial electricity customers and wind energy tends to obtain publicity in this respect disproportionate to its 27.4% share of the levy. Furthermore the lowering effect wind has on the wholesale price of electricity is not part of the PSO process and hence not recognized by the consumer. Subsequent work carried out by SEAI and EirGrid shows that this effect can be such that it cancels out the PSO costs (2), see section 3.4 for more details. Please refer to the IEA Wind 2008 Annual Report for more details on REFIT.

Other support measures include the Business Expansion Scheme (BES) which allows individual investors to obtain income tax relief on investments in wind energy in each tax year. In 2008, the Irish government introduced an Accelerated

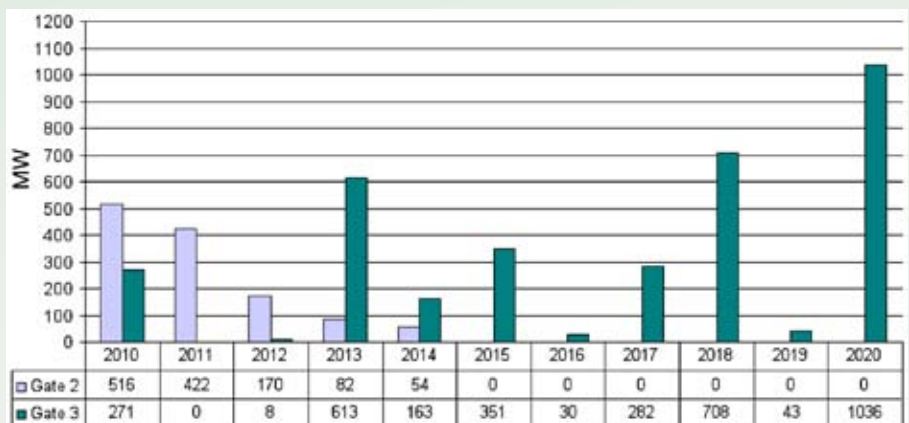


Figure 2 Indicative firm access quantities and timelines for remaining Gate 2 and Gate 3 projects



Capital Allowances scheme for companies investing in qualifying technologies including wind turbines ([www.seai.ie/aca](http://www.seai.ie/aca)).

## 2.4 Issues affecting growth

Well established factors continue to be challenges in Ireland.

- Grid Development

Lead times for grid connection and wider reinforcements  
Connection costs  
Way leaves for new lines

- Planning Constraints

Limited areas designated as suitable for wind  
Implementation of the EU Habitats Directive may affect >50% of Gate 3 projects on or adjacent to EU Natural sites  
Access to finance  
Credit scarcity and cost

- Access to REFIT support mechanism

REFIT I is fully allocated as of 2010 and its replacement REFIT II is awaiting EC state-aid clearance  
Without a support mechanism finance is not forthcoming so developers must wait.

With the support of Intelligent Energy Europe, the industry body EWEA published a report on construction and grid consenting processes across Europe titled 'Wind Barriers' (8). The average construction consent lead-time for on-shore wind in the EU was 42.3 months requiring consultation with an average of 18 relevant authorities. In Ireland, the consent to construct is usually referred to as 'planning permission'. Ireland has ongoing planning and consenting issues but is ahead of the index with an average period of 33.5 months with 15 relevant authorities. Finland was the shortest at 8.2 months even though they require consultation with 34 authorities. Portugal was the longest at 58 months with an average of 14 authorities consulted.

Grid consenting figures for onshore projects showed an average consenting period of 26 months via 1.5 system operators and consultation with 24 other parties. Ireland reported an average lead time for grid consent of 31.4 months via 1.8 system operators and in consultation

with five other parties. Ireland has just two system operators, one for distribution (ESB Networks) and one for transmission (EirGrid). It is worth noting that the Wind Barriers statistics only include successful project applications and do not account for the projects which are rejected.

## 3.0 Implementation

### 3.1 Economic impact

The design, development, construction, equipping, and connection of wind farm facilities in Ireland is estimated to be worth 300 million euro/yr (403.2 million USD/yr) over the past three years. Up to 80% of the outlay is spent on imported equipment, including the turbine and associated electrical equipment. Therefore, the value to the local and national economy could be estimated to be worth approximately 60 million euro/yr (80.6 million USD/yr). The value of civil and construction costs to the local economies is approximately 30 million euro/yr (40.3 million USD/yr).

### 3.2 Industry status

Development of wind farms in Ireland has historically been undertaken by a wide range of individuals and organizations. There has been a recent trend towards consolidation and an increasing proportion of the new projects developed by large utilities. 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 the increase in local employment as generator stock increases if the build rate

remains steady. Letterkenny Institute of Technology has begun a technical wind energy course which aims to produce the skilled professionals required.

The small wind turbine sector is suffering from the effects of an economic downturn and credit controls. At the end of 2010 there was 1.8 MW of micro-wind connected to the grid. The average micro-turbine installed was 5.1 kW (9). Most of the turbines installed to date have been imported, a number of local manufacturers now have a range of turbines in production from 2.5 kW to 50 kW. SEAI will publish a register of certified products in the second quarter of 2011. In early 2011 The Natural Power Company secured a license to manufacture Turbowind 500-kW turbines for the Irish and UK markets.

### 3.3 Operational details

Due to abnormally low winds, the capacity factor for wind is expected to drop considerably from 31% in 2009 to 23.6% in 2010 (Figure 3).

### 3.4 Wind energy costs

Current total capital costs are in the range of 1.6 to 2 million euro (2.1 to 2.7 million USD) per MW installed for wind developments in the 10 MW range. Turbine costs currently range between .9 and 1.0 million euro (1.2 to 1.34 million USD) per MW, depending on the size of the turbine and the project. A typical cost for connection would be in the range of 150,000 to 300,000 euro (201,600 to 403,200 USD) per MW. Typical project costs can be apportioned in Ireland as follows: turbines 65%, grid connection 12%, onsite electrical 8%, civil engineering 8%, development 4%, and legal/financial 3%.

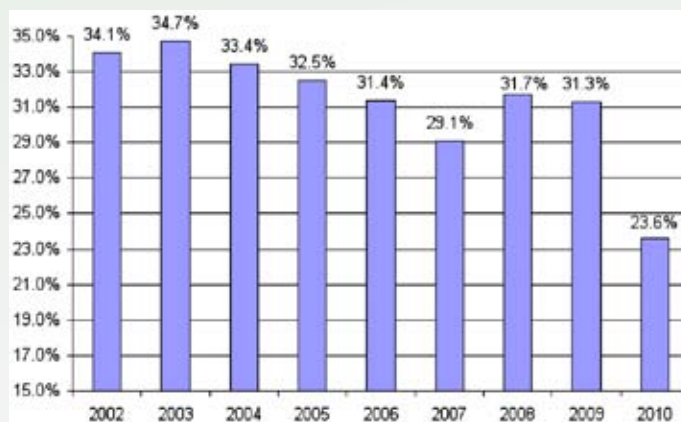


Figure 3 Average national wind generator capacity factor (Source: EirGrid)

**Table 2 shows the new wind farms and extensions connected during 2010. Please see previous reports for an explanation of the term 'Gate'.**

Wind Project	County	Grid Ref.	Installed (MW)	Max. Exp. (MW)	Gate	Month
Garvagh 1	Leitrim	TG23/TG32	48.00	58.23	2	June
Kingsmountain 2	Sligo	TG40	11.05	11.05	2	June
Ballincollig Hill	Kerry	DG984	15.00	15.00	Pre-gate	January
Cuillalea 2	Mayo	DG906	1.59	1.59	2	Sept.
Drumlough Hill 2	Donegal	DG173	5.40	9.99	Pre-gate	May
Flughland 2	Donegal	DG60	9.60	9.20	2	July
Gortahile	Laois	DG69	20.00	21.00	2	July
Lenanavea 2	Mayo	DG16	4.50	4.70	2	August
		<b>Total</b>	<b>115.14</b>	<b>130.76</b>		

A study on the wholesale Irish electricity market has established that the growing levels of wind generation are not adding to the wholesale price of electricity (2). The report by the modeling group of Sustainable Energy Authority of Ireland and transmission grid operator EirGrid draws on detailed system and market modeling tools to assess the expected wholesale prices of electricity during 2011. The total value of the wholesale market equates to 1.91 billion euro (2.58 million USD). The study demonstrates that wind energy in Ireland is not contributing to higher wholesale electricity prices. The wind driven 74 million euro (99.5 million USD) reduction in the wholesale market is approximately equivalent to the sum of the PSO costs (est. 50 million euro; 67.2 million USD) plus the increased constraint costs incurred due to wind. Wind driven constraints or balancing costs occur when the electricity system operator has to deviate from a forecast schedule of generators because of variations in wind production. In light of recent debates on the cost of wind, it is useful to have this information modeled using the best objective assumptions available today and the appropriate assessment tools.

#### 4.0 R, D&D Activities

An SEAI report to be published in 2011 will show that only 1% (2 million euro; 2.7 million USD) of funding of all energy research between 2004 and 2010 was specifically for wind technology even though wind is Ireland's key renewable resource for the foreseeable future and primary enabler of RES-E target achievement (10).

It is perhaps that Ireland does not have a large wind turbine manufacturing industry driving the requirement for wind energy technology RD&D or a reflection of the perception of wind technology maturity.

More substantial funding (15.8 million euro; 21.2 million USD) was, however, applied to issues of grid integration which is an indicator of the challenges identified for high penetrations of intermittent resources on a relatively isolated grid. The Electricity Research Centre in UCD has built an international reputation as one of the leading centers of excellence in the study of power systems and renewable electricity integration and helped establish Task 25 as the project setting the standard on the issue.

The major R, D&D activity at the smaller scales, SEAI's field trials, continued during 2010. Financial support to meet 40% of the start-up and short-term-maintenance costs was available for approximately 50 trial locations (50% wind) with an overall program budget of 2 million euro (2.7 million USD) which includes funds for associated studies on the micro-generation sector. The program will assess the performance of the technologies and inform future decisions on possible incentives, tariffs, or deployment programs. The data which is collected at each installation will be made available to researchers during 2011.

Research continued into wind supporting technologies and measures such as smart metering and smart grids. The TSO completed their 'Facilitation of Renewables' program which concluded very high

penetrations of wind energy (60–80%) could be accommodated on the system if mitigating measures are implemented (11). The TSO now intends to continue to build on this research in 2011 with a new program of work entitled 'Programme for a Secure Sustainable Power System'.

SEAI and the Department of Community, Rural and Gaeltacht Affairs (DCRGA) are investigating a novel system to deliver a high utilization of intermittent wind and ocean energy resources through use of distributed energy storage systems. The study will focus on the development of a system which will maximize the use of local energy resources and reduce the need for imported energy on the Aran Islands ([www.seai.ie/aran](http://www.seai.ie/aran)).

#### 4.1 National R, D&D efforts

Early in 2010 the primary body with responsibility for funding academic research in Ireland, Science Foundation Ireland, processed applications for a Strategic Research Cluster (SRC) on Energy. Academic institutions with existing energy clusters joined to submit a proposal with the support of a number of utilities, the regulator, multi-nationals and indigenous enterprises. It is envisaged that the program of work will facilitate 18 doctorate degrees in priority areas of research. The topics to be researched include: flexibility, control, loads and storage, electricity markets and policy, as well as ICT and demonstrations.

The University of Limerick's Charles Parson Institute focuses on Energy and a Sustainable Environment. The centre consolidates separate research centers on campus and has a broad range of expertise. The

Charles Parsons Awards were distributed in 2007 to seven institutions on the island of Ireland. The total value of the fund was 20 million euro over 7 years (26.7 million USD). University College Cork (UCC) was another one of the seven beneficiaries. The Sustainable Energy Research Group in UCC (SERG) consists of a cluster of on-campus faculties and researchers with a focus on wind, marine energy, bio-energy, energy modeling and efficiency.

SEAI's new energy research portal sets out the landscape of past, ongoing and future research in Ireland (10). Local planning authorities are required to draft wind strategies but there is no defined methodology for developing these strategic plans. SEAI has commissioned a project which will deliver, through close co-operation with planners and an exemplar implementer, a template for local authority wind strategies. The ultimate aim is to develop consistency nationally across all the local authorities. SEAI has also commissioned a national project which will build on Ireland's involvement in IEA Wind Task 28 Social Acceptance of Wind Energy Projects. The goal of the project is to build a good practice methodology for the promotion of social acceptance of wind energy projects. Acceptance levels have remained high in Ireland but further work is required to maintain the good-will the Irish public has towards clean, local energy sources if the risks to our 2020 goals are to be minimized.

#### 4.2 Collaborative research

Ireland is participating in a number of IEA Wind Tasks: Task 25 on the integration of large amounts of wind on power systems, Task 27 on small wind turbine labeling, and Task 28 on the social acceptance of wind energy projects. Details of each of these tasks are provided in a separate chapter. As a small country, Ireland has benefited greatly from participation in IEA Wind and other implementing agreements. Membership represents excellent value for money as information and knowledge is shared, networks and professional relationships are forged and research benefits from economical synergies. Ireland has also been to the fore in its own contribution to the benefit of other partners.

Ireland is also participating in the GP-Wind project of the Scottish government. This Intelligent Energy Europe funded, co-operation shares good practices with the goal of developing a tool-kit for community and environmental good practices

in onshore and offshore wind development (12). The project aims to:

- Assist in the achievement of national and EU-wide 2020 renewable energy targets;
- Decrease lead-times for planning consents and increase the consenting rates;
- Increase the efficiency of the planning process with a resultant reduction in process costs;
- Build evidence based support for the design, planning and implementation of projects which are sensitive to environmental and community concerns.
- Secure endorsement and adoption of the project outputs by member states and their agencies.

#### References:

- (1) List of connected wind farms 07-12-10: [www.eirgrid.com/customers/connectedandcontractedgenerators/](http://www.eirgrid.com/customers/connectedandcontractedgenerators/)
- (2) Impact of Wind on Wholesale Price of Electricity: [www.seai.ie/Publications/Statistics\\_Publications/Energy\\_Modelling\\_Group/](http://www.seai.ie/Publications/Statistics_Publications/Energy_Modelling_Group/)
- (3) Energy in Ireland 1990-2009. Download from: [www.seai.ie/Publications/Statistics\\_Publications](http://www.seai.ie/Publications/Statistics_Publications)
- (4) NREAP. Download from: [www.dcenr.gov.ie/Energy/Sustainable+and+Renewable+Energy+Division](http://www.dcenr.gov.ie/Energy/Sustainable+and+Renewable+Energy+Division)
- (5) Indicative Firm Access Quantities and Dates. Download from: [www.eirgrid.com/gate3/itcfirmaccessquantities/](http://www.eirgrid.com/gate3/itcfirmaccessquantities/)
- (6) Decision Documents by Year, 2010. Download from: [www.cer.ie/en/documents-by-year.aspx?year=2010](http://www.cer.ie/en/documents-by-year.aspx?year=2010)

(7) Single Electricity Market Committee Position Paper: [www.allislandproject.org/en/renewable\\_decision\\_documents.aspx](http://www.allislandproject.org/en/renewable_decision_documents.aspx)

(8) Wind Barriers. Download from: [www.windbarriers.eu/](http://www.windbarriers.eu/)

(9) Report on Microgeneration in Ireland: [www.seai.ie/Renewables/Microgeneration/Status\\_report\\_on\\_Microgeneration\\_in\\_Ireland.pdf](http://www.seai.ie/Renewables/Microgeneration/Status_report_on_Microgeneration_in_Ireland.pdf)

(10) SEAI Energy Research Portal: <http://research.seai.ie>

(11) EirGrid's Facilitation of Renewable Energy Study. Download from: [www.eirgrid.com/renewables/facilitationofrenewables/](http://www.eirgrid.com/renewables/facilitationofrenewables/)

(12) GPWind Project Portal: [www.project-gpwind.eu](http://www.project-gpwind.eu).

Please visit [www.seai.ie/renewables/wind\\_energy](http://www.seai.ie/renewables/wind_energy) for more information on wind energy in Ireland

Author: Martin McCarthy, Renewable Energy Information Office, Sustainable Energy Authority of Ireland, Ireland.





Photo courtesy Nordex Italia

### 1.0 Overview

Installation of new wind farms in Italy slowed its pace in 2010. Total online grid-connected wind capacity reached 5,797 MW at the end of the year, with an increase of 948 MW over 2009. As usual, the largest development took place in the southern regions, particularly in Apulia, Calabria, Campania, Sardinia, and Sicily. In 2010, 615 new wind turbines were deployed in Italy and their average capacity was 1,541 kW. The total number of online wind turbines thus became 4,852, with an

overall average capacity of 1,195 kW. All plants are based on land, mostly on hill or mountain sites. The 2010 production from wind farms could provisionally be put at about 8.4 TWh, which would be about 2.6% of total electricity demand on 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 66.9 euro/MWh (89.91 USD/MWh) in 2010. The additional income from the sale of TGCs on the free market was on average 84.4 euro/MWh (126.87 USD/MWh). Owners of wind plants between 1 kW and 200 kW can opt for other schemes: either a fixed feed-in tariff of 300 euro/MWh (403.2 USD/MWh) or exchange (net-metering) contracts.

The main issues affecting growth came from permitting and grid connection, and from wind production curtailments ordered by the TSO. A new decree giving permitting guidelines has however been issued by the government and new regulations on grid connection have been issued by the Regulatory Authority AEEG.

Most new turbines were supplied by foreign manufacturers (Vestas has an establishment in Italy). The Italian manufacturers are currently Leitwind (1.5-MW turbines), Moncada (850-kW machines), and other firms that supply small-sized units. The market for small wind systems is still at the beginning.

There has been no national R, D&D program running on wind energy, but activities have been carried out by different entities, mainly RSE (formerly ERSE) under contract to the Italian government

**Table 1 Key Statistics 2010: Italy**

Total installed wind generation	5,797 MW
New wind generation installed	948 MW
Total electrical output from wind	<b>8.374 TWh</b>
Wind generation as % of national electric demand	<b>2.6 %</b>
Wind generation goals from Italy's National Action Plan (PAN) for RES issued by the Italian Government on 30 June 2010:	12,680 MW and 20 TWh/year by 2020
Italy's overall RES target from Directive 2009/28/EC	17% of total energy consumption from RES by 2020
<b>BOLD ITALIC</b> indicates an estimate	

in the interest of Italy's electricity system, ENEA, some universities, polytechnic schools, and other companies.

## 2.0 National Objectives and Progress

### 2.1 National targets

Previous IEA Wind reports showed that Italy met or exceeded the former targets set for wind energy by the White Paper for Valorisation of Renewable Energy Sources in 1999 (2,500 MW of wind generating capacity and 5 TWh/yr of electricity production from wind by 2008-2010). However, more ambitious targets have since been established for wind energy by the Italian government 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 has also required the government to lay down a RES action plan sharing this target among 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, which has set 26.39% of the country's total consumption of electricity to 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 on-line capacity and 98.9 TWh/yr production from RES to be reached in 2020, up from 26.5 GW and 69.3 TWh/yr recorded at the end of 2009. Considering that the contribution of hydropower and geothermal plants is unlikely to grow significantly, expectations have been laid mainly on wind, biomass, and solar energy. As to 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 shore 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

New wind farms were installed in 2010, although the amount (Figure 1) exhibits a slowdown with respect to 2009. Nevertheless total online grid-connected wind capacity reached 5,797 MW at the end of 2010, with an increase of 948 MW over

2009. The growth rate was lower than the previous year: nearly 20% (in 2009 it was 30%, with capacity increase of 1,114 MW). 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 (1,450 MW), Apulia (1,286 MW), Campania (814 MW), Sardinia (674 MW), and Calabria (587). A full picture is given in Figure 2.

Provisional figures from Terna (the Italian Transmission System Operator) indicate a 2010 production of about 15 TWh from wind, photovoltaic, and geothermal plants combined. The production from wind farms alone could provisionally be put at about 8.4 TWh, which would equal about 2.6% of total electricity demand on the Italian system (total consumption plus grid losses).

Total electricity demand in 2010 (326.2 TWh) showed a 1.8% increase from 2009, probably due to a slight economic recovery. According to Terna's provisional data, 87% of the 2010 demand was met by domestic production and 13% by imports. Gross domestic production came from thermal plants (79%, mostly gas-fired and, to a lesser extent, burning oil, coal and biomass), hydropower (16%, including pumped-storage plants), and other sources including wind (5%).

### 2.3 National incentive programs

As in previous years, the scheme based on a RES quota obligation and the related issuing of TGCs was the main support available for RES plant developers, with the exception of PV solar plants, which benefited by another, more advantageous scheme specifically devised for them.

According to the main scheme, those who have produced or imported more than 100 MWh of electricity from non-renewable sources are obliged to feed into the Italian grid a given amount of RES electricity the following year. In 2010, this quota rose to 5.3% of the electricity they got from conventional sources the previous year. Compliance with this obligation has to be shown by returning to GSE (Manager of Energy Services) an equivalent number of TGCs, either obtained by their own RES plants or bought from other RES electricity producers. TGCs are granted to certified RES plants (IAFR plants) for a period of 15 years if they started operations after 31 December 2007 and for 12 years if older. One TGC is granted for 1 MWh of RES production; the latter is obtained by multiplying actual production by a coefficient depending on technology (e.g. 1 for onshore wind, 1.5 for offshore wind).

Unlike earlier, for some years now the number of offered TGCs has exceeded demand and this has pulled down the TGC market price (producers blame it on the quota being too low). The weighted average of TGC prices in the 2010 trading was calculated by GME (Manager of Energy Markets) at 84.41 euro/MWh (113.45 USD/MWh). GSE, too, can sell its own TGCs, but only at a price fixed by law (112.82 euro/MWh; 151.63 USD/MWh in 2010). However, TGCs are valid for three years and then, if unsold, they are bought back by GSE upon request at the average market price of the previous three years. RES producers are thus actually guaranteed an income that adds to that from selling energy on the electricity market. Owners of non-programmable RES plants like wind farms can choose to sell their energy

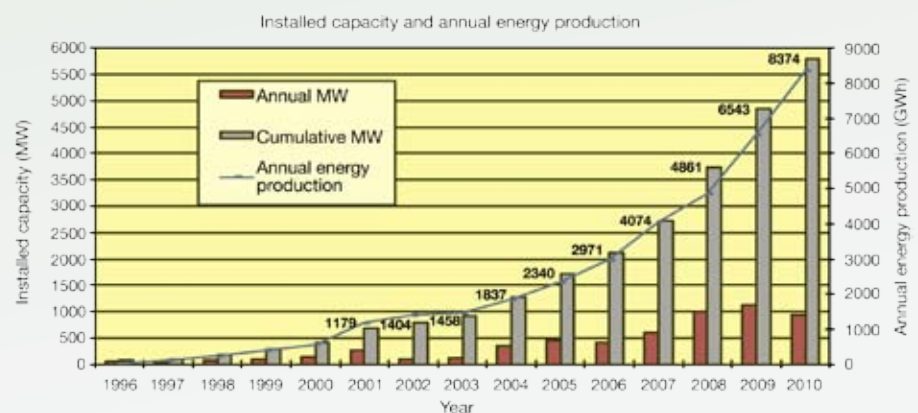


Figure 1 Trend of annual and cumulative wind turbine capacity and electricity production from wind in Italy



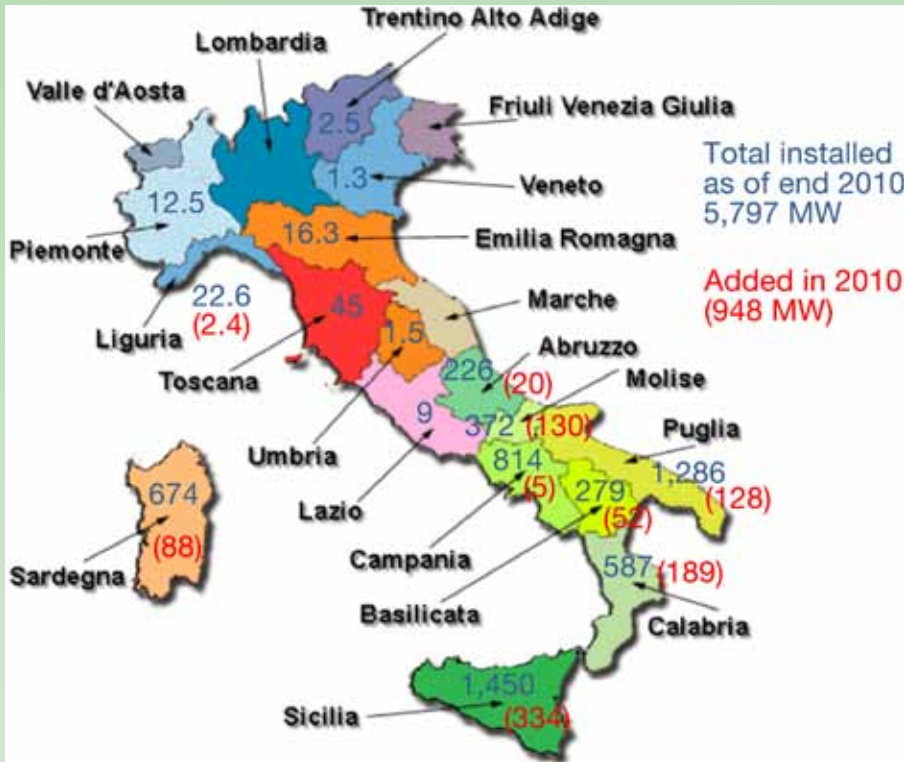


Figure 2 Wind capacities in the regions of Italy at the end of 2010 (wind capacities added in 2010 are indicated in parentheses)

straight to GSE through dedicated purchase contracts, at prices depending on time and market zone. This option is by far the most common and the relevant 2010 average price has been calculated at 66.90 euro/MWh (89.91 USD/MWh) by the AEEG (Regulatory Authority for Electricity and Gas).

As an alternative to the mainstream support scheme, it should be recalled (see also previous IEA Wind annual reports) that smaller RES plants have other opportunities. Specifically, wind plants of rated capacity between 1 kW and 200 kW are entitled to a fixed comprehensive feed-in tariff for the energy fed into the grid during the first 15 years. The tariff is currently 300 euro/MWh (403.20 USD/MWh). Another option is the possibility for owners of RES plants between 1 kW and 200 kW to sign a contract for on-the-spot exchange of their production with the energy they take in from the grid as customers (net metering). In this case, TGCs can also be applied for, if production is large enough.

Lastly, mention should be made of RES plants that still benefit from the feed-in tariffs of the old CIP 6/92 scheme, actually ending by 2013 (for wind, up to

163.3 euro/MWh; 219.48 USD/MWh in the second half of 2010).

The RES support schemes as described above are however going to be reshaped in the next few years. This came up in late 2010, when the Italian government worked out the draft of the Legislative Decree implementing the provisions of the aforementioned EU Directive 2009/28/EC on RES promotion at national level. Among other things, this draft provided for new incentives available to RES plants that will start operations after 31 December 2012. Very briefly, according to the new scheme, wind plants up to 10 MW capacity should be granted a premium tariff for energy production, to be fixed by subsequent provisions, while wind plants above 10 MW should be awarded premium tariffs through calls for tenders (lower bids would gain contracts). The present quota-TGC scheme would expire gradually. This draft Decree was released on 30 November 2010 for discussion in the Parliament and among RES stakeholders, who are concerned especially about the transition phase, which could affect the future of already ongoing plants and projects.

### 2.4 Issues affecting growth

In 2010, wind energy developers were still facing the two main issues that were pointed out in previous years: permitting procedures and market aspects, on the one side, and grid connection and operation, on the other. There was however some significant news to be reported.

In past years, due to the lack of nation-wide guidelines, the governments of the various regions entrusted with granting authorizations to set up RES plants by Legislative Decree No. 387 of 29 December 2003, developed their own regulations for wind farms. This approach inevitably brought about differing rules from one area of Italy to another, which caused wind investors additional troubles, not to mention delays due to unclear and lengthy procedures. The Decree issued by the Ministry of Economic Development on 10 September 2010 at last provided the National Guidelines for Authorization of Plants fed by Renewable Sources, worked out jointly by the state government and the conference of regions. Only offshore installations were left outside the scope of this Decree, as they come first under the sphere of the Ministry of Infrastructure and Transports according to Law No. 244 of 24 December 2007. These guidelines have now set a common framework, within which each region should trim its own regulations. Among others, to speed up procedures, regions are allowed to single out areas definitely unfit for one or more kinds of RES installation. On the other hand, regions are required to make efforts to harmonize their needs to safeguard landscape and environment with the needs to meet the RES targets that each region is allotted when sharing the burdens imposed by national RES engagements. The Decree's guidelines devote special attention to wind farms, giving advice on how to handle their integration with land and mitigate any possible kinds of impact. In principle, these national guidelines should streamline and facilitate the permitting process of wind farms from now onwards, but it will however take some more time for regions to conform fully with the new framework.

Another setback to wind developers came up in 2010 as a consequence of persisting rumors about changes to RES support schemes, which obviously increased uncertainty among investors. Particularly, the prospect that the option to have unsold TGCs bought back by GSE (see above in the incentive section) might



be cancelled, aroused a lot of concern by mid-2010 and prompted wind developers and their associations to draw attention to the problems that might ensue to the RES industry. Later on, as said above, RES investors' concerns grew even more following the draft Decree of 30 November 2010, which envisaged a full reshaping of the RES support scheme from 2013 onwards.

As for grid connection and operation aspects, it has first to be reported that the AEEG (Italian Regulatory Authority for Electricity and Gas) issued Deliberation ARG/elt 125/10 of 4 August 2010, to modify and supplement former Deliberation ARG/elt 99/08 of 23 July 2008 (the so-called TICA, Integrated Text of Active Connections). Both these documents set technical and economic conditions for connecting generating plants to the grid, granting more favourable terms for RES and CHP (Combined Heat and Power) plants, with a view to speeding up their connection and alleviating costs to investors. The new Deliberation 125/10, among others, has also taken measures (including compulsory surety payments) to assure that only grid connection applications based on real and sound projects are filed with the TSO Terna. In the wind sector alone, applications for connecting 94 GW of wind farms had been submitted to Terna as of October 2010, obviously choking up the whole evaluation process to the detriment of more valuable and earnest projects.

Another issue involving Terna and wind producers was curtailment of production of wind farms, which had occurred already in previous years, but grew further in 2010. Even though the law (e.g. Decree 387/2003) gives RES plants priority in dispatching, Terna was sometimes compelled to safeguard efficiency and security of the electrical system by ordering wind operators to shut down their wind farms, or reduce their output, because of temporary overloads or planned work at some points in the grid. This stemmed from the fact that wind plants are densely located in some areas (especially in Apulia, Campania, Basilicata, and Sardinia) where the electricity grid is not yet fully adequate, even though Terna has been enhancing lines and substations to accommodate growing wind capacities without affecting operation of existing networks and quality of electricity supply to customers. For this purpose, in recent years Terna has undertaken also the construction of

dedicated substations ("power collectors") through which 150 kV lines coming from wind farms can feed power straight into the very high voltage (380 kV) national transmission system. Some new major links being built in the electrical system will also help transport wind power from one area of Italy to another, e.g. from Sardinia and Sicily to mainland Italy, and also between Italy and neighboring countries in the future.

In spite of these improvements, wind farm owners have suffered production far from negligible because of curtailments in southern Italy in the last few years. The AEEG has seen to this problem by issuing Deliberation ARG/elt 5/10 of 25 January 2010 on dispatching of non-programmable RES power plants. GSE has been entrusted with the task of calculating wind farm production losses caused by dispatching orders, with a view to indemnifying producers (wind models with inputs from reference anemometers should be applied). For 2010, GSE recognized curtailments totalling 467 GWh. The wind farms liable to dispatching orders are typically those rated at 10 MVA or more and connected to the high voltage grid. Another AEEG Deliberation (ARG/elt 4/10 of 25 January 2010), however, charged GSE with similar estimates for smaller wind farms as well.

AEEG Deliberation ARG/elt 5/10 of 25 January 2010 also confirmed the requirement that HV-connected wind farms that have started operation after 25 July 2008 be able to provide the system with some ancillary services (output modulation, power ramp control, fault ride-through capability, contribution to frequency and voltage regulation).

### 3.0 Implementation

#### 3.1 Economic impact

In spite of the decrease in new installations compared to 2009, the 615 wind turbines added in 2010 (948 MW) and the relevant civil and electrical engineering work corresponded to an estimated turnover of around 1.7 billion euro (2.28 billion USD). 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.

ANEV (the National Wind Energy Association), in co-operation with the Trade Union UIL, recently updated its study on the employment potential of wind energy with 2010 data. About 8,200 people are reported working directly in the wind energy sector at the end of the year, and this figure rose to over 28,000 when including those engaged in ancillary jobs. As reported in previous IEA Wind annual reports, the same study by ANEV and UIL estimated that, if a wind potential of 16,200 MW were to be fully exploited in Italy, some 67,000 people would be employed in the wind sector by 2020, including indirect employment.

#### 3.2 Industry status

As in previous years, most of the new wind turbines set up in Italy were supplied by foreign manufacturers. The overall market shares of wind turbine manufacturers in Italy at the end of 2010 are shown in Figure 3 as percentages of total online capacity. As for wind turbines erected in 2010 alone, 313 MW were Vestas (Denmark) and 221 MW were Gamesa (Spain), REpower (Germany) supplied 124 MW, Nordex (Germany) 96 MW, Enercon (Germany) 91 MW, Acciona (Spain) 51

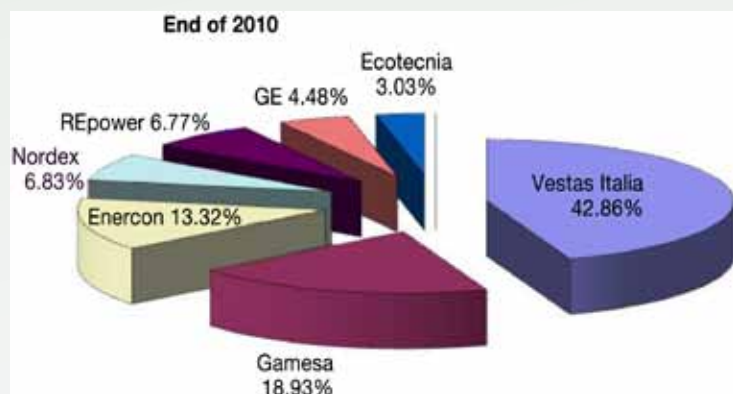


Figure 3 Market shares of wind turbine manufacturers in Italy at the end of 2010 (as percentage of total online capacity)

MW, GE Wind (U.S.) 28 MW, and PowerWind56 (Germany) 17 MW.

It should be pointed out that the Vestas group has a major establishment in Italy since 1998. Specifically, the subsidiary company Vestas Italy now runs two commercial offices based in Taranto (Apulia) and in Rome. These offices are responsible for sale, installation, and operations assistance of wind turbines over an area comprising Italy, Switzerland, and countries of North Africa and the Southern Balkans (including Albania, Egypt, Jordan, and Libya). Particularly, the Service and Maintenance Centre at Taranto monitors and assists wind farms spread over this area for a total of more than 1,800 turbines corresponding to a capacity of more than 1,800 MW. In addition, Vestas factories are located at Taranto, one for assembly of medium-sized (V52) and large (V90) machines (Vestas Nacelles), and the other for manufacturing blades (Vestas Blades). Vestas currently employs more than 700 people in Italy.

Leitwind (belonging to Leitner group), based at Vipiteno in South Tyrol, is currently the only Italian large wind turbine manufacturer on the market. In 2010, this company reached the target of the 100th plant supply. Leitwind turbines have been installed in Europe (Austria, Bulgaria, Croatia, France, and Italy), Asia (India), and America (Canada). The Leitner line includes the LTW70 (1.7 MW and 70-m rotor diameter), LTW77 (1.5 or 1.0 MW, 77 m) and LTW80 (1.5 MW, 80 m). Recently the new LTW80 (1.8 MW, 80-m rotor diameter) and LTW101 (3 MW, 101 m) turbines have been added to the product line. All models feature a three-bladed, variable speed rotor, no gearbox, and permanent-magnet synchronous generator. On 25 September 2009, Leitwind officially opened its new manufacturing facility for the production of 1.5-MW wind turbines in Chennai, India.

The Moncada Energy Group based at Aragona near Agrigento (Sicily) has invested substantial resources mostly as a wind farm developer, but has also developed an 850-kW wind turbine on its own and is looking to other machines of various sizes. Moncada has set up a number of wind farms in Sicily through subsidiary companies, and has several other plants awaiting authorization. They have also been developing a project to build a 500-MW wind farm in Albania, in Valona's region. Other projects of wind farms in Bulgaria, Mozambique, and Tunisia are being considered. A new wind farm having

a capacity of 40 MW, located at Cattolica Eraclea (Sicily) was connected to the grid in 2010, increasing Moncada Group's total wind capacity in Italy to more than 145 MW.

In 2010 the first ten 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 (10%) and Enel GreenPower (9.8%). The former is a well-known multi-national power producer, the latter 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 the wind developer FRI-EL (8.1%), by Edens - Edison Energie Speciali (7.1%), subsidiary of the electricity utility Edison, and by the IVPC group (6.6%), a wind developer that manages and maintains its own farms as well as third parties' plants, for an overall capacity of about 1,300 MW. Another primary producer is E.ON Italia (5.1%), which has taken over the former Endesa Italia. Various other producers hold market shares lower than 5%: Veronagest (4.7%), ERG Renew (4.2%), Alerion Clean Power (3.4%), and Moncada Energy Group (2.5%).

As to the sector of small-sized wind plants, the number of Italian firms entering this market has been growing as a consequence of the special incentives recently made available (see above).

Among manufacturers of machines up to 30 kW, mention should be made of Salmini (horizontal-axis units, below or just above 1 kW), Tozzi Nord (vertical-axis machines up to 5 kW and horizontal-axis ones above 5 kW), En-Eco (vertical-axis,

3 kW), Jonica Impianti (horizontal-axis, 20-25 kW), Deltatronic (horizontal and vertical axis, up to 10 kW), Ropatec (vertical-axis, up to 20 kW), Layer Electronics (horizontal-axis, up to 20 kW), EolPower (horizontal and vertical axis, 1 to 50 kW) etc. Horizontal-axis machines in the range of 50-80 kW capacity have been developed by ARIA, Terom, Eolart, Jonica Impianti, Klimeko, Italtech Wind, etc.

### 3.3 Operational details

In 2010, 615 new wind turbines were deployed totaling 948 MW, and their average capacity (Figure 4) was 1,541 kW. This confirms that large-sized machines have come more in use in Italy, too, in spite of sites where the terrain is often rough and access difficult. The total number of online wind turbines is 4,852, corresponding to 5,797 MW and an overall average capacity of 1,195 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 wind farms are fairly large. The opening photo shows one of these, the Monte Grighine wind farm built by Greentech/EDF in Sardinia, with 43 Nordex turbines totalling 99 MW. About one-third of wind farms completed in 2010 had a capacity of 20 MW or more. The record capacity is the San Martino in Pensilis plant built by Alerion in Molise: 48 MW with 29 machines. Among the largest plants are those of Ascoli Satriano I in Apulia (47 MW), Sambuca in Sicily (44 MW), Ripacandida in Basilicata (nearly 41 MW), and Rocchetta Sant'Antonio in Apulia (40 MW).

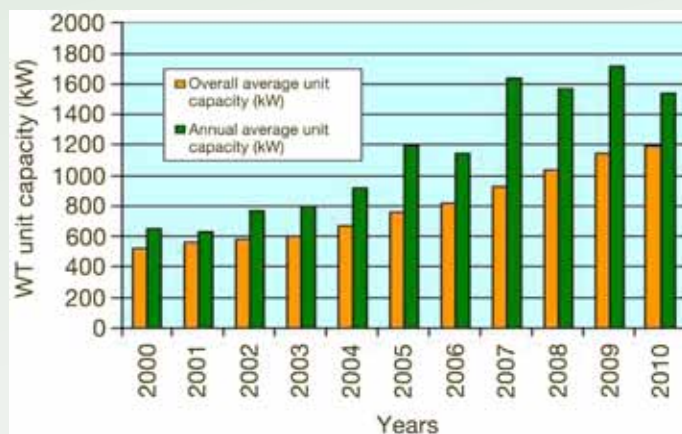


Figure 4 Average annual and cumulative unit capacity of wind turbines in Italy



Assuming the production of 8.4 TWh from wind in 2010 (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

As in previous years, the capital costs of wind farms in Italy have generally been higher than in other countries, largely because most plants have been located at rather remote hill or mountain sites, with ensuing increase in costs of transportation, installation, grid connection and operation. Permitting procedures, which commonly take a long time and are very demanding for the reasons given in the foregoing, also add to cost.

The overall plant cost could be split as follows: 10–20% for project development (wind surveys, plant design, permitting process with related environmental impact assessment etc.); 60–70% for wind turbines, including their transportation, erection and commissioning; 20–25% for civil and electrical infrastructures, grid-connecting lines and other facilities. According to estimates by GSE (1), the average installed plant cost of a typical land-based wind farm of medium capacity (20 MW) at a site of medium complexity in Italy could be put at 1,740 euro/kW (2,338.56 USD/kW), within a cost range from a minimum of 1,550 euro/kW (2,083.20 USD/kW) (large plants at sites of low complexity) to a maximum of 2,000 euro/kW (2,688 USD/kW) (rather small plants in very complex terrain). The same source, assuming an annual O&M cost growing over the plant's 20-year lifetime from 1% to 4% of capital cost, and 1,800 hours/year of equivalent operation at rated power, has calculated unit energy production costs of 127.50 and 138.50 euro/MWh (171.36 and 186.14 USD/MWh) for the above average wind farm with actualization rates of 5% and 7%, respectively.

Of course, these results from a “typical” case are to be extended with much care, as each wind project faces peculiar issues due to the many factors that can bias the business plan of a wind undertaking in Italy.

Regarding small wind systems, which have not yet become very widespread in Italy, less information is available about actual production costs. Information on the revenues that could be obtained by a wind developer from selling energy production

and relevant incentives has already been given in the section on national incentive programs (see above).

## 4.0 R, D&D Activities

### 4.1 National R,D&D efforts

Lacking a coordinated R,D&D program in the wind energy sector, research and demonstration activities are carried out rather independently by a number of entities, among which RSE S.p.A. (former ERSE), ENEA, the Polytechnics of Milan, Turin and Bari, some Universities (Genoa, Naples, Perugia, Trento, Bologna, Florence, Rome, Padua, Lecce etc.), industrial companies and also associations such as APER (Association of RES Producers) and the already mentioned wind energy association ANEV. Some of the activities carried out in 2010 are described in more detail below.

RSE continued working under its Contract Agreement with the Ministry of Economic Development for research on the electrical system, which, for wind energy involves a total financial commitment of 6.5 million euro (8.74 million USD) for the 2009–2011 period. In 2010, additional information on environmental constraints was mapped into the Wind Atlas of Italy (<http://atlanteoelico.rse-web.it/viewer.htm>) and a software tool for evaluating the environmental impact of prospective wind farms was developed and tested over a specific area (the Province of Parma) with a view to making it fully suitable for use by local planners. With reference to the same area, a new methodology for in-depth assessment of onshore wind potential was also tested. Wind measuring stations were set up to fine-tune the Wind Atlas of Italy especially in offshore areas, and a software tool based on GIS (Geographical Information System) was developed for singling out exploitable offshore areas along Italy's coastline.

Some control aspects of wind farms operating within large electricity systems were studied and a further survey was undertaken about the reliability and performance of small wind systems sold on the Italian market. Research was carried out on the application of limited-area meteorological models (LAM), combined with post-processing filtering, to the forecasting of wind farm production. This work area also saw RSE co-operating with GSE and Terna by providing models to estimate production losses suffered by wind producers because of dispatching orders (see the above section on issues affecting growth).

ENEA, in co-operation with the Polytechnic of Bari, the University of Lecce and industry, carried out work to develop non-destructive inspection methods for composite materials based on thermographic techniques, as well as design methods and manufacturing processes for use of thermoplastic resins in small wind turbines (0.5 million euro (0.672 million USD) funding by the Apulia region).

The Polytechnic of Milan, through the Department of Aerospace Engineering, has long been working closely with industry, also by performing tests in its wind tunnel. Work touched on many subjects, among which aero-servo-elastic multi-body modeling of wind turbines; cross-sectional modeling of composite blades; multi-disciplinary optimization of blade design; stability analysis of wind turbines; identification of blade properties; individual higher-harmonic blade-pitch control; wind observers for description of wind field over the rotor disc; and aero-elastic wind tunnel models.

One of the most advanced experiments on high-altitude wind energy is carried out by KiteGen Research and Sequoia Automation with the patented concept of KiteGen. A pre-industrial 3-MW KiteGen “Stem” machine was built in 2010 and is currently under test near Turin in order to develop a commercial product. Also the Polytechnic of Turin has continued interest in research and experiments on kite wind generators.

The University of Genoa is engaged in wind energy through the Department of Construction, Environment and Land Engineering, which, on the one hand, has pursued evaluation of wind fields and potential also abroad (Montenegro) and, on the other, has been concerned with safety and fatigue of wind turbines. The Department of Naval and Electrical Engineering has been concerned with integration of RES into power systems.

The University of Naples, through the Department of Aerospace Engineering, has mainly been designing, developing, and testing innovative small-sized wind turbines also with the help of its wind tunnel. Turbine sizes go from 1.5 to 60 kW for horizontal-axis models and from 1 to 3 kW for vertical-axis ones, also suitable for urban environments. There has also been work on devices for exploiting sea and river currents.

Two major demonstration projects were awarded funding by the State under the “Industria 2015” program, but have since remained waiting for start-up. The



first (GEOMA) is led by the BlueH company and aims at developing a 3.5-MW floating turbine for offshore application (investment of 18 million euro or 24.2 million USD). The second (3MW+), led by Leitwind, aims at developing a 3-MW turbine optimized for mountain sites (investment of 17.2 million euro or 23.1 million USD).

In addition to the ANEV study on employment (see above in the economic impact section), another study undertaken by APER has analyzed how Italy's electricity grid has developed over time and how the evolving grid structure has matched with the operating needs of wind power plants. This study was clearly prompted by the issue of wind production curtailments.

#### 4.2 Collaborative research

Italian organizations collaborate mainly with the IEA Wind agreement and the European Commission on wind energy research. RSE has long been the Italian participant in IEA Wind Task 11 Base Technology Information Exchange. In early 2010, Terna (the Italian TSO) officially joined Task 25 Power Systems with Large Amounts of Wind Power, while the Department of Aerospace Engineering of the University of Naples joined Task 27 Development and Deployment of Small Wind Turbine Labels for Consumers. Some organizations (the universities of Genoa and Perugia, CNR-INSEAN and the electricity producer Sorgenia) are considering joining in Task 31 Wake-bench: Benchmarking of Wind Turbine Flow Models. ENEA, Enel, the University of Florence, APER and other entities are taking part in the European Wind Energy Technology Platform (TPWind) set up by the European Commission. 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). Finally, CNR and ENEA are considering joining the European Energy Alliance (EERA) Joint Wind Program as full and associate participants, respectively.

#### 5.0 The Next Term

Notwithstanding the drop in newly installed wind capacity during 2010, the TSO Terna still foresees continuing development on the basis of financial engagements already taken by investors for connecting wind farms to the grid. According to the TSO, total wind capacity could be expected to reach 6,500 MW by 2011–2012 and 10,250 MW in 2014–2015, all on land. 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 National Action Plan (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, which feature 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.

#### References:

(1) F. Trezza "Aspetti economici legati all'utilizzo dell'energia eolica," (2010), Chapter 6 of *Vie del Vento 2011*, Eds. L. Pirazzi and A. Gargini. Franco Muzzio Editore, ISBN 978-88-96159-28-6 (Italian).

Authors: Giacomo Arsuffi, ENEA and Claudio Casale, RSE, Italy.

# Chapter 22

## Japan

### 1.0 Overview

In 2010, the total installed wind capacity in Japan reached 2,304 MW with 1,742 turbines, including 25.2 MW from 14 offshore wind turbines. The annual net increase was 211 MW. Total energy produced from wind turbines during 2010 was 3.936 TWh, and this corresponds to 0.44% of national electric demand (901.523 TWh).

On 22 September 2009, the former Prime Minister Yukio Hatoyama declared at the general assembly of United Nations that as a midterm goal, Japan will aim to reduce GHG emissions 25% by 2020, as compared to the 1990 level. This is an ambitious target when compared with the Kyoto Protocol target, which was 6%. Wind energy will play a part in meeting this target. To attain this target, the present incentive programs of renewable portfolio standards (RPS) and investment subsidies will be replaced by a new feed-in-tariff (FIT) system for renewable energy sources including wind. The FIT system will start from the beginning of the fiscal year 2012 (April 2012).

### 2.1 National targets

The national target for total installed wind capacity is 3,000 MW by the end of the fiscal year 2010 (March 31, 2011), which will be rather difficult to achieve. 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 campaigns by noise problems, bird strikes, and restricted grid connection. Although setting new national targets for the next few decades are demanded from the industry and other relevant stakeholders, new medium- and long-term targets have not been set by the government. The Japan Wind Power Association (JWPA) published the new long-term targets and roadmap version 2.1 in June 2010. In this version, most of the social restrictions were considered. JWPA set the long-term target of 50 GW total installed capacity by 2050 (catchphrase: Fifty-Fifty) in order to supply 10% of national electric demand from wind.



Photo courtesy Nihonkai Hatsuden Co.

### 2.2 Progress

Cumulative wind power capacity reached 2,304 MW (1,742 turbine units) with 221 MW of annual net increase in 2010. Figure 1 shows the history of wind power development in Japan. Wind power generation in 2010 was 3.936 TWh in 2010 and the contribution of wind power to the national electric demand accounted for 0.44%.

### 2.3 National incentive programs

The current main incentive programs are investment subsidies and the Renewables Portfolio Standard (RPS). The most important incentive program until 2010 had been the New Energy Development Supports Subsidy program, which shared the greater part of the total national wind energy budget administered by the Ministry of Economy, Trade and Technology (METI). The standard subsidy rate was 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 1.19 % of national electricity demand in fiscal year 2010. This target is for the total of new and renewable energy sources and is not broken down into individual 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.

The annual targets were formerly set by fiscal year 2014, however, the target after fiscal year 2013 was abandoned because a new FIT system will be starting in fiscal year 2012. A new incentive program of FIT systems for renewable energy sources was prepared to replace the current incentive programs of RPS and investment subsidies. The first FIT system that started in November 2009 was only for PV, however the new FIT system will cover all practical renewable energy sources such as wind (including small wind), small hydro, geothermal, and biomass. The draft of the new FIT law was prepared by the METI, and the Prime Minister will submit the draft

**Table 1 Key Statistics 2010: Japan**

Total installed wind generation	2,304 MW
New wind generation installed	211 MW
Total electric output from wind	3.936 TWh
Wind generation as % of national electric demand	0.44%
Target:	3,000 MW by 2010

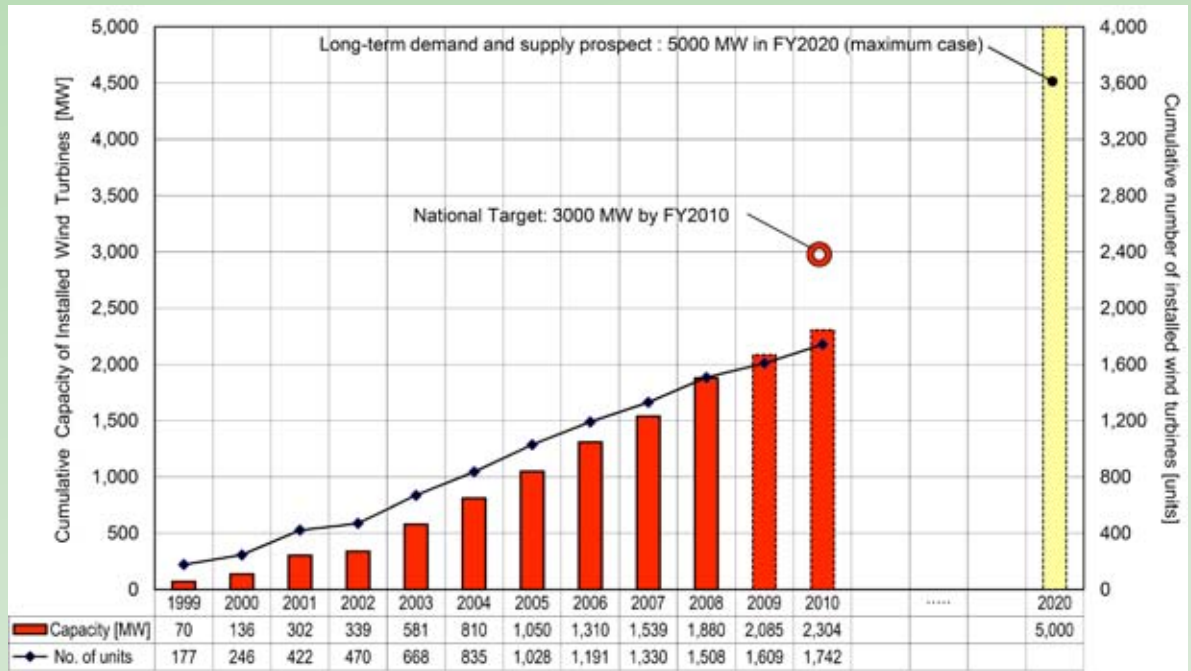


Figure 1 Total installed wind capacity, number of units in Japan.

to the Diet through cabinet decision in early 2011, aiming to start the new FIT system from the beginning of the fiscal year 2012 (April 2012).

**2.4 Issues affecting growth**

It is expected that the new FIT system beginning in fiscal year 2012 will stimulate the market. The feed-in guaranteed price has not been decided yet, however, 15-20 JPY/kWh (0.134-0.179 euro/MWh; 0.18-0.24 USD/MWh) for 15 to 20 years has been suggested. It has also been suggested that the premium FIT of 48 JPY/kWh (0.43 euro/kWh; 0.58 USD/kWh) for 10 years in 2010 for residential PV will be applied to electricity from small wind for residential use.

The government has settled the Advancing Energy Supply Structure Law (Act on the Promotion of the Use of Non-fossil Energy Sources and Effective Use of Fossil Energy Source Materials by Energy Suppliers) in 2009. This law forces the electric companies in Japan to use more than 50% non-fossil energy sources by 2020. This is considered as one of the favorable factors for the promotion of wind energy development in Japan.

**3.0 Implementation**

**3.1 Economic impact**

The sum of the subsidies provided to wind power developers by the government in

fiscal year 2009 (from April 2009 to March 2010) was about 22.7 billion JPY (203 million euro; 273 million USD). Considering the average rate of the subsidy is 30%, it can be estimated that 76 billion JPY (681 million euro; 915 million USD) is involved in domestic development. As considered below, the scale of the activities of the Japanese wind industry is much larger. Supported by the driving force of global wind power development, the benefit to the national economy from the wind industry was more than 300 billion JPY (2.69 billion euro; 3.6 billion USD), which corresponds to more than 3,000 jobs.

**3.2 Industry status and operational details**

The cabinet issued the New Growth Strategy (Basic Policies) in December 2009 and the Growth Strategy Blueprint in June 2010. Strategic visions to promote the renewable energy industry including the wind industry were indicated in the New Growth Strategy.

Two main wind industry associations, the Japanese Wind Power Association (former JWPA) and the Wind Power Developers Association (WPDA) merged to the Japan Wind Power Association (JWPA) in April 2010.

Three Japanese wind turbine manufacturers produce turbines above 1 MW: Mitsubishi Heavy Industries, Ltd. (MHI),

The Japan Steel Works, Ltd. (JSW), Fuji Heavy Industries Ltd. (FHI) and Hitachi Ltd. (Hitachi). Since FHI produces wind turbines and Hitachi sells them, FHI and Hitachi are regarded as one group. The relatively new manufacturers, JSW supplied 49 units and FHI & Hitachi supplied 12 units in the home market. The opening photo shows the Fukura Wind Power Plant with nine MHI 2.4-MW wind turbines commissioned in 2010. MHI made a considerable contribution to U.S. market. As a result, these three companies supplied 899.4 MW (534 units) in 2009 and 338 MW (149 units) in 2010. Most of these turbines are exported. Additionally, these three companies have around a 50% share in the Japanese market from 2005-2010.

MHI announced plans to develop a 5- to 7-MW class offshore wind turbine and JSW started designing a new PMSG gearless 2.7 MW wind turbine with a rotor diameter of 102 m. Hitachi has built a new generator factory with a 4 billion JPY (358,000 euro; 481,000 USD) investment to expand production capacity up to 2,400 units/yr by 2013.

Japan has three near-shore wind power plants. One is the 1.2-MW plant (two Vestas 600-kW units) that is 700 m offshore of Setana Port, Hokkaido, and operated by the Setana Town since 2003. The second is a 10-MW plant (five Vestas 2-MW units) that is in the channel of



Sakata Port, Yamagata, and operated by Summit Wind Power Sakata since 2003. The third is a remarkable new plant of 40 m offshore of Kamisu, Ibaraki. It is the first open-sea wind power plant, and generates 14 MW with seven FHI/Hitachi 2-MW downwind turbines on monopile foundations. It is being developed by Wind Power Ibaraki Ltd.

### 3.3 Wind energy costs

Under the co-operative investigation by METI, New Energy and Industrial Technology Development Organization (NEDO), JWPA, and the Japan Wind Energy Association (JWEA) values/costs are estimated as follows:

- Turbine cost: 200,000 JPY/kW (1,792 euro/kW; 2,408 USD/kW),
- Installed project cost: 300,000 JPY/kW (2,688 euro/kW; 3,612 USD/kW),
- COE: 11.0 JPY/kWh (0.098 euro/MWh; 0.132 USD/MWh),
- Wind electricity purchase price 7 to 9 JPY/kWh (0.063 to 0.081 euro/MWh; 0.083 to 0.107 USD/MWh),
- O&M costs: 6,000 JPY/kW/unit/yr (53 euro/kW/unit/yr; 71 USD/kW/unit/yr)
- Subsidy: 0.8 multiplied by one third of initial investment.

### 4.0 R, D&D Activities

NEDO's Renewable Energy White Paper, issued in July, 2010, provides technical roadmaps for all renewable energy

technologies. For wind, it contained the first detailed technical roadmaps and targets for COE by a government body in Japan. These were based on an analysis of the prior and present status of the market and technology of wind. The targets of COE are 7 to 11 JPY/kWh (0.063 to 0.099 euro/MWh; 0.083 to 0.133 USD/MWh) in 2020 and 5 to 8 JPY/kWh (0.045 to 0.072 euro/MWh; 0.060 to 0.097 USD/MWh) in 2030 for onshore, and 12 to 17 JPY/kWh (0.108 to 0.152 euro/MWh; 0.145 to 0.204 USD/MWh) in 2020 and 8 to 11 JPY/kWh (0.072 to 0.099 euro/MWh; 0.097 to 0.133 USD/MWh) in 2030 for offshore. The necessary R&D subjects were identified and the technical roadmap through 2030 were described to achieve these cost targets.

#### 4.1 National R, D&D efforts

The national R&D programs by METI are as follows (see also figure 2):

- A. Research and Development of Next-Generation Wind Power Generation Technology (2008 to 2012)
  - A1. R&D of Basic and Applied Technologies
  - A2. Natural Hazard Protection Technologies (Lightning Protection measures)
  - A3. Natural Hazard Protection Technologies (Statistical Analysis of Failures)
  - A4. Natural Hazard Protection Technologies (Wind Turbine Noise Reduction)

#### B. Research and Development of Offshore Wind Power Generation Technology (2008 to 2013).

Although the area of the exclusive economic zone (EEZ) and territorial waters in Japan is sixth in the world (4.48 million km<sup>2</sup>), the shallow water area is relatively small. Therefore, R&D of deep water offshore wind technology is necessary for future wide-scale offshore wind development. The Ministry of Environment has decided to organize a deep offshore project of the floating type. The group of Kyoto University, National Maritime Research Institute (NMRI), FHI, and other companies was selected as a developer to promote this project (Figure 3). They selected a site in the Goto islands of Nagasaki prefecture in the Kyushu area for a deep offshore test area for floating type down-wind turbines. They plan to install a full size 2-MW wind turbine in three years after a preliminary project with small scale wind turbines.

Severe external conditions including typhoons, tsunamis, earthquakes, and open sea are technical problems for offshore wind development in Japan. The Japanese national committee for IEC TC88 has proposed the revision of treatment for wave conditions in the open sea to IEC TC88 MT03, based on the abundant research achievement in this research area.

A wind power forecasting system for the utility grid has been operating for the first time in 2010 in Japan. The system

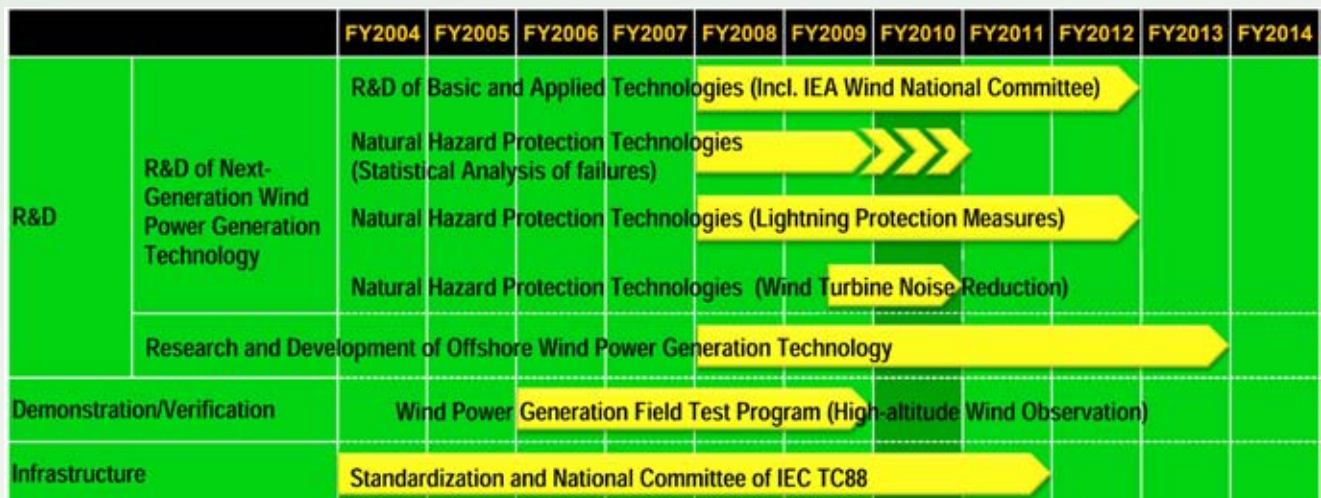


Figure 2 National R, D&D programs for wind by METI

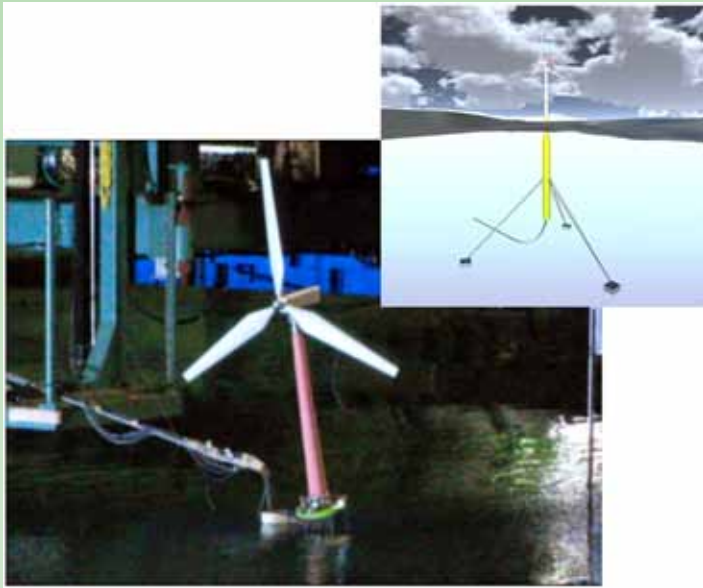


Figure 3 Experiment of offshore wind turbine with spar type floaters by National Maritime Research Institute (NMRI).

was developed jointly by Tohoku Electric Power Co. and ITOCHU Techno-Solutions Co. (CTC). It forecasts the total wind power until the next day for the grid of Tohoku Electric Power Co. where the most wind farms have been installed in Japan.

#### 5.0 The Next Term

Though the national target of 3,000 MW by 2010 is not likely to be attained, some

favorable indications exist for wind power development, such as the introduction of a new FIT system, settlement of new law, issuing the technical roadmap, and developing cost targets for the promotion of wind energy development in Japan. The present R&D projects will continue for the next four to five years, which will create advanced wind technologies, including offshore technology and safe and reliable technology for high turbulence and tropical cyclones.

Author: Tetsuya Kogaki, National Institute of Advanced Industrial Science and Technology (AIST), Japan.

# Chapter 23

## Korea, Republic of

### 1.0 Overview

The cumulative installed wind power in the Republic of Korea was 348 MW in 2009 and 381 MW in 2010, increasing by 9.5% over one year. Local turbine system manufacturers supplied 70% of the wind power installed in 2010. The Renewable Portfolio Standards (RPS) proposal for new and renewable energy was approved by the Congress, and the government is preparing to enact the program in 2012. The required rate of RPS in 2012 will be 2% and will increase to 10% by 2020. A nine-year project to construct a 2.5-GW offshore wind farm off the west coast was announced in 2010, and the first stage of the project, construction of a 100-MW wind farm, will begin in 2011. The 2.5-GW offshore wind farm construction and the RPS will cause dramatic growth of wind energy in Korea. Since 2009, the government has concentrated on encouraging local manufacture of components to secure the supply chain of wind energy systems. Additional government funds are allocated to supporting R&D 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, possibly replacing fossil fuel, and as a new area of heavy industry to escalate the Korean economy. Therefore, the Korean government has increased the R&D budget continuously to support wind turbine and component manufacturers to develop their own technologies and products. Most major shipbuilding and heavy industry companies are involved in the renewable energy business, especially wind energy. In 2010, total installed capacity of turbines larger than 200 kW was 381 MW with nearly a 10% increase in 2010 over 2009 (Table 2).

#### 2.1 National targets

The national target is to promote wind energy to reach 7.3 GW by 2030 and replace 11% of total energy consumption as stipulated in the Third National Energy Plan 2030, sharing about 12.6% among



the new and renewables. Another key goal is advance the technology associated with wind energy and become a leader in the wind energy industry.

#### 2.2 Progress

In 2010, 33 MW of wind power were newly installed, increasing the amount of wind power by 9.5%. Although the amount of wind capacity installed in 2010 is much less than 2009, several domestic turbine manufacturers developed their systems and began commercial production. Among newly installed wind turbines in Korea in 2010, 70% were supplied by domestic manufacturers. Net sales of the Korean wind energy business increased 76% over the previous year with an estimated 1,565 million USD (1,164 million euro). This amount is 22.6% of all renewable energy industries. The number of manufacturers has doubled from 12 to 24 since 2004, and an estimated 1,103

people were employed by the wind industry in 2010. Because most manufacturers are still concentrating on developing products and technologies, the majority of the employees are dedicated to R&D rather than to production.

The history of wind energy in Korea is short compared with some other countries and Korea has strived to catch up with the core technologies (Table 3). Although the level of technology is still behind the cutting-edge technologies, it has been improved and the level was roughly estimated as 81% over the leading countries in 2010.

#### 2.3 National incentive programs

The government subsidizes the installation of New and Renewable Energy (NRE) facilities to enhance deployment and to relieve the end user's burden. For wind power installation (especially for demonstrations or private use), 50% of

**Table 1 Key Statistics 2008: Korea**

Total installed wind generation	381 MW
New wind generation installed	33 MW
Total electrical output from wind	0.812 TWh
Wind generation as % of national electric demand	0.18 %
Target:	7.3 GW by 2030



Year	~2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Capacity (MW)	7.9	4.7	5.4	50	31	79	18	108	44	33	381
Electrical Output (GWh)	25	15	23	38	125	234	371	421	678	812	

Year	2004	2005	2006	2007	2008	2009	2010
Total Sales (million USD)*	87	167	397	532	1,070	889	1,566
* conversion to euro = 0.744							

the installation cost is compensated by the government.

Other incentive programs are as follows:

- **Million Green Homes Program:** To encourage the use of renewable energy in residential areas, the government expanded the 100,000 solar roof program to one million green homes program for diversifying and optimizing the renewable energy use. The target is to construct one million green homes equipped with green energy resources by 2020.
- **Green requirement to public buildings:** New construction, expansion, or remodeling of public buildings having floor area exceeding 3,000 m<sup>2</sup> have been required to invest more than 5% of their total construction expense in the installation of new or renewable energy systems.
- **Feed-in Tariff:** The standard price is adjusted annually reflecting the change of the NRE market and economic feasibility of NRE. Concerning wind energy, the feed-in tariff was 0.092 USD/kWh (0.068 euro/kWh) as a flat rate for 15 years in 2010. The FIT will be applied to wind farms installed by 2011 and new farms constructed from 2012 will be supported with RPS.
- **RPS (Renewable Portfolio Standards):** An RPS was approved by the Congress and 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 of power to customers. The required rate will increase to 10% in 2020. The weight factors for an onshore wind farm, an offshore farm less than 5 km, and a farm with more than 5 km are 1.0, 1.5, and 2.0, respectively.

In addition, Loan & Tax Deduction, Local Government NRE Deployment Program, and others are available as national incentive programs.

#### **2.4 Issues affecting growth**

Two issues will have a major part in affecting the growth of wind energy. The first issue is the construction of the 2.5-GW offshore wind farm in the west sea. According to the roadmap announced by the government, a 2.5-GW farm will be constructed through three stages over nine years beginning in 2011. For the first three years, 100 MW (20 turbines at 5 MW) of wind power will be installed to demonstrate the turbines and the technology of site design. Then 180 units of 5-MW turbines will be installed to accumulate operational experience and commercial track record for the next three years. At the final stage, a 1.5-GW wind farm will be constructed with 5-MW wind turbines for commercial operation. The total budget is estimated to be 7.9 billion USD (5.9 billion euro). The other issue affecting the growth of wind energy in Korea is an RPS program beginning in 2012. Major electric power suppliers will be required to provide 2% of the power with renewable energy including wind power in 2012, and the rate will increase to 10% in 2020. This regulation will

encourage the power suppliers to invest in the installation or purchase of renewable resources.

### **3.0 Implementation**

#### **3.1 Economic impact**

As reported in the *IEA Wind 2009 Annual Report*, major shipbuilding and heavy industry companies develop their own wind turbines and some companies have accumulated good track records. The export of turbine systems began in 2009 with sales of 50 million USD (37.2 million euro). In 2010, more turbines were exported and total sales are estimated at 207 million USD (154 million euro). Employment also increased dramatically due to rapid growth of the industry. Half of employment is related to R&D and total employment is about one thousand people.

#### **3.2 Industry status**

Some manufacturers expanded their business into other renewable resources such as solar energy, tidal energy, etc. to provide stable renewable energy.

#### **3.3 Operational details**

In 2010, 33 MW of wind power was added and 70% of turbines were supplied by domestic manufacturers. Twelve units of a 750-kW turbine and one 2-MW turbine were from Unison. Three turbines (one 1.65-MW and two 2-MW turbines [opening photo]) were from Hyundai heavy industries. Doosan and Samsung heavy industries provided one unit each of 3-MW and 2.5-MW turbines respectively.

### 3.4 Wind energy costs

Newly installed wind turbines, especially supplied by domestic manufacturers, are not operated for commercial purpose but for system checks and accumulating track record. So there is not enough electric output record and it is still difficult to estimate the real wind energy cost.

## 4.0 R, D&D Activities

### 4.1 National R, D&D efforts

The government has continuously increased the R&D budget and demonstrating the strong will for improving the wind energy industry (Figure 1). Even the Korean president mentioned wind energy as one of candidates to escalate the Korean economy at the New Year's news conference in 2011. The government has allocated an R&D budget for local production of wind turbines but also realizes the importance of stable supply chain. The government, therefore, has

increased the budget to develop technology for components, and several R&D projects are under way. More component development projects are launched every year. Table 4 presents the portion of components among the government R&D. In 2010, 40% of R&D budget was provided to support component development. 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 the 2.5-GW offshore wind farm begins in 2011 and RPS will be enacted in 2012. These major issues will encourage electric power suppliers and turbine system manufacturers to

plan for profitable wind farm construction. Also, many wind farm construction projects are planned by private companies and provincial governments. Therefore, it is quite difficult to accurately predict the detailed future of wind energy activities.

Authors: Cheolwan Kim, Korea Aerospace Research Institute; Sukhyun Chun, Korea Energy Management Corporation; and Jong Hoon Lee, Korea Institute of Energy Technology Evaluation and Planning, Korea.

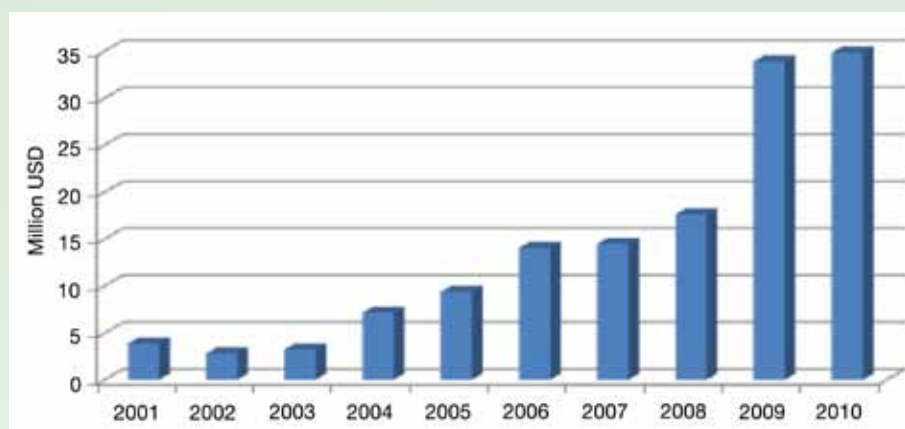


Figure 1 The budget trend of government sponsored R,D&D. Relevant conversion to euros 0.744.

Category	2009			2010		
	No. of Project	Budget (million USD)	Rate (%)	No. of Project	Budget (million USD)	Rate (%)
System	3	11.6	34	7	5.7	16
Field Test	3	9.2	27	2	12.1	35
Component	11	9.2	27	17	13.9	40
Electric, Control	5	2.6	8	3	2.2	6
Others	3	1.3	4	3	0.9	3
<b>Total</b>	<b>27</b>	<b>33.9</b>	<b>100</b>	<b>32</b>	<b>34.8</b>	<b>100</b>

\* conversion to euro 0.744



### 1.0 Overview

During 2010, 64 new wind turbines were commissioned in México, bringing the total wind generation capacity to 520 MW. The Law for Renewable Energy Use and Financing of Energy Transition (enacted in November 2008) is successfully achieving its main objectives. Wind energy is emerging as 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. The Comisión Federal de Electricidad (CFE)

awarded contracts for five IPP (Independent Power Producer) 100-MW wind power plants.

As stated by the Mexican Wind Energy Association (AMDEE) and in accordance with permits granted by the Energy Regulatory Commission, about 2.5 GW of wind power capacity should be installed by the end of 2012. At present, it is estimated that full implementation of technologically and economically feasible projects would lead to the construction of more than 10,000 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 m above the ground. It is estimated that more than 3,000 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 and Tamaulipas are emerging as the next wind energy deployment regions in México.

### 2.0 National Objectives and Progress

#### 2.1. National targets

In accordance with the Special Program for Renewable Energy, by the end of 2012 wind energy installed capacity will be close to 2,500 MW. Assuming this capacity operated at an average of 35% during 2013, contribution of wind generation to national electric demand would be around 3%.

#### 2.2 Progress remarks:

- La Venta I, Guerrero Negro, and La Venta II (Figure 2) were the first experiences 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 awarded includes a complement to the electricity buyback price of about 0.015 USD/kWh (0.20 euro/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 2010, 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<sub>2</sub> emissions for the year 2010 was 780,000 tonnes, considering a mitigation rate of 0.6 tonnes CO<sub>2</sub> per each wind generated MWh.

**Table 1 Key Statistics 2010: Mexico**

Total installed wind generation	520 MW
New wind generation installed	105 MW
Total electrical output from wind	<b>1.3 TWh</b>
Wind generation as % of national electric demand	<b>0.6</b>
Target:	2.5 GW by the end of 2012; 3% of 2013 national electric demand
<b><i>BOLD ITALIC</i></b> indicates an estimate.	



Table 2 Progress on wind generation capacity								
Wind power station	No. WT	WT (KW)	WT Manuf	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
La Venta III	121	850	Gamesa	102.9	U. Construction	IPP	2010	OAX
Oaxaca I	51	2,000	Vestas	102.0	U. Construction	IPP	2011	OAX
Fuerza Eólica	12	2,500	Clipper	30.0	U. Construction	POSS	2011	OAX
Oaxaca II	68	1,500	Acciona	102.0	Contr. awarded	IPP	2012	OAX
Oaxaca III	68	1,500	Acciona	102.0	Contr. awarded	IPP	2012	OAX
Oaxaca IV	68	1,599	Acciona	102.0	Cont. awarded	IPP	2012	OAX
DEMSA	45	2,000	Gamesa	90.0	Not initiated	POSS	2012	OAX
Eoliatec Istmo				164.0	Not initiated	POSS	2012	OAX
Eoliatec Pacífico				160.5	Not initiated	POSS	2012	OAX
Vientos Istmo				180.0	Not initiated	POSS	2012	OAX
E.A. Istmeña				215.6	Not initiated	POSS	2012	OAX
Bii Hioxo				227.5	Not initiated	POSS	2012	OAX
Fuerza Eól. 2				50.0	Not initiated	POSS	2012	OAX
C. Tamaulipas				54.0	Not initiated	POSS	2012	TAM
F.E. B. Cal.				300.0	Not initiated	POSS	2013	BC
San Matías				20.0	Not initiated	POSS	2013	BC
Rumocannon				72.0	Not initiated	POSS	2013	BC
B. Cal. 2000				10.0	Not initiated	POSS	2013	BC
Sta. Catarina				17.5	Not initiated	POSS	2013	NL
Accumulated				2,868.7				

(1) FGOB=Federal Government, SGOB= State Government, POSS= Private owned self-supply, IPP= Independent Power Producer, IIE = Instituto de Investigaciones Eléctricas

(2) Commissioning year

### 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 research and development. Some

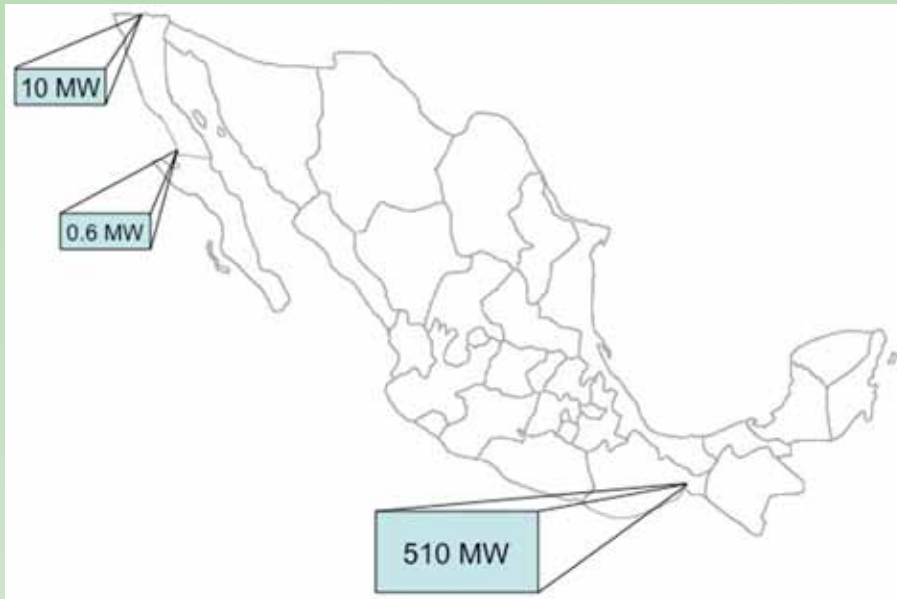


Figure 1 Wind generating capacity installed in México as of December 2010

of the regulatory instruments for this law have already been issued while others are still under development. The existing incentives are:

- Model agreement for the interconnection of renewable energy power plants to the national electrical grid (2001), allows administrative interchange of electricity among billing periods
- Accelerated depreciation (up to 100% in one year) (2004)
- Recognition of certain capacity credit for self-supply projects
- Reduced tariffs for electricity transmission.

#### 2.4 Issues affecting growth

There is a critical need to include fitting and fair social benefits to wind landowners (especially to peasants) 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 2010, it was estimated that the total investment in the construction of wind power plants was around 1,040 million USD (773.8 million euro). Assuming that around 80% of this amount corresponds to the cost of the wind turbines, the rest, around 208 million USD (154.8 million euro)

could be considered as the economic distribution to México. Nevertheless, still a good part of the work is carried out by foreign employees.

#### 3.2 Industry status

The Spanish wind turbine manufacturers Acciona Windpower and Gamesa Eólica are leading the Mexican wind turbine market, but other prestigious

companies like Clipper Windpower, Vestas, and Siemens have been with 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.



Figure 2 La Venta II 83.3-MW wind farm in the Isthmus of Tehuantepec, México



Figure 3 The Wind Energy Technology Center operated by the IIE

### 3.3 Operational details

Operational details for each of the wind power stations are not available. During 2010, the total average capacity factor for wind energy was around 28 %. Being that 105 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 (1,420 euro/kW). In that region, the buy-back price for IPP generators is around 0.065 USD/KWh (0.046 euro/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) (Figure 3). 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 access is difficult,

turbulence intensity is up to 20%, and seismic hazard is high.

With the support of the Sener and the National Council for Science and Technology, the IIE is working on national capacity building on the most relevant topics involved in the implementation of wind

energy. The IIE is also carrying out specific studies and projects for CFE. The IIE developed a National Wind Energy Resource Atlas (Figure 4) that was presented by President Calderón during the COP 16 meeting.

### 4.2 Collaborative research

The IIE participates in IEA Wind Task 11 Base Technology Information Exchange.

## 5.0 The Next Term

Up to now, 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 2,500 MW by the end of 2012.

Author: Marco A. Borja, Instituto de Investigaciones Eléctricas (IIE), México.



Figure 4 Mexican Wind Energy Atlas





Photo credit: Jaap 't Hooft, NL Agency

### 1.0 Overview

The installed wind capacity in the Netherlands is 2,245 MW, an increase of 29 MW from 2009, however statistics for 2010 are not final at the time of publication. The year 2010 was a very poor wind year. Because of that, the wind electricity generated was around same as in 2009, 4.6 TWh, or approximately 4.0% of the total electricity demand (Table 1).

## 2 National Objectives and Progress

### 2.1 National targets

In September 2010, a new government started. The government considers the European targets for renewable energy supply as leading. This results in a target of 20% CO<sub>2</sub> reduction compared to the 1990 level and a share of 14% renewable energy in 2020. The government intends to achieve these goals by:

- Elaborating on a green deal with society, aimed at energy efficiency and local production of energy and heat,
- Support of research and development for new energy sources,
- Converting the SDE (stimulerend duurzame energie) production subsidy into changed SDE-plus,

- Increased use of Kyoto flexible mechanisms,
- Implementation of nuclear energy.

The new government rearranged several departments. This resulted in the Ministry of Economic Affairs, Agriculture and Innovation— a merger of the Ministry of Economic Affairs and the Ministry of Agriculture. Likewise, the Ministries of Housing, Spatial Planning and the Environment (VROM) and Public Works merged into the Ministry of Infrastructure and Environment.

The former government's target of 6,000 MW wind capacity installed on land in 2020 has not been confirmed. However, the present government considers wind on land a relatively cheap option for renewable energy, and as such expects an important share of it in complying with the CO<sub>2</sub> and renewable energy targets set. The status of the draft vision for spatial planning (May 2010) of 6,000 MW in 2020, prepared by the former Ministry of VROM (now part of the Ministry of Infrastructure and Environment) with various parties involved, was not clear at the end of 2010.

### 2.2 National incentive programs

In 2010, two incentive programs relevant for wind energy projects could be used in the Netherlands: the SDE production subsidy and the EIA tax incentive on investment. The EIA is a tax deduction scheme for investments including wind energy. In the SDE scheme, a base subsidy tariff is determined on the basis of average production costs. The amount of support per kWh which a producer receives varies yearly by decreasing the base subsidy tariff with the average market price of electricity (but if the average market price is lower than the base energy price, then with the base energy price). The *IEA Wind 2007 Annual Report* describes the SDE mechanism.

#### 2.2.1 Wind on land

The SDE subsidy for 2010 was published early 2010. The main characteristic is that it introduced a new category of wind turbines with installed capacity of >6 MW, which has allowed for 3,095 full load hours in stead of the 2,200 for all other turbines.

At the end of 2009, the Ministry of Economic Affairs published a one-time subsidy scheme for the wind farm Noordoostpolder. Under this one-off subsidy scheme, the minister allocated in 2010 a production subsidy of 880 million euro (1.2 billion USD) for the wind farm with a total installed capacity of 429 MW. Under the scheme two categories are awarded differently:

1. For wind turbines on land with a capacity of 6 MW or higher, the base subsidy is 0.096 euro/kWh (0.129 USD/kWh) with a maximum of 3,095 full load hours per year during 15 years.
2. For wind turbines near shore with a capacity of 3 MW or higher but smaller than 5 MW, the base subsidy is 0.121 euro/kWh (0.162 USD/kWh) with a maximum of 3,118 full load hours per year during 15 years. Also under this scheme, the Ministry on top of the production subsidy has allocated an innovation subsidy of 116 million euro (156 million USD). This was awarded because

**Table 1 Key Statistics 2010: The Netherlands**

Total installed wind generation	2,245 MW
New wind generation installed	29 MW
Total electrical output from wind	~ 4.6 TWh
Wind generation as % of national electric demand	~ 4.0 %
Target: 2020	14% renewable energy
Target: 2020:	20% reduction CO <sub>2</sub> as compared to 1990 level

of the unique character of the wind farm, technical uncertainties, and other higher costs. Also part of the wind farm is in deep water in the IJsselmeer. The wind farm will consist of 46 wind turbines in the water with a diameter of 107 m, a tower height of 95 m, and an installed capacity of approximately 4 MW. The other 30 wind turbines on land will have a tower height of 135 m and an installed capacity of around 7.5 MW.

### 2.2.2 Wind offshore (short-term)

Following the developments initiated under the previous government, the tender for the SDE subsidy closed on 1 March 2010. Parties in possession of a building permit submitted a bid for production subsidy (euro/MWh). After a correction for the distance of the project to shore (landfall point), the proposals were ranked according to the corrected price (bid) levels. This resulted in the decision to award subsidy for two projects with the lowest bids. The projects located in the Dutch part of the Watten Sea will have a total of 600 MW of installed capacity (Figure 1). They are owned by the companies Buitengaats CV and ZeeEnergie CV, both daughter companies of the German Bard Group. Construction of the wind farms awarded is expected to start in 2012-2013 and needs to be completed within five years after granting the subsidy. The subsidy consists of the bid for production subsidy minus the average (grey) electricity price in a given year (euro/MWh). It is given for 15 years at a maximum of 2,900 full load hours per year. According to Bard, their bid was around 170 euro/MWh (228.5 USD/MWh) excluding distance correction.

The SDE budget allocated still leaves room for subsidy to wind farms with approximately 120-130 MW installed capacity. At the end of 2010, this budget had not been allocated. The allocation has to follow the special procedure defined as part of the terms of the tender for a remaining budget that does not fit an entire wind farm.

### 2.2.3 Overview of production subsidies in 2010

In all subsidy schemes, the base energy price is 0.049 euro/kWh (0.066 USD/kWh) and the subsidy period is 15 years. The total maximum subsidy is determined by the prospective energy yield of the wind farm in 15 years and the difference

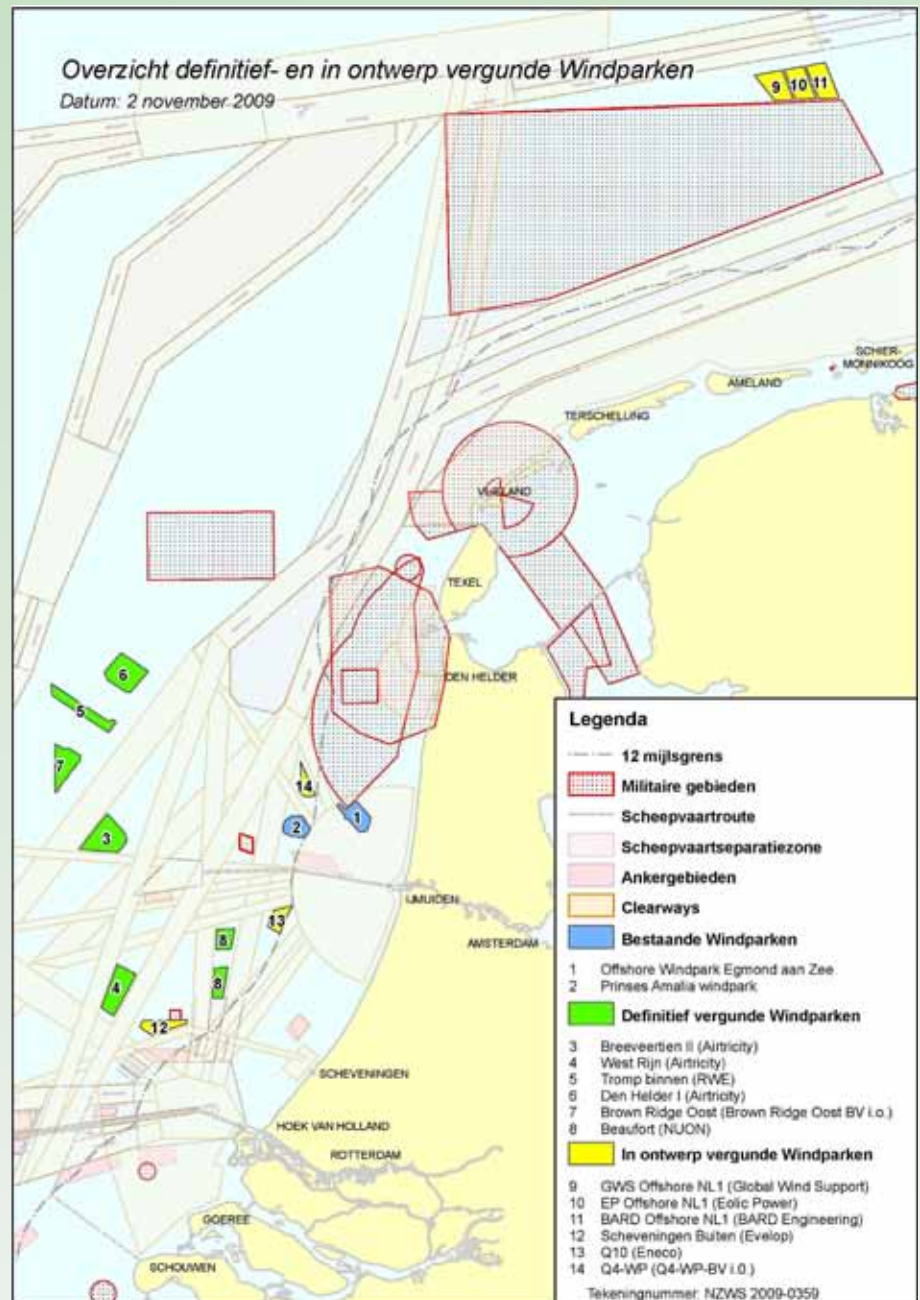


Figure 1 Location of the offshore wind farms of Buitengaats CV(9) and ZeeEnergie CV(11)

between the base subsidy per kWh minus the base energy price is 0.049 euro/kWh (0.066 USD/kWh).

### 2.3 Wind offshore (long-term)

Preparations for a third round of subsidies are continuing. However, an exact timetable is not available. Offshore wind is seen as a relatively costly option by the new government. Because of that, the main emphasis will be on research and development to achieve cost reduction.

The former Minister of Economic Affairs established the Task Force on Offshore Wind Energy in May 2009. It issued its report to the Minister in May 2010. The work of the Task Force concentrated on the financial base for offshore wind energy and on preferred ways of cooperation between public and private sectors, directed to reach the target of 6,000 MW of offshore wind in 2020. The main recommendations to the government from the Task Force are:



**Table 2 Overview and allocations of the production subsidy and innovation subsidy in 2010\***

Category	Base subsidy 2010 euro/kWh	Full load hours hours/year	Maximum subsidy Million euro	Capacity MW	Allocated %
<b>Wind op land</b>					
Up to 6 MW	0.096	2200	937	n.a.	n.a.
> 6 MW	0.096	3095		n.a.	n.a.
<b>Wind farm Noordoostpolder</b>					
> 6MW	0.096	3095	880	~ 225	100%
near shore >3 MW and <5 MW	0.121	3118		~ 204	100%
Innovation subsidy			116		
<b>Offshore tender</b>					
Buitengaats C.V.	~ 0.170	2900	2250	300	100%
ZeeEnergie C.V.	~ 0.170	2900	2250	300	100%
Remaining budget			~ 1000	~ 120	0%
Total available subsidy			~ 7433		

\*conversion to USD=1.344

- take a leading position in the preparatory phase
- assume a (co-)investor role, resulting in reduced capital costs
- reduce the lead time for development of offshore wind farms

At the end of 2010, it was not clear to what extent the new government had adopted the above recommendations.

The Ministry of Economic Affairs, Agriculture and Innovation is actively participating in the North Seas Countries' Offshore Grid Initiative. The Political Declaration at the end of 2009 was followed by a Memorandum of Understanding (MoU) signed by 10 countries. These countries want to cooperate actively in the further development and a compatible political and regulatory basis for long-term development of offshore electricity infrastructure. TSOs and electricity regulators in the participating countries support the MoU by means of a letter of commitment (1).

### 3.0 Implementation

#### 3.1 Economic impact

Total investment in wind energy installations in the Netherlands for 2010 can be estimated at 38 million euro (51 million USD), assuming an average investment cost for land-based wind of 1,325 euro/kW (1,780 USD/kW) for the 29 MW

installed. The total investment in wind energy installations from 1995 to 2010, not corrected for inflation, is estimated at some 3 billion euro (4 billion USD).

#### 3.2 Industry status

##### TenneT

The European Commission approved the takeover of all shares of E.ON's German daughter company Transpower (Transpower Stromübertragungs GmbH) by the Netherlands transmission system operator TenneT. The German transmission system operator Transpower is the largest in Germany and amongst others responsible for the expansion of the German transmission grid to the German offshore wind farms. The takeover has the approval of the State of the Netherlands the sole shareholder of TenneT.

##### Lagerwey Wind Turbine

Lagerwey Wind Turbine started prototype testing of its new wind turbine at the German test site Grevenbroich in January 2011 (Figure 2). The main characteristics of the turbine are: capacity 2 MW, rotor diameter of 82 m, and tower height of 80 m. The generator is a self-designed direct-drive with variable speed between 7.5 and 18.5 rpm. The nacelle weight including rotor is as low as 100 tons, which is comparable to a turbine with gear box. Lagerwey Wind Turbine developed the turbine

for Reliance in India. A second prototype is under test there. Reliance is marketing the turbines under the name of Global Wind Power.

### 4.0 R, D&D Activities

#### 4.1 National R, D&D efforts

##### 4.1.1 R, D&D priorities and budget

The research, development, and demonstration priorities in 2010 continued to be



Figure 2 Prototype of Lagerwey at test site Grevenbroich



offshore wind energy. This was reflected in the various budgets that were allocated by the Ministry both direct to research allocations for ECN and TU Delft and through programs run by the NL Agency (Table 3). National government allocations for wind energy R, D&D in 2010 amounted to approximately 38 million euro (51 million USD), mainly for offshore wind energy. This includes base finance of ECN and TU Delft of approximately 4.5 million euro (6 million USD).

#### 4.1.2 EWOZ

As part of the Energy Innovation Agenda, NL Agency on behalf of the Ministry organized a tender to support the development of offshore wind turbines larger than 4 MW and/or related support structures. The tender closed in early 2010 and 9 million euro (12 million USD) were awarded to support two projects by XEMC-Darwind and 2-B-Energy.

#### XEMC-Darwind

XEMC-Darwind and many third parties completed the development and built a prototype of a wind turbine with a three-bladed rotor of 116 m with 18 rpm and a tip speed of 108 m/S and a 5-MW, direct-drive, permanent-magnet generator of 5.3-m diameter. The turbine is especially designed for offshore wind farms. XEMC-Darwind will build a prototype on the ECN test site at the Wieringermeer. There it will be tested for type certification and the validation of the design. After that XEMC-Darwind and its partners TNO, Ecofys, ECN, TU Delft en Marin will use the prototype as full-scale test platform for further experimental research.

#### 2-B-Energy

2-B Energy and Heerema are working together to develop, install, and test the first prototype of a new offshore wind



Figure 3 back-to-back test configuration 2 generators of XEMC-Darwind 5-MW, direct-drive, permanent-magnet generator

power plant concept. The new concept distinguishes itself by a turbine with a two-bladed, active-stall, downwind rotor, 6-MW generator, a truss tower as support structure with all the way from sea-bottom to the nacelle yawing mechanism. Electrically, the whole farm will run at variable-frequency, medium voltage, and the total power will be converted to 150 kV DC at the central transformer station and then run to the onshore high-voltage DC/AC transformer station.

#### 4.1.3 FLOW

In September 2009, the FLOW (Far and Large Offshore Wind) proposal was

presented to the Minister of Economic Affairs Van der Hoeven. The large-scale innovation program for the development of wind energy far out at sea comprises an R&D program. It initially contained a demonstration wind farm with 20 to 60 turbines 75 km off the Dutch coast. RWE Offshore Wind, Eneco, TenneT, Ballast Nedam, Van Oord, IHC Merwede, 2-B Energy, XEMC Darwind, ECN, and TU Delft are participating in the initiative. In the course of 2010, the Ministry of Economic Affairs, Agriculture and Innovation decided to support the R&D part of the program (47 million euro or 63 million USD in five years) up to a maximum of

Table 3 In 2010 awarded subsidies for wind R,D&D			
Beneficiary	Subsidy in million euro/million USD	Type	Subject
Direct government funded research			
ECN and TU Delft	4.5/6.0	R	Various offshore research
Programs run by NL Agency			
XEMC Darwind	4.5/6.0	R&D	DD 5-MW offshore
2B-Energy	4.5/6.0	R&D	6-MW 2-Blade downwind
Emergya Wind Technologies B.V.	1.0/1.3	Demo	2-MW Direct Drive (outside rotor)
FLOW project	23.5/31.6	R&D	Large offshore wind farm
<b>Total</b>	<b>38.0/51.0</b>		



Figure 4 Artist impression of the 2-bladed 6-MW downwind turbine of 2B-Energy

50% with funding from the Energy Innovation Agenda. The R&D program concentrates on, wind farm design, support structures, electrical system and grid integration, and turbine development.

**4.1.4 Projects under EOS**

**Actiflow**

Actiflow is a young company specializing in boundary layer suction technologies (Figure 5). It will test suction technology to change the aerodynamic properties of wind turbine blades, the lifetime, and possible fouling of different porous materials. The first test will be on a 7-m diameter Aircon wind turbine. Preparation is by simulating several concepts for a 62-m blade, then selecting conceptual designs for a 3.5-m blade, then building and testing the blades on the Aircon wind turbine.

**Emergya Wind Technologies B.V.**

Emergya Wind Technologies (EWT) will demonstrate its prototype turbine (DW90), with a rated power of 2 MW, a hub height of 85 m, a rotor diameter of 90 m, and a rated wind speed of 11.5 m/s. The generator is a synchronous type, with permanent magnet excitation, a liquid cooled generator stator, an outside rotor, and a main single bearing. EWT will erect the prototype at the new ENECO test site near Lelystad. EWT developed the technology together with the Chinese company CALT. EWT has the sales rights to the world market, CALT for the Chinese market.

**4.1.5 Results of OWEZ**

Further results of the Monitoring and Evaluation Program (MEP) of the offshore wind farm OWEZ (Offshore Windfarm Egmond aan Zee), formerly known as NSW, became available in 2010 (opening photo shows the beach at Bergen with offshore wind farms Egmond aan Zee and Amalia). Most of them can be downloaded from [www.offshorewind.nl](http://www.offshorewind.nl) and [www.noordzeewind.nl](http://www.noordzeewind.nl). During the summer, repairs to the wind farm were carried out. Earlier inspections showed that some minor clearance had arisen in the vertical direction between the foundation pile and the transition piece. The foundation piles were filled up with concrete. This formed a solid basis and prevented further shifting. For this work, the work ship VOS Sympathy was equipped with concrete silos and pumps.

**4.2 Collaborative research**

The Netherlands have continued to play an important role in several IEA Wind tasks including: 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; and Task 28 Social Acceptance of Wind Energy Projects, in which NL Agency directly participates. Also the Netherlands research institute ECN acts as Operating Agent in Task 29 MexNext Analysis of wind tunnel measurements and improvement of aerodynamic models. Delft Technical University and AERotortechiek are

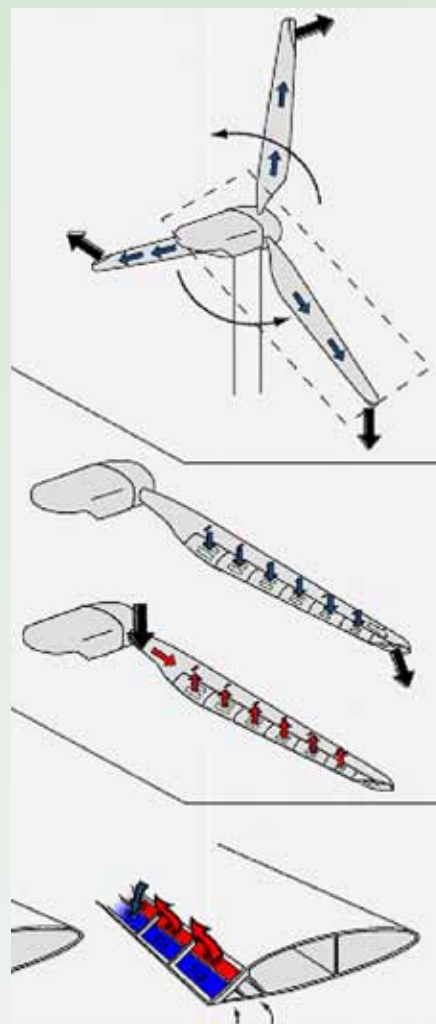


Figure 5 Principle of suction blade technology

also participating in this Task. Additionally, interest exists to participate in new tasks including 30 and 31).

At the end of 2010, preparation started for the meeting of the Executive Committee planned to take place in the Netherlands in April 2011. Accompanying events will include a workshop to foster participation of Dutch industry and research and development organizations in the IEA Wind Energy Implementing Agreement activities. 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 the value of five euro of research spent in the other participating countries.

## 5.0 The next term

### 5.1 Incentives

On 1 January 2011, the new government announced a stop to the SDE production subsidy. As of July 2011 it will be replaced with the so-called SDE+ scheme. Although details of the SDE+ are not yet known, the Minister of Economic Affairs, Agriculture and Innovation provided Parliament with a general outline of the scheme. The SDE+ concentrates on the lowest subsidy costs per kWh. Three factors take care of this: a) a cap on the cost per kWh for eligible technologies, b) a phased tender approach, and c) introduction of a so called "free category." The first factor limits access of the more expensive technologies, such as solar PV,

to the subsidy. Each technology has its standard cost and a related maximum production subsidy level. The second aspect, the phased tender approach, first allows the cheapest technologies (e.g. electricity from waste incineration plants). Later in the year, somewhat more expensive technologies (such as wind on land) are included, and so on. In this way, cheaper technologies are first served and others have possibility if budget is still available. The third element consists of a free category, allowing for innovative approaches requiring less subsidy than the established maximum, and also allowing for the normally more expensive technologies to obtain a (probably only partially covering) production subsidy. Wind offshore is not included in the SDE+ approach although it could enter under the free category.

### 5.2 R&D

Although no formal changes took place in research priorities concerning wind

energy in 2010, the government developed a new focus with more emphasis on the role of industry and economic benefits. The implications of the new focus will be clear in 2011.

### References:

(1) information on MoU: <http://www.tennet.org/tennet/nieuws/noordzeelandencoördinerenplanningenonderzoek-naarverdereontwikkelingoffshoregrid.aspx>

Author: Jaap L. 't Hooft, NL Agency NL Energy and Climate Change, The Netherlands.





Photo credit: Bernhard Kvaal, Trønder Energi AS

### 1.0 Overview

The installation of new wind power capacity in Norway was low during the past year. In 2010, the new capacity installed was 18.4 MW. However, about 14 MW were also taken out of production, resulting in a net capacity installed in 2010 at 4.4 MW. Total production of wind power was 906 GWh compared to 980 GWh last year. Wind generation constitutes 0.75% of the total electric production in the country. Electric energy in Norway is generated using a very high share of renewables. 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

potential economical renewable resources are wind power, but there is also a potential for about 20 TWh of hydropower, mostly small-scale hydropower. The key statistics for 2010 are shown in Table 1.

### 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 of at least 3 TWh of wind power production in 2010 has been abandoned. For the longer term (2016), the government has established a target of 30 TWh above the 2001 level of production from renewable energy sources and energy efficiency.

### 2.2 Progress

Renewable sources of electricity supplied 90% of the national electrical demand of Norway in 2010. About 0.75% of the renewable supply came from wind power, which saw the net installed capacity increase by 4.4 MW, with 18.4 MW of new wind generation installed, and 14 MW removed. 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 dry year resulting in a net power import of 7.5 TWh.

### 2.3 National incentive programs

For renewable power production, the support system has so far been administrated through the state-owned organization Enova SF. The support for wind development is given as a grant (investment subsidy) through Enova's Wind Power Program. There are no support systems for hydropower. The last call for the wind power program was in 2010, where Enova granted four projects with a total of 923 million NOK (110.76 million euro; 156.91 million USD). These four projects are expected to produce 460 GWh, and will be in operation in 2012 and 2013.

Since 2001, Enova has signed contracts with energy utilities for 18 wind power projects. The projects represent an estimated 2.1 TWh/yr of energy production. The calculated grant (support) for each wind power project is based on a cash flow analysis, where the grant shall provide an Investment Rate of Return (IRR) of 8% before taxes. The wind power companies are in competition with each other and are being ranked by cost efficiency (kWh/support level). The most cost efficient projects are being supported in every round. The Wind Power Program is announced annually.

It is expected that the Wind Power Program will be replaced by a green certificate system in 2012. The Norwegian Government has come to an agreement with the Swedish Government for a common electricity certificate system. The new system is expected to open 1 January 2012 and it is intended to increase the production of renewable electricity and

**Table 1 Key Statistics 2010: Norway**

Total installed wind generation	435 MW
New wind generation installed	4.4 MW
Total electrical output from wind	0.91 TWh
Wind generation as % of national electric demand	0.75%
Target:	No target

also make the production more cost-efficient. The objective of the electricity certificate system is to increase the production of renewable electricity with 26.4 TWh by year 2020 compared to year 2012 (in both Norway and Sweden). It is expected that the electricity certificate system will contribute with 6-7 TWh of new wind power in Norway by 2020. The system replaces earlier public grants and subsidy systems. The principle of the system is that there are sellers and purchasers of certificates and the market brings them together.

There is also an interim arrangement, an investment aid with a payback rule if the investor chooses to enter the certificate market. This arrangement is for wind power plants and small hydro power plants that fulfill certain requirements on installed capacity and building start.

In January 2011, Innovation Norway launched a new call, Miljøteknologiordningen (Green technology scheme). The budget for the call is 30 million euro/yr (40.32 million USD/yr) (and will also be launched in 2012 and 2013). The call is targeting pilot plants and prototypes within renewable energy. Additional to that, Enova has a program supporting innovative technologies within offshore renewable power production, and the yearly budget is approximately 25 million euro (33.6 million USD).

The report 'Offshore Wind in Norway – Suggested Areas for SEA' was published in November 2009 and sent out for public consultation by The Norwegian ministry for Petroleum and Energy. The report was prepared by a group of directorates consisting of the Norwegian Water Resources and Energy Directorate (NVE), the Norwegian Directorate for Nature Management (DN), the Directorate for Fisheries (FD), the Norwegian Coastal Administration (KV), and the Norwegian Petroleum Directorate (OD). In addition, the energy and petroleum industry, the fishing industry, environmental organizations, and other relevant parties have been included in the work. The report considers technical, economic, environmental, and geographical aspects of offshore wind power development. Fifteen areas have been singled out for potential strategic environmental assessment (SEA). In addition, a plan for the SEA has been suggested. An SEA will be carried out before areas can be made available for the development of offshore energy production.

The areas recommended for further investigation stretch from the southern part of the North Sea to the Barents Sea in

the north (Figure 1). A final plan for the SEAs is expected in mid 2011.

#### 2.4 Issues affecting growth

The low increase of wind power capacity during the last years (Figure 2) is due to an inconclusive and insufficient support regime.

The three-year forward price on the Nord Pool (Nordic electricity market place), by the end of January 2011 was 45.00 euro/MWh (60.50 USD/MWh). Although the long-term future electricity price has risen during past years, it is still not sufficient to spur new wind

power projects. So far, wind energy is not competitive with the price of many new hydropower projects, which are still an option in Norway for new green power. The grid-connection cost is also a problem. Generally, areas with the best wind conditions are located in the Northern part of the country, but these areas are too far from the large consumers (Figure 3).

### 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

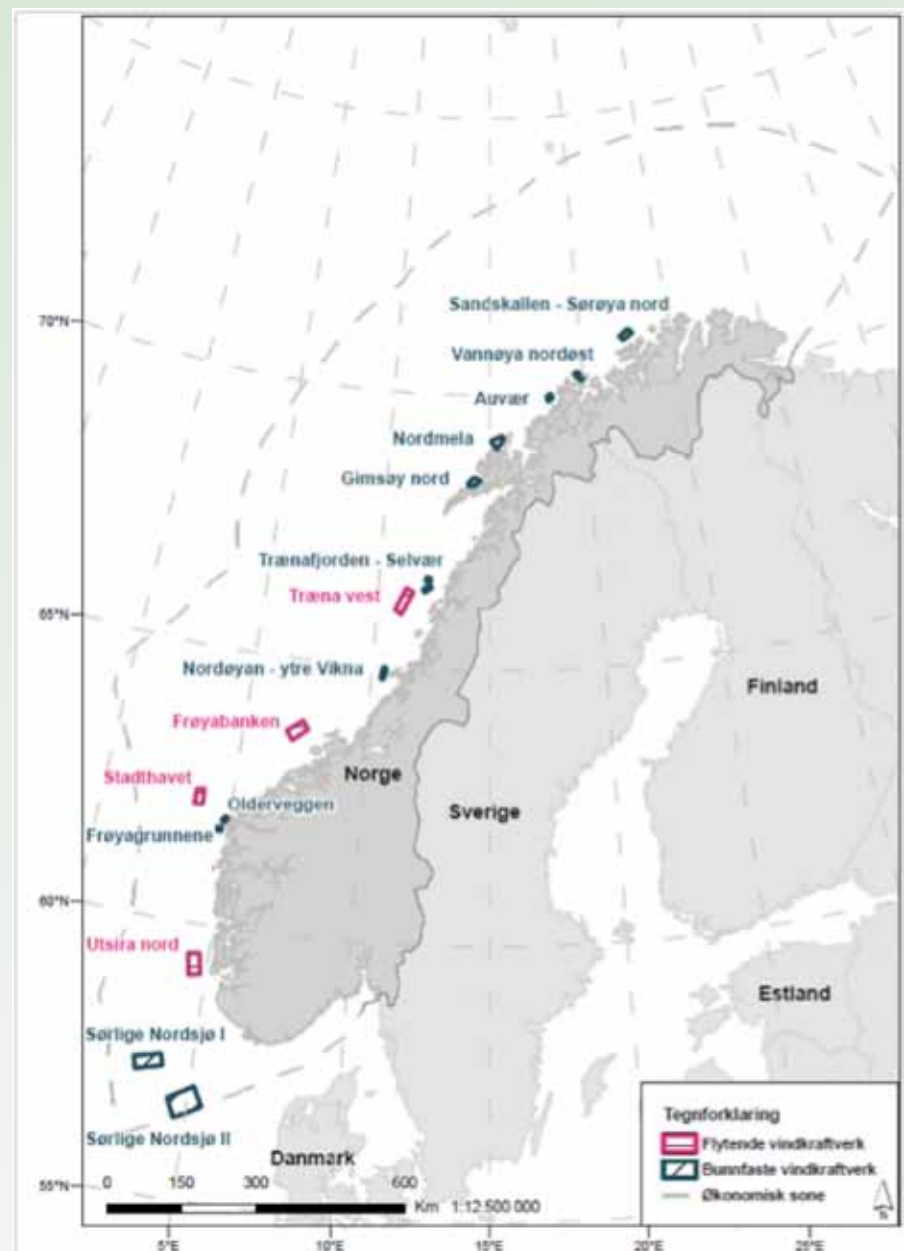


Figure 1 Fifteen areas have been singled out for potential strategic environmental assessment (SEA)

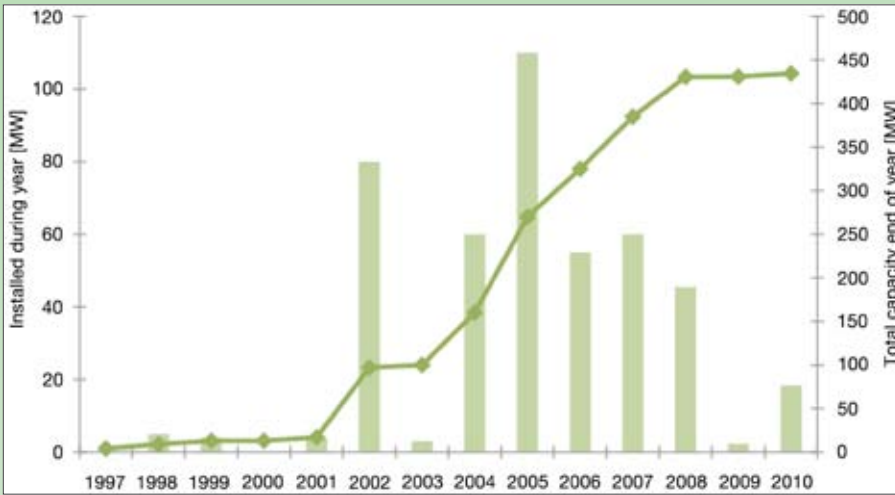


Figure 2 Installed wind power capacity in Norway

and nacelles. Companies with experience from the offshore oil industry (OEW 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 UK. So far, there is no significant wind turbine manufacturing industry in Norway.

**3.3 Operational details**

In 2009, the capacity factor of wind turbines varied between 17% and 43%. The average capacity factor was 24%. The technical availability of new wind turbines in Norway is usually in the range of 97% to 99%. Some wind farms are exposed to very harsh and turbulent wind. In those areas the availability is considerable lower, and in some places is even less than 80%. The mechanical impact of turbulent wind has apparently been underestimated.

**3.4 Wind energy costs**

The total wind farm installation costs are estimated between 12 and 14 million NOK/MW (1.4 to 1.7 million euro/

MW; 2.04 to 2.4 million USD/MW). Annual maintenance is reported to be between 0.12 and 0.22 NOK/kWh (0.014 to 0.026 euro/kWh; 0.02 to 0.037 USD/kWh), with an average cost of 0.14 NOK/kWh (0.017 euro/kWh; 0.024 USD/kWh). Estimates of production costs from sites with good wind conditions (33% capacity factor) suggest a production cost of about 530 NOK/MWh (64 euro/MWh; 90.1 USD/MWh), including capital costs (discount rate 8.0%, 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



Figure 3 Location of wind power installations



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 euro; 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 (NOWI-TECH) 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 following wind energy R&D projects were approved for funding in 2010:

- Innovative installation vessel: Ingenium AS
- Fred Olsen Wind energy drive train: Alfamor 7125 AS

In addition to this, several projects have been funded through the RENERGI budget the last few years. One of them is ChapDrive AS, that is developing a new turbine where the gearbox is placed on the ground and with hydraulic transmission of wind power. This was successfully tested through a 225 kW wind turbine at the VIVA AS test facility ([www.vivawind.no](http://www.vivawind.no)). An upgraded version on a 900-kW wind turbine was put into operation in June 2009. Another system for locating the generator at ground level is being developed by Anglewind. The system is comprised of a novel gear concept and a new drive train system for mechanical transmission of power. Workshop testing

of a gear prototype has been successfully carried out, and installation of a 225-kW wind turbine prototype is expected by early 2011.

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. The wind turbine can be placed at ocean depths of between 120 and 700 meters.

During 2009, a complete Norwegian Wind Atlas (onshore and offshore) has been developed. So far, the wind resources along the coastline have been mapped where most of the resources are located, but the project also revealed large wind resources in the inland areas.

#### 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

At the end of 2010, four large wind projects were under construction. There is great attention in the market regarding the upcoming green certificate system. One important milestone is the final decision by The Norwegian Parliament, which is expected to take place during spring 2011.

Authors: Karen Nybakke and Knut Hofstad, Norwegian Water Resources and Energy Directorate; and Espen Borgir Christophersen, Enova, Norway.



Photo Credit: Luis Marinho

### 1.0 Overview

In 2010 electric energy consumption grew 4.7% in Portugal reaching 52.2 TWh, the highest annual value recorded (1). The wind sector continued to grow although at half the rate of 2009. Presently Portugal accounts for an installed capacity of 3,987 MW, which accounted for 17% of the country's electric demand (Table 1). The renewable energy generating capacity arose to 9,490 MW (2) and is now 53% of the total installed capacity in Portugal. During 2010, the Portuguese government approved the PNAER - Plano Nacional de Acção para as Energias Renováveis setting the pace for continued growth of the wind energy sector, aiming for an installed capacity of 6,800 MW onshore and 75 MW offshore (6, 5).

### 2.0 National Objectives and Progress

#### 2.1 National targets

The targets established within the European Directive 2001/77/CE of 3,750 MW by the end of 2010 (5) were achieved during the first half of the year. In December 2010, a total installed capacity of 3,987 MW were already grid connected, alongside 543 MW that were already licensed (2).

In April 2010, the Portuguese government published the National Energy Strategy until 2020 (ENE2020) with the purpose of reducing by 25% the dependence on foreign energy sources pursuing the commitments with the EU on climate change policies that included a national target of 8.5 GW for the wind capacity (5). In June 2010 the PNAER

was published reviewing the installed capacity targets and establishing a course of action needed to reach an installed a minimum capacity of 6,875 MW by 2020. From which, 6,800 MW will be installed onshore and 75 MW offshore. The efforts will be centered on repowering existing facilities and developing of new licenses in order to reach the proposed targets (3, 5, 6).

#### 2.2 Progress

In 2010, deployment of 371 MW of new wind generation capacity was achieved. This represents a cut of 50% in the installation rate (which had been growing for the last three years) of 2009 which recorded a record value of 797 MW installed. The installed capacity during 2010 is distributed over 13 new wind farms with a total of 188 wind turbines deployed across the country, elevating the number of wind parks to a total of 208 and the number of wind turbines installed to 2,067.

The yield of generated wind energy was 9,024 GWh, which represented 17% of the national electric demand, an increase of 20% compared to the 2009 production (1). Figure 1 shows the evolution of the installed capacity, accumulated capacity, and the percentage of wind in the Portuguese energy demand in the past ten years.

A mean annual production of 2,403 hours at full capacity was observed during 2010, 173 hours more than the average in 2009. The production of wind energy by classes of number of hours at full capacity (NEPs) was mainly concentrated on wind parks with a NEPs ranging from 1,750 to 2,250 hours (46% of the total production) and on wind parks with a NEPs of 2,250 to 2,750 hours (39%). The wind farms with NEPs above 2,750 contributed with 12% of the production and the ones with lower NEPs, below 1,750 hours, contributed with 3% of the production (2) which re-enforces the perception of Portugal as a high wind resource country.

The renewable electricity production represented 52% of the gross electric demand. In renewable energy production, hydropower raised its contribution from

**Table 1 Key Statistics 2010: Portugal**

Total installed wind generation	3,987 MW
New wind generation installed	371 MW
Total electrical output from wind	9.024 TWh
Wind generation as % of national electric demand	17%
Target:	6,875 MW by 2020

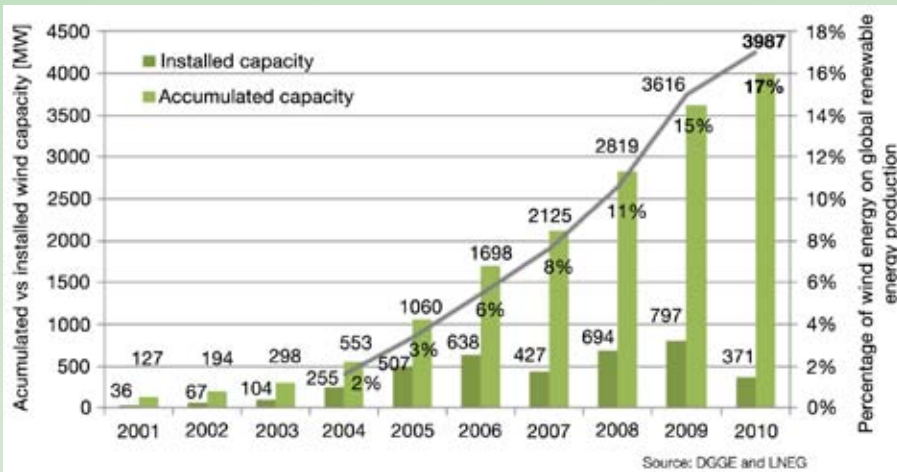


Figure 1 Installed versus accumulated wind capacity and percentage of wind in energy production

47% in 2009 to 57.6% in 2010, a growth of 82% in energy output. The wind energy yield increased by 20% in 2010. However the sector's contribution only represented 32% of the renewable production, decreasing from the 40% registered in 2009. The biomass sector represented 9.7% and PV represented 0.8% of the renewable energy yield (2). The first half of 2010, was especially good hydrologically. Hydropower plants more than doubled their production (approximately 128%) compared to the same period in 2009. This was the main driver for the lower relative contribution of the remaining renewable sources to the energy production of 2010.

### 2.3 National incentive programs

Within the European directive 2009/28/CE, the Portuguese government has approved the National Plan of Action for Renewable Energies (PNAER). This plan establishes minimum targets for all forms of renewable energy generation and energy efficiency (3). Under the scope of this program, several incentive programs are to be developed in order to achieve the proposed targets.

One of the most popular incentive programs for renewable generation has been micro-generation. Working since 2007, the procedure was suspended in the beginning of 2010 for reformulation of tariffs and operating capacity. On 25 October 2010 the Decree-Law 118-A/2010 (7) revising the micro-generation procedure was published. New limits for grid

connected power were established, rising from 14 MW to 25 MW per year. A new tariff, now lower than the previous, of 400 euro/MWh (537.60 USD/MWh) for the first 15 years was set.

Furthering the commitment to incentive programs on small-scale renewable energy generation, the Portuguese government approved in August 2010 (8) a program for facilities with maximum capacity of 250 kW. Named "mini-generation" the program has the target of installing a capacity of 500 MW until 2020 and foresees a total investment of 2,000 million euro (2,688 million USD).

### 2.4 Issues affecting growth

The Portuguese company E.Value publishes a monthly index on energy

generation and CO<sub>2</sub> emissions for the electricity sector. The month of December 2007 is used as a reference (value 1000). The purpose of the index is to follow the evolution of energy consumption and GHG emissions during the implementation period of the Kyoto protocol (2008–2012). The CO<sub>2</sub> emissions have been decreasing since October 2009 reflecting not only the growing importance of renewables on the energy mix but also a transfer of coal-based production to natural gas. The energy index grew steadily during 2010 reflecting as expected the electric demand.

In electric systems such as the Portuguese, a design parameter limit for the growth of its wind capacity is the excessive penetration of renewable non-dispatchable sources (e.g. wind power or river run-off hydropower). Contribution from these should never exceed the no-load consumption added by a reserve value of conventional controllable power. During the winter of 2010, the power system reached the highest instantaneous penetration (75%) and on the same day a record value of 61% of consumption supplied by wind energy was obtained (Figure 3). It is to be stressed that no technical problems were reported during the occurrence of these extremely high atypical wind penetration values.

## 3.0 Implementation

### 3.1 Economic impact

An economic impact study of wind energy on the Portuguese economy made by the Portuguese Renewable Energy Producers Association (APREN) and

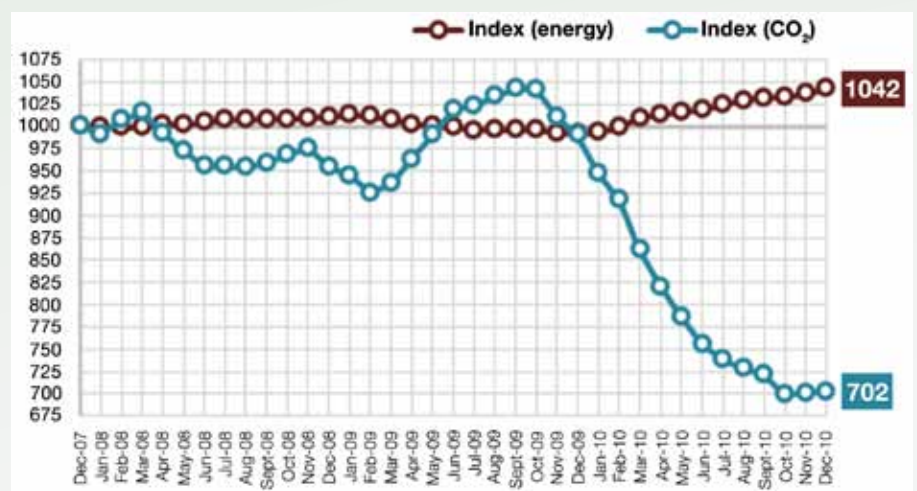


Figure 2 Energy and CO<sub>2</sub> E.Value Index for Portugal. Source: www.evalue.pt



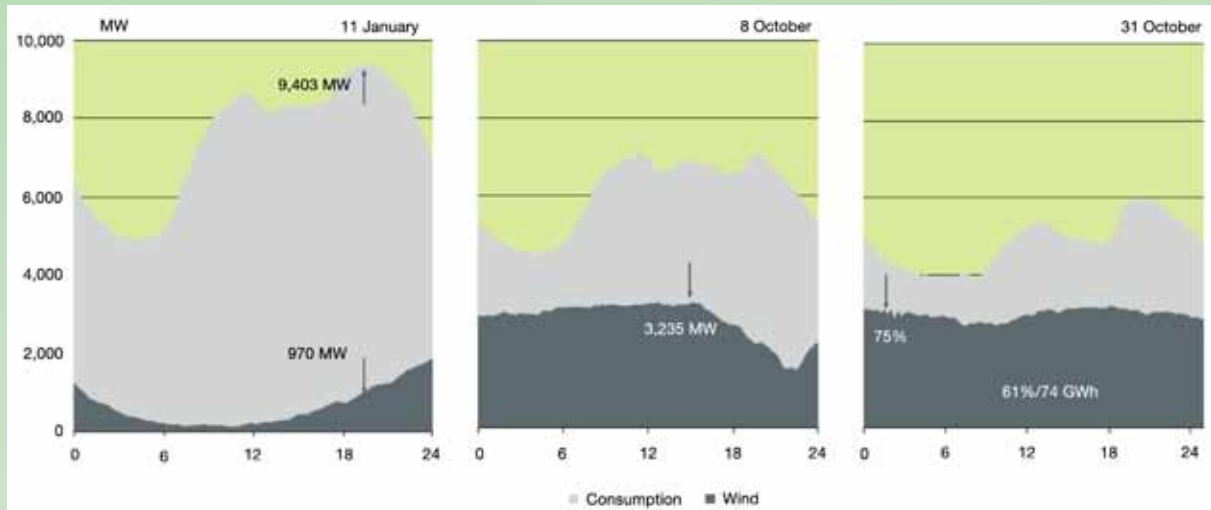


Figure 3 Record wind power penetration and energy generation during 2010 (31 October)

Deloitte (Portuguese economic consultancy company) was recently divulged (9). An analysis of the period between 2005 and 2008 and prospects for 2015 were made. At the end of the analysis period the wind energy sector was valued in 640 million euro (860.2 million USD), which is 32% of the entire renewable sector worth 2,000 million euro (2,688 million USD). The renewable sector came forth as one of most active sectors of the Portuguese economy with an average employment rate of 9% contrasting with the average 0.3% of all economy. The prospects for 2015 are very good for the renewable sector; it is expected that the sector should be responsible for 2.5% of GDP with the creation of 25,000 jobs. Adding to the existing capability, the sector should represent 60,000 jobs or 6% of the current unemployment level (9). The calculated savings on energy importations by the end of the analysis period ascended to 1270 million euro (1,707 million USD). The estimates from APREN and Deloitte point out to accumulated savings by 2015 of 13,000 million euro (17,472 million USD).

### 3.2 Industry status

During 2010, Enercon reinforced its leadership in the Portuguese market with its local production and now has a share of 48.1%. Enercon and Suzlon were the only players to increase their share during 2010. In second place with a share of 16% is Vestas followed by Gamesa (11%), Nordex (9.6%), Repower (4.4%), GE Wind (2.7%), Ecotecnia (2.7%), Suzlon (2.6%), and Izar Bonus (1.9%) (10).

The Enercon's wind technological cluster located in Viana do Castelo, a harbor city on the north of Portugal, employing nearly 1,500 workers has worked at full capacity during 2010 (10). Producing at a weekly average of 15 rotor blades, five concrete towers and three generators, the industrial cluster has already exported to countries like France, Ireland, Italy or even Germany according to its general manager Mr. Francisco Laranjeira. Expansion plans already exist for an investment of 55 million euro (73.9 million USD) that will allow the creation of 500 jobs. The project has been postponed since 2007 due to the financial crisis affecting the industry (11).

### 3.3 Operational details

Reviewing the 208 wind parks installed in Portugal by the end of 2010, 48% have

an installed capacity below 10 MW, 44% have a capacity between 10-50 MW, and the remaining 8% are above 50 MW (2). During 2010, 13 new wind farms were built, compared to the 21 deployed during 2009. From these, approximately half (46%) have a capacity between 10 and 50 MW, 31% have a capacity below 10 MW, and the remaining 23% have a capacity above 50 MW. The tendency to build large wind parks revealed during 2009 was maintained in 2010.

The two typical regions where wind turbines are operating in Portugal are the coastal and the mountainous regions. In terms of wind and production indexes, 2010 has been a contrast year between the two regions. According to LNEG (Figure 4), it was a year below average for resource availability, namely 0.96 at the mountain

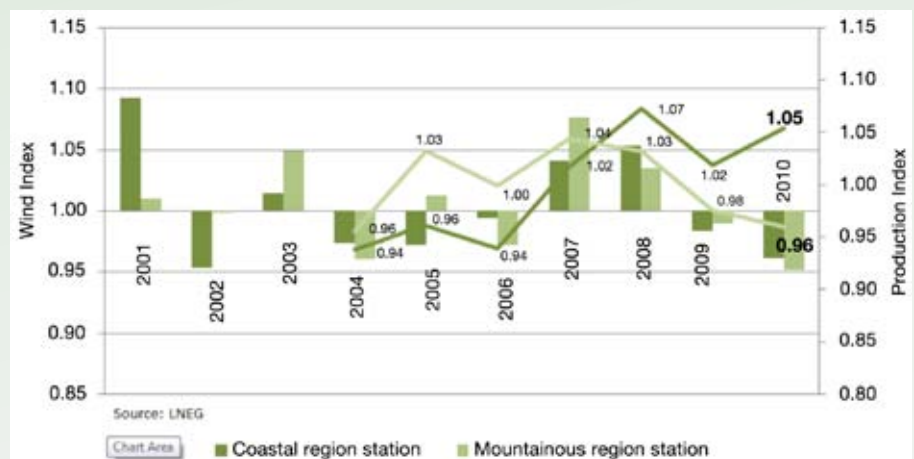


Figure 4 Wind (bar graph) and production indexes (line graph) on the coastal and mountainous regions of Portugal

and 1.05 on the coastal regions. At the latter corresponded a production index of 0.96, the lowest in six years but on the contrary a highly productive period occurred at the coastal region leveling the overall production index to values above one. Data from the Portuguese TSO (1) indicates a historical maximum in the production system with an overall wind generation index of 1.08 above average production between 2001 and 2009.

### 3.4 Wind energy costs

During 2010, the average cost per MW installed laid between 1,060 million euro and 1,470 million euro (1,425 million USD and 1,976 million USD), excluding grid connection and land contracting. The mean tariff paid to wind energy utilities during 2010 was 91.60 euro/MWh (123.10 USD/MWh) for wind power plants and 97.00 euro/MWh (130.37 USD/MWh) for mean tariff of the renewable independent producers (PRE) according to ERSE (the Portuguese energy regulator).

## 4.0 R, D&D Activities

### 4.1 National R, D&D efforts

Continuing the initiatives started in 2009, the national R&D efforts are mainly centered on the development of offshore wind and the development of tools and methodologies to maximize the penetration of renewable energy, as well as promoting energy sustainability.

The wind energy R&D activities are mostly developed in the regions of Oporto and Lisbon, where some of the groups are housed in academic or research institutes and are financed through national or European programs. The main R&D activities ongoing in Portugal include the following projects:

- NORSEWind “Northern Seas Wind Index Database” project, funded by EC FP7 for the characterization and evaluation of wind resource on the northern seas with the Portuguese participation of LNEG;
- ROADMAP project, funded by the Portuguese Foundation (FCT), with the purpose of identifying the constraints and barriers to the development of offshore energy in Portugal, developed by several Portuguese R&D institutes and companies;
- SEANERGY 2020, funded by EC-IEE to evaluate and further develop the maritime spatial planning

on the European space with the Portuguese participation of LNEG;

- REIVE “Redes Eléctricas Inteligentes com Veículos Eléctricos”, in the area of “Smart Vehicle to Grid” funded by FAI (Portugal), coordinated by INESC-Porto with the participation of LNEG and several leading industrial and energy companies;
- ANEMOS PLUS “Advanced Tools for the Management of Electricity Grids with Large-scale wind Generation” project funding by EC FP6 with the Portuguese participation of INESC-Porto;
- TWENTIES “Transmission system operation with large penetration of wind and other renewable electricity sources in networks by means of innovative tools and integrated energy solutions” project funding by EC FP7 with the Portuguese participation of INESC-Porto;
- MERGE “Mobile Energy Resources in Grids of Electricity” project funding by EC FP7 with the Portuguese participation of INESC-Porto among several others.

Assigned by the Portuguese government in 2008, the draft proposal of the Portuguese maritime spatial planning (MSP) was finally completed. Named POEM, the program aims to regulate the usage and coordinate the activities that take place on the Portuguese Exclusive Economic Zone (EEZ). Offshore wind and wave energy development guidelines have been developed and areas for the deployment were identified. LNEG has been at the forefront of the program contributing with the development of the Portuguese offshore Wind Atlas and identification of the sustainable offshore wind potential.

### 4.2 Collaborative research

The European Strategic Energy Technology Plan (SET-Plan) till 2020, has four strategic subjects for funded research. On each of the subjects of the SET-Plan, several projects have kicked off in Portugal. The first subject addresses the development of new turbines, components and materials. Projects FP7 Safetower, RFCS and Phasewind have cooperation of several industrial partners, including ISQ, A. Silva Matos, Martifer and others. The second subject covers offshore technology.

Project WindFloat from Portuguese utility Energias de Portugal (EDP) in collaboration with A. Silva Matos and Principle Power. The latter had already started in 2009 but was further developed when an agreement with Vestas for the supply of a 2-MW Vestas V80 was negotiated during 2010 and announced in the beginning of 2011. The third subject aims at developing the techniques for wind energy grid integration and productive system. Portuguese projects under the third subject involve several research institutions, namely INESC-Porto, LNEG, IST and others, are undergoing projects for clusters and aggregation of wind energy production, namely project FP7 Twenties, FP6 Wind-grid, FCT -Fluctwind and IEAWind Task 25. Finally, the fourth subject covers the characterization of the wind resource and planning of its exploitation. Projects under the scope of the fourth subject include: project Norsewind, project IEE Seenergy and project FCT Roadmap(12).

LNEG represents Portugal and participates actively in the European Energy Research Alliance Wind Programme (EERA - Wind), an initiative funded by leading European research institutes. EERA aims to strengthen, expand and optimize EU energy research capabilities and is actively supporting the SET-Plan.

### 5.0 The Next Term

Expectations are high for the recently approved “mini-generation” program as wind developers are awaiting the disclosure of procedures to submit their projects. Another highly expected event is the deployment of a WindFloat prototype equipped with a 2-MW Vestas turbine scheduled for mid-summer on the Portuguese coast.

For the ongoing R&D activities, the next term will bring some important milestones. Project Norsewind has scheduled towards the end of 2011 the publication of the preliminary offshore wind energy map for the Northern seas. The recently approved project Fluctwind is scheduled to kick off during the first months of the year. Financed by FCT, Fluctwind will contribute to characterize and categorize wind power fluctuations by a time-spectral wavelet analysis. Several other R,D&D areas related to wind energy are currently very active in Portugal with electric mobility, smart-grids, and hydro-wind management being the most relevant.

## Portugal

In what concerns the wind capacity deployment, it is expected that the 2010 installation rate will be maintained in the coming years, at least until 2015.

### References:

(1) A energia eólica em Portugal 2010. Technical report, Redes Energéticas Nacionais (REN), 2010.

(2) Renováveis - estatísticas rápidas. Technical Report 70, Direcção Geral de Energia e Geologia (DGEG), 14 March 2011 Dezembro 2010. Downloaded from <http://www.dgge.pt>.

(3) Plano nacional de acção para as energias renováveis (PNAER). Available at: <http://www.dgge.pt/default.aspx?cr=11260> (accessed on 11th of May 2011).

(4) Resolução do conselho de ministros n° 63/2003. Diário da República, n° 98:Série II-B, pp. 2722-2731, 28 of April 2003.

(5) ENE2020. Estratégia nacional para a energia. URL, available at <http://www.renewable.pt/pt/Paginas/default.aspx> (access on 11th of April 2011).

(6) Resolução do conselho de ministros n°29/2010. Diário da República, n° 73:Série I, 15 of April 2010.

(7) Decreto-lei n°118-a/2010. Diário da República, 207:Série I, 25 of October 2010.

(8) Resolução do conselho de ministros n°54/2010. Diário da República, 150:Série I, 4 of August 2010.

(9) Estudo impacto macroeconomico do sector das energias renováveis. available at [http://www.eneop.pt/destaque\\_esquerda.asp?id\\_destaque=120](http://www.eneop.pt/destaque_esquerda.asp?id_destaque=120) (accessed on 5th of April 2011).

(10) Parques eólicos em Portugal (dezembro 2010) - draft. Technical report, Instituto de Engenharia Mecânica e Gestão Industrial (INEGI), 2010.

(11) Enercon instala a sua milésima torre eólica em Portugal. Available at: [http://www.eneop.pt/destaque\\_direita.asp?id\\_destaque=131](http://www.eneop.pt/destaque_direita.asp?id_destaque=131) (accessed on 5th of April 2011).

(12) Ana Estanqueiro. Set plan: a iniciativa industrial europeia em energia

eólica (eii wind). In presented at Desafios e Oportunidades do SET-Plan e do Plano Solar Mediterrânico, 12 of May 2010.

Authors: Miguel Fernandes, Teresa Simões, and Ana Estanqueiro, LNEG-Laboratório Nacional de Energia e Geologia, Portugal.



# Chapter 28

## Spain



Photo credit: Antonio Perez

### 1.0 Overview

Installed wind capacity in Spain reached 20,676 MW in 2010 with the addition of 1,515.95 MW, according to the Spanish Wind Energy Association's Wind Observatory. Such smaller growth was expected after the 2,461 MW increases in 2009 in which companies made a big effort to keep the planned number of wind farms after spectacular wind capacity growth in previous years. The 20,676 MW of capacity establishes Spain as the fourth country in the world in terms of installed capacity and reaches the 2010 objective (20,155 MW set by the Renewable Energies Plan 2005–2010). The total electricity produced from wind in Spain in 2010 reached 42,702 GWh.

The creation of the new mandatory Pre-allocation Register by the Spanish central government has operated as a bottleneck to 2010 wind energy sector deployment. Because of this, the wind capacity increase has been moderate compared with the last few years. The addition of 1,515.95 MW in 2010 is an increase of 7.9%.

Electrical energy demand in 2010 was 259.94 TWh, an increase of 1.01% from 2009. Wind energy met 16.4% of this demand and was the third largest contributing technology in 2010. Other big contributors to the system were gas combined-cycle power plants (24.85% of total demand) and nuclear power plants (23.74%) (Figure 1).

Wind energy is a driving force for industrial development in Spain. In 2010, investment was more than 1,400 million euro (1,882 million USD), and about 50% of Spanish wind energy equipment production was dedicated to the export

market. But the Spanish Wind Energy Association (AEE) warns that a wind industry slowdown will be caused by the Register of Pre-Assignment by the Spanish government. In addition to this new requirement, uncertainty has been introduced because no regulatory framework has been established beyond 2013. Also, the economic crisis has caused the suspension of orders and the loss of jobs mainly in the industrial sector.

In 2011, according to sector forecasts, the industry will only install about 1,500 MW, the lowest figure since 2000. The Register of Pre-Assignment limits new wind capacity to 3,000 MW during the biennium 2011–12. But possibly the worst news for the sector, whose projects take five to eight years to realize, is that after 31 December 2012, it is not known if facilities shall receive remuneration, which will slow the installation of wind farms for the future.

In conclusion, it will be necessary to clarify the future regulatory framework in the wind sector without further delay if Spain is to reach 38,000 MW in 2020, the

goal of the NREAP sent by the Spanish government in Brussels last June.

### 2.0 National Objectives and Progress 2.1 National targets

The objective for 2010 established in the Spanish NREAP 2005–2010 has been reached and even exceeded. A new NREAP 2011–2020 is under development by the Spanish Ministry of Industry, Commerce and Tourism. The targets drafted in this plan were to add 35,000 MW onshore, with 34,630 MW for new large wind farms and repowering old wind farms and 360 MW for small wind (wind turbines up to 100 kW rated power) and finally 3,000 MW should be dedicated to offshore wind farms. This last figure is still under debate because of the difficulty to promote offshore wind farms in Spain. The difficulties include lack of adequate electrical infrastructure near shore, excessive requirement of permits, deep marine platforms required, low social acceptance, clash of interest, etc. The aim of this new plan is to meet

**Table 1 Key Statistics 2010: Spain**

Total installed wind generation	20,676 MW
New wind generation installed	1,516 MW
Total electrical output from wind	42,702 TWh
Wind generation as % of national electric demand	16.4%
Target 1. Official Network Planning	29,000 MW by 2016
Target 2. New National Renewable Energies Action Plan (NREAP)	38,000 MW by 2020

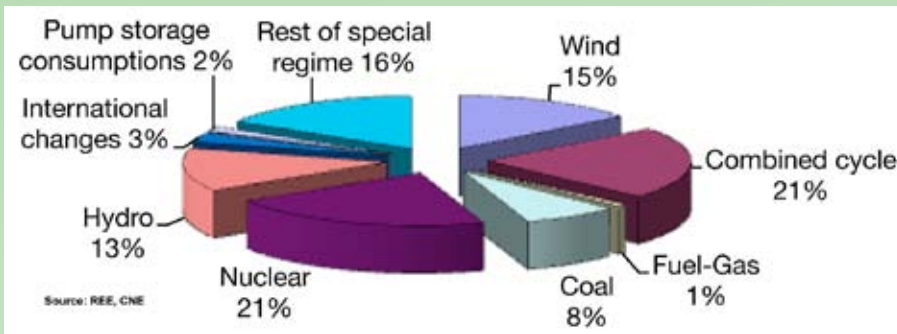


Figure 1 Electricity generation mix in Spain for 2010

at least 20% of total energy use from renewable sources by 2020.

### 2.2 Progress

The electrical generation capacity in the Spanish mainland system increased more than 3,717 MW during 2010 for a total of 97,447 MW according to the data of Red Eléctrica de España REE (the Spanish TSO) (3). Wind power and gas combined cycle were the technologies that contributed most to this growth.

With more than 20,676 MW of wind power installed, more than 18,933 turbines are operating in Spain, grouped among 889 wind farms. The average size of an installed wind farm in 2010 was 26 MW. Wind energy is present in 15 of the 17 autonomous communities. Castilla-Leon has the most installed power among them, with 4,803.82 MW. This autonomous community has had the biggest growth with 917.02 MW added in 2010, and it has a wind capacity forecast of 6,898 MW including the wind farms already under construction once the administrative permit goes into operation. Catalonia experienced 62.32% growth, the second biggest, with 326.87 MW installed in 2010. It has 851.41 MW of total capacity installed. The third biggest growth has been in Murcia with 24.69% (37.60 MW) reaching 189.91 MW. With only 6 MW of new capacity installed in 2010 in Castilla-La Mancha region, it stays in second place with total capacity of 3,709.19 MW. This autonomous community approved a new so-called “wind decree” in 2010. It is similar to the regulation already approved in Galicia, which establish a new tax on wind farms developers (different tax depending on the number of wind turbines included in the wind farm) with the compensation based on territory and visual impact produced by the wind farms. The

autonomous government estimates that during the first year of operation the permit fees will raise about 15 million euro (20.2 million USD).

Castilla-La Mancha is followed by Galicia, which added 54.8 MW for a total of 3,298.33 MW and Andalucía which added 139.41 MW for a total capacity of 2,979.33MW. Only two autonomous regions, Extremadura and Madrid, have not yet installed any wind power capacity. However, they have advanced projects and regulation to start wind energy activities, especially Extremadura region.

It should be noted that unlike many other countries with significant wind development, Spain has increased its distribution throughout the country. Figure 3 shows wind energy development and annual growth by region.

Use of wind power has lowered CO<sub>2</sub> emissions by about 23 million tons just

during 2010. Furthermore, wind generation has saved up to 8.5 million tons of conventional fuels and has supplied the electrical consumption of more than 13.5 million households.

### 2.3 National incentive programs

The promotion of renewable energies has been a stable national policy for several years. All political parties have similar policies regarding support of renewable energies. The main tools within this policy at a national level are:

- A payment and support mechanism enacted by the Parliament through Electric Act 54/1997: Producers of renewable energy sources are entitled to connect their facilities and transfer the power to the system through the distribution or transmission grid and receive remuneration in return.
- The previous NREAP (2005–2010), which included midterm objectives for each technology, has been fulfilled. Until the new NREAP (2011–2020) is launched, the tariff schemes are guaranteed.
- Royal Decree (RD) 661/2007 regulates the price of electricity from renewable sources in Spain. The new 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.

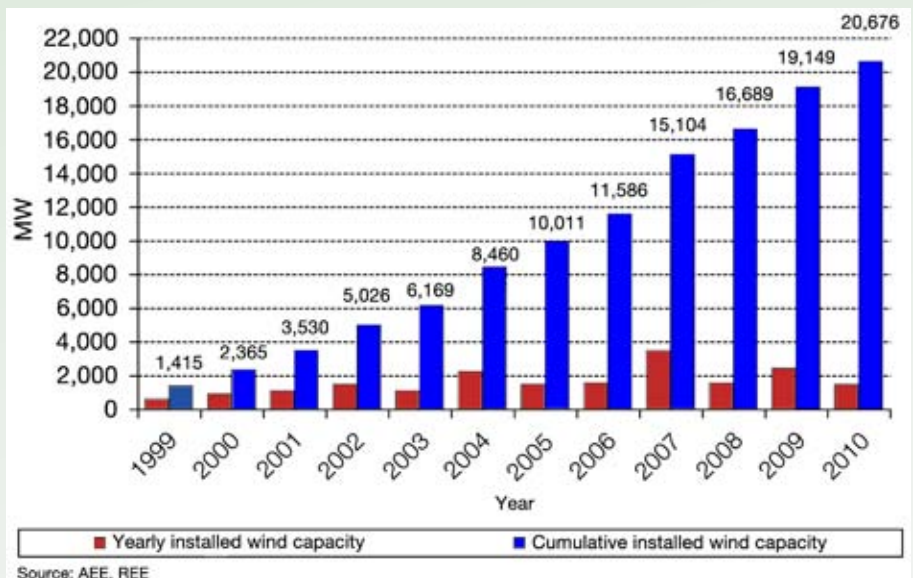


Figure 2 Annual cumulative wind capacity installed in Spain in 2010

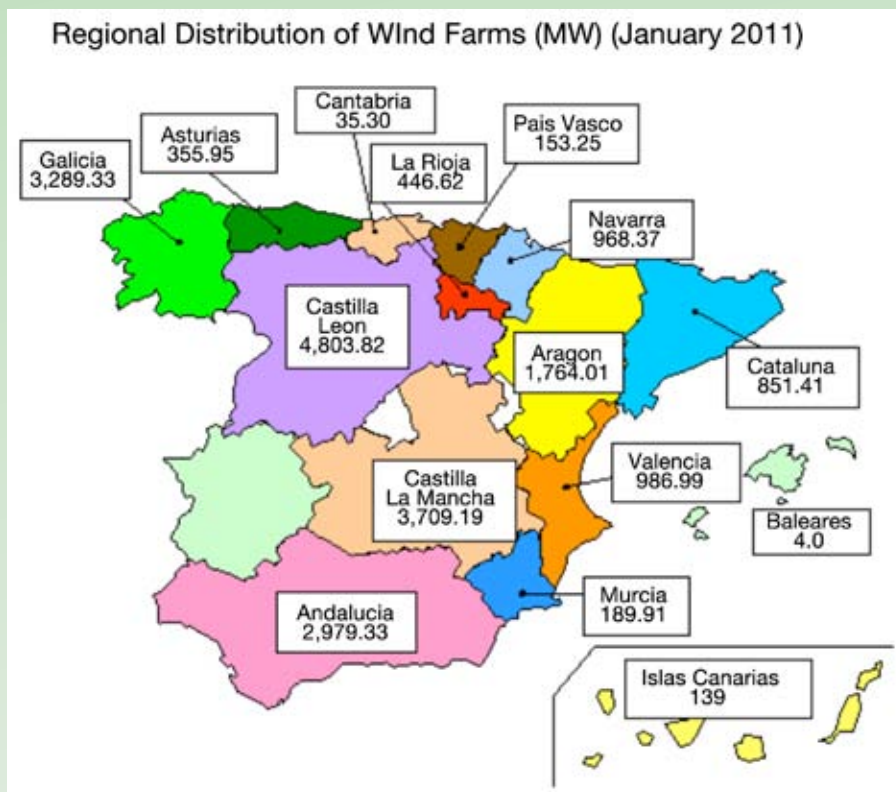


Figure 3 Wind energy capacity distributions by autonomous communities (MW)

- Royal Decree Act (RDA) 6/2009 established a new mandatory instrument called “Pre-allocation Register” where all new promotions must be included before obtaining the required permit. This instrument aims to define the adequate 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 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 2010, the value was 77.47 euro/MWh (104.12 USD/MWh); the update is 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, and 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 2010 are reference premium 30.99 euro/MWh (41.65 USD/MWh), lower limit 75.41 euro/MWh (101.35 USD/MWh), and upper limit of 89.87 euro/MWh (120.79 USD/MWh).

A new Royal Decree 1614/2010, establish the review in terms of temporary limitation of the feed-in tariffs for the wind installations included in the RD 661/227 for the period 1 January 2011 to 31 December 2012.

Finally a new small wind systems grid connection requirements act and feed-in tariff for small wind is under discussion.

#### 2.4 Issues affecting growth

The economic slowdown has affected the wind industry toward the end of 2010. Also, a new mandatory instrument called “Pre-allocation Register” aims to define

adequate RES progress taking into account, energy prices, electricity tariff deficit, and network capacity. As a result of this decision, wind turbine production is declining and more than 10,000 jobs have been lost. The regulatory modifications have resulted in declining demand for wind turbines and consequently many companies have started job layoffs. Development in 2011 may be as low as 1,500 MW, the lowest figure since 2000.

### 3.0 Implementation

#### 3.1 Economic impact

The number of installations during 2010 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 2010, the largest manufacturers were Gamesa (760.7 MW new capacity), Vestas (500.4 MW new capacity), Alston Wind (141.78 new capacity), and GEWind (94.5 MW). In addition, some companies have appeared in the Spanish market like the German manufacturer Furlander with 12 MW or the Spanish SWEG (Former MTorres, now owned by an Egyptian industrial holding) with 6.6 MW (Figure 4).

Gamesa is still the top manufacturer in Spain with 11,108.07 MW total wind capacity installed, although in 2010 was the first time 100% of its sales were outside Spain. In the second position is Vestas Windpower with 3,528.72 MW total wind capacity installed, and Alston Wind moved into third place with 1,559.85 MW.

Several new manufacturers are developing small wind turbines from 3 kW to 100 kW for grid-connected applications, and two manufacturers are working on new mid-sized wind turbine prototypes in the range from 150 kW to 300 kW.

Iberdrola Renovables, the largest Spanish utility, has the largest accumulated capacity (5,168.50 MW) thanks to the addition in 2010 of 289.22 MW. However, the company installed more than 1,780 MW outside of Spain, with 39 new installations in eight countries.

Acciona Energy, in second place, has accumulated capacity of 4,036.82 MW



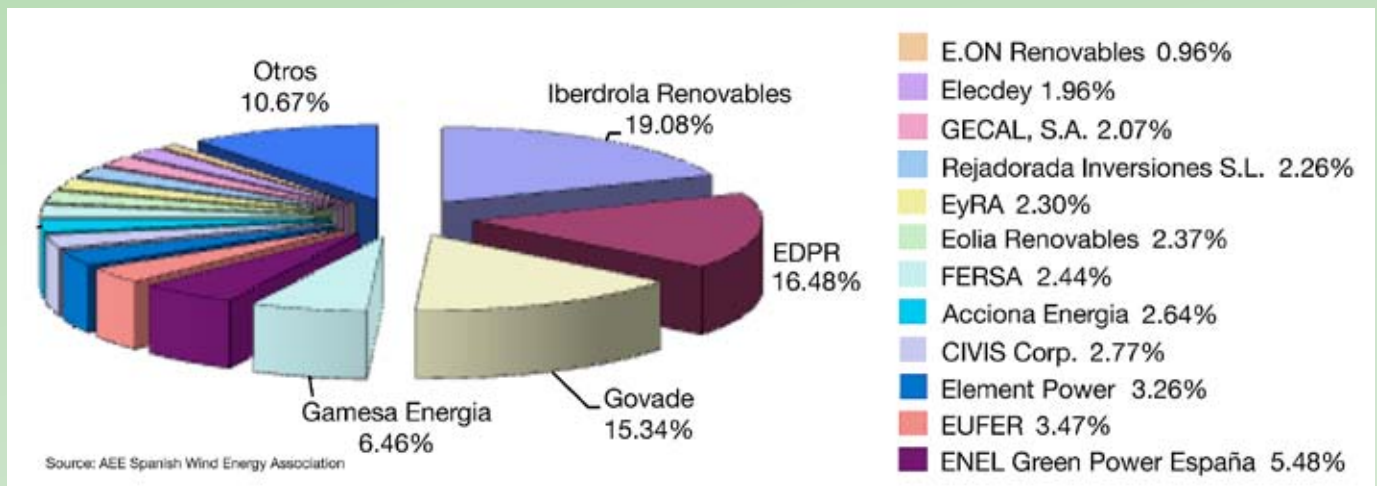


Figure 4 Installed wind capacity by manufacturer at the end of 2010

with little new capacity (40 MW) in 2010. The Portuguese EDPR, with 1,862.92 MW total, installed 249.78 MW during 2010. The Spanish property group Govade installed 232.52 MW and several other developers have installed wind power capacity during 2010 (Figure 5).

### 3.3 Operational details

The number of wind turbines in Spain increased by more than 882 in 2010, and the total number of turbines is more than 18,933 units. The average size of a wind turbine installed in 2010 was 1.85 MW.

Wind turbines operating in Spain show important seasonal behavior. Total electricity generated by wind farms was more than 42,702 GWh, and the equivalent hours at rated power were slightly higher than 2,000 hours for all of the wind farms. On several occasions during 2010, wind power exceeded previous historical instantaneous power peaks and maximum hourly and daily energy production. On 9 November 2010 the most daily energy was produced, 315,258 MWh; this production covered 43% of the power demand of that day. Also in February there was a monthly maximum of generated wind power covering 21% of the demand for that month. However, the variability that characterizes this energy has led to extreme situations. On 9 November (3:35 am), 54% of total power demand was covered by wind energy, while on 26 June (10:32 am) only 1% of the power demand was covered by wind energy. On the other hand, the high wind resource during the

first quarter of the year forced some power curtailment during hours of low power demand, which means losses of 0.6% of yearly production.

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.

### 3.4 Wind energy costs

The increasing use of large wind turbines (2 MW of nominal power), the increasing prices of raw materials, the shortage of main components, and the excess demand for wind turbines have increased prices for wind generators. The average cost per kilowatt installed during 2010 in Spain was about 1,250 euro/kW (1,680 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 (R&D&I) programs funded by the national government and by the autonomous communities. The national R&D plan covers the period from 2008 to 2011 for the R&D and technological program prepared by the Spanish national government. It is based on the national science and technology strategy instead of thematic areas as in previous calls. The national program consists of basic research and innovation programs. The basic research program is not oriented research and the leaders are researchers from universities and public and private R&D centers.

The Innovation Program is focused on technological research and leaders

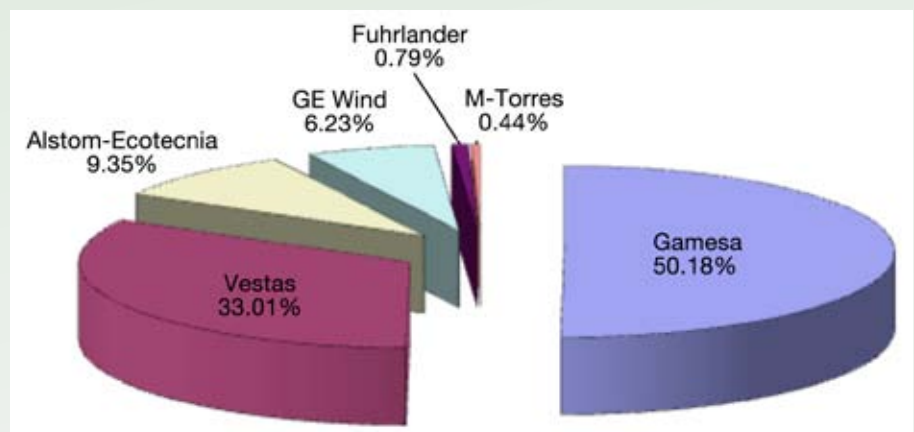


Figure 5 Percentage of installed wind capacity by developer at the end of 2010

must be researchers from private or public companies (SME's or large companies) with the collaboration of research centers (private or public research centers, universities). Three main subprograms are included in the innovation program:

- Industrial and public research collaboration
- Strategic consortia for technical research
- Support actions

The industrial and public collaboration subprogram was launched to increase the collaboration between companies and research centers with clearly defined objectives and results oriented to the development of innovative devices, systems, processes, service, or equipment with clear market orientation. For this reason, most of the funding is based on soft loans for the companies and granting only available for public research centers and partially for private research centers.

The first instrument within this program was called "PSE -Singular and Strategic Projects" which are Strategic National Consortia for Technological Research led by the industrial sector in collaboration with the public and private research centers. This program is already closed but there are still projects on going until mid-2011.

A project called Minieolica is developing to promote the Spanish small wind energy sector (new development of turbines up to 100 kW). This project involves more than six manufacturers of small wind turbines and components, three engineering companies, five public and private research centers, three universities, and three end users. The 16 projects are organized in three main areas:

- Product development supports manufacturers to develop new products from 1 kW and 5 kW for urban and residential applications (innovative horizontal- and vertical-axis wind turbines) and from 20 kW to 100 kW very reliable, robust, and efficient new designs of small wind turbines for residential, industrial, and agricultural applications.
- Technical development supports breaking technological barriers and advancing development in key areas for small wind turbines.
- Infrastructure development promotes, disseminates, sensitizes, and

collects information for the small wind turbine sector.

Another important PSE project approved within the R&D strategic public-private entities collaboration is a new project called Emerge lead by the company Iberdrola Renovables. It was approved in 2009 for four years. This project is developing useful technology to build offshore wind farms in deep waters. The partnership is composed of private companies as Iberdrola Renovables, Alston Wind, Acciona Energia, and KV Consultores and R&D centers as Robotiker (Tecnalia Corp), the Catalonia Institute for Energy Research IREC and public research organizations such as the Basque Country University and UPV and Cadiz University UCA. This project is composed of four sub-projects:

- Subproject 1: Design and development of wind turbines for offshore application
- Subproject 2: Design and development of floating support structures for offshore wind applications
- Subproject 3: Analysis and development of electrical link technology for deep waters offshore applications.
- Subproject 4: Analysis and development of wind turbine-support structure coupling solutions.

The total budget of the Emerge project is 9.2 million euro or 12.4 million USD (2009-2012).

In 2010 the PSE Instrument has been replaced by a new instrument called the INNFACTO Program.

In 2010, two projects were approved:

- Offshore wind generation system in deep seawaters lead by Iberdrola Renovables (the second phase of project Emerge). The goal is to develop useful technology to build offshore wind farms in deep waters, including floating platforms and HVDC connections. The consortium includes private companies like Iberdrola, Alston wind, Acciona energia and KV Consulting and R&D centers like Tecnalia Corporation (Robotiker), Irec, Cener, Cantabrian Institute of Hydraulic - ICH and Universities like University of Basque Country UPV and Cadiz University UCA. The budget is 5.53 million euro (7.43 million USD).

The Project duration is 30 months (6/2010 - 12/2013). This project is structured into four sub-projects:

- o Subproject 1: Design and development of wind turbines for offshore application
- o Subproject 2: Design and development of floating support structures for offshore wind applications
- o Subproject 3: Analysis and development of electrical link technology for deep waters offshore applications.
- o Subproject 4: Analysis and developments of wind turbines-support structure coupling solutions.
- Project titled "Development of a Intelligent floating Meteorological tower for ocean and wind resource characterization."

The strategic consortia for technical research sub programs was launched to increase the collaboration between companies and research centers. It has clearly defined objectives to build capacities in private strategic consortiums to address technical challenges and make these companies leaders in innovative technologies. The leaders of the consortia must be market leaders with interest to develop innovative technology for the future. Most of the funding is grants for the companies (50% of the total budget); the rest must be fund by the company itself and by public research centers and private research centers must be subcontracted by the companies.

In this subprogram, the most important instrument, CENIT, 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 aimed at increasing investment in R&D for both public and private initiatives over the next few years, with the objective of reaching 2% of GDP. The program started in 2006, and so far four R&D projects have been approved: Windlifer 2015 (completed), Eolia (in progress), Ocean-Lider (in progress), and Azimut (New).

Eolia is a consortium of 16 companies led by Acciona Energia with a CDTI grant of 16.7 million euro (22.5 million USD), not quite half the overall 33.9 million euro (45.6 million USD) estimated total investment required. Eolia includes 25 research centers and seven private companies subcontracted by the consortium. Its objective

is to develop technologies enabling deployment of offshore wind plants in deep waters (over 40 m). The project's research activities integrate a series of technologies, including energy (wind power and other electricity technologies) aquaculture, desalination, construction, naval and marine grid connections, and O&M technologies.

The Ocean-Lider project is designed to help develop breakthrough technologies to implement integrated facilities for the use of renewable ocean energy (wave, currents and hybrid systems: wave/wind and currents/wind). Iberdrola will lead the project for 38 months (From 9/2009 to 12/2012). The eligible budget is 29.75 million euro (39.9 million USD) and the grant approved is 14.68 million euro (19.7 million USD). The Partnership of the project includes Iberdrola Ingeniería y construcción SAU, Acciona Energía S.A, Areva, Igeotes, Gmv Sistemas, Ibaia, Iberdrola Renovables, Idesa, Ingeteam, Norvento S.L, Nem Solutions, Oceantec, Praesensis S.L., Proes, Prysmian Cables, Seaplace, Sener Sistemas, Tecnoambiente, Taf and Vincinay Marine Innovations.

The Azimut project will generate knowledge to achieve new large wind turbines (15 MW) for offshore applications that will overcome challenges like efficiency, availability, cost of energy, and capital cost. Gamesa will lead this project with an eligible total budget of 25.1 million euro (33.7 million USD) and approved grant of 11 million euro (14.8 million USD) (43.71%). The industrial consortium includes wind turbine manufacturers (Gamesa, Acciona Windpower, Alston Wind); wind farm owners; utilities like Iberdrola; individual industrial developers (Acciona Energía); and industrial suppliers (Ingeteam, Ingeciber, Técnicas Reunidas, Imatia, Digsilent, Tecnitest). The research centers subcontracted are Cener, Tecnalia Corp (Robotiker, Inasmet), Ikerland, Irec, Csic-IcMab, Aimp-las, Circe, Eupla, Catec, Cehpar, Imdea, and IIT. The Universities subcontracted are University of Coruña, University of Cantabria, Politechnical University of Madrid, and University of Valencia.

The "support actions" subprogram funds 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 INNPLANTA Program, managed by the Ministry of Science and Innovation (MICINN), also funds some projects. One project will foster the development of a new, highly complex technology for deep-water offshore wind turbines that will allow installation of wind farms far enough from the coast to avoid visual impact on the landscape. The budget was 70 million euro (94.1 million USD) and the grant 12.5 million euro (16.8 million USD). Collaboration agreements have been signed with Iberdrola, Enel, Alstom, Acciona, FCC, Prysmian, EDPRE, Gas Natural Fenosa, Gamesa, Siemens, Comsa Emte, Enerfin, Vortex, Normawind, and Barlovento.

In relation to new infrastructure for research purposes two new facilities are under development:

#### **CENER New experimental onshore wind farm**

This new test facility operated by the National Renewable Energy Centre CENER is located in Aoiz (Navarra). The topography is defined as complex terrain and there are six calibrated positions to install prototypes of large wind turbines up to 5 MW each (separation 280 m), and five additional meteorological towers, 120 meters high. The main purpose of this facility is prototype testing and certifying wind turbines. The 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 Test Station (IREC)**

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). The test station will serve as a laboratory for testing new technology required in this field 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 Q4 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 Q4 2012.

#### **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 and Task 27 Labeling Small Wind Turbines. A new task led by Spanish experts in wind flow modeling in complex terrain is under development.

#### **5.0 The Next Term**

Expectations for the Spanish wind energy industry for 2011 are not very optimistic. The slowdown in 2010 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. Wind was included mainly because of the high feed-in tariff cost, and also because of some local grid integration constraints.

Electricity prices seem likely to be flat in 2010 and may not exceed 80 euro/MWh (107.5 USD/MWh) (especially if the contribution of hydropower to the system continues increasing and oil prices do not increase too much). During 2011, technology and installation costs are expected to be lower than 2010. With a joint effort of the transmission system operator, utilities, and the wind energy sector, wind parks will continue to increase their contribution to meeting electrical demand.



The target defined in the PER 2005–2010 of 20,155 MW by the end of 2010 has been reached. A review of the support scheme has been done. The new NERAP 2011–2020 with new objectives and tariffs will be delivered during 2011. A realistic estimate for wind energy in Spain is that 35,000 MW of onshore and 3,000 MW of offshore wind capacity could be operating by 2020, providing close to 30% of Spain's electricity.

**References:**

(1) The Spanish Renewable Energy Plan 2005–2010, Instituto para la Diversificación y Ahorro de la Energía (IDAE; Institute for Diversification and Saving of Energy) July 2005. [www.idae.es](http://www.idae.es).

(2) Wind Power Observatory. 2010, Asociación Empresarial Eólica (AEE; Spanish Wind Energy Association). January 2011. [www.aeeolica.org](http://www.aeeolica.org).

(3) The Spanish Electricity System. Preliminary Report 2010, Red Eléctrica de España. REE. December 2010. [www.ree.es](http://www.ree.es).

(4) REOLTEC. Spanish Wind Power Technological Platform IV General Assembly. [www.reoltec.net](http://www.reoltec.net)

Authors: Ignacio Cruz, CIEMAT, Spanish Ministry of Science and Innovation; and Enrique Soria Lascorz, Asociación Empresarial Eólica (AEE, the Spanish Wind Energy Association), Spain.



Photo Credit: StorRotliden Vattenfall AB

### 1.0 Overview

Nearly three times as much capacity (604 MW) was installed in 2010 compared to the installations of 2008 (216 MW) and more than in 2009 (512 MW). The goal is to increase renewable generation by 25 TWh/yr by 2020 compared to the level in 2002. A major part of the wind power related research financed by the Swedish Energy Agency is carried out in the research programs Vindforsk III and Vindval. The technical program Vindforsk III runs from 2009 to 2012 and has a total budget of about 80 million SEK (8.6 million euro; 11.6 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 euro, 5.1 million USD). The new research center, Swedish Wind Power Technology Center (SWPTC) at Chalmers Institute of Technology has started

during 2010. 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 on land 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 2.5 TWh in 2009 to 3.5 TWh in 2010 (Figure 1).

The Swedish electricity end use in 2010 was 132.2 TWh, a decrease of about 4% compared to 2009. Decreased electricity demand in industry was the major reason for the decrease. In the household and service sectors, a minor increase was noted, mostly explained by colder weather

conditions during 2010. The wind power electricity generation share is now 2.6%.

### 2.1 National incentive programs

Two main incentive programs are promoting 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 MWh of renewable electricity that they produce. This certificate can be sold to provide additional revenue above the sale of the electricity, improving the economics of electricity production from renewable energy sources and encouraging the construction of new plants for the purpose. The demand for certificates is created by a requirement under the Act that all electricity suppliers and certain electricity users purchase certificates equivalent to a certain proportion of their electricity sales or use, known as their quota obligation. The price of certificates is determined by supply and demand, and it can vary from one transaction to another.

#### 2.1.2 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. From 2003 to 2007, the budget was 350 million SEK (38 million euro, 51.1 million USD). The market introduction program has been prolonged

**Table 1 Key Statistics 2010: Sweden**

Total installed wind generation	2,163 MW
New wind generation installed	604 MW
Total electrical output from wind	3.497 TWh
Wind generation as % of national electric demand	2.6 %
Target	30 TWh wind power by 2020

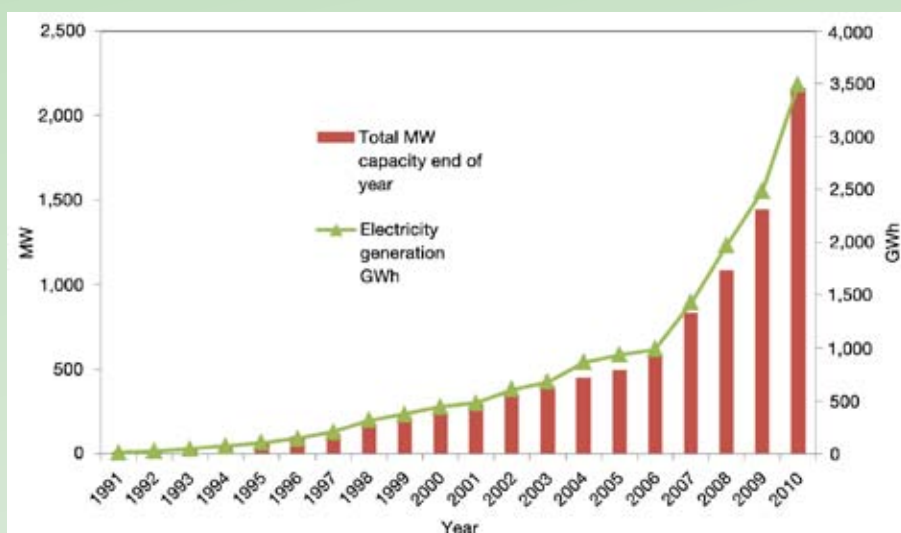


Figure 1 Installed wind power capacity in Sweden 1991 to 2010

another five years with an additional 350 million SEK for the period 2008 to 2012. The projects funded 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

The Swedish Energy Agency is the expert authority appointed by the government to promote the development of wind power, taking a holistic approach to encouraging the rapid expansion of wind power (1). Therefore, the Swedish Energy Agency has started a national network for wind utilization. A national network is of importance 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 – facilitating the permission process

One of the key obstacles prolonging the permission process for wind power is the huge number of stakeholders in

**Table 2 Projects with support from the market introduction program**

Project	Recipient company	Support In millions	Location	Estimated yearly production year of operation
Lillgrund	Örestads vindkraftpark AB (owned by Vattenfall)	213 SEK (23 euro, 30.9 USD)	Offshore	330 GWh; operating since late 2007
Vindpark Vänern	Vindpark Vänern Kraft AB	40 SEK (4.3 euro, 5.8 USD)	Largest Swedish lake	89 GWh; operation in 2009
Uljabouoda	Skellefteå Kraft AB	35 SEK (3.8 euro, 5.1 USD)	Onshore arctic	100 GWh (2008)
Kriegers Flak	Sweden Offshore Wind AB (Vattenfall AB)	9.45 SEK (1 euro, 1.34 USD)	Offshore	No production. Only development program, reported
Storrun	Storrun AB	26.25 SEK (2.8 euro, 3.8 USD)	Onshore	80 GWh, 2009
Large scale wind power in northern Sweden	Svevind AB	115 SEK (12.4 euro, 16.7 USD)	Onshore	197 GWh, 2009-2011
Large scale wind power in southern Swedish forests	Arise Windpower AB	50 SEK (5.4 euro, 7.3 USD)	Onshore	140 GWh, 2009-2010
Large scale wind power in highland areas	O2 Vindkompaniet	72.5 SEK (7.8 euro, 10.5 USD)	Onshore	260 GWh, 2011
Havsnäs	NV nordisk Vindkraft AB	20 SEK (2.2 euro, 2.9 USD)		256 GWh, 2009-2010
Vindval		35 SEK (3.8 euro, 5.1 USD)		Environmental research program



the process (2). Hence information a developer of wind power has to take into consideration is widespread, comes in different formats and quality, or simply is not accessible. Furthermore staying up-to-date on this information requires considerable work. Some stakeholders might also be overlooked.

The website Vindlov.se (e.g. wind permit), launched in February 2010, takes a unique approach targeting 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](http://www.vindlov.se/kartstod)) enables the wind power developer to get an on the fly view, share and attach up-to-date public geographic information to a project without being a specialist in Geographic Information Systems. The service is free of charge and can also be accessed via a so-called WMS service in order to easily combine own wind park layouts and localisations 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 kind, electricity trunk lines, valuable natural and cultural

environments, and concession areas for mineral excavation.

### 3.0 Implementation

The expansion onshore is mostly driven by the large utilities like Vattenfall and E.ON but also by other actors. Utilities, developers, real estate companies, and private persons are developing smaller and larger projects. Of the erected wind power in 2010, Vestas achieved a market share of 59%, Enercon 25%, Nordex 4%, Simens 3%, WinWinD 3%, GE Wind 2% and Kenersys, Suzlon, Fuhrländer about 1% (Figure 2).

The large, international manufacturers of turbines, Vestas, Enercon, Nordex, 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 (former 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 relevant to their know-how are also established in Sweden.

### 3.1 Operational details

Wind power in mountainous terrain and cold climate is gaining more and more interest. Northern Sweden exhibits many such areas, where the wind potential is high. Two new projects began operation in such areas: Havsån, 94 MW; and

StorRotliden, 78 MW. Both wind farms are built with Vestas 1.8–2-MW machines. StorRotliden is owned and operated by Vattenfall and was built in two phases, the first started with civil works and the construction of foundations from early summer 2009. After a minor winter break, the remaining construction was carried out during 2010.

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 Task 11. 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.

### 4.0 R, D&D Activities

Publicly funded wind energy research in 2010 was mainly carried out within the Vindforsk (4) and Vindval research programs (5). The present phase of Vindforsk (Vindforsk III) runs from 2009 to 2012 with a total budget of 20 million SEK/yr (2.2 million euro, 3 million USD). 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

At the end of 2010, Vindforsk, Vindval, and SWPTC together invited interested actors to a conference where researchers and organizations participated and presented research projects. During 2010, intensive work has been 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 administered 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 euro, 5.3 million USD). Within this time period, the

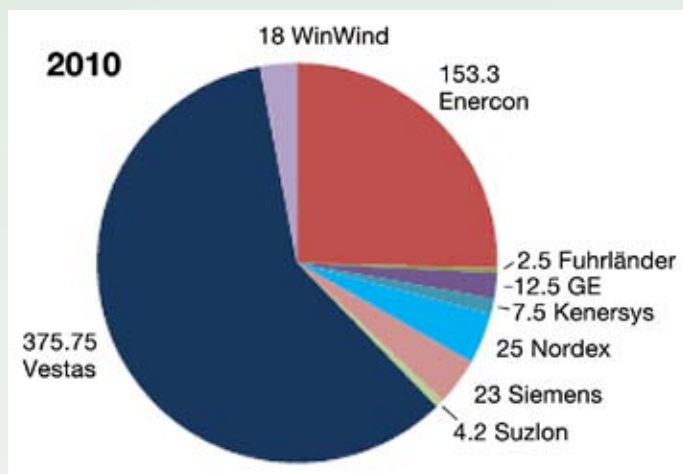


Figure 2 Installed capacity 2010 (603.75 MW) (4)



Figure 3 StorRotliden Vattenfall AB

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.

Some of the projects in these programs and other R&D projects that have been funded.

- High Voltage Direct Current (HVDC) electricity system for off-shore wind power
- The Swedish Wind Power Technology Center started in 2010 and has a focus on research for development of wind turbine design to optimize costs of manufacture and maintenance: the objective is to build component and system knowledge and to support Swedish industry with knowledge of design technology in the field of wind.
- Stochastic model predictive control of wind turbines. The primary control objective is mitigation of turbine loads at high wind speeds. More precise regulation close to limits has the potential to improve turbine efficiency at high wind speeds.

- Models of electrical drives for wind turbines. The project will develop suitable models of the electrical drive system for integration with the mechanical system in a wind turbine.

### 5.0 The Next Term

The two research programs Vindval and Vindforsk continue with new research projects in 2011. 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 activities at SWPTC will continue and with new research projects in 2011.

### References and notes:

- (1) [www.natverketforvindbruk.se/](http://www.natverketforvindbruk.se/)
- (2) [www.vindlov.se](http://www.vindlov.se)
- (3) [www.svenskvindenergi.org/files/Statistik\\_vindkraft20110218.pdf](http://www.svenskvindenergi.org/files/Statistik_vindkraft20110218.pdf)
- (4) [www.vindenergi.org/](http://www.vindenergi.org/)
- (5) <http://www.naturvardsverket.se/sv/Start/Verksamheter-med-miljopaverkan/Energi/Vindkraft/Vindval/>

Authors: Andreas Gustafsson, Swedish Energy Agency; and Sven-Erik Thor, Vattenfall AB, Sweden.



Photo credit: Suisse Eole

### 1.0 Overview

By the end of 2010, 47 wind turbines were operating in Switzerland with a total rated power of 42.3 MW. These turbines produced 35 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 politics in promoting wind energy led to a boost of new wind energy projects. The installed capacity multiplied within one year by 2.3-fold from 17.8 MW to 42.3 MW. By the end of 2010, 17 new turbines with a mean rated power of 1.9 MW were installed. Financing was requested for additional 1,212 MW under the FIT scheme. The targets for 2010 (100 GWh/yr) will indeed not be achieved, but based on the rapid development in 2010, wind energy capacity installed has a potential energy yield of about 74 GWh/yr.

The vast majority of these turbines were installed by utilities.

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 euro (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. Wind energy should contribute 600 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:

Time horizon 2010: 100 GWh

Time horizon 2030: 600 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 2010, 17 turbines were put in operation with an average rated power of 1.9 MW, which is an absolute record, the installed capacity multiplied by more than 2.3 fold. In total, 47 wind turbines are installed with a rated capacity of 42.3 MW. These turbines produced 35 GWh (Figure 1). During an average wind year, these turbines would generate 74 GWh. Due to various obstacles in the planning procedures, there is no additional project under construction, but project with a capacity of 52 MW have been submitted to planning bodies (Figure 2).

#### 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 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. About 165 million euro/yr (221.76 million USD), financed by a 0.40 euro/kWh (0.54 USD/kWh) fee on electricity sold in Switzerland, will

**Table 1 Key Statistics 2010: Switzerland**

Total installed wind generation	42.3 MW
New wind generation installed	24.5 MW
Total electrical output from wind	0.035 TWh
Wind generation as % of national electric demand	0.05%
Target:	600 GWh/yr in 2030



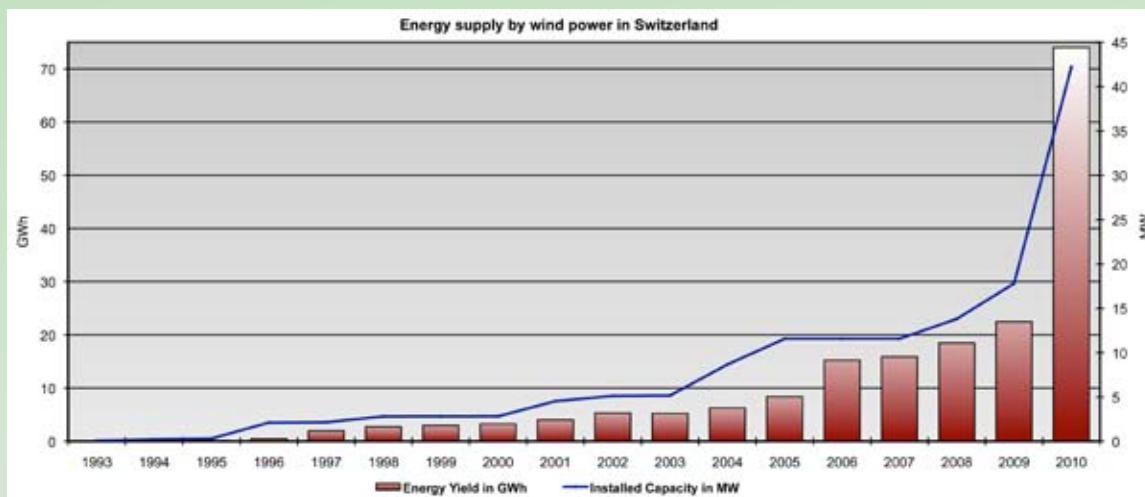


Figure 1 Installed capacity and energy yield of wind turbines in Switzerland 2010

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 0.153 euro/kWh (0.201 USD/kWh) and the lower price is 0.13 euro/kWh (0.17 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.

Switzerland has pursued a consistent energy policy since 1990 through the Energy 2000 and SwissEnergy programs (4). In view of the diminishing fossil fuel reserves, the challenges associated with climate change, and the high degree of dependence of Switzerland's energy supply on imports, the focus is increasingly shifting toward renewable forms of energy. Wind energy is an important element within the SwissEnergy program. Suisse Eole, the Swiss Wind Energy Association, is the leading authority on the use of wind energy in Switzerland and coordinates all activities in collaboration with the

cantonal (state) institutes of energy, energy suppliers, and energy planners (5).

#### 2.4 Issues affecting growth

The high number of registrations within the FIT scheme (also for other technologies) led to the situation that the Swiss Federal Office of Energy (SFOE) had to declare a moratorium from 1 February 2009 for all technologies. Based on a new legislation, the available amount will be 385 million euro (517.44 million USD), financed by 0.65 euro/kWh (0.87 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 various activities in the context of the IEA Wind Task 28

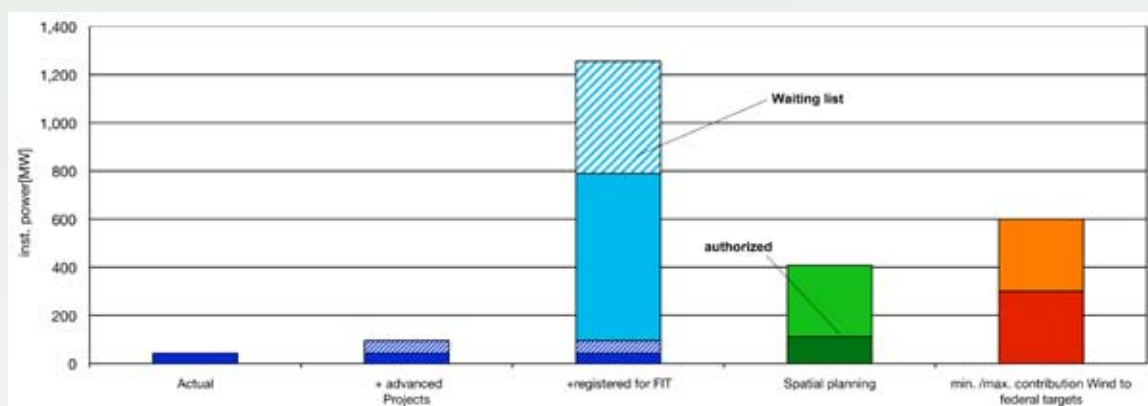


Figure 2 Estimated development of wind energy in Switzerland 2009

“Social Acceptance” keep playing 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 euro (2.15 million USD) underestimates a potential in the year 2010 of 8.6 billion euro (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.); 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. The experiences of operating the small wind park in the Swiss Alps on an altitude of 2,300 m above sea level on mount Güttsch (opening photo) will further contribute to the knowledge of utilization of wind energy in mountainous regions.

#### 3.4 Wind energy costs

The specific costs of existing larger wind power plants is about 1,450 euro/kWh (1,949 USD/kWh), including installation 1,885 euro/kWh (2,533 USD/kWh). These prices will result in cost-covering tariffs

in the range from 0.115 to 0.192 euro / kWh (0.155 to 0.258 USD/kWh). Unfortunately, the regulation for the compensatory feed-in remuneration scheme provides only 0.13 to 0.153 euro/kWh (0.175 to 0.206 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 2010, the budget for wind energy related R&D projects was 397,000 CHF (305,690 euro; 410,895 USD). This is even less than 2009, but still more than 2007. An amount of 631,000 CHF (485,870 euro; 653,085 USD) is spent on promoting activities.

Several innovative research projects were underway in 2010.

##### Icing map of Switzerland (8)

Based on information on water droplet content of clouds, temperature, and wind speed (supplied by the weather model COSMO-2), an icing map of Switzerland has been produced. This map has been verified with on-site measurements and in addition, the resulting ice loads on structures have been calculated. (Figure 3).

**Antifreeze coatings for rotor blades of wind turbines (9)** The Swiss specialty chemicals expert Clariant is supporting the ZHAW School of Engineering in Winterthur in a major R&D collaboration on-target to achieve a breakthrough in anti-freeze technology. Sectors such as wind power, refrigeration, and aviation will benefit from more reliable cold temperature performance and cuts in energy use if trials led by researchers at the ZHAW to prevent or drastically minimize surface ice build-up are successful.

Backed by Clariant, the GEBERT RÜF STIFTUNG, the Swiss Federal

Office of Energy (SFOE), and RETC Renewable Energy Technology Center GmbH, a Hamburg-based joint venture between REpower Systems AG and Suzlon Energy Ltd, the project focuses on three research areas:

- anti-adhesion coatings to prevent ice from sticking to surfaces;
- condensation delay to slow-down the creation of condensation on cold surfaces; and
- anti-freeze coatings to prevent water freezing on glass.

#### Increase of the acceptance of wind energy (10)

Since 2008, Switzerland has managed IEA Wind Task 28 Social Acceptance of Wind Energy Projects, which aims to help countries reach their ambitious renewable energy goals and the industry to get their wind parks built. During the last few decades, knowledge on how to “win hearts and minds” has been built up, but this experience has to be translated into the language of developers, planners, and administrative bodies. This might help to prevent misunderstandings, reduce the time for project development, and therefore minimize project risks. A state of the art report was published in 2010.

#### 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. At the end of 2010, the energy research concept 2013 – 2016 was being elaborated by the Swiss Federal Office of Energy. 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,

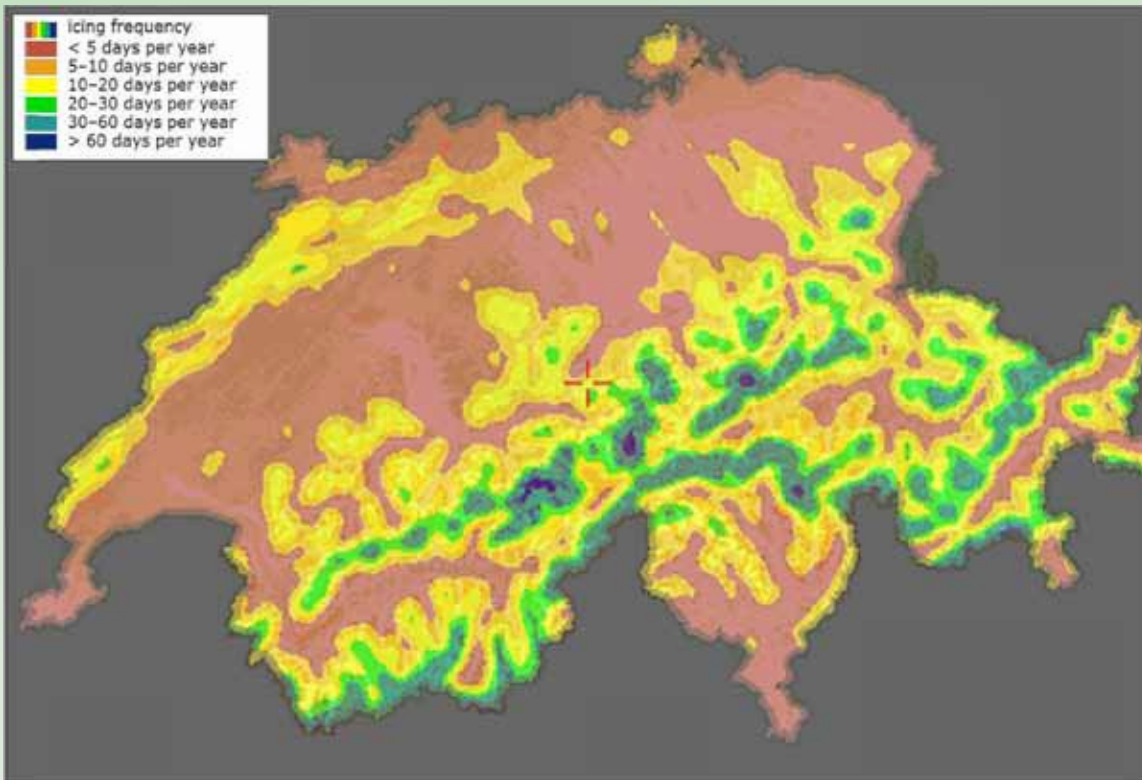


Figure 3 Icing map of Switzerland 2009

- 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.

#### References:

- (1) Cost-covering feed-in-tariff” (FIT) <http://www.bfe.admin.ch/themen/00612/02073/index.html?lang=en#>
- (2) Konzept Windenergie Schweiz, Bundesamt für Energie, 2003 <http://www.wind-data.ch/konzept/index.php?lng=en>
- (3) Richtlinie kostendeckende Einspeisevergütung (KEV), Art. 7a EnG, Windenergie Anhang 1.3 EnV [http://www.bfe.admin.ch/themen/00612/02073/index.html?lang=en&dossier\\_id=02168](http://www.bfe.admin.ch/themen/00612/02073/index.html?lang=en&dossier_id=02168)
- (4) The SwissEnergy program [http://www.bfe.admin.ch/energie/00458/index.html?lang=en&dossier\\_id=00720](http://www.bfe.admin.ch/energie/00458/index.html?lang=en&dossier_id=00720)

- (5) The Swiss Wind Energy Association “Suisse Eole”

<http://www.suisse-eole.ch/de.html>

- (6) McKinsey, Rolf Bättig: Wettbewerbsfaktor Energie, Chancen für die Schweizer Wirtschaft, 2010

[http://www.mckinsey.com/locations/swiss/news\\_publications/pdf/Wettbewerbsfaktor\\_Energie.pdf](http://www.mckinsey.com/locations/swiss/news_publications/pdf/Wettbewerbsfaktor_Energie.pdf)

- (7) Energie Forschungs-Programm Windenergie für die Jahre 2008–2011

[http://www.bfe.admin.ch/forschungwindenergie/02331/index.html?lang=en&dossier\\_id=02802](http://www.bfe.admin.ch/forschungwindenergie/02331/index.html?lang=en&dossier_id=02802)

- (8) Icing map of Switzerland : Silke Dierer, Philippe Steiner, Michael Lehning, René Cattin, Meteotest / MeteoSchweiz / WSL Institut für Schnee- und Lawinenforschung (SLF), [silke.dierer@meteotest.ch](mailto:silke.dierer@meteotest.ch), [www.meteotest.ch](http://www.meteotest.ch)

- (9) Non icing coatings for rotor blades of wind turbines, Martina Hirayama, zhaw, Zürcher Hochschule für Angewandte Wissenschaften, Winterthur ([martina.hirayama@zhwin.ch](mailto:martina.hirayama@zhwin.ch), [www.zhaw.ch/de/zhaw.html](http://www.zhaw.ch/de/zhaw.html))

- (10) IEA Wind Task 28 “Social Acceptance of Wind Energy, Robert Horbaty, ENCO AG, [robert.horbaty@enco-ag.ch](mailto:robert.horbaty@enco-ag.ch), [www.enco-ag.ch](http://www.enco-ag.ch).

Author: Robert Horbaty, ENCO Energie-Consulting AG, Switzerland,





Photo Courtesy: Found Ocean

### 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, particularly offshore wind, will be an important contributor to this target.

In 2010, total wind capacity in the UK was 5.27GW, representing 2.8% of the UK's national electricity demand, an increase of 876 MW from the 2009 figure (a 16.5% increase). Offshore wind generation increased 75% in terms of electricity generated between 2009 and 2010.

The new government elected in May 2010 continues to prioritize renewable energy. In late 2010, it published a consultation document on Electricity Market Reform (EMR) examining the reforms necessary to achieve the government's objectives on decarbonization, renewable energy, security of supply, and affordability. This EMR will develop and deliver a new market framework for the cost effective delivery of secure supplies of low carbon energy.

Other advances in 2010 included:

- Development rights were granted for up to 32 GW of new offshore wind generation (by The Crown Estate) under Round 3 offshore wind leases. The total acreage awarded in UK waters is now about 47.1GW.
- A Feed-In Tariff (FIT scheme) was introduced to incentivize small-scale (less than 5 MW), low-carbon electricity generation including small-scale onshore wind.
- A scoping exercise was completed for the Strategic Environment Assessment of a draft plan to enable future renewable leasing for offshore wind, wave, and tidal devices and licensing/leasing for seaward oil and gas rounds, hydrocarbon, and carbon dioxide gas storage.
- The Scottish government announced a consultation on 'The

strategic Environmental Assessment and Development Plan for Offshore Wind,' setting out proposals for the sector in Scotland up to 2020 and beyond.

- The UK government launched a scheduled review of the Renewable Obligation banding levels. A consultation on banding proposals will be held in summer 2011 and confirm the new bands in autumn 2011. Changes will come into effect on 1 April 2013 (with the exception of offshore wind for which changes come into effect on 1 April 2014). At present, the offshore wind industry receives 2 ROCS per MWh for stations accrediting between 1 April 2010 and 31 March 2014.
- A Green Investment Bank was established to overcome barriers to investment in renewable energy projects.

### 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. The UK currently has 436 offshore wind turbines but by 2020 it has been estimated we could have in excess of 7,000 offshore turbines. The Carbon Trust estimates that the investment required could be about 75 billion £ (84.45 billion euro;

**Table 1 Key Statistics 2010: United Kingdom**

Total installed wind generation	5,270 MW
New wind generation installed	876 MW
Total electrical output from wind	10.02 TWh
Wind generation as % of national electric demand	2.8%
Target:	15% RES by 2020

Table 2: Wind Projects Prospects at End of 2010	
Description	MW
Planning application submitted	9,248.8
Planning approved (awaiting/under construction)	8,717.2
<b>Total planned and/or in construction</b>	<b>17,966.0</b>

113.5 billion USD) with the potential to create up to 70,000 jobs.

## 2.2 Progress

UK electricity is generated from a range of sources: in 2010 natural gas generated 46%, coal (28.5%), nuclear (16.3%), other (2.5%), renewables (6.6%). Additionally the total amount of electricity generated in 2010 increased compared to 2009 due to the cold weather. Provisional 2010 figures indicate that renewables contributed 6.6%, a similar figure to 2009 (where it was 6.7%).

Generation from wind increased between 2009 and 2010 but not by as much as expected (given the increase in capacity) due to low wind speeds in 2010. Hydro generation also fell in 2010 due to low rainfall. Offshore wind generation grew by 75% from 1,740 GWh in 2009 to 3,042 GWh in 2010. Onshore wind, despite an increase in capacity, fell by 8% from 7,564 GWh to 6,979 GWh in 2010 due to decreased wind speeds. Overall wind generation grew by 7.7%.

In 2010, 876 MW of new wind generation capacity was commissioned, bringing the total UK capacity to 5.27GW, an increase of 16.5% above the 2009 level. This includes 1,341.2 MW of offshore wind. The UK continues to be the world leader in the development of offshore wind. Substantial further growth is predicted particularly following the Crown Estate Round 3 offshore awards.

## 2.3 National incentive programs

The Renewables Obligation (RO) is the government's chief incentive mechanism for eligible renewable electricity generation. It is also an important part of the government's program for securing reductions in carbon dioxide emissions, working in support of other policy measures such as the EU Emissions Trading System. It requires licensed electricity suppliers for Great Britain and northern Ireland to provide a specified and increasing number of Renewable Obligation Certificates

(ROCs) as evidence that an increasing proportion of their electricity comes from eligible renewable sources, or pay a buy-out price. Previously, generators were issued with 1 ROC for each MWh of eligible generation, regardless of technology. As of 1 April 2009 banding was introduced meaning different technologies now receive different

numbers of ROCs/MWh. This reflects differences between technologies, including cost of generation and potential for large-scale deployment. Under banding, onshore wind continues to receive 1 ROC/MWh whilst offshore wind was awarded 1.5 ROCs/MWh.

Further amendments to the RO were introduced last year by way of the Renewables Obligation (Amendment) Order 2010 which came into effect on 1 April 2010, these amendments included:

- extending the RO to 2037
- limiting RO support to 20 years (subject to the RO end date of 2037)
- increasing the level of support for offshore wind projects that are granted accreditation between 1 April 2010 and 31 March 2014 up to 2 ROCs/MWh



Figure 1 Gunfleet Sands Offshore Wind farm under construction (Image courtesy of Seatrax Inc and Semco Inc.)

- making provisions for the transition of certain categories of generator to the FITs scheme.

The following amendments will come into effect on 1 April 2011, subject to Parliamentary approval:

- phasing of support for offshore wind stations, allowing generators to register up to five phases of turbines over a maximum period of five years with each phase receiving the full 20 years of RO support
- extending sustainability reporting for solid biomass and biogas
- implementing mandatory sustainability criteria for bioliquids

Since its introduction in 2002, the RO has succeeded in almost tripling the level of renewable electricity (from 1.8% of total UK supply in 2002 to 6.6% in 2009).

The Feed-in Tariffs scheme (FITs), which applies to Great Britain, was introduced in April 2010. The scheme is designed to help the country meet the binding targets to generate 15% of energy from renewable sources by 2020 and to reduce carbon emissions by 80% by 2050. The FITs scheme offers three strands of benefit:

- a generation tariff for every kWh of electricity produced, whether used on site or not;

- an export tariff for every kWh of electricity exported to the grid;
- the savings to FITs generators their electricity bills by needing to import less electricity from the grid.

The generation tariffs vary depending on the technology and the capacity of the installation. The FITs export tariff is uniform across the scheme and is currently 0.03 £/kWh (0.034 euro/kWh; 0.049 USD/kWh). All tariffs are linked to the Retail Price Index. The scheme is administered by Ofgem. As of 31 December 2010, the 1,016 FITs wind installations had a capacity of 13.5 MW.

### 3.0 Implementation

#### 3.1 Industry status

Although no established wind turbine manufacturer is 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 £ (67.6 million euro; 97.3 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 £ (78.8 million euro; 113.5 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 2010, the UK saw key achievements in wind power development. Onshore, extensions to the Crystal Rig wind farm increased capacity to 200 MW. Offshore, construction activities began on five separate wind farms with a total capacity of 1.65 GW including the Greater Gabbard Wind Farm (504 MW) and West of Dutton Sands (500 MW). The UK's largest operational offshore wind farm at Thanet (300 MW) began operations in September 2010. Also, the UK saw all Round 1 offshore wind farms, with one exception, either in operation or in construction – producing over 1 GW when complete. Round 2 when fully complete will generate over 7 GW.

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 although there are plans to open another centre, in Scotland, near Aberdeen. Work is currently on-going to determine whether further test facilities will be required to meet the demands of the massive expansion in offshore deployment.

Table 3 Offshore Wind Projects Completed by the end of 2010				
Wind farm name	Turbine type	Number of turbines	Total capacity (MW)	Date online
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



#### 4.0 RD&D Activities

In order to accelerate development of both onshore and offshore wind energy, UK Government provides funding for research and development projects in partnership with industry. Technology innovation reduces the cost of commercial 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 research and development through to demonstration and pre-commercial deployment.

The Spending Review of November 2010 announced funding of over £200 million for low carbon technologies over the next four financial years, from April 2011. This includes up to £60 million for offshore wind manufacturing infrastructure at port sites. Plans are being developed for the allocation of the remainder of that funding.

The Low Carbon Innovation Group, which brings together the prime government bodies supporting low carbon innovation, has been developing Technology Innovation Needs Assessments (TINAs) on a range of key low carbon technology families, to help inform decision making for the allocation of these funds. This is a link to DECC's innovation pages on our website

[http://www.decc.gov.uk/en/content/cms/what\\_we\\_do/lc\\_uk/innovation/innovation.aspx](http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/innovation/innovation.aspx)

The Research Council's continue the offshore wind SUPERGEN program with the principal objective of the current phase being to undertake research to achieve an integrated, cost-effective, reliable and available Offshore Wind Power Station. The SUPERGEN Wind project is the primary research activity supported by the research councils in this area and it is due to be refreshed in 2013. There is also a Centre for Doctoral Training in Wind energy based at Strathclyde and is co-located with the main research effort of the SUPERGEN Wind project. Together these two activities make up the bulk of the Research Councils support for Wind energy Research.

#### Technology Strategy Board (TSB)

The Technology Strategy Board 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's vision is for the UK to be seen

as a global leader in innovation and a magnet for technology-intensive companies, where new technology is applied rapidly and effectively to create wealth.

The activities of the TSB 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 through to innovate faster and more effectively than would otherwise be possible, using its expertise, connections and funding. It provides support to UK businesses conducting research and development in certain technology areas in the form of 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.

TSB's Priorities for RD&D in wind energy focused on reducing the cost of electricity from wind power by capital cost reduction and operational improvements in turbine blades and drive systems, foundations, monitoring and by reduction of operational impacts such as radar interference.

A number of projects continued to be supported through 2010; No new projects were started with direct TSB funding in 2010, largely to minimize overlap with other publicly funded strategic programs in the ETI and Carbon Trust. Projects receiving funding from TSB in 2010 included

- Innovative High-Power Direct-Drive Superconducting Generator for Offshore Wind
- Affordable Innovative Rapid Production of Offshore Wind Energy Rotor-Blades
- In-situ wireless monitoring of offshore wind towers and blades
- Development of an innovative radar absorbing composite structure for wind turbine blades
- Cost – Effective Manufacture of Offshore Wind Turbine Foundations

During 2010, the new government undertook a review of the innovation landscape. One of the main changes is based on a report published for BIS in March titled the Current and Future Role of Technology and Innovation Centres (TICs) in the UK. In October 2010 it was announced that 200 million £ (225.2 million euro; 324.4 million USD) would be

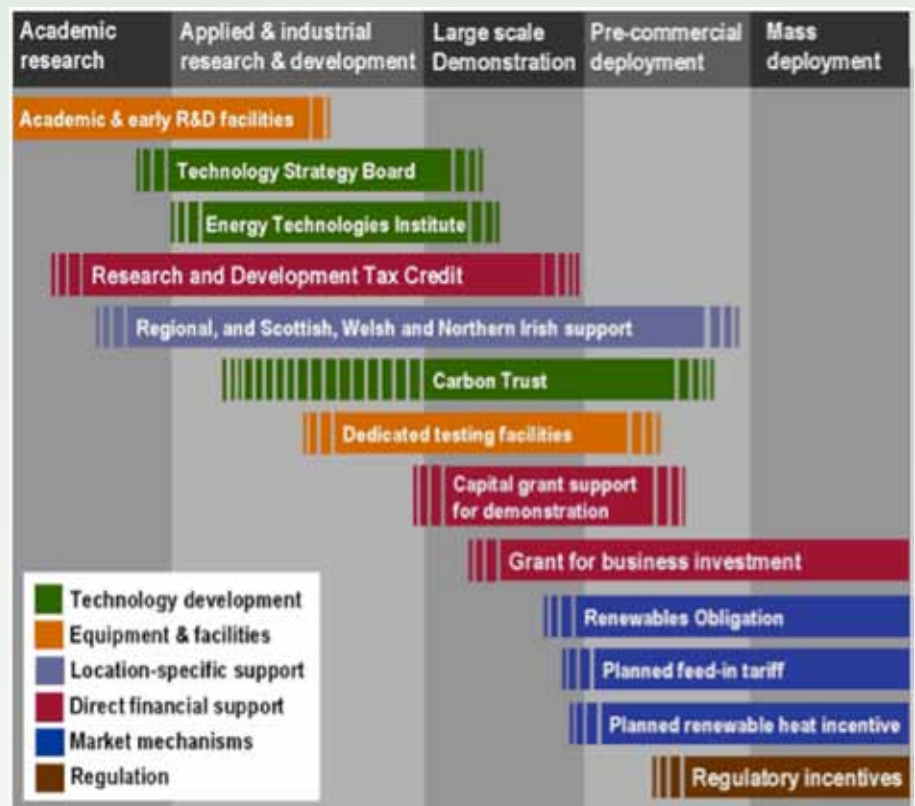


Figure 2 The UK Innovation Landscape

made available to the TSB over the following four years to develop a TIC strategy, establish and oversee a network of TICs across the UK in the technology areas where such centers can most benefit the UK economy. A consultation on the selection and focus of these technology areas which will include 'energy and resource efficiency is to be undertaken in early 2011, with broader strategy publication expected midyear.

**Energy Technologies Institute (ETI)**

The ETI is a partnership established by BIS with leading international engineering and energy companies (BP, Caterpillar, E.ON, EDF Energy, Rolls-Royce, and Shell) to invest in the development of low carbon energy technologies and solutions. It is a 50:50 public-private partnership to which BIS has committed to provide up to 500 million £ (581 million euro; 811 million USD) to be matched by industry partners, over the decade to 2018. Operating at a strategic level it is delivering large-scale engineering solutions for the UK energy system, helping to meet 2050 challenges.

The ETI has projects across eight program areas - offshore wind, marine, distributed energy, buildings, energy storage and distribution, carbon capture and

storage, transport and bio energy - covering heat, power, transport and their supporting infrastructure. The ETI sees offshore wind in particular as a strategic priority. To support increasing levels of deployment in line with the government's ambition, with projects focusing on a number of goals including

- Reduce electricity costs to be competitive with onshore wind by 2020 and with conventional generation by 2050;
- Increased yields: annual farm availability to be increased to 97%-98% or better, equivalent to onshore wind today by 2020;
- Reduce technical uncertainties to allow farms to be financed in a manner, and at costs, equivalent to onshore wind today.

**Energy Technologies Institute Projects**

The Wind Energy Programme projects are:

**Project Nova:** A UK-based consortium led by Guildford energy specialists OTM Consulting and including representatives from three universities - Cranfield, Strathclyde and Sheffield - the Centre for Environment, Fisheries and Aquaculture (CEFAS) and SME Wind Power. This project assessed the feasibility of a vertical

axis wind turbine based on the aero-generator principal. This project finished in the autumn of 2010. It concluded that vertical axis wind turbines based on the aero-generator concept had the potential to provide a credible, cost effective, alternative to traditional horizontal offshore turbines in some circumstances.

**Project Helm Wind:** A UK-based consortium led by E.ON Engineering and including Rolls-Royce, BP and the University of Strathclyde. The project delivered a concept design and feasibility study for a new offshore-specific wind turbine. This project completed in late 2010, providing concepts that have the potential to reduce the cost of energy from offshore wind by over 1/3 compared to current best technology.

**Project Deepwater:** A consortium led by Blue H Technologies with BAE Systems, the Centre for Environment, Fisheries and Aquaculture (CEFAS), EDF Energy, Romax, PAFA Consulting Engineers and SLP Energy. The project produced a design for and determine the technical and economic feasibility and potential of an integrated solution for a 5-MW floating offshore wind turbine for deepwater deployments between 60 and 100 metres. This project completed in the autumn of 2010 and concluded that a Tension Leg Platform has the potential to provide a cost effective platform for floating offshore wind turbines.

**Condition Monitoring:** A £5m project to reduce the cost of electricity from offshore wind generation by developing and demonstrating a groundbreaking 'holistic' condition monitoring system. The aim is a significant improvement in offshore wind farm reliability as developing a monitoring system that can detect causes of faults and component failures in offshore wind turbines. The project is being led by wind turbine blade monitoring specialists Moog Insensys in partnership with EDF Energy, E.ON, Romax technology, SEEByte and Strathclyde University. The consortium will develop and demonstrate advanced systems to monitor the condition and performance of turbines and predict future maintenance requirements for key components so they can be corrected before expensive damage occurs.

**Offshore Wind Drivetrain Test Rig:** ETI is working with NaREC (The National Renewable Energy Centre) and ONE North-East (RDA) to create a wind turbine drive test facility. The test rig is being designed to allow the whole turbine

Table 4 Wind Research Projects with TSB support		
Project Name	Start Date	Initial End Date*
Stealth Technology for Wind Turbines	November 2005	December 2007
Deepwater Offshore Windfarm Demonstrator Project	September 2004	March 2009
A Low Cost, Safety Critical Radar Absorbing Material for Wind Turbine Nacelles and Towers	November 2006	March 2009
Stealthy Wind Turbines - Addressing the Radar Issue	November 2005	August 2009
Development of an innovative radar absorbing composite structure for wind turbine blades	March 2008	January 2010
Cost - Effective Manufacture of Offshore Wind Turbine Foundations	June 2008	May 2010
Affordable Innovative Rapid Production of Offshore Wind Energy Rotor-Blades	February 2007	September 2010
Innovative High-Power Direct-Drive Superconducting Generator for Offshore Wind	December 2005	October 2010
In-situ wireless monitoring of offshore wind towers and blades	June 2008	May 2011

drive train to be tested onshore before being taken offshore, reducing the technical and commercial risks of mass production and deployment. The rig is expected to be operational during 2013 and it will include two competing technical designs for an indoor test-rig capable of dynamically testing a complete wind turbine drive train and nacelle with input power up to 15MW.

### **The Carbon Trust: Offshore Wind Accelerator**

The Carbon Trust (TCT) launched the Offshore Wind Accelerator, a ground-breaking research and development initiative which has an aim of reducing the cost of energy by 10%.

TCT are co-funding the Offshore Wind Accelerator in collaboration with five international energy companies. The co-funders in the Offshore Wind Accelerator are:

- Dong Energy, RWE, Europe-
- Scottish Power Renewables
- SSE Renewables; and
- Statoil,

the OWA research and development programme is focusing on four areas:

- Developing new turbine foundations and installation techniques;
- Facilitating access to distant turbines for maintenance;
- Finding the best wind farm array layouts to optimise yield; and
- Researching ways to reduce electricity transmission losses

Additionally, the European Union coordinates a Strategic Energy Technology Plan (SET Plan). This aims to support the development of energy technologies that will be necessary to meet the EU's 2020 targets and 2050 vision, for security of supply; sustainability; and competitiveness. The EU's approach includes the development of a range of European Industrial Initiatives (EIIs). Intended to be Industry led, the EIIs aim to strengthen industrial participation in energy research and demonstration, boost innovation and accelerate deployment of low-carbon energy technologies. EIIs target key technologies for which working at EU level adds most value, and technologies for which the barriers, the scale of the investment and the risk involved can be better tackled collectively. The SET Plan includes the European Wind Initiative, a long-term, large-scale Program for improving and increasing funding to EU wind energy R&D, both onshore and offshore.

As part of UK involvement in the development of the SET Plan and its activities, we are keen to also explore the potential linkages with other international activity, for example the technology development work happening via the Implementing Agreements under the International Energy Agency. By looking for areas of co-operation and collaboration more widely, we can help to minimize duplication and waste of resources, speed development and increase value for money. We will be seeking to encourage this collaborative approach, both from our involvement with the European Commission and with the International Energy Agency.

Environmental Transformation Fund (ETF): Funding for Low Carbon Technologies

The ETF is an initiative to bring forward the development of new low carbon energy and energy efficiency technologies in the UK. The fund formally began operation on 1 April 2008.

### **Offshore Wind Demonstration Call**

On 26 June 2008, the UK Government announced their intention to launch an Offshore Wind Technology capital grants competition, supporting the demonstration of next generation technology for offshore wind.

In 2009, the UK Government launched two calls for this program, providing grant support of 23 million £ (6.7 million euro; 37.3 million USD) to 10 projects (details can be found on the DECC website):

[http://www.decc.gov.uk/en/content/cms/what\\_we\\_do/lc\\_uk/lc\\_business/lc\\_economy/env\\_trans\\_fund/wind\\_demo/wind\\_demo.aspx](http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/lc_business/lc_economy/env_trans_fund/wind_demo/wind_demo.aspx)

In 2010 a third call, providing grant support of 5 million £ (5.63 million euro; 8.11 million USD) to seven projects was awarded. Projects under these three calls include

- Siemens – to develop a new power convertor for their next generation offshore turbine;

- Vestas – to design and develop advanced manufacturing blade processes and a second project to develop test and certification processes for a large multi-megawatt offshore blade;
- Artemis – to develop a new hydraulic transmission system for larger offshore turbines;
- Mitsubishi – to develop design and supply chain capability for a new design of offshore turbine;
- Burntisland Fabrications– to develop advanced manufacturing for a jacket foundation; and
- Teeside Alliance Group – to develop advanced manufacturing processes for monopile foundations
- NGenTec – design, building and testing of a 1MW C-GEN Generator to form part of a 6MW Generator for offshore wind.
- South Boats – Modular Design of Offshore Wind Farm Support Vessels.

### **5.0 The Next Term**

In 2011, there will be a number of significant announcements and activities in wind, mainly:

(i) The Government will publish a White Paper in late Spring 2011, incorporating a response to the EMR consultation, setting out detailed legislative and administrative proposals to support these reforms

(ii) The Renewables Obligation (RO) banding review consultation will take place during summer 2011 with the new bandings being confirmed by Autumn 2011.

Author: Ian Furneaux, DECC, GSI, United Kingdom





Courtesy: NREL

### 1.0 Overview

The United States added about 5.1 GW of wind generating capacity in 2010; about half of the amount that was added in 2009. Through U.S. Department of Energy (DOE) Wind Program activities, American Recovery and Reinvestment Act of 2009 (Recovery Act) funds, state and local initiatives, and private sector efforts, the nation is working toward a goal of producing 80% of U.S. electricity from clean energy sources by 2035.

In 2010, DOE expanded existing wind technology test centers in an ongoing effort to improve wind technology reliability and performance. DOE continued work on additional facilities around the country, such as a blade test facility, a large drivetrain testing facility, university-led research centers, and regional test centers for small wind technologies. DOE also launched a project to develop midsize wind turbines (100-kW to 1,000-kW).

DOE analyses resulted in strategies for offshore wind technology development, workforce development, and gearbox reliability improvement. The Wind Program studies provide utilities and regulators detailed analyses of the integration of high penetrations of wind generation (between 20% and 30%) on a large scale in the synchronous electricity grids covering the contiguous 48 states. The Department of the Interior, the Department of Commerce, and DOE are working together to mitigate administrative and technical barriers to both land-based and offshore wind energy development.

### 2.0 National Objectives and Progress

Culminating a year of in-depth analysis, President Obama announced a goal to generate 80% of the nation's electricity from clean energy sources by 2035. Wind energy will make critical contributions toward this long-term goal and to the

shorter-term goal of doubling the nation's electricity generation capacity from renewable sources by 2012.

### 2.1 National targets

DOE's report *20% Wind Energy by 2030* (3) examines the feasibility, costs, and benefits of supplying 20% of the nation's electricity from wind by the year 2030. This report, developed in collaboration with a broad range of wind industry and energy sector experts, identifies priority needs for accelerating wind energy expansion in the United States, and provides a foundation for coordinated action between the DOE Wind Program, industry, utilities, government, and other stakeholders.

### 2.2 Progress

In 2010, the U.S. wind industry installed 5,115 MW of generating capacity, increasing the country's installed wind capacity by 15%, according to the American Wind Energy Association's (AWEA) U.S. Wind Industry Year-End 2010 Market Report (1). This was about half of the capacity that was added in 2009. While 3,195 MW came on line in the last quarter of the year, 5,600 MW were under construction as the year ended. Wind power now can contribute about 3% of the total U.S. electricity supply, and, in some states, wind contributes up to 25% of their electrical generation during peak production.

Generation from wind energy is making a difference to the nation's energy supply. In early 2011, Texas wind power helped reduce the impact of cold and icy conditions that caused 50 fossil-fueled power plants with about 7.0 GW of generation to go offline. During the peak of the electricity shortage, wind was providing between 3.5 GW and 4.0 GW of power, demonstrating the importance of developing and maintaining a diverse energy portfolio.

### 2.3 National incentive programs

Federal tax and grant incentives and state renewable portfolio standards (RPS) have played important roles in the wind capacity growth for the past four years. In February 2009, federal incentives were expanded and extended to 2012.

**Table 1 Key Statistics 2010: United States**

Total installed wind generation (1)	40,267 MW
New wind generation installed (1)	5,113 MW
Total electrical output from wind (2)	94.647 TWh
Wind generation as % of national electric demand	2.3%
Target:	No official target for wind

State	Generating capacity (MW) end of 2010
Texas	10,089
Iowa	3,675
California	3,253
Minnesota	2,205
Washington	2,104
Oregon	2,104
Illinois	2,045
Oklahoma	1,482
Wyoming	1,412
Indiana	1,339

### 2.3.1 Federal incentive programs

Because of its national importance, the energy sector receives research and development (R&D) funding (see Section 4.0) and tax incentives from the U.S. government. Since its inception in 1992, the production tax credit has become one of the most important federal incentives for wind power. The production tax credit provides an income tax credit of 0.022USD/kWh (.016 euro/kWh), adjusted for inflation, for the first 10 years of the wind power project's operation. The Emergency Economic Stabilization Act of 2008 (P.L. 110-343) and the Recovery Act of 2009 extended and expanded the federal incentives offered for wind energy, most notably by allowing project owners to elect to receive an investment tax credit instead of a production tax credit. The investment tax credit allows 30% of the investment in a wind power project to be refunded in the form of reduced income taxes. Both the production and investment tax credits were extended to December 31, 2012. Under Section 1603 of the Recovery Act, the production tax credit may also be taken in the form of an up-front cash grant equivalent to 30% of total project value.

Tax credits are also available to businesses and homeowners who purchase and install qualified small wind systems. Businesses and homeowners can claim 30% of the cost as a tax credit for qualified small wind systems (under 100 KW) through 2017. The Recovery Act also included a 30% credit for investment in new or re-equipped facilities that manufacture wind

energy equipment, added several grant programs, and extended the eligibility of DOE-issued loan guarantees to include commercial wind power technologies.

In 2010, the DOE finalized a partial loan guarantee to support the 845-MW Caithness Shepherds Flat project, the largest wind farm to receive a loan guarantee under the Financial Institution Partnership Program. According to company estimates, the project will directly employ 400 workers during construction and 35 workers during operation. The company projects the wind farm will mitigate more than 1.2 million tons of CO<sub>2</sub> per year, which is equivalent to the amount of CO<sub>2</sub> from approximately 200,000 passenger vehicles.

### 2.3.2 State and local incentive programs

State-mandated RPS programs require utilities to purchase a percentage of their overall generating capacity from renewable resources. By the end of 2010, RPS programs had been adopted in 47 states.

Other market stimulus programs offered by states include grant programs, loan programs, production incentives, and utility resource planning. Green pricing is an optional utility service that supports a greater level of investment in renewable energy technologies. Participating utility customers pay a premium on their electric bills to cover the additional incremental cost of renewable energy. To date, more than 750 utilities, including investor-owned utilities, municipal utilities, and cooperatives, offer a green pricing option. Premiums vary from 0.002 to 0.116 USD/kWh (0.086 euro/kWh).

### 2.4 Issues affecting growth

The United States faces several major challenges along the path to 20% wind energy by 2030. Investment in the electric transmission system is needed to deliver wind-generated electricity to urban centers, as well as for larger electric load balancing areas, and improved regional planning. The manufacturing supply chain must grow to provide wind turbine components, and a skilled workforce must be trained to staff these facilities. Advancements in wind turbine technology and manufacturing should decrease capital costs and improve turbine performance. Finally, concerns about wind plant siting, including environmental impacts and social acceptance, must be addressed. DOE is targeting its investments to address these barriers.

Cooperation among federal agencies is breaking down barriers to wind development that were identified in analysis reports such as the *20% Wind Energy by 2030* report (3) and the *Large-Scale Offshore Wind Power in the United States* assessment issued in 2010 (4). For example, DOE and the U.S. Department of Commerce are collaborating on renewable energy modeling and weather forecasting to improve meteorological, oceanic, and climatological observations and forecasting. Building on work begun in 2009, the Department of the Interior launched a "Smart from the Start" wind energy initiative in 2010 (6). The initiative will speed offshore wind development on the Atlantic Outer Continental Shelf by facilitating project siting, leasing, and construction, and by working with coastal state governors to identify offshore locations suitable for wind energy development. The accelerated leasing process is being simplified through a regulatory change so that leases may be issued in 2011 or early 2012.

Transmission system planning and analysis is ongoing as potential contributions from wind and solar are being considered. The California Independent System Operator (CAISO) group concluded, in September 2010 (7), that the state's grid can reliably accommodate the integration of the renewable energy needed to meet California's 20% RPS. The study assumed the state grid operator will have a total installed capacity of 2,246 MW of solar and 6,686 MW of wind generation to meet the RPS by 2012. Similar studies at national, regional, and state levels also have found that wind penetrations of 20% to 40% can be reliably accommodated if cost-effective grid reforms are implemented.

## 3.0 Implementation

### 3.1 Economic impact

The *20% Wind Energy by 2030* report estimated that during the decade preceding 2030, the U.S. wind industry could support more than 150,000 jobs directly related to the wind industry, 100,000 jobs in associated industries (e.g., accountants, lawyers, steelworkers, and electrical manufacturing), and 200,000 jobs resulting from local economic expansion (3).

In 2010, the U.S. wind industry employed about 75,000 workers in all 50 states. The DOE Wind Program, in conjunction with AWEA, sponsors activities to promote workforce training. DOE's Wind for Schools project, active in 11 states nationwide, helps address the need for a skilled wind energy workforce. In



# United States

2010, DOE, the National Renewable Energy Laboratory (NREL), and AWEA developed a draft Wind Workforce Development Roadmap to direct future activities.

## 3.2 Industry status

### 3.2.1 Manufacturing

Wind energy manufacturing continued to grow in 2010. GE Energy provided the majority of the new capacity in the United States, installing 2,543 MW (Figure 1). In October, Vestas Towers America, Inc., opened the world's largest tower manufacturing plant for wind turbines. Located in the state of Colorado, the facility will employ 400 workers and will be able to produce up to 1,090 towers per year. Other overseas manufacturers to invest in the U.S. market in 2010 included: Chinese manufacturer Goldwind, which announced that it will supply the turbines for the 106.5-MW Shady Oaks project in Illinois; German manufacturer Nordex opened a nacelle assembly plant in Arkansas and Siemens inaugurated a new nacelle plant in Kansas; France's Alstom Power started construction on a nacelle assembly plant in Texas; and Japanese manufacturer Mitsubishi gained approval to move ahead with a new facility in Arkansas to assemble the company's 2.4-MW turbine.

As in previous years, 95% of all small wind systems sold in the United States

were made by U.S. manufacturers. These same manufacturers also export one-third of their production.

### 3.2.2 Offshore deployment

The United States could potentially generate an estimated 4,000 GW of electricity from its offshore wind resources, according to a new resource assessment released in 2010. This is roughly four times the generating capacity currently carried on the U.S. electric grid. The gross resource value likely will shrink by 60%, or more, after all environmental and socioeconomic constraints have been taken into account. Responding to this opportunity, the DOE Wind Program and the Department of the Interior issued a joint report, *National Offshore Wind Strategy: Creating an Offshore Wind Industry in the United States* (5). Although no offshore wind plants have been built in the United States, in April 2010, the Department of Interior approved development of the first offshore wind project located on the Outer Continental Shelf, Cape Wind, and by the end of 2010, more than twenty offshore projects representing more than 2 GW of capacity were in the planning and permitting process.

The mid-Atlantic region offers more than 60 GW of offshore wind potential in the relatively shallow waters of the outer continental shelf. To help capture

this potential, construction of an Atlantic Wind Connection (AWC) backbone transmission project has been proposed by the well-established, independent transmission company, Trans-Elect, and sponsored by Good Energies, Google, and Marubeni Corporation. Without such a transmission backbone, offshore wind developers would have to transmit energy to land using radial lines that can make balancing the region's existing grid more difficult. In addition, a single offshore backbone, with a limited number of landfall points, would have fewer environmental impacts than building multiple individual radial lines to shore. The AWC project will begin the planning process by filing with the Federal Energy Regulatory Commission in 2011.

### 3.2.3 Community and tribal wind

Rural landowners, public and customer-owned utilities, school districts, colleges, and Native American tribes are all benefiting from community wind projects, that represent about 2% of the overall market. In 2009, DOE selected five community renewable energy deployment projects to receive more than 20.5 million USD (15.25 million euro) in Recovery Act funding awards. One of these awards will support the development of a 30-MW wind project in the state of Colorado.

The United States is home to 2.4 million Native Americans living on 96 million acres of tribal lands. DOE Wind Program researchers estimate that tribal lands could provide 14% of the nation's annual electricity demand while supplying electricity and revenue to the tribes. Through DOE's Wind Powering America initiative, DOE experts have worked with more than seven tribal entities to move wind projects forward. In 2010, construction or feasibility studies began on four wind projects totaling more than 475 MW stimulated by Recovery Act funding.

### 3.2.4 Distributed wind

Distributed wind is a term used to describe small and mid-sized turbines that generate electricity for a home or business. Market data for 2009 showed the distributed wind industry reached 100 MW of installed capacity, more than 80 million USD (59.5 million euro) in sales, and more than 250 million USD (186 million euro) in private equity investment. To further promote this growing sector, the Distributed Wind

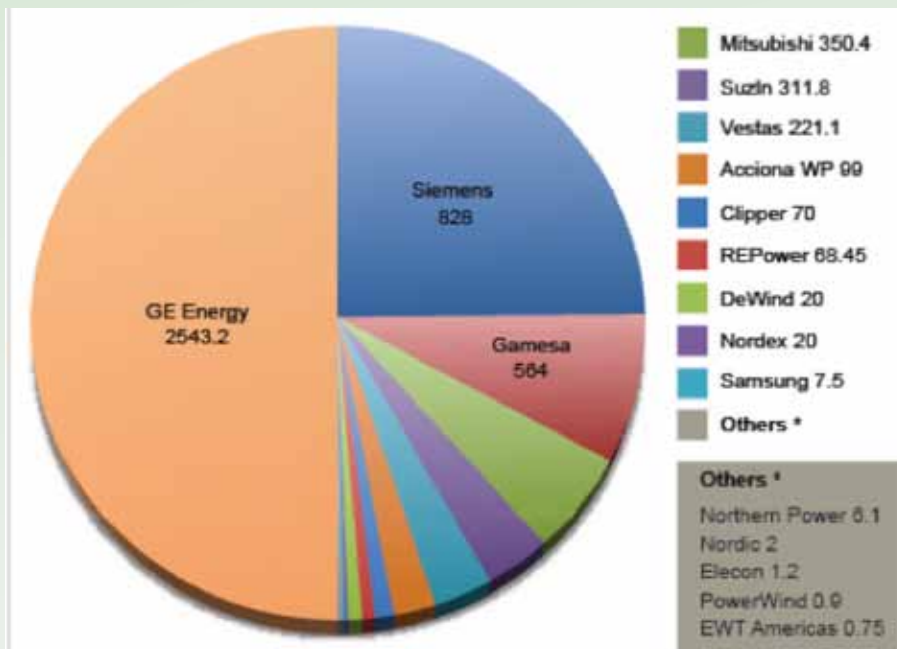


Figure 1 Manufacturer market share in MW for new installations in 2010 in the United States tabulated from data in reference (1)



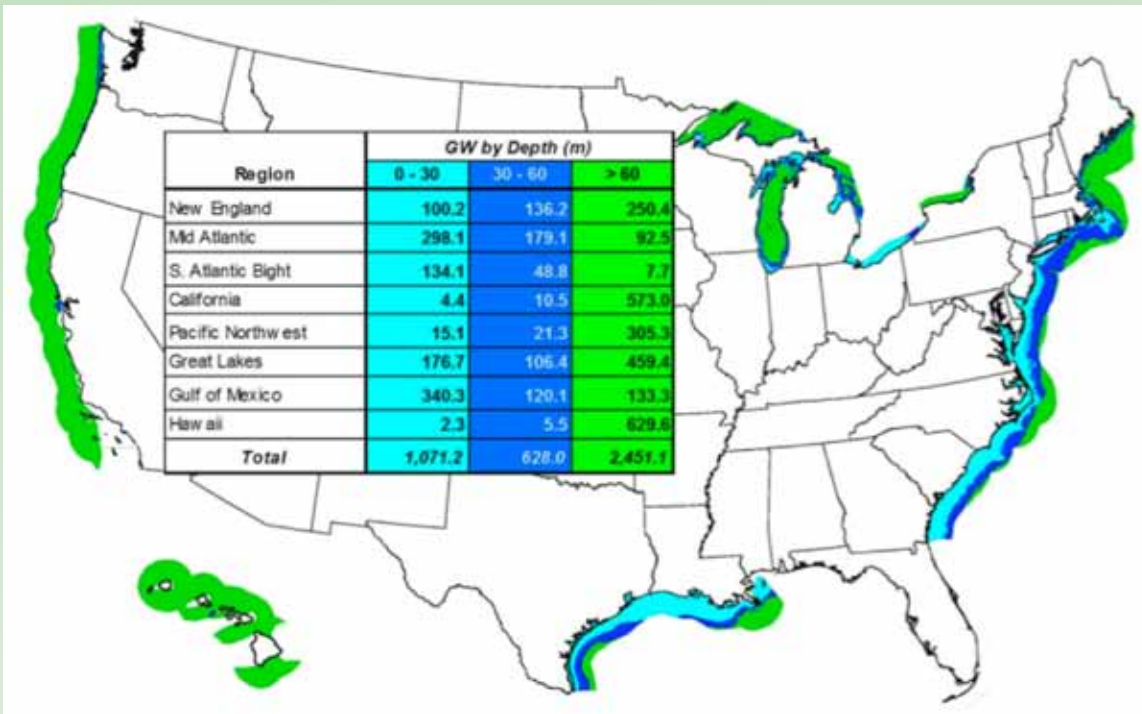


Figure 2 United States offshore wind resource by region and depth for annual average wind speed sites above 7.0 m/s (Source: NREL)

Energy Association was formed in 2010 and will produce an annual statistical report and advocate for distributed wind on the state and federal levels.

Several important developments in standards and certification took place in 2010 that will ensure a responsible small wind market. The AWEA Small Wind Turbine Performance and Safety Standard, approved by the AWEA Standards Development Board (formerly the Standards Coordinating Committee), established minimum strength and safety criteria, as well as a procedure for reporting on duration testing, sound, performance, and annual energy output. The Small Wind Certification Council (SWCC) began certifying that turbine test results have met the AWEA standard. Intertek also began certifying small wind turbines in 2010. A new Section 694 for small wind was added to the National Electric Code (NEC) and takes effect in 2011.

The North American Board of Certified Energy Practitioners (NABCEP), an organization that tests and certifies practitioners in several renewable energy fields, established a Small Wind Installer Certification process in 2010. The first group of installers took their exams in 2010. In

2011, NABCEP will develop a certification process for Small Wind Site Assessors.

In 2010, DOE's Small Wind Turbine Independent test project tested three small turbines to International Electrotechnical Commission (IEC) standards. The tests included power performance, acoustic noise, duration, safety and function, and power quality. Test results are made publicly available on NREL's small wind website.

### 3.3 Operational details

According to AWEA, nearly 36,000 wind turbines with capacity ratings greater than 1 MW are in commercial operation in the United States. The average capacity of new turbines installed in 2010 was 1.77 MW compared with 1.75 MW for 2009. More than 2,890 turbines were installed in 2010. The average size of projects installed in 2010 was 46 MW; however, when projects with turbines smaller than 1 MW are excluded, the average project size rises to 69 MW.

### 3.4 Wind energy costs

According to a report published by DOE, there was little change in the capacity-weighted average installed cost of wind power plants in the United States from

2009 to 2010. The capacity-weighted average installed cost in 2010 was 2,155 USD/kW (1,603 euro/kW). In 2009, the capacity-weighted average installed cost was 2,144 USD/kW (1,595 euro/kW). Capacity-weighted average wind power price among 26 sample projects for 2010 was 73 USD/MWh (54 euro/MWh); up from the 62 USD/MWh (46 euro/MWh) for the sample of projects in 2009. This price includes incentives such as the production tax credit or cash grants under the 1603 program; it would be higher without these incentives (8). At the end of 2010 wind power purchase agreements were in the range of 0.05 to 0.06 USD/kWh (0.037 to 0.045 euro/kWh). According to AWEA's 2009 Small Wind Global Market Study, the cost of electricity generated by an "average" well-sited small turbine is 0.15 to 0.20 USD/kWh (0.11 to 0.149 euro/kWh).

## 4.0 R, D&D Activities

### 4.1 National R, D&D efforts

The DOE Wind Program works through competitively funded awards to the wind industry, universities, and 12 U.S. national laboratories. The funding supports the deployment of existing technologies

and the discovery of innovative solutions to the challenges of wind energy. Areas of research include electrical grid integration, wind resource assessment and forecasting, wind turbine reliability and cost, innovative technology development and improved manufacturing methods, public acceptance through education, and responsible siting and environmental barriers. In addition, the DOE Wind Program is increasing its focus on lowering the cost of offshore wind. The tremendous potential of the offshore environment will require unique industry-government partnerships.

DOE's budget for the Wind Program was 79 million USD (58.8 million euro) in fiscal year 2010, up from 55 million USD (40.9 million euro) the previous year. An infusion of 106 million USD (78.9 million euro) in Recovery Act funds for wind R, D&D has supplemented the congressionally-appropriated budget. DOE requested 122 million USD (90.8 million euro) for 2011 and 126.9 million USD (94.4 million euro) for 2012 (9).

**4.1.1 Test facilities update**

Recovery Act funds allocated in 2010 are expanding research and testing capabilities to advance wind turbine designs.

- Wind turbine drivetrain test facilities are being upgraded (from 2.5-MW to 5-MW) at NREL's National Wind Technology Center (NWTC) in Colorado, and a new large drivetrain test facility (5-MW to 15-MW) is being built in South Carolina. Both

facilities will improve reliability by investigating gearbox failures, validating gearbox design codes, developing direct drive generator designs, and developing and testing advanced components.

- Full-scale blade testing is carried out at the NWTC (up to 50 m in length). A new 90-m blade test facility is under construction in Massachusetts, with the help of 25 million USD (18.6 million euro) in Recovery Act funds.
- Full-scale turbine testing takes place at the NWTC. New test sites are under construction at university-led wind energy research consortia in Illinois, Maine, and Minnesota.

**4.1.2 Large turbine development and testing**

The DOE Wind Program is working with industry to instrument and test large wind turbines to provide data on aerodynamics, power characteristics, vibrations, system fatigue, and acoustics. The tests will provide information to optimize turbine structures, mitigate loads, increase power production, test safety systems, develop and validate controls, improve system and component reliability, and better understand wind turbine aerodynamics. Under a cooperative research agreement with Siemens, a late-stage prototype turbine that features a novel blade design was installed at the NWTC in 2009. Researchers instrumented the 2.3-MW turbine and conducted power quality tests in 2010. They will collect data from pressure instrumentation on the experimental blade in 2011.

A 1.5-MW DOE turbine purchased from GE is being used for long-term research and testing at the NWTC to assess the aerodynamics of its design, the effects of turbulence on its load and performance. Power performance tests, in accordance with IEC Technical specification, were conducted in 2010.

As part of the effort to bring new wind turbine designs to the U.S. market, researchers at the NWTC will conduct the tests necessary to certify Alstom Power's 3-MW turbine for 60-Hz operation. The turbine was installed at the NWTC late in 2010. Tests also will provide Alstom with performance reports on its unique drivetrain concept.

**Drivetrains**

More than 30 companies and organizations worldwide now participate in the wind turbine Gearbox Reliability Collaborative launched by the U.S. DOE Wind Program in 2006. Under the dynamometer and field test program, two gearboxes underwent testing. The first, a 750-kW gearbox was instrumented and tested in the NWTC's dynamometer to establish baseline characteristics. Then, it was installed at a wind farm for three months of instrumented field testing. After field testing, it was retested on the NWTC dynamometer to detect any changes or damage caused during field operation. Meanwhile, an identical 750-kW gearbox was tested and run only on the dynamometer. The data (more than 170 channels) from the two gearboxes were compared, evaluated, and shared among collaborative participants to improve gearbox design codes.

To evaluate next-generation drivetrain technologies, DOE assembled a group of experts in 2010 from industry, academia, the federal government, and national laboratories. The resulting report, *Advanced Wind Turbine Drivetrain Concepts Workshop*, describes the benefits and challenges of developing superconducting drivetrains, advanced permanent magnet generators, continuously variable transmissions, fluid drive systems, and nontraditional drivetrain concepts (10).

**Resource assessment and forecasting**

A new national wind resource map and new state resource maps were released in 2010. The maps were based on a hub height of 80 m rather than the 50 m previously used. The new maps depict the nation's wind resources at three times previous estimates. The 80-m



Figure 3 The new DOE/NREL/MassCEC large blade test facility, the Wind Technology Testing Center (WTTTC), under construction in Boston, Massachusetts



estimates correspond to the height and expected future size of multi-megawatt turbines.

In 2010, the DOE Wind Program initiated projects in partnership with the National Oceanic and Atmospheric Administration to enhance short-term wind energy forecasting to improve utility operations. The projects will deploy advanced atmospheric measurement systems over a broad area that will provide data for advanced weather prediction systems. These advanced weather prediction systems will improve short-term, turbine-level wind forecasts and demonstrate the value of the forecasting improvements for electric utility operations.

#### Grid integration

The Western Wind and Solar Integration Study and the Eastern Wind Integration Study were released in early 2010. These studies showed that large amounts of wind energy could be integrated into these systems without affecting system performance or reliability, but that transmission planning and system operation policy and market development need to continue to evolve for large penetration levels to be achieved. The reports also found that interconnection-wide costs for integrating large amounts of wind generation are manageable with large regional operation pools.

#### Storage

Xcel Energy, an electric and natural gas utility, has shown in preliminary tests of a 1-MW battery-storage system that the system can shift wind energy from off-peak to on-peak availability. This storage capability could support the regional electricity market by responding to real-time imbalances between generation and load. Twenty 50-kW sodium sulfur battery-storage modules in Minnesota are connected as direct energy storage to a nearby 11-MW wind farm. Fully charged, the battery could power 500 homes for more than seven hours. Testing will continue to ascertain the system's ability to handle larger amounts of wind energy transfers to the grid. The next phase of the project will determine the potential cost-effectiveness of the technology.

#### Environmental and social impacts

The DOE Wind Program works with groups like the National Wind Coordinating Collaborative, the Grassland Shrub Steppe Species Collaborative, Bat Conservation International, the Bats and Wind

Energy Cooperative, and the U.S. Fish and Wildlife Service, to understand and mitigate the effects of wind projects on wildlife. In 2010, a two-year study conducted by Bat Conservation International at Iberdrola Renewables' Casselman Wind Power Project in southwestern Pennsylvania showed that modifications to turbine cut-in speeds during low wind periods, in the late summer and early fall, reduced bat mortality up to 93%.

DOE's Argonne National Laboratory is developing a prototype GIS-based system that creates risk maps relating to the visual impacts of wind energy development. In addition, the system details location-specific visual impact mitigation measures and best management practices. The system will be tested at two pilot locations, and the results verified through independent assessments by visual impact assessment professionals.

Researchers at Idaho National Laboratory, Sandia National Laboratories, and Savannah River National Laboratory are working with federal radar agencies to determine the extent of wind-radar interactions and to develop measures to mitigate the possible effects of wind turbines on civilian and military radar systems.

#### 4.1.3 New projects

##### Offshore wind technology

In support of the joint DOE/Department of Interior National Offshore Wind Strategy (*National Offshore Wind Strategy: Creating an Offshore Wind Industry in the United States* [5]), DOE released three solicitations, representing up to 50.5 million USD (37.8 million euro) over five years, to develop breakthrough offshore wind energy technology and to reduce specific market barriers to its deployment.

- **Technology Development:** innovative wind turbine design tools and hardware projects, including the development of open-source computational tools, system-optimized offshore wind plant concept studies, and coupled turbine rotor and control systems
- **Removing Market Barriers:** baseline studies and targeted environmental research, including market and economic analysis, environmental risk reduction, manufacturing and supply chain development, transmission planning and interconnection strategies, optimized infrastructure and operations, and wind resource characterization

- **Next-Generation Drivetrain:** next-generation designs for wind turbine drivetrains, including refinements of existing designs and new concepts for offshore applications.

#### Midsized turbine

DOE announced a 6 million USD (4.5 million euro) effort in 2010 to support the development and commercialization in the United States of midsize wind turbines (between 100 kW and 1 MW) for the global market. Three of the projects awarded will accelerate the first phase of development, testing, and commercialization of domestically manufactured midsize wind turbines with rated generating capacities between 200 kW and 500 kW.

#### 4.2 Collaborative research

Collaborative research with international partners included work with the IEA Wind Implementing Agreement and contributed to the DOE Wind Program's R&D efforts. U.S. researchers participated in topical expert meetings for IEA Wind Task 11, Base Technology Information Exchange. Active participation in Task 19, Wind Energy in Cold Climates, informed U.S. strategy for wind development in the northern states. The DOE Wind Program supported U.S. researchers, who acted as managers (operating agents), for Task 23, Offshore Wind Energy Technology and Deployment (which issued final technical reports in 2010); Task 24, Integration of Wind and Hydropower Systems; Task 26, Cost of Wind Energy; Task 30, Comparison of Dynamic Computer Codes and Models for Offshore Wind Energy; and Task 31, WAKEBENCH - Benchmarking Wind Farm Flow Models. U.S. experts participated in Task 25, Power Systems with Large Amounts of Wind Power, which addressed issues of grid connection that are relevant in all countries. The United States is working on Task 27, Consumer Labeling of Small Wind Turbines, to develop a labeling protocol for small wind turbines. The DOE Wind Program participated in Task 28, Social Acceptance of Wind Energy Projects. Data from wind tunnel tests conducted at NASA contributed to the cooperation in aerodynamic research for Task 29, Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models.

The DOE Wind Program also makes important contributions to IEC and standards groups and has several productive bilateral agreements.



### 5.0 The Next Term

In 2011, DOE will invest in activities that promote responsible offshore wind project development. Public investments will address common barriers and risks to offshore projects including financial, regulatory, technical, environmental, and social issues. DOE also will expand its efforts to analyze and facilitate technology supply chains and to improve manufacturing processes, and will continue its ongoing R, D&D activities to improve the reliability and performance of utility-scale wind turbines.

#### References:

Opening photo: A 12.5-MW wind farm in Kansas comprised of ten 1.25-MW wind turbines that supply electricity to the town of Greensburg (NREL/PIX 17592).

U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, [eere.energy.gov](http://eere.energy.gov)

(1) American Wind Energy Association, U.S. Wind Industry Year-End 2010 Market Report, January 2011. [www.awea.org](http://www.awea.org)

(2) US EIA, Electric Power Monthly, Mar 2011. Net generation through December 2010. This is 28% more output than for 2010. <http://www.eia.gov/ftp-root/electricity/epm/02261103.pdf>, page 14.

(3) EERE, 20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply, [windandhydro.energy.gov/wind\\_2030.html](http://windandhydro.energy.gov/wind_2030.html)

(4) U.S. DOE and NREL, Large-Scale Offshore Wind Power in the United States: Assessment of Opportunities and Barriers, NREL/TP-500-49229, September 2010.

(5) DOE and DOI, National Offshore Wind Strategy: Creating an Offshore Wind Industry in the United States, February 2011. [windandhydro.energy.gov/pdfs/national\\_offshore\\_wind\\_strategy.pdf](http://windandhydro.energy.gov/pdfs/national_offshore_wind_strategy.pdf)

(6) DOI, Smart from the Start Initiative, [www.doi.gov/news/pressreleases/Salazar-Launches-Smart-from-the-Start-Initiative-to-Speed-Offshore-Wind-Energy-Development-off-the-Atlantic-Coast.cfm](http://www.doi.gov/news/pressreleases/Salazar-Launches-Smart-from-the-Start-Initiative-to-Speed-Offshore-Wind-Energy-Development-off-the-Atlantic-Coast.cfm)

(7) ISO and GE Energy Consulting, Integration of Renewable Resources at 20% RPS, August 31, 2010. <http://www.caiso.com/2804/2804d036401f0ex.html>

(8) EERE, 2010 Wind Technologies Market Report, DOE/GO-102011-3322, 2011.

(9) DOE, FY 2011 Congressional Budget, EERE/Wind Energy, pp 181-208, <http://www.cfo.doe.gov/budget/10budget/Content/Volumes/Volume3.pdf>, accessed February 18, 2010. <http://www.cfo.doe.gov/budget/11budget/Content/Volume%203.pdf>, Wind Energy p 181.

And FY 2012 Congressional Budget, EERE/Wind Energy, pp 135-152, <http://www.cfo.doe.gov/budget/12budget/Content/Volume3.pdf>

(10) NREL, Advanced Wind Turbine Drivetrain Concepts: Workshop Report <http://www.nrel.gov/docs/fy11osti/50043.pdf>

Author: U.S. Department of Energy's National Renewable Energy Laboratory, United States.



The 66th ExCo meeting held in Palermo, Italy

# Appendix B

## IEA WIND EXECUTIVE COMMITTEE 2010

For current membership and contact information, visit [www.ieawind.org](http://www.ieawind.org) "contact list"

### CHAIR

**Brian Smith**  
National Renewable Energy Laboratory  
Email: [brian\\_smith@nrel.gov](mailto:brian_smith@nrel.gov)

### CHAIR ELECT

**Hannele Holttinen**  
Technical Research Center of Finland VTT  
Email: [hannele.holttinen@vtt.fi](mailto:hannele.holttinen@vtt.fi)

### VICE CHAIR

**Joachim Kutscher**  
Forschungszentrum Jülich GmbH  
Email: [j.kutscher@fz-juelich.de](mailto:j.kutscher@fz-juelich.de)

### SECRETARY

**Patricia Weis-Taylor**  
PWT Communications, LLC  
Email:  
[PWT\\_Communications@comcast.net](mailto:PWT_Communications@comcast.net)

### MEMBERS and ALTERNATE MEMBERS

#### AUSTRALIA

**Member**  
**Eva Oberender**  
Clean Energy Council  
Email: [eva@cleanenergycouncil.org.au](mailto:eva@cleanenergycouncil.org.au)

#### Alternate

**Leah Knight**  
Clean Energy Council  
Email: [leah@cleanenergycouncil.org.au](mailto:leah@cleanenergycouncil.org.au)

#### AUSTRIA

**Member**  
**Theodor Zillner**  
Bundesministerium für Verkehr,  
Innovation und Technologie  
Email: [theodor.zillner@bmvit.gv.at](mailto:theodor.zillner@bmvit.gv.at)

#### Alternate

**Johann Winkelmeier**  
Energiewerkstatt  
Email: [hw@energiewerkstatt.org](mailto:hw@energiewerkstatt.org)

#### CANADA

**Member**  
**Open**

**Alternates**  
**Simone Lalonde**  
Natural Resources Canada  
Email: [simone.lalonde@nrcan.gc.ca](mailto:simone.lalonde@nrcan.gc.ca)

#### Antoine Lacroix

Natural Resources Canada  
Email: [ALacroix@NRCan.gc.ca](mailto:ALacroix@NRCan.gc.ca)

## CHINESE WIND ENERGY ASSOCIATION

**Member**  
**He Dexin**  
Chinese Wind Energy Association  
Email: [hdx@cwea.org.cn](mailto:hdx@cwea.org.cn)

#### Alternate

**Qin Haiyan**  
Chinese Wind Energy Association  
Email: [qinhy@cwea.org.cn](mailto:qinhy@cwea.org.cn)

## DENMARK

**Member**  
**Hanne Thomassan**  
Danish Energy Agency  
Email: [hth@ens.dk](mailto:hth@ens.dk)

#### Alternate

**Jørgen K. Lemming**  
Organization Risø DTU  
Email: [jkle@risoe.dtu.dk](mailto:jkle@risoe.dtu.dk)

#### Peter Hauge Madsen

Risoe National Laboratory  
Email: [npha@risoe.dk](mailto:npha@risoe.dk)

## EUROPEAN COMMISSION

**Member**  
**Thierry Langlois d'Estaintot**  
DG Research  
Email: [thierry.d'estaintot@ec.europa.eu](mailto:thierry.d'estaintot@ec.europa.eu)

## EUROPEAN WIND ENERGY ASSOCIATION

**Member (proposed)**  
**Jacopo Moccia**  
EWEA  
Email: [jacopo.moccia@ewea.org](mailto:jacopo.moccia@ewea.org)

#### Alternates

**Justin Wilkes**  
EWEA  
Email: [justin.wilkes@ewea.org](mailto:justin.wilkes@ewea.org)

#### Filippo Gagliardi

EWEA  
Email: [filippo.gagliardi@ewea.org](mailto:filippo.gagliardi@ewea.org)

## FINLAND

**Member**  
**Mauri M. Marjaniemi**  
TEKES, Finnish Funding Agency for  
Technology and Innovation  
Email: [mauri.marjaniemi@tekes.fi](mailto:mauri.marjaniemi@tekes.fi)

#### Alternates

**Esa Peltola**  
Technical Research Center of Finland  
VTT  
Email: [esa.peltola@vtt.fi](mailto:esa.peltola@vtt.fi)

#### Hannele Holttinen (see chair elect)

## GERMANY

**Member**  
**Joachim Kutscher (see vice chair)**

#### Alternate

**Stephan Barth (proposed)**  
ForWind - Center for Wind Energy Research  
Email: [Stephan.barth@forwind.de](mailto:Stephan.barth@forwind.de)

## GREECE

**Member**  
**Kyriakos Rossis**  
Centre of Renewable Energy Resources (CRES)  
Email: [kros@cres.gr](mailto:kros@cres.gr)

## IRELAND

**Member**  
**John McCann**  
The Sustainable Energy Authority of Ireland  
Email: [john.mccann@seai.ie](mailto:john.mccann@seai.ie)

#### Alternate

**Martin McCarthy**  
The Sustainable Energy Authority of Ireland  
Email: [martin.mccarthy@reio.ie](mailto:martin.mccarthy@reio.ie)

## ITALY

**Member**  
**Claudio Casale**  
ERSE S.p.A  
Email: [claudio.casale@rse-web.it](mailto:claudio.casale@rse-web.it)

#### Member

**Giacomo Arsuffi**  
ENEA Casaccia  
Email: [giacomo.arsuffi@enea.it](mailto:giacomo.arsuffi@enea.it)

#### Alternate

**Alberto Arena**  
ENEA Casaccia  
Email: [alberto.arena@casaccia.enea.it](mailto:alberto.arena@casaccia.enea.it)

## JAPAN

**Member**  
**Yasuo Hasegawa**  
National Institute of Advanced  
Industrial Science (AIST)  
Email: [hasegawa.y@aist.go.jp](mailto:hasegawa.y@aist.go.jp)

#### Alternates

**Hikaru Matsumiya**  
National Institute of Advanced  
Industrial Science (AIST)  
Email: [hikaruwind@aol.com](mailto:hikaruwind@aol.com)

#### Tetsuya Kogaki

National Institute of Advanced  
Industrial Science (AIST)  
Email: [kogaki.t@aist.go.jp](mailto:kogaki.t@aist.go.jp)

#### Katsuhiko Kadoguchi

National Institute of Advanced In-  
dustrial Science (AIST)  
Email: [k.kadoguchi@aist.go.jp](mailto:k.kadoguchi@aist.go.jp)



**KOREA****Member****Sungwoo Lyoo**

Ministry of Knowledge Economy

**Email: lyoosw@mke.go.kr****Alternate****Cheolwan Kim**

Korea Aerospace Research Institute

**Email: cwkim@kari.re.kr****MEXICO****Member****Marco A. Borja**

Instituto de Investigaciones Electricas

**Email: maborja@iie.org.mx****NETHERLANDS****Member****Imar O. Doornbos**

Ministerie van Economische Zaken

**Email: I.O.Doornbos@minez.nl****Alternate****Jaap 't Hooft**

NL Agency

**Email: jaap.thoof@agentschapnl.nl****NORWAY****Members****Karen Nybakke**

Norwegian Water Resources and Energy Directorate (NVE)

**Email: kany@nve.no****Espen Borgir Christophersen**

The Research Council of Norway

**Email: ebc@forskningsradet.no****Alternate****Knut Hofstad**

Norwegian Water Resources and Energy Directorate (NVE)

**Email: kho@nve.no****PORTUGAL****Member****Ana Estanqueiro**

LNEG - Laboratório Nacional de Energia e Geologia, I.P.

**Email: ana.estanqueiro@lneg.pt****Alternate****Alvaro Rodrigues**

Universidade do Porto

**Email: ahr@fe.up.pt****SPAIN****Member****Enrique Soria**

CIEMAT

**Email: enrique.soria@ciemat.es****Alternate Member****Ignacio Cruz (see Task 27)****SWEDEN****Member****Andreas Gustafsson**

Swedish Energy Agency

**Email: andreas.gustafsson@swedishenergyagency.se****Alternate****Sven-Erik Thor**

Vattenfall

**Email: sven-erik.thor@vattenfall.com****SWITZERLAND****Member****Katja Maus**

Swiss federal office of energy

**Email: katja.maus@bfe.admin.ch****Alternates****Markus Geissmann**

Swiss federal office of energy

**Email: markus.geissmann@bfe.admin.ch****Robert Horbaty**

ENCO Energie-Consulting AG

**Email: robert.horbaty@enco-ag.ch****UNITED KINGDOM****Member****Allan Taylor**

Department of Energy and Climate Change

**Email: allan.taylor@decc.gsi.gov.uk****Alternate****Richard Brooks**

Department of Energy and Climate Change

**Email: richard.brooks@decc.gsi.gov.uk****UNITED STATES****Member****Megan McCluer**

Department of Energy

**Email: Megan.Mccluer@ee.doe.gov****Alternates****Jim Ahlgrimm**

Department of Energy

**Email: Jim.Ahlgrimm@ee.doe.gov****Brian Smith (see chair)****Robert W. Thresher**

National Renewable Energy Laboratory

**Email: Robert.thresher@nrel.gov****OPERATING AGENT****REPRESENTATIVES****Task 11 Base Technology****Information Exchange****Félix Avia**

CENER

**Email: favia@cener.com****Task 19 Wind Energy in Cold Climates****Esa Peltola**

VTT Processes

**Email: esa.peltola@vtt.fi****Timo Laakso**

Pöyry Finland Oy, Energy

**Email: Timo.Laakso@poyry.com****Task 25 Power Systems with Large****Amounts of Wind Power****Hannele Holttinen (see chair elect)****Task 26 Cost of Wind Energy****Maureen Hand**

National Renewable Energy Laboratory

**Email: Maureen.hand@nrel.gov****Task 27 Consumer Labeling of****Small Wind Turbines****Ignacio Cruz**

CIEMAT

**Email: ignacio.cruz@ciemat.es****Task 28 Social Acceptance of****Wind Energy Projects****Robert Horbaty**

ENCO Energie-Consulting AG

**Email: robert.horbaty@enco-ag.ch****Task 29 MexNex(T): Wind Tunnel****Measurements and Aerodynamic Models****Gerard Schepers**

ECN

**Email: schepers@ecn.nl****Task 30 Offshore Codes Comparison (OC4)****Walt Musial**

National Renewable Energy Laboratory

**Email: walter.musial@nrel.gov****Jason Jonkman**

National Renewable Energy Laboratory

**Email: jason.jonkman@nrel.gov****Fabian Vorpahl**

Fraunhofer Institut für Windenergie und Energiesystemtechnik (IWES)

**Email: vorpahl@iwes.fraunhofer.de****Task 31 WAKEBENCH****Benchmarking of wind farm flow models****Javier Sanz Rodrigo**

National Renewable Energy Centre (CENER)

**Email: jsrodrigo@cener.com****Patrick Moriarty**

National Renewable Energy Laboratory (NREL)

**Email: Patrick.Moriarty@nrel.gov****INTERNATIONAL ENERGY AGENCY****Takatsune Ito**

Renewable Energy

**Email: takatsune.ito@iea.org**

# Appendix C

Currency Conversion Rates IEA Wind Annual Report 2010			
Country	Currency	1 euro	1 USD
Australia	AUD	0.734	0.987
Austria	Euro	1.000	1.344
Canada	CAD	0.744	0.999
China	Yuan	0.113	0.152
Denmark	DKK	0.134	0.180
Finland	Euro	1.000	1.344
Germany	Euro	1.000	1.344
Greece	Euro	1.000	1.344
Ireland	Euro	1.000	1.344
Italy	Euro	1.000	1.344
Japan	JPY	0.00896	0.01200
Korea	KRW	0.00060	0.00086
Mexico	MXP	0.062	0.083
Netherlands	Euro	1.000	1.344
Norway	NOK	0.120	0.170
Portugal	Euro	1.000	1.344
Spain	Euro	1.000	1.344
Sweden	SEK	0.112	0.149
Switzerland	CHF	0.770	1.035
United Kingdom	GBP	1.126	1.622
United States	USD	0.744	1.000

“Source: Federal Reserve Bank of New York (www.x-rates.com) 31 December 2010”

## Abbreviations and Terminology

**Availability:** the percentage of time that a wind plant is ready to generate (that is, not out of service for maintenance or repairs).

**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, and the accuracy of nameplate rating. Most wind power plants operate at a capacity factor of 25% to 40%.

**CCGT:** combined cycle gas turbines  
**CEN/CENELEC:** European Committee for Standardization/European Committee for Electrotechnical Standardization (the original language is French) and it is similar to ISO/IEC.

**CHP:** Combined heating and power or cogeneration of heat and power

**CIGRE:** International Council on Large Electric Systems

**CO<sub>2</sub>e:** carbon dioxide equivalent

**COE:** Cost of energy

**DFIG:** doubly fed induction generator

**DSM:** demand side management

**EC:** European Commission

**EEZ:** exclusive economic zone

**EIA:** environmental impact assessment

**ENARD:** Electricity Networks Analysis, Research and Development an IEA Implementing Agreement

**EU:** European Union

**ExCo:** Executive Committee (of IEA Wind)

**(FITs)Feed-in Tariffs:** 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 Electrotechnical 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

**£:** United Kingdom pound

**m:** meter

**m a.g.:** meters above ground

**m.a.s.l.:** meters above sea level

**Mtoe:** million tonnes of oil equivalent

**MW:** megawatt (one million watts)

**MWh:** megawatt hour

**m/s:** meters per second

**NA:** not applicable (or not available)

**NGO:** non-governmental organisations.

**O&M:** operations and maintenance

**PJ:** peta joule

**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)

**RETD:** Renewable Energy

Technology Deployment and

IEA Implementing Agreement

repowering: taking down old

turbines at a site and installing newer

ones with more generating capacity.

**RPS:** renewables portfolio standard

**S.A.:** Sociedad Anonima

**tCO<sub>2</sub>-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



## **Production Credits**

### **Technical Editors**

Patricia Weis-Taylor  
Sophia Latorre  
Linda Bevard

### **Cover Design, Document Layout, and Computer Graphics**

Rick Hinrichs

Produced for IEA Wind by  
PWT Communications, LLC  
5191 Ellsworth Place  
Boulder, Colorado 80303  
United States  
[www.pwtcommunications.com](http://www.pwtcommunications.com)

July 2011

ISBN 0-9786383-5-2

Cover photo: Lillgrund Offshore Wind Park, 10 km off the coast of Sweden, was commissioned in December 2007. The 48 turbines have a capacity of 2.3 MW each, and together generate 330 GWh annually. This corresponds to the domestic electricity demand of more than 60,000 Swedish homes. Photo credit: Rick Hinrichs



# Wind

IEA

Member countries of the International Energy Agency Wind Implementing Agreement (IEA Wind) represented 85% of the world's wind generating capacity in 2010. During that year, these countries added nearly 32 GW (32,000,000,000 Watts) of wind generation for about 170 GW of total wind capacity.

Through IEA Wind, the participating countries share information and research efforts to increase the contribution of wind energy to their electrical generation mix. This work has contributed significantly to wind development in IEA Wind member countries and potential member countries are welcome to attend meetings and begin the process of joining.

This *IEA Wind 2010 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.

This report also presents information for 2010 supplied by the 20 member countries, the European Commission, the Chinese Wind Energy Association, and the European Wind Energy Association 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.