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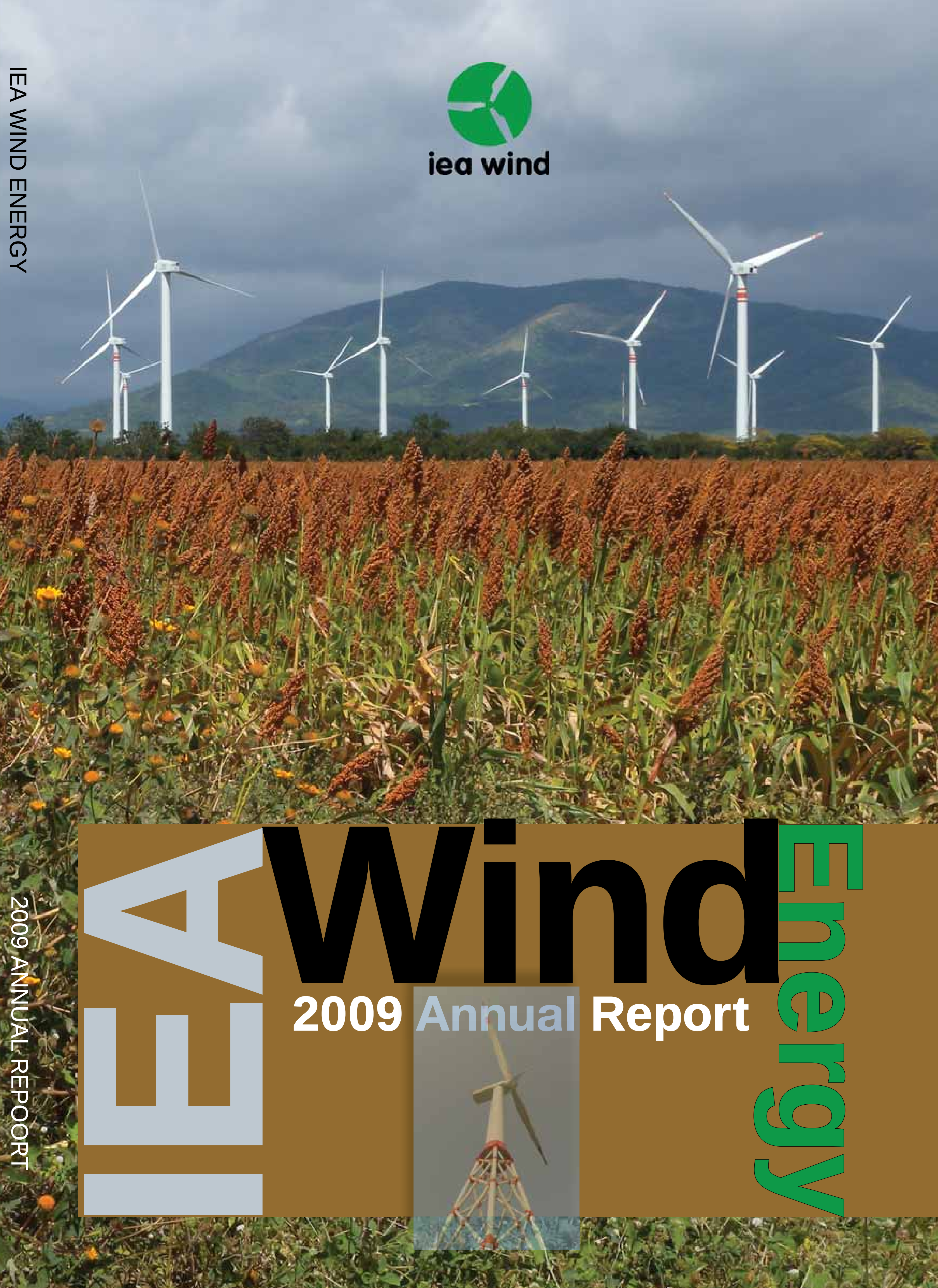

IEA Wind Energy

2009 Annual Report

IEA WIND ENERGY
Annual Report 2009

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

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MESSAGE from the CHAIR

Welcome to the 2009 IEA Wind Annual Report where we document the state of the wind industry and the results of cooperative research, development, and deployment efforts of our member governments and organizations. This was a record-setting year for wind energy in the IEA Wind member countries, which installed more than 20 gigawatts (GW) of new wind capacity. This growth led to a total of 111 GW of wind generating capacity, with more than 2 GW operating offshore. Wind energy supplied 2.5% of the collective electricity needs of the member countries and provided additional economic benefits including more than 287,000 jobs and 37,000 million euro of economic activity.

Following the IEA Wind 2009 to 2013 Strategic Plan, we are making significant progress on wind technology research to improve performance and reliability at competitive costs and to increase acceptance. We completed research in tasks addressing offshore wind technology deployment and the integration of wind and hydropower systems. Members began a new research task to improve the accuracy of computer codes and models used to estimate structural loads for offshore wind turbines. Technical expert meetings were held on: radar, radio, and links with wind turbines; sound propagation models and validation; and remote wind speed sensing techniques. Members agreed to continue research on power systems with large amounts of wind energy for another three-year term as more countries experience periods with wind generation approaching or exceeding 50% of total electricity demand. The State-of-the-Art of Wind Energy in Cold Climates report published in 2009 showed the impact of icing on wind turbine blades and on energy production. The research tasks benefited from contributions of industry, utilities, and regulatory institutions and the research results are stimulating joint technical conferences and journal publications that transfer information quickly into the marketplace.

We look forward to another successful year in 2010. Efforts to expand our membership to include China, France, India, and Russia look promising. Key technical reports will be published in the areas of offshore wind energy deployment, integration of wind and hydropower systems, cost of wind energy, and social acceptance of wind energy projects. Work on consumer labeling of small wind turbines will move ahead in cooperation with the International Electrotechnical Commission standards committee. Recommended practices will be finalized on the remote wind speed sensing techniques using SODAR and LIDAR. Finally, we will further our cooperation with the IEA Secretariat and align our activities with the new IEA Wind Technology Roadmap to ensure that our mutual efforts will accelerate the development and deployment of advanced wind technology.

Brian Smith

Brian Smith
Chair of the Executive Committee, 2009 to 2010

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EXECUTIVE SUMMARY

1.0 Introduction

In 2009, worldwide wind power capacity increased nearly 32% (ref 1), and electrical output from wind was enough to cover the electricity consumption of Australia and Ireland combined. Seventy percent of the world's wind capacity was operating in the IEA Wind member countries, where installed capacity grew by 20.3 GW. With more than 111 GW of generating capacity, electrical production from wind met 2.5% of the total electrical demand in the reporting IEA Wind member countries (Table 1, ref 2, 3).

In this 2009 IEA Wind 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 2009, data from the past 14 years as reported in documents of IEA Wind (ref 4, 5) are also included. The contribution of electricity from wind continues to grow even in this time of economic slowdown.

2.0 National Objectives and Progress

Governments and industry in IEA Wind member countries recognize that renewable energy in general and wind and solar 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 designed incentive programs to help reach these targets. In 2009, success in meeting targets for renewable energy contribution to electricity demand prompted several countries to propose or adopt more aggressive targets.

2.1 National targets

Encouraging national policy in many countries is the European Union's (EU's) climate and energy package (the RE Directive, December 2008), which includes directives for the promotion of renewable energy sources. The objective is to have 20% of renewable energy in the European energy mix in 2020, which could represent 35% of European electricity coming from renewable sources. More than one third of renewable electricity is set to come from wind energy. 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%. Each EU member state will outline the "appropriate measures" needed to reach its target in a National Renewable Energy Action Plan (NREAP) to be submitted by 30 June 2010 to the European Commission.

Outside the EU, the other IEA Wind member countries are also working toward ambitious goals for wind energy. In Australia, the expanded Renewable Energy Target (RET) scheme, which was passed in August 2009, mandates 45,000 GWh, or 20% of Australia's electricity supply, to be sourced from renewable energy in 2020. This target is four times the previous target introduced in 2001. Canada has no national wind energy deployment targets. However, the industry is pursuing a strategic vision for wind energy to supply 20% of the country's electrical demand by 2025, or an installed capacity of 55,000 MW. Japan's national target is 3,000 MW by 2010. South Korea's goal is for wind power to reach 7.3 GW by 2030 as stipulated in the Third National Energy Plan 2030. Mexico's Special Program for Renewable Energy plans for nearly 2,500 MW by the end of 2012. The United States has the goal to double the nation's electricity generation from renewable sources (excluding conventional hydropower) by 2012. For wind energy, a 2008 report found that a scenario where wind energy would supply 20% of U.S. electricity by 2030 was feasible and would have substantial economic and environmental benefits.

Some countries have specific goals for offshore deployment. For example, the Netherlands has a target of 6,000 MW of offshore wind by 2020.

2.2 Progress

Capacity in the IEA Wind member countries as a whole has increased from less than 5 GW in 1995 to more than 111 GW in 2009 (Figure 1). In 2009, the member countries added more than 20 GW of new wind generating capacity, and much more is being planned for 2010 and beyond. Fourteen countries added more than 100

Table 1 Key Statistics of IEA Wind Member Countries 2008 and 2009*

	2008	2009
Total installed capacity	91.771 GW	111.531 GW
Total offshore wind capacity	1.323 GW	2.041 GW
Total new wind capacity installed	17.000 GW	20.399 GW
Annual increase in capacity from previous year	23%	22%
Total annual output from wind	194 TWh	207 TWh
Wind generation as % of national electric demand	2.3%	2.5%

*Data for Greece and the United Kingdom are reported by GWEC (ref 1), IEA (ref 3)

Table 2 Worldwide Installed Capacity for 2009*

IEA Wind Members		Rest of World*	
Country	MW	Country	MW
United States	35,086	China	25,104
Germany	25,777	India	10,926
Spain	19,149	France	4,492
Italy	4,850	Turkey	801
United Kingdom	4,051	Poland	725
Portugal	3,616	Brazil	606
Denmark	3,480	Belgium	563
Canada	3,319	New Zealand	497
Netherlands	2,216	Taiwan	436
Japan	2,056	Egypt	430
Australia	1,712	Morocco	253
Sweden	1,448	Chile	168
Ireland	1,264	Costa Rica	123
Greece	1,109	Iran	91
Austria	995	Tunisia	54
Norway	431	Nicaragua	40
Mexico	415	Caribbean	35
Korea	392	Philippines	33
Finland	147	Argentina	31
Switzerland	18	Jamaica	23
Total	111,531	Colombia	20
		Uruguay	20
		Others	1,675
		Total	47,146
		Grand Total	158,677
		*Numbers reported by GWEC (ref 1)	

MW (net) of new capacity, and five countries added more than a gigawatt (net) of new capacity: the United States (10.010 GW), Spain (2.459 GW), Germany (1.880 GW), Italy (1.114 GW), and the United Kingdom (1.077 GW) (Table 3). Australia, Canada, Denmark, Mexico, Portugal, and Sweden added 300 MW or more. Record increases in capacity were reported in Canada, Italy, Korea, Mexico, Portugal, Sweden, and the United States for the year despite difficult economic times. Increases in capacity were less than hoped for in other countries such as Austria, Finland, the Netherlands, Norway, and Switzerland because of uncertainty about government programs or very low prices for competing energy. Growth rates also varied greatly (Table 4). Mexico increased its capacity by an impressive 387%, and another 3.5 GW of projects are planned or under construction in that country. Seven countries increased capacity by 30% or more.

In the EU, wind power installations accounted for 39% of new power installations and grew more than any other power-generating technology. Wind energy now represents 9% of the total EU installed power capacity. Total wind power capacity installed by the end of 2009 will produce 163 TWh, or 4.8 % of EU power demand in an average wind year. In the United States, wind power represented 40% of all new electric generation capacity for the year.

Wind generation capacity increased in every country except Austria, with totals ranging from the United States with 35,086 MW to Switzerland with about 18 MW (Table 3). A growing trend is repowering—the replacement of older, smaller turbines with fewer, larger turbines representing the state of the art in power production. In Denmark in 2009, 162 new wind turbines were installed and 159 turbines were decommissioned, with a net 319-MW increase in capacity. The Netherlands decommissioned 106 turbines (total capacity 34.8 MW) and installed new turbines totaling 101.4 MW.

Annual national electrical demand for 2009 decreased in 12 of the 19 countries reporting. The percent contribution of wind-generated electricity increased overall and new records were set. In Ireland, wind farm output at times was meeting 45% of the national electricity demand, and EirGrid, the Irish transmission system operator, reported no issues with the transmission system. In 2009, the Portuguese power systems experienced extremely high wind production— instantaneous power penetration of 70%— with no operational problems to be reported. In Spain, historic highs in wind power were recorded meeting 43% of total demand on the best day.

The contribution of wind to meeting electrical demand in Denmark held steady at 19%. However, the wind index was 88%, so in a normal year, the installed capacity would meet 22% of electrical demand.

Offshore wind farm capacity increased by 610 MW in 2009 or by more than 42% in the IEA Wind member countries. Germany installed its first offshore wind project, joining Denmark, Finland, Ireland, Japan, the Netherlands, Sweden, and the United Kingdom in this type of wind installation. In the entire European Union, at the end of 2009, offshore wind farm installations represented nearly 2.8% of the total installed wind power capacity. Japan's first offshore wind plant was under construction 40 m offshore.

Table 3 National Statistics of the IEA Wind Member Countries for 2009

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	1,712	0	406	984	2,000	***4.28***	***267.0***	1.6%
Austria	995	0	0	618	2,000	2.10	70.7	3.0%
Canada	***3,319***	***0***	***950***	***2,130***	***2,000***	***9.98***	***549.9***	1.8%
Denmark	3,480	665	319	5,108	2,200	6.72	34.8	19.3%
Finland	147	24	4	118	2,000	0.28	80.8	0.3%
Germany	25,777	72	1,880	21,164	2,013	37.50	***582.5***	6.5%
Greece	1,109	0	116	***1,270***	***1,339***	***2.55***	***57.0***	***4.4%***
Ireland	1,264	25	237	939	2,230	2.96	***27.4***	10.5%
Italy	4,850	0	1,114	4,237	1,715	***6.50***	316.8	2.1%
Japan	2,056	11	176	1,609	1,680	3.14	846.1	0.4%
Korea	392	0	88	152	1,579	0.68	446.1	0.2%
Mexico	415	0	330	366	1,136	0.50	204.0	0.2%
Netherlands	2,216	228	67	1,978	1,982	4.59	114.0	4.0%
Norway	431	0	2	200	2,310	0.98	121.5	0.8%
Portugal	3,616	0	797	1,976	1,900	7.49	49.9	15.0%
Spain	19,149	0	2,459	18,400	1,854	36.19	251.5	14.4%
Sweden	1,448	133	363	1,359	1,830	2.52	144.0	1.8%
Switzerland	18	0	4	30	2,000	0.02	58.7	0.04%
United Kingdom*	4,051	883	1,077	***2,490***	***2,060***	***6.96***	***406.0***	***1.7%***
United States	35,086	0	10,010	33,000	1,750	70.76	3,741.0	1.9%
Totals	111,531	2,041	20,399	98,128	1,994	206.70	8,369.7	2.5%

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

Bold italic = estimated

* Numbers reported by GWEC (ref 1)

2.3 National incentive programs

All member countries have government structures designed to encourage development of renewable energy that apply to wind energy (Table 5). Spain's exclusive use of enhanced feed-in tariffs has been very successful in stimulating wind energy development. Feed-in tariffs were used by 13 of the 19 IEA Wind member countries to encourage wind development, and several additional countries (Finland, Japan, the United Kingdom, and the United States) are considering this approach. Similar to tariffs, green electricity schemes allow consumers to buy wind-generated electricity, often at a premium price. Such schemes were used by eight countries in 2009. Also popular with the IEA Wind member countries are programs that mandate utilities to supply a portion of electricity from renewables. Nine countries use these utility obligations.

Some new incentive programs were employed or announced in 2009. In Australia, one state, South Australia, will use a payroll tax rebate beginning in 2010 that allows developers of renewable energy projects with capacities greater than 30 MW to receive a rebate for payroll tax incurred during project construction. Australia also uses a unique link between wind power and its aggressive program to build desalination plants. Commissioned and proposed desalination plants must offset their electricity use by wind power, providing assured income for development of wind farms. In Germany, incentives passed in 2008 went into effect in 2009, including encouragement of repowering. The dramatic increase of wind activity in Mexico is attributed to The Law for Renewable Energy Use and Financing of Energy Transition (enacted in November 2008), which provides income

Table 4 Wind Energy Capacity Increases IEA Wind Member Countries		
Country	Capacity added in 2009 (MW)	Percent wind capacity increase
United States	10,010	39%
Spain	2,459	15%
Germany	1,880	8%
Italy	1,114	30%
United Kingdom*	1,077	32%
Canada	***950***	40%
Portugal	797	28%
Australia	406	31%
Sweden	363	49%
Mexico	330	387%
Denmark	319	10%
Ireland	237	24%
Japan	176	9%
Greece	116	12%
Korea	88	37%
Netherlands	67	3%
Finland	4	3%
Switzerland	4	29%
Norway	2	0%
Austria	0	0%
Bold italic = estimated		
* Numbers reported by GWEC (ref 1)		

tax incentives and the construction of a 2,000-MW, 400-kV, 300-km electrical transmission line for wind energy projects in the Isthmus of Tehuantepec. The Norwegian government has joined with the Swedish government for a common green electricity market to open during 2012 that should spur new investment in wind energy.

To encourage investment in durable turbines, the Japanese government provides a higher subsidy rate for 1-S class turbines (designed against either extreme wind or lightning strike) and 2-S class turbines (designed against both) than for normal turbines.

Offshore development is being promoted in countries with shorelines to meet ambitious targets for wind generation capacity. In the EU, around 1,000 MW of offshore projects are expected to be installed during 2010, in more than 10 projects. Denmark's installation of 238 MW offshore in 2009 shows the success of political initiatives, and Danish municipalities are taking part in planning offshore projects for 2010 through 2012. In Ireland, a feed-in tariff program was announced for offshore wind at 140 €/MWh. A part of that program includes 785 MW of offshore connection applicants. In the United States, consolidated permitting procedures should facilitate offshore projects in the coming years.

In several countries, special incentive programs are being introduced to encourage small wind development (Italy, Japan, and the United States).

2.4 Issues affecting growth

More than 12 GW of projects were under construction at the close of 2009 in the member countries, and another 21 GW had received planning approvals (Table 6). These statistics project more than 30 GW of added capacity for 2010 in the IEA Wind member countries. These countries added just over 20 GW in 2009. 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.

2.4.1 Economic climate

Most countries listed the economic climate as having a slowing effect in 2009 and likely to reduce growth in 2010. Government programs to increase access to financing, provide larger subsidies, and issue targeted grants are mentioned as designed to reduce the effects of this problem.

2.4.2 Limited line capacity and grid integration issues

In many countries, the electrical grids are adapted to the needs of a system made up of centralized, large-scale power plants, and their capacity is limited to existing generation and demand. Some of these systems are absorbing large amounts of wind power. In Portugal, regulations limit growth of wind capacity to the no-load consumption plus a reserve value of conventional controllable power in the system. During the winter of 2009, the power system reached instantaneous penetration of 70% wind power. Although no technical problems for power system operation were reported, reaching this design and technical parameter with only 3,616 MW of wind power installed is expected to slow wind power deployment in Portugal until grid management strategies can develop.

In some countries, wind power production overloaded the transmission system in 2009. In Italy, the transmission system operator sometimes required wind operators to shut down their wind farms because of temporary overloads on electrical lines. An estimated 500 GWh of wind production was lost in this way during 2009. This prompted the Italian Regulatory Authority for Electricity and Gas to regulate grid operations of new generating plants to avoid undue damage both to wind investors and to the electrical system.

To address impacts of large amounts of wind energy, utilities are developing technical and economic strategies. In Denmark, a negative pricing scheme was introduced in October 2009 into the Nordic Power Exchange (NordPool). The minimum price for buying electricity was set to −1,650 DKK/MWh (–200

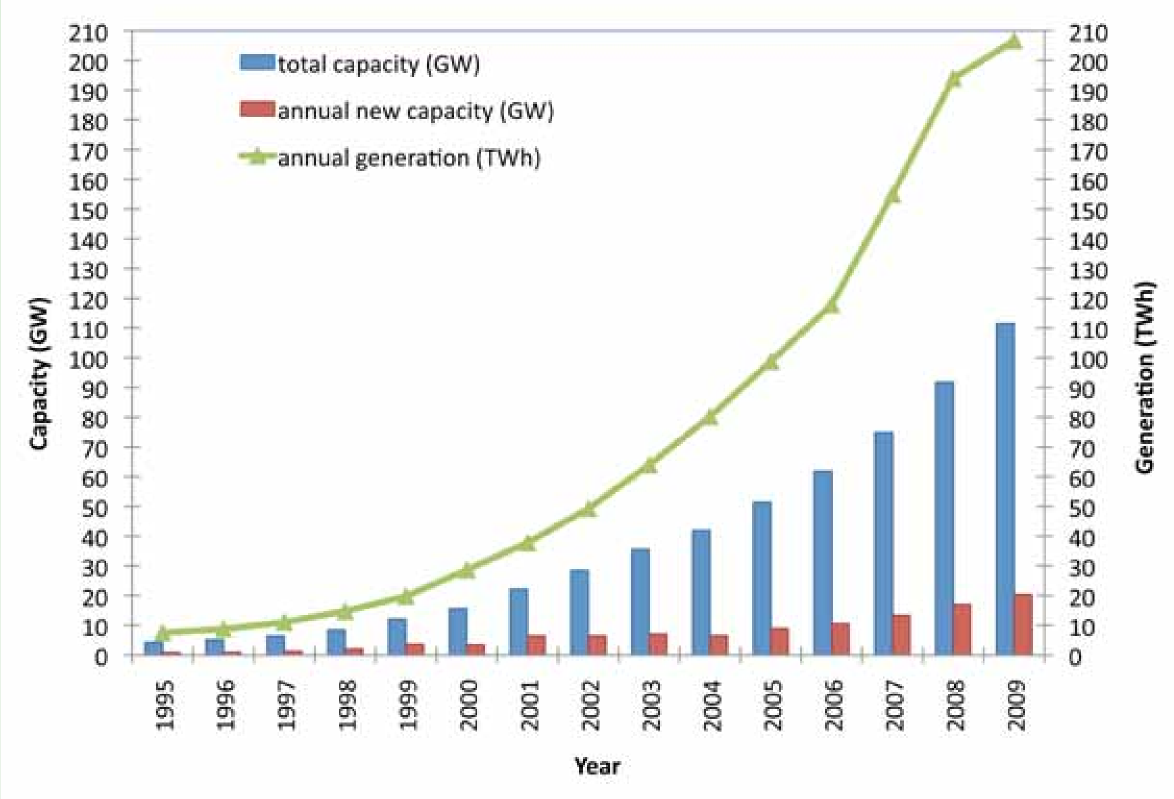

Figure 1 Annual installed capacity, cumulative installed capacity, and annual generation as reported by IEA Wind member countries, 1995-2009

€/MWh) as compared with 0 DKK/MWh previously. In Italy, new wind farms must be equipped to provide the system with ancillary services, such as power output modulation, output power ramp control at cut-in, grid fault ride-through capability, contribution to frequency and voltage regulation, and so on. In Finland, an addition to the Electricity Market Act set a ceiling for 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.

The large amounts of wind-generated electricity possible in windy areas can require new transmission and distribution lines. Adding new line capacity is a necessary solution that can also increase the reliability of aging distribution systems. Since constructing or upgrading lines also provides employment, countries are using this activity as a tool for economic recovery (Italy, Mexico, and the United States).

2.4.3 Long permitting times

Delays due to permitting requirements have limited wind developments in several countries. In Finland, Greece, and Italy, the permitting process has been improved by national guidelines for planning and building permission procedures for wind power plants. Adding wind power to regional plans has also helped with this issue.

3.0 Implementation

3.1 Economic impact

Wind energy development provides significant positive economic impacts. Table 7 shows reported effects for 2009. The European Wind Energy Association estimates that the 10.163 GW of new wind power capacity installed in the European Union represented a wind turbine manufacturing turnover of 13 billion €, of which 1.5 billion € is from offshore wind investments. The Netherlands estimates that the total investment in wind energy installations in that country from 1995 to 2009, not corrected for inflation, was about 3 billion €. In Portugal, wind-generated electrical energy produced an income of 0.7 billion € for private wind plant developers. However, several countries report reduced economic benefits compared with previous years because of the poor economy. In Spain, according to the “Macroeconomic Study on the Impact of the Wind Energy Sector in Spain,” the number of jobs related to wind power declined during 2009 by 35%.

3.2 Industry status

The wind industry is growing, and several countries succeeded in adding wind turbine manufacture to their domestic economies. In Korea, the first locally manufactured turbines were installed in 2009; they accounted for 2.4% of the capacity installed that year. In Finland, wind power technology exports amounted to about 1 billion € in 2009. In Portugal, a German technological complex that began in 2007 reached full production in 2009, making Portugal an exporter of wind turbines for the first time. In Sweden, a new supplier of onshore wind turbines, Kenersys, installed megawatt-scale prototypes. In Mexico, more than 200 companies have the capacity to manufacture parts required for wind power plants. The number of developers increased even as some consolidation was reported.

3.3 Operational details

Project sizes increased in many countries, and a good amount of new capacity in 2009 was reported as additions to existing wind farms. Portugal reported that wind parks larger than 50 MW accounted for 44% of projects, and 47% of wind parks had between 10 and 50 MW.

Table 5 Types of Incentive Programs in IEA Wind Member Countries		
Countries implementing	Type of program	Description
Australia, Austria, Canada, Denmark, Germany, Ireland, Italy, Japan (small wind), Korea, the Netherlands (special definition), Portugal, Spain, Switzerland, UK (2010) (14 countries)	Enhanced feed-in tariff	An explicit monetary reward is provided for wind-generated electricity, paid (usually by the electricity utility) at a rate per kilowatt-hour somewhat higher than the retail electricity rates being paid by the customer
Australia, Canada, Italy, Japan, Korea (2012) Portugal, Sweden, United Kingdom, United States (9 countries)	Renewable portfolio standards (RPS), renewables production obligation (RPO), or renewables obligation (RO)	A mandated requirement 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	Allows customers to 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 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	Allows some or all expenses associated with wind installation to be deducted from taxable income streams
Canada, Italy, Korea, Sweden (requires agreement), 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
Korea, Mexico, Netherlands, Sweden, Switzerland (5 countries)	Special planning activities	Areas of national interest are set aside for considering wind energy development
Portugal (microgeneration only), Sweden (requires agreement), United States (4 countries)	Net billing	The electricity taken from the grid and the electricity fed into the grid are tracked separately, and the electricity fed into the grid is valued at a given price
Canada, Sweden, Switzerland, United States (4 countries)	Electric utility activities	Includes 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	Allows customers to purchase green electricity from wind plants from the electricity utility, usually at a premium price
Australia, Canada, Switzerland (3 countries)	Investment funds for wind energy	Provides share offerings in private wind investment funds plus other schemes that focus on wealth creation and business success using wind energy as a vehicle to achieve these ends
Canada, Ireland (2 countries)	Sustainable building requirements	Includes requirements on new building developments (residential and commercial) to generate electricity from renewables including wind microgeneration
Australia (South Australia only), 2010 (1 country)	Payroll tax credit	Allows developers of renewable energy projects with capacities greater than 30 MW to receive a rebate for payroll tax incurred during project construction
Switzerland (1 country)	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

Table 6 Potential Increases to Capacity after 2009 in IEA Wind Member Countries (blank means no data available)				
Country	Planning application* (MW)	Planning approval** (MW)	Under construction*** (MW)	Total planned and/or under construction (MW)
Australia	3,615	3,179	588	7,382
Austria	350	30		380
Canada				4,400
Denmark		400	207	607
Finland	160	3	21	113
Ireland	3,995	215	200	5,410
Italy	3,600		1,150	4,750
Japan	***342***		***987***	1,329
Korea			420	420
Mexico	1,440	1,245	839	3,524
Norway	3,808	2,110	41	5,959
Portugal	1,158	639	287	926
Spain	14,000	3,545	2,382	19,927
Sweden		2,168	397	2,565
Switzerland	250	1.8	16	268
United Kingdom****		7,599	1,713	9,312
United States			2,786	2,786
Totals	32,718	21,134.8	12,034	70,058
	*Means all paperwork has been submitted to official planning bodies	**Means all relevant planning bodies have approved the projects	***Means all approvals are received and physical work has begun on the projects	
Bold italic = estimated **** Numbers reported by GWEC (ref 1)				

In the IEA Wind member countries, the average size of new turbines increased again to 1.9 MW in 2009. Capacity factors varied markedly among plants, months, and seasons. Averages reported ranged from 18% (Italy) to 34% (Mexico). Capacity factors up to 40% are reported in the best areas of the United States and Mexico. Finland reported an average capacity factor of 20% in 2009 due to the lower than average wind index (production index was 75% to 92% in different coastal areas in Finland). Portugal reported record production, due in part to a better than average wind year in that country. The average reported availability of wind turbines ranged from 91% (Finland) to 97% to 99% in most other countries. Some wind farms are exposed to very harsh and turbulent wind. In those areas, the availability is considerably lower, in some cases even less than 80%.

3.4 Wind energy costs

Table 8 shows reported turbine costs in 2009, and Figure 2 shows trends of installed costs for wind projects by country. Ireland reported costs declining as global demand for turbines and raw materials moderated. 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%). A typical cost for connection was from 150,000 to 300,000 €/MW. In Italy, the average installed plant cost of a land-based wind farm at a site of medium complexity, with15 km of roads and 12 km of electric line for connection to the high-voltage grid, was around 1.8 million €/MW. About 70% of this cost was for turbines and their installation and commissioning, and 30% for the other items. Of these other items, development costs (site qualification, design, administrative procedures, and so on) took nearly half.

Operation and maintenance costs are tracked in some countries. In Norway, average maintenance cost is reported as 140 NOK/MWh (17.0 €/MWh). Estimates of production costs from sites with good wind conditions (33% capacity factor) suggest a production cost of about 530

Table 7 Capacity in Relation to Estimated Jobs and Economic Impact in 2009 (blank means no data available)			
Country	Capacity (MW)	Estimated number of jobs	Economic impact (Million €)
United States	35,086	85,000	14,450
Germany	25,777	90,000	5,650
Spain	19,149	16,970	
Italy	4,850	18,000	2,000
United Kingdom*	4,051	16,000	
Portugal	***3,616***	***2,500***	***956***
Denmark	3,480	26,000	5,300
Canada	3,319		1,500
Netherlands	2,216	1,000	60
Japan	2,056	6,000	3,200
Australia	1,712	1,600	666
Sweden	1,448	2,500	
Ireland	1,264	1,500	60
Greece	1,109		
Austria	995	2,500	350
Norway	431		
Mexico	415	2,000	470
Korea	392		
Finland	147	3,000	1,000
Switzerland	18	12,600	1,400
Total	**111,531**	**287,170**	**37,062**
bold italic = estimated			
* Numbers reported by GWEC (ref 1)			

NOK/MWh (64 €/MWh), including capital costs (discount rate 8.0%, 20-year period), operation, and maintenance. In Denmark, the components of total O&M costs are as follows: repairs (21%), insurance (21%), service agreements (29%), administration (16%), land rent (12%), and other (1%). Many turbines have had gearbox problems after seven to ten years of operation, causing significant additional costs over and above the normal operating costs. A wind turbine gearbox is replaced on average four times in a turbine's lifetime and costs about 20% of the price of a wind turbine.

Some countries reported estimates for the cost of wind energy and compared those estimates to the incentive payments developers can expect. A comparison of wind energy costs among participating countries using a consistent methodology is being explored in IEA Wind Task 26 Cost of Wind Energy, and a state of the art report is expected in 2010.

The costs reported here have been calculated with different assumptions but are interesting nonetheless. Denmark reported that the cost of wind electricity onshore in 2009, excluding risk factors and profit, was calculated to be 30 to 50 €/MWh. 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 large investors like utilities. Private investors require 40 to 80 €/MWh on top of the raw cost (includes profit and risk factor) to invest in wind production. In 2009, an investor in Denmark received approximately 70 €/MWh; half was subsidy and half was the free market price. In Mexico, the levelized generation price over a 20-year period was estimated at 65 USD/MWh (45 €/MWh) in 2009. In Finland, on coastal sites, the cost of wind energy production was estimated to be about 60 to 80 €/MWh without subsidies. The estimated cost of offshore production could exceed 100 €/MWh. The average spot price in the electricity market Nordpool was 37 €/MWh in 2009 (51 €/MWh in 2008). In Finland, wind power still needs subsidies to compete, even on the best available sites. The planned feed-in guaranteed price of 83.5 €/MWh for 12 years (90.2 €/MWh for the first projects) is expected to start for the onshore market in 2011.

Considering these estimated generation costs, it is interesting to compare reported incentive payments. In Ireland, by January 2010, the value of the REFIT incentive program for large-scale wind projects was 67.35 €/MWh. In Italy, the sale of energy production from wind yielded an average price of 67 €/MWh in 2009. The additional income from the sale of tradable green certificates (TGCs) was, on average, nearly 88 €/MWh in the 2009 trading. Owners of wind plants between 1 kW and 200 kW in Italy can also opt for either a fixed tariff of 300 €/MWh for energy fed into the grid or exchange (net metering) contracts. In net metering, their income equals the avoided price of the electricity they would have bought as customers, an average of 200 €/MWh.

4.0 R, D&D Activities

4.1 National R, D&D efforts

Table 9 lists major research areas discussed in the individual country chapters. Those 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, Finland, Germany, Italy, Japan, Korea, the Netherlands, Norway, Portugal, Spain, Sweden, and the United States). It is difficult to calculate the total research dollars supporting wind energy technology. Table 10 lists some general trends reported by some countries.

4.1.1 New test and research facilities

Many new research centers opened or were planned in 2009. Denmark is working on new test centers for components

Table 8 Estimated Average Turbine Cost and Total Project Cost for 2009 (blanks mean no data available)

Country	Turbine cost (€/kW)	Total installed cost (€/kW)
Australia	990 to 1,320	1,385 to 2,240
Austria	1,400 to 1,500	1,700 to 1,800
Canada	1,050 to 1,330	1,500 to 1,800
Denmark		1,300 onshore 2,600 offshore
Greece		1,100 to 1,400
Ireland	950 to 1,000	1,602
Italy	1,270	1,740
Japan	1,500	2,250
Mexico	1,000 to 1,200	1,300 to 1,500
Netherlands		1,325
Norway		1,400 to 1,600
Portugal	950 to 1,300	***1,300 to 1,500***
Spain	930	1,250
Sweden	970 to 1,300	1,510 to 2,160
Switzerland	1,450	1,885
United Kingdom		1,050 to 1,575 onshore; 2,100 to 3,150 offshore
United States	744 to 1,148	1,444

bold italic = estimated

and for wind turbines up to 250 m total height and has planned two offshore demonstration wind farms. Finland began operation of an icing wind tunnel for instrument and material research and testing for cold climate conditions. Germany opened a new test center for rotor blades up to 70 m in length and began construction on another center for rotor blades of up to 90 m in length. The Korean government began development of an offshore test bed with a total capacity of 100 MW by 2012. In the Netherlands, a new octagonal 500-kW 30 m/s open jet facility began operation that will test model rotors up to 1.8 m, for concepts such as flexible smart dynamic rotors and controls. Norway established two new research centers focused on offshore wind energy and one working on issues such as integration of wind energy. In Spain, a new public-private collaboration approved in 2009 will develop technology over the next four years to build offshore wind farms in deep waters. The Swedish Wind Power Technology Center (SWPTC) at Chalmers institute of technology was launched to focus on complete design of an optimal wind turbine which takes account of the interaction among all components. The United States government is expanding its large land-based and offshore wind turbine component testing capability. A wind turbine drivetrain test facility under construction at Clemson University, South Carolina, will test drivetrains up to 15 MW in size, and a new test facility at the Massachusetts Clean Energy Center in Boston will test wind turbine blades up to 90 meters long. The U.S. government is also investing in three university-led consortia aimed at improving land-based and offshore wind turbine performance and reliability; this includes three pilot-scale floating wind turbine systems being researched at the University of Maine.

4.1.2 Highlights of research

Research and demonstration of offshore wind technology is yielding interesting results. In the Netherlands, data from the extensive monitoring of the offshore wind farm Egmond aan Zee became available in 2009. Data include availability, energy production, corrosion and lightning, dynamics of turbines, scour protection, birds and marine life, and more. During the pile-driving of one of the tripods for the German alpha ventus offshore test project, scientists tested a bubble curtain to reduce sound emissions caused by the ramming of the piles. Despite operational difficulties, a sound reduction of about 12 dB in the direction of the sea current was detected.

Several countries began demonstrations of offshore wind plants. In Japan, the first offshore wind farm was being developed that will generate 14 MW with seven FHI/Hitachi 2-MW downwind turbines on monopile foundations. In Korea, the first 3-MW offshore wind turbine by Doosan Heavy Industries was erected in the national test bed situated in Jeju Island. A government feasibility study is under way on 5 GW of offshore wind on the west coast of Korea. In the Netherlands, ten groups worked together to develop a concept for an artificial offshore port to support future offshore wind development and maintenance.

Several projects promise information about floating wind systems. In Italy, a floating system with an 80-kW turbine was operated by the BlueH company for a few months 20 km offshore in 100-m to 110-m deep waters. Another prototype with a 2.5-MW turbine will be tested at the same site in 2010. A feasibility study was completed of a floating 6-MW turbine on a Tension Leg Platform structure and a new project began on stability control of such a structure. In Norway, a full-scale floating wind turbine (Hywind concept developed by Statoil) became operational and will be tested over the next two years. The wind turbine can be placed at ocean depths of between 120 and 700 meters. A Portuguese utility announced plans to develop and install a floating deep water offshore structure in a wind power project.

Good wind resource areas can have extreme conditions that jeopardize consistent production. In Japan and Mexico, durability of conventional turbines during high winds has been a problem. The two countries have co-operated to develop a special turbine to withstand high wind and lightning strikes. The prototype is undergoing tests in Mexico's Regional Wind Technology Center in the extreme environment of La Ventosa. The 300-kW wind turbine is designed to operate where turbulence intensity is up to 20% and

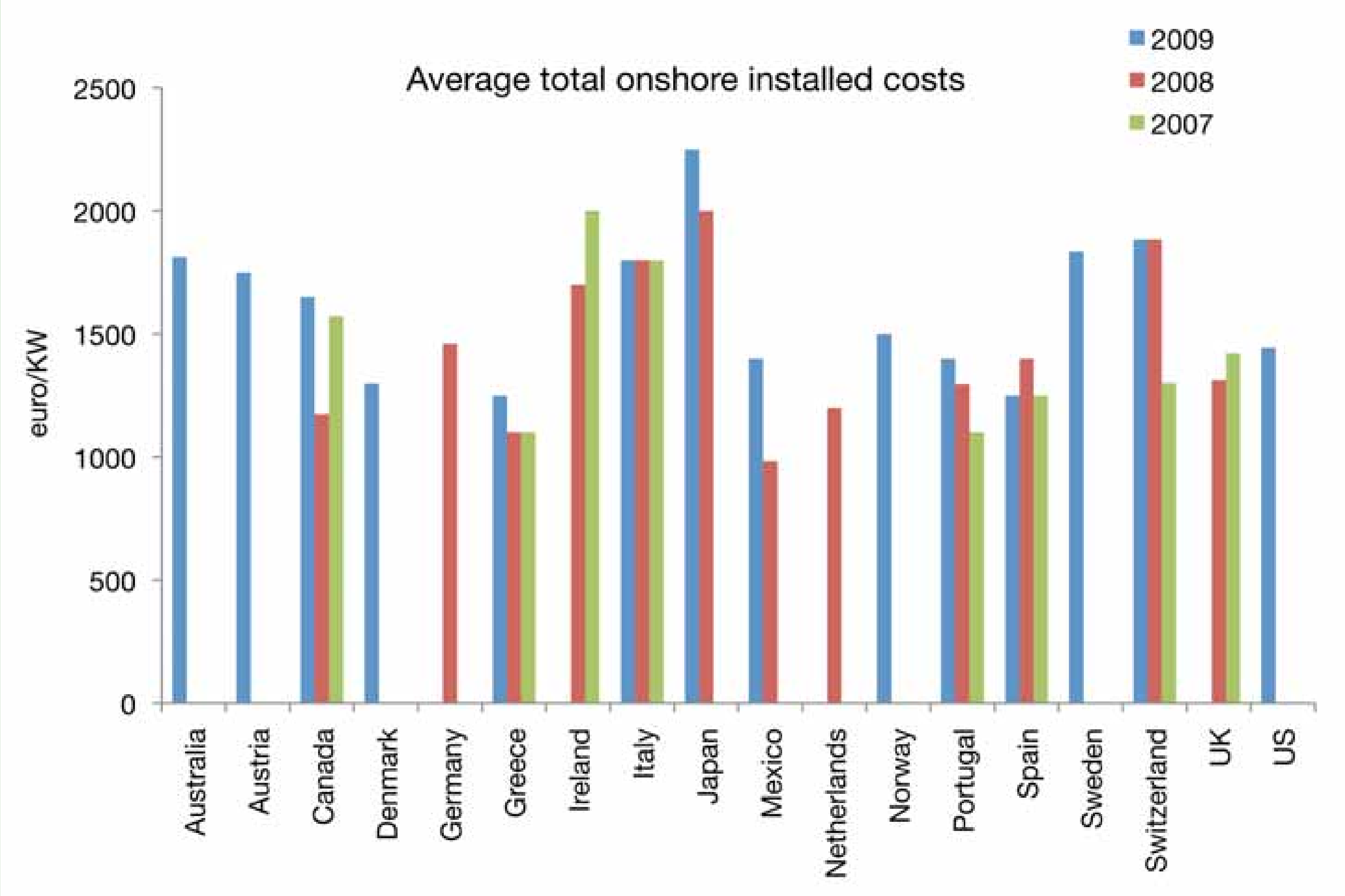

Figure 2 Average total installed costs of wind projects 2007–2009 as reported by IEA Wind member countries. These include costs for turbines, roads, electrical equipment, installation, development, and grid connection.

seismic hazard is high. This size turbine will be appropriate especially where access is difficult.

Much work is under way to develop new technology. The United States will launch a project in 2010 to develop mid-size turbines (100 kW to 1,000 kW) to meet a projected 220-GW market for this size turbine. In Switzerland a new coating that influences the freezing behavior of water shows promise to combat icing on rotor blades. In Norway, a new 900-kW turbine was installed to test the concept of hydraulic transmission of wind power. Several countries are supporting work on horizontal-axis wind turbines.

Effective methods to integrate large amounts of wind power into the grid are being explored in most IEA Wind member countries. In Ireland, up to 45% contribution from wind was seen during 2009 with no problems; however the grid operators are conducting technical studies to increase understanding of the power system with very high levels of renewable generation. In the United States, two large studies of the operational impact of 30% wind generation on major regional grids concluded that sub-hourly scheduling and co-operation between utility balancing areas will be important. Transmission planning, system operation policy, and market development need to continue to evolve for these integration levels to be achieved. Australia is conducting an international benchmarking study to identify the world's best practice for a wind energy forecasting system, an important tool for managing wind output.

4.1.3 Small wind

Small wind turbines are attracting considerable interest within research programs. In Austria, three new projects are addressing a new small turbine design, identifying legal and economic barriers, and developing resource assessment tools for the urban environment. Ireland will continue its field trials of small turbines through 2010. The study will assess the performance of the technologies and inform future decisions on possible incentives, tariffs, or deployment programs. Canada is working with the Small Wind Coordinating Council on a North American standard for reporting energy and sound performance of small wind turbines. Work is also underway to test small turbines. In Korea, it was found that more than 100 companies had entered the small wind turbine business by the end of 2009, prompting the establishment of a government training program for installers. The United States tests small wind turbines to International Electrotechnical Commission (IEC) standards and draft American Wind Energy Association Standards.

4.2 Collaborative research

The collaborative research conducted by organizations within the IEA Wind member countries made significant progress in 2009. Task 11 Base Technology Information Exchange organized three Topical Expert Meetings in 2009 that gathered 75 invited researchers from 13 countries of IEA Wind: Radar Radio and Links with Wind Turbines, Sound Propagation

Table 9 Reported Research Activities in IEA Wind Member Countries		
Type of program	Country activities reported	IEA Wind co-operative activities in 2009
Offshore wind	Includes technology development and testing for turbines and foundations, design work, transmission issues, and resource assessment	Task 23 Offshore Wind Technology and Deployment: Subtask 1 workshops "Power Fluctuations from Offshore Wind Farms" and "Workshop on Wake Effects" Subtask 2 Offshore Code Comparison Collaborative (structures) and, approved in 2009 to begin in 2010, Task 30 Comparison of Dynamic Codes and Models for Offshore Wind Energy (structures)
Small wind	Technology development and testing of turbines generating 50 kilowatts or less	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	
Resource assessment, mapping, and forecasting	Measurement programs and model development to assess and map the wind resource; remote sensing programs and techniques; wind atlas development; forecasting techniques	Task 11 Base Technology Information Exchange: Topical Expert Meeting "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	Task 26 Cost of Wind Energy and work to draft *IEA Wind Recommended Practice for calculating cost*; Task 29 Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models
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 and Task 24 Integration of Wind and Hydropower Systems
Innovative concepts	Vertical axis, hydraulic drive, kites, etc.	

Table 10 Reported Status of Research Budgets in IEA Wind Member Countries	
Research budget status	Country reporting (not all countries provided information)
Increased budget in 2009 over 2008	Finland, Japan, Korea, Norway, Sweden, the United States
Constant budget in 2009 compared to 2008	Italy
Reduced budget in 2009 compared to 2008	Denmark, Germany, Switzerland

Models and Validation, and Remote Wind Speed Sensing Techniques using SODAR and LIDAR. These meetings and proceedings were available to researchers in the seventeen 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 Turbine Drive Train Dynamics and Reliability and The Application of Smart Structures for Large Wind Turbine Rotor Blades. Meeting topics planned for 2010 include Wind Park Performance Assessment in Complex Terrain; Micro Meteorology Inside Wind Farms and Wakes Between Wind Farms; High Reliability Solutions and Innovative Concepts for Offshore Wind Turbines; Wind Conditions for Wind Turbine Design; and Control Strategies for Integration on Weak Grids.

Task 19 Wind Energy in Cold Climates released three key reports in 2009. Recommendations for Wind Energy Projects in Cold Climates included information on available best practices, site measurement techniques, and ways to estimate ice-induced production losses. It described key safety aspects, and technical solutions provided by wind turbine manufacturers. The State-of-the-Art of Wind Energy in Cold Climates report found that keeping turbine blades free from ice is essential for reliable energy production. The report provides information on indirect and direct icing measurements and an analysis of available icing models. A Final Report on the term ending in 2009 was also published summarizing findings and results. At the request of the eight participating IEA Wind countries, Task 19 was extended for another three-year research program.

Participants in Task 23 Offshore Wind Technology and Deployment and Task 24 Integration of Wind and Hydropower Systems finished their research programs in preparation for writing the final reports that will be published in 2010.

Task 25 Power Systems with Large Amounts of Wind Power has served as an international forum on the topic. System operators from Denmark, Germany, Ireland, Portugal, and the United Kingdom have joined task meetings; and representatives from TSO working groups at the Utility Wind Integration Group (UWIG), 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. Other IEA Implementing Agreements have exchanged information with Task 25 participants (Demand Side Management, Electricity Networks Analysis, Research and Development (ENARD), and Ocean Energy Systems). The Task 25 Report of Phase One (2006 to 2008) was published in early 2009. The report found that large balancing areas and aggregation benefits of large areas help in reducing the variability and forecast errors of wind 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 is scheduled for release in 2010.

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. The final outcome will be an international sector guide: Recommended Practice for Consumer Labeling of Small Wind Turbines. 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 began work in 2009 by holding five meetings in conjunction with IEC MT2 to develop and begin implementing a detailed work plan.

Task 28 Social Acceptance of Wind Energy Projects was started to translate the findings of social scientists into the language of planners and engineers in order to improve the process of bringing wind energy projects to completion. In 2009, a library of resource documents was assembled and participants contributed to The State of the Art on Social Acceptance of Wind Energy Projects scheduled to be published in 2010.

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. In 2009, the first analyses of the databases were published in journals and presented at conferences.

To improve the accuracy of existing computer codes and models for estimation of structural loads for offshore wind turbines, the code comparison work of Task 23 Subtask 2 was approved to continue in 2010 as Task 30 Comparison of Dynamic Codes and Models for Offshore Wind Energy.

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 2010. The cooperative research efforts of IEA Wind will publish significant reports on offshore wind energy, integration of wind and hydropower, integration of large amounts of wind power, cost of wind energy, and social acceptance of wind energy projects. The work of these tasks should support efforts worldwide to increase the contribution of wind energy.

References and notes:

(1) Global Wind Energy Council (GWEC). 2010. Global Wind 2009 Report. http://www.gwec.net/fileadmin/documents/Publications/Global_Wind_2007_report/GWEC_Global_Wind_2009_Report_LOWRES_15th.%20Apr.pdf. Brussels: GWEC.

(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 2010.

(3) International Energy Agency (IEA). (2009). Key World Energy Statistics, 2009. http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=1199. Paris: IEA.

(4) International Energy Agency (IEA). (1995–2008). IEA Wind Annual Reports. www.ieawind.org. Boulder: PWT Communications, LLC.

(5) IEA Wind. (2008). End-of-Term Report and Strategic Plan, 1 November 2008 to 31 October 2013. http://www.ieawind.org/Publications.html.

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

Photo credit Patricia Weis-Taylor

1.0 Introduction

Participation in IEA Implementing Agreements is determined at the national government level of a country. Once a country becomes a contracting party to the IEA Wind Implementing Agreement, researchers, utilities, companies, and universities may contact their country representative (see appendix B) about ways to benefit from the 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 24 contracting parties from 20 Member Countries, 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-second *IEA Wind Energy Annual Report*. In Section I, Implementing Agreement and Active Research Tasks, the managers (Operating Agents or OAs) of the IEA Wind 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. The Executive Summary compiles information from all countries and tasks in a shorter format suitable for decision makers.

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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 2009, participants in the IEA Wind Agreement worked on nine cooperative research tasks, which have been approved by the ExCo as annexes to the Implementing Agreement text. Additional tasks are planned when new areas for cooperative research are identified by Members. Progress in cooperative research is described in chapters 2 through 10. The numbers of active tasks are not sequential because some tasks have been completed and so do not appear as active projects in

★ 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. In 2008, 28 countries and the European Commission participated in 42 Implementing Agreements of the IEA. OECD Member countries, non-Member countries, and international organisations may participate. For more information, visit www.iea.org.

† The IEA Wind implementing agreement functions within a framework created by the International Energy Agency (IEA). Views and findings 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 2009	
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	ERSE 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
Sponsor Participants	
EWEA	European Wind Energy Association

this report. Task 30 Offshore comparison of dynamic computer codes and models offshore code comparison collaborative (OC3) extension project was approved in 2009 to begin in 2010. This task will continue work begun under sub-task 2 of Task 23 Offshore wind energy technology and deployment.

The combined effort devoted to a task is typically the equivalent of several people working full-time for a period of three years. Some tasks have been extended so that work can continue. Some projects are cost-shared and carried out in a lead country. Other projects are task-shared, in which the participants contribute in-kind effort, usually in their home organizations, to a joint research program coordinated by an Operating Agent (OA). In most projects each participating organization agrees to carry out a discrete portion of the work plan. This means that each participant has access to research results many times greater than could be accomplished in any one country. 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: 6.237 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 three years; total value of shared labor received: 9.528 million Euro (13.263 million USD).

By the close of 2009, 18 tasks had been successfully completed and two tasks had been deferred indefinitely. Final reports of tasks are available through the IEA Wind Web site: www.ieawind.org. Table 3 shows participation by members in active research tasks in 2009.

To obtain more information about the cooperative research activities, contact the operating agent representative for each task listed in appendix B or visit our Web site at www.ieawind.org (click on the tab for cooperative research or follow the links to individual task web sites).

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 is presented in the Executive Summary of this Annual Report. Individual country activities are presented in chapters 11 through 30.

4.0 Executive Committee

Overall control of information exchange and of the R&D tasks is vested in the Executive Committee (ExCo). The ExCo consists of a Member and one or more Alternate Members designated by each participant 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

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) changing to CENER, Spain (2009-2010)
Task 19	Wind energy in cold climates OA: Technical Research Centre of Finland - VTT (2001 to 2011)
Task 23	Offshore wind energy technology deployment OA: Risø National Laboratory, Denmark and NREL, United States (2004 to 2009)
Task 24	Integration of wind and hydropower systems OA: NREL, United States (2004 to 2009)
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 Comparison of Dynamic Computer Codes and Models Offshore Code Comparison Collaborative (OC3) Extension Project OA: NREL, the United States and Fraunhofer IWES, Germany (2010 to 2013)

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, such as preparation of this Annual Report, approved by the ExCo in the annual budget.

Officers

In 2009, Brian Smith (United States) served as Chair. Hannele Holttinen (Finland) and Joachim Kutscher (Germany) served as Vice Chairs. All three were elected to continue their posts in 2010.

Participants

In 2009, there were no changes in IEA Wind country participation however there were personnel changes among the Members and Alternate Members. (See Appendix B IEA Wind Executive Committee for members, alternate members, and operating agent (OA) representatives who served in 2009.)

Meetings

The ExCo meets twice a year. The first meeting of the year is devoted to reports on R&D activities in the member countries and in the Tasks, and the second meeting is devoted to reports from member countries and Tasks about deployment activities.

The 63rd ExCo meeting was hosted by Germany in the city of Bremerhaven on 21, 22, and 23 April 2009. There were 28 participants from 17 of the contracting parties. Attendees included eight OA representatives of the Tasks and an observer from RusHydro/NIIEA in Russia. At the request of participants, the ExCo approved extensions to the following tasks: Task 11 through 2010; Task 19 through 2011; Task 23 through 2009; Task 24 through 2009; and Task 25 through 2011. The final report for Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power was approved. A final task proposal was approved for Task 26 Cost of Wind Energy. The ExCo unanimously approved the IEA Wind audit report of the Common Fund for 2008. The ExCo unanimously approved a motion to invite the Russian Federation or any entity it may designate to join as a full Member Country (contracting party) IEA Wind. On April 23 the meeting participants visited the Multibrid and RePower 5-MW turbines, the Fraunhofer Institute for Wind Energy and System Integration Research, the PowerBlades production facility and the Multibrid production facility, all in the city of Bremerhaven.

The 64th ExCo meeting was hosted by Mexico in the city of Huatulco, on 3, 4, and 5 November, 2009. There were 24 participants from 14 contracting parties. The two reports 1. Expert Group Study on Recommendations for Wind Energy Projects in Cold Climates Edition 2009 and 2. State-of-the-art of Wind Energy in Cold Climates were unanimously approved by email ballot. The ExCo approved the final task proposal and work plan of Task 27 Development and Deployment of Small Wind Turbine Labels for Consumers. The proposal for Task 30 Offshore Comparison of Dynamic Computer Codes and Models Offshore Code Comparison Collaborative (OC3) Extension Project was also approved for 2010 through 2013. The ExCo unanimously approved adoption of the Implementing

Table 3 Participation of member countries in Tasks during 2009 (OA indicates operating agent that manages the Task)

	Research Task Number								
Participant	11	19	23	24	25	26	27	28	29
Australia				x			x		
Austria		x							
Canada	x	x		x	x		x	x	x
Denmark	x		OA		x	x	x	x	x
European Commission	x								
EWEA					x	x			
Finland	x	OA		x	OA			x	
Germany	x	x	x		x	x		x	x
Greece	x								
Ireland	x				x			x	
Italy	x				x				
Japan	x				x		x	x	x
Korea	x		x						x
Mexico	x								
Netherlands	x		x		x	x		x	OA
Norway	x	x	x	x	x			x	x
Portugal			x		x				
Spain	OA		x		x	x	OA		x
Sweden	x	x	x	x	x	x	x		x
Switzerland	x	x		x		x		OA	
United Kingdom	x		x		x		x		
United States	x	x	OA	OA	x	OA	x	x	x
Totals	18	8	10	7	15	8	8	10	10

Agreement legal text that incorporates the IEA Framework document. The ExCo approved the budgets for the ongoing tasks and for the Common Fund for 2010. On 5 November, meeting participants visited Puchitan and La Ventosa to see the wind farms La Ventana 1 and 2 and the IIE Wind Energy Technology Center.

5.0 Outreach activities

The 31st issue of the *IEA Wind Energy Annual Report* was published in July 2009 and the Web site, www.ieawind.org continued to expand coverage of IEA Wind activities. In all, eight technical reports of IEA Wind were published in 2009. Countless journal articles, conference presentations, and poster presentations drew upon the work of the IEA Wind research tasks.

A planning committee consisting of the Chair, Vice Chairs, the Secretary, the former Chair, and the Operating Agent 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 Networks of Expertise in Energy Technology (NEET) meetings in India, attending Renewable Energy Working Party (REWP) meetings, supplying materials for ministerial meetings, reviewing draft IEA documents that address wind technology, and supplying text for drafts of IEA annual reporting documents.

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.

1.0 Introduction

Task 11 of the IEA Wind Agreement has the objective of promoting and disseminating 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. The Spanish National Centre of Renewable Energies (CENER) is the current Operating Agent.

Task 11 is an important instrument of IEA Wind. It can react flexibly on 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.

All meetings and documents are available to organizations in the 16 countries that participate in Task 11, pay fees to support the activity, and send experts to the meetings. All documents more than a year old can be freely accessed on the public Task 11 web pages at www.ieawind.org.

2.0 Objectives and Strategy

The objective of Task 11 is to promote wind turbine technology through information exchange among experts on R&D topics of common interest. The main action to enable the exchange of information between the participant countries is the arrangement of Topical Expert Meetings (TEM) focused on priority issues. During 32 years of activity to promote wind turbine technology through information exchange, more than 85 expert meetings have been organized. The meetings are hosted by organizations based in countries that participate in the Task. Four TEM on different topics are arranged every year, gathering active researchers and experts from the 16 participating countries. The IEA Wind Executive Committee chooses the topics of the meetings. Table 2 lists the latest TEM arranged. TEM cover the most important areas of the wind energy sector and can also begin the process of organizing new research tasks as additional annexes to the IEA Wind Implementing Agreement. Figure 1 shows the share of TEM by subject.

A second activity of the Task is to develop Recommended Practices (RP) for wind turbine testing and evaluation. Many of the RP documents have served as the basis for both international and national standards.

3.0 Progress in 2009

Three TEM were organized in 2009 and the fourth was postponed until 2010. Proceedings are available to participants until

Table 1 Task 11 participants

	Country	Institution
1	Canada	National Resources Canada (NRCan)
2	Denmark	Risø National Laboratory (DTU)
3	European Commission	European Commission
4	Finland	Technical Research Center of Finland (VTT Energy)
5	Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)
6	Greece	Center for Renewable Energy Resources (CRES)
7	Ireland	Sustainable Energy Authority Ireland (SEAI)
8	Italy	CESI S.p.A.; National Agency for New Technologies, Energy and Sustainable Economic Development, Casaccia Research Center (ENEA Casaccia)
9	Japan	National Institute of Advanced Industrial Science and Technology (AIST)
10	Republic of Korea	Posttech
11	Mexico	Institute of Electrical Investigations (IIE)
12	Netherlands	Agentschap NL
13	Norway	The Norwegian Water Resources and Energy Directorate (NVE)
14	Spain	Research Center for Energy, Environment and Technology (CIEMAT)
15	Sweden	Swedish Energy Agency
16	Switzerland	Swiss Federal Office of Energy (SFOE)
17	United Kingdom	Department for Business, Enterprises and Regulatory Reform (BERR)
18	United States	Department of Energy (DOE)

Table 2 Topical expert meetings held since 2005			
NO.	Titile	Year	Location
60	Radar Radio and Links with Wind Turbines	2009	Amsterdam, The Netherlands
59	Remote Wind Speed Sensing Techniques using SODAR and LIDAR	2009	Boulder, USA
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, USA
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, UK
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
47	Methodologies for Estimation of Cost of Wind Energy and the Impact of Research on the Cost	2005	Paris, France
46	Obstacle Marking of Wind Turbines	2005	Stockholm, Sweden

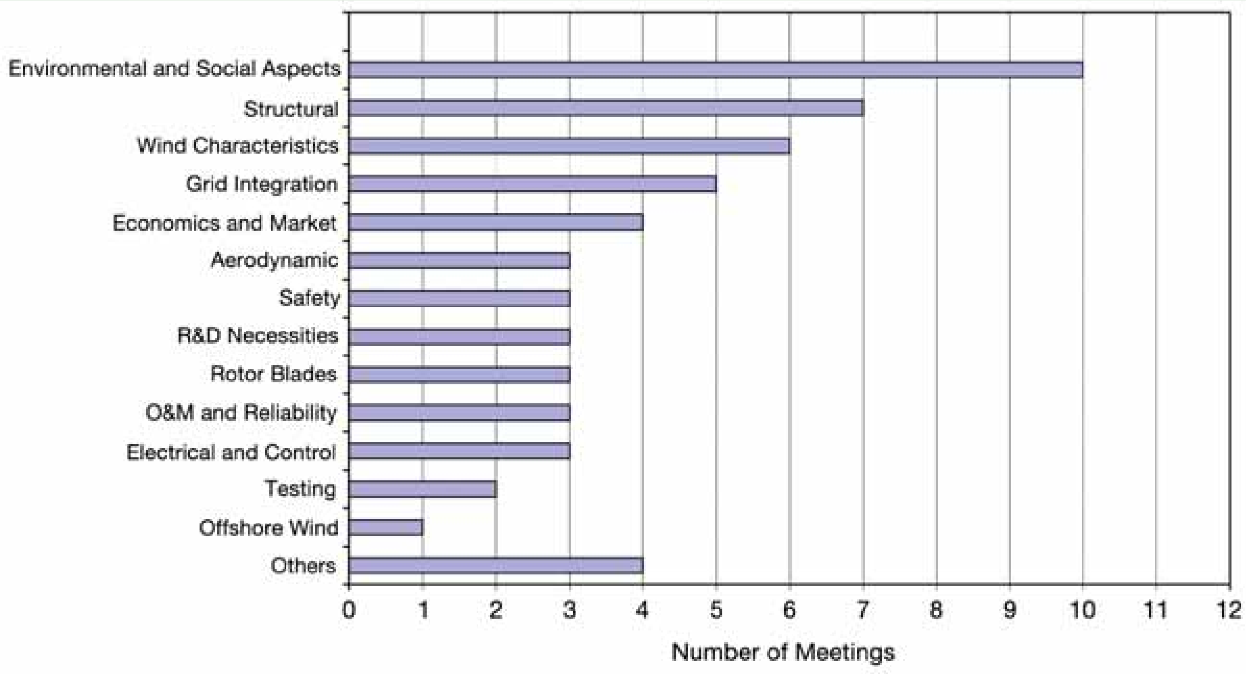

Figure 1 Topical Expert Meetings by subject

one year after the meeting date when they become public. During 2009, a list of topics was sent by the OA to the task members, to identify new topics of interest for future TEM. Preparation of the 2010 meetings is in progress.

During 2009 and 2010, two RP documents are in preparation. Other issues for new RP are in the analysis process, in accordance with the outcome suggestions from the Executive Committee.

3.1 Topical Expert Meetings

To complete the work plan approved by the ExCo, three TEM were planned and completed during 2009:

- #58 Sound Propagation Models and Validation
- #59 Remote Wind Speed Sensing Techniques using SODAR and LIDAR
- #60 Radar Radio and Links with Wind Turbines.

Another TEM on "Micrometeorology Inside Wind Farms and Wakes Between Wind Farms" planned for December 2009 in Pamplona, Spain was postponed, because a similar meeting was held in October 2009 by Euromech (The European Mechanics Society).

3.1.1 Sound Propagation Models and Validation

Held in May 2009, Stockholm, Sweden, this meeting was hosted by the Swedish Energy Agency (STEM) to report and discuss developments in this field that can be a potential barrier to the social acceptance of wind energy implementation. A recent important activity has been the development of the IEC standards (61400-11: Acoustic noise measurement techniques) for wind farms noise generation and emission. However, on the immission side, that is, the calculation of noise levels and the measurement and assessment of noise at receptor locations, less has been done and no generally accepted procedures for estimating noise immission exist.

The meeting was attended by 17 participants representing nine countries: Denmark, Finland, Germany, Italy, Japan, Norway, Spain, Sweden, and the United Kingdom. The participants represented universities, research centers, public organizations, and industries. A total of 13 presentations were given. Presentations covered the following topics:

- Long range sound propagation in the atmosphere
  - Modelling
  - Experimental investigations
  - Offshore wind farms
  - Meteorological data
- Background noise (wind driven)
- Masking of wind turbine noise.

Following the two days of presentations, a general discussion took place of the following topics:

- Country noise limits
- Long propagation noise on offshore installations
- Procedure for immission noise measurement
- Measured data for validation of sound propagation models
- Background noise (masking the noise)
- Future actions under the umbrella of IEA Wind.

Many of the participants agreed that a general method for noise immission measurement from wind turbines is needed. These kinds of measurements are made all over the world, but using different techniques. It was deemed necessary to elaborate a RP document for "Noise Measurement Immission," and an "Ad-hoc" group should be created for this purpose. Several of the participants expressed their interest to be included in the group.

3.1.2 Remote Wind Speed Sensing Techniques using SODAR and LIDAR

Held in October 2009, at the U.S. National Wind Technology Center in Boulder, USA, this meeting was hosted by the United States. A total of 31 persons attended from Denmark, Finland, Germany, Japan, Korea, Norway, Sweden, the Netherlands, Spain, the United Kingdom, and the United States (Figure 2). The participants represented a great variety of stakeholders: research organizations, universities, consultants, and some manufactures of equipments. A total of 21 presentations were given covering the following topics:

- Overview of existing knowledge and experience on LIDAR and SODAR technical issues regarding the measurement of mean wind speeds, turbulence quantities, and vertical wind profiles for wind energy applications
- Calibration of SODAR and LIDAR systems
- Accuracy and reliability of the different systems and comparisons with other point measurement techniques, e.g. cup anemometers
- The need for a "good measurement practice" using remote sensing equipment
- Future options for wind energy using SODAR and LIDAR.

After the two days of presentations, a general discussion took place covering the following topics:

- Validation of remote sensing systems vs. meteorological tower measurements
- Simple terrain vs. complex terrain issues
- Field practices
- Uncertainty and turbulence measurements
- Applications of remote sensing systems
- Structure of the RP documents
- Future actions.

The participants in the meeting wanted to continue the efforts in this area, and reiterated the need to elaborate the RP on the use of remote sensing equipment. Some of the participants will collaborate to prepare the RP.

3.1.3 Radar, Radio, and Links with Wind Turbines

Held in November 2009, Amsterdam, the Netherlands, this meeting was hosted by SenterNovem. Experts on radar-turbine interactions from the scientific community, the radar industry, and the wind turbine industry, as well as radar system operators and policy makers were invited to exchange knowledge and to come to a common understanding of the developments, conflicts, and their solutions. Twenty seven people from Belgium, Finland, Germany, Sweden, the Netherlands, Norway, the United Kingdom, and the United States viewed 18 presentations. The participants represented stakeholders related to this topic, including research organizations, universities, consultants, government units, military organizations, and some manufactures of equipment. Presentations covered policies, types of interference, and technical possibilities to mitigate.

The general discussion addressed the following topics:

- Air traffic control (ATC) and national security

- Assessment methodology
- Mitigation options
- Who has to pay the cost of mitigation options?
- Future actions under the umbrella of IEA Wind

Most participants favored establishing a new IEA Wind Task to analyze the impacts of wind turbines on radar systems at selected sites, using the same assessment methodology. The output of such a study would be very useful for developers, air traffic control organizations, and national security departments. A working group was assembled to put forward a proposal to make a Task Proposal to address issues surrounding the interactions of radar, radio, and wind turbines.

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 no standards were available. Fortunately, now there are a large number of IEC standards available in the wind energy sector. Much work is going on under the umbrella of the IEC for developing new standards. However, the long time period required for development of standards is a problem. IEA Wind RP can be prepared in a shorter period of time under Task 11 and can be an important input for the future elaboration of IEC standards.

3.2.1 Recommended Practices on SODAR and LIDAR

Currently two RP are under development dealing with wind measurements with SODAR-type equipment and wind measurements using the LIDAR-type instrument. The RP documents on SODAR and LIDAR are scheduled to be completed by the end of 2010. The SODAR document was drafted in 2009. However, after the TEM on Remote Wind Speed Sensing Techniques using SODAR and LIDAR, the developers decided to include the new contributions from the meeting to improve the document. Once modified, the draft document will be distributed for comments. The final document is expected to be ready in the middle of 2010. The LIDAR RP document should be finished before the end of 2010.

3.2.2 Other Recommended Practices

As result of the TEM on Sound Propagation Models and Validation, the opportunity was identified to develop an RP document for Noise Measurement Immission. Several of the participants expressed their interest to be included in the Ad-hoc group for this action.

Figure 2 Topical Expert Meeting at the U.S. National Wind Technology Center, NREL, USA

New topics for RP documents were also suggested at the 63rd ExCo meeting in Bremerhaven, Germany. One was an RP on calculation of performance and load conditions of wind turbines in cold climates to be coordinated with Task 19 Wind Energy in Cold Climates. Another was an RP to calculate the cost of wind energy to be developed in coordination with Task 26 Cost of Wind Energy. The Task 11 OA has contacted the OA of both tasks to explore the possibility of obtaining the information required to prepare the new RP documents.

4.0 Plans for 2010 and beyond

Task 11 Base Technology Information Exchange is a "continuous" task. Started in 1987, every two years it is extended by agreement of the participants and the ExCo. The last extension for the period 2009-2010, was formally approved at the 63rd IEA Wind ExCo meeting in Bremerhaven, Germany, 21–23 April 2009. The next proposal for extension should be presented to the 66th ExCo meeting in October 2010.

Planned TEM for 2010 are:

- # 61: Wind Park Performance Assessment in Complex Terrain, Republic of Korea
- # 62: Micro Meteorology Inside Wind Farms and Wakes Between Wind Farms, Spain
- # 63: Offshore Wind Technology, Norway
- # 64: Wind Conditions for Wind Turbine Design, Japan
- # 65: Control Strategies for Integration on Weak Grids, Mexico.

The Republic of Korea, Norway, Japan, and Mexico will host a TEM for the first time.

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 RPs on "Performance and Load Conditions of Wind Turbines in Cold Climates" and "Cost of Wind Energy."

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Photo Credit: Andrea Vignaroli

1.0 Introduction

Wind energy is increasingly being used in cold climates, and technology has been adapted to meet these challenges. As the turbines that incorporate new technology are being demonstrated, the need grows for gathering experiences in a form that can be used by developers, manufacturers, consultants, and financiers. To supply needed information on the operation of wind turbines in cold climates, Annex 19 to the IEA Wind Implementing Agreement was officially approved in 2001. As a result, Task 19 began its work in May 2001 and continued for three years. At the end of the first three-year period, the participants decided to extend the collaboration. The main drivers were the need to better understand wind turbine operation in cold climates and to gain benefit from the results of the national projects launched during the first three years. Table 1 lists the participating countries in 2009.

Table 1 Task 19 participants

	Country	Institution(s)
1	Austria (new member)	Division for Energy and Environmental Technologies, Austrian Federal Ministry for Transport, Innovation and Technology
2	Canada	Natural Resources Canada (NRCan)
3	Finland	Finnish Funding Agency for Technology and Innovation, Energy and Environment Industries (TEKES); VTT Technical Research Centre of Finland (Operating Agent)
4	Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU); Institute of Solar Energy Distribution Technology (ISET)
5	Norway	Enova SF; Kjeller Vindteknikk
6	Sweden	Swedish Energy Agency; WindREN AB
7	Switzerland	Swiss Federal Office of Energy (SFOE); ENCO
8	United States	U.S. Department of Energy; National Renewable Energy Laboratory (NREL)

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 cold conditions retard energy production during the winter. Such sites are often elevated on hills above the surrounding landscape or located in high northern latitudes (1).

2.0 Objectives and Strategy

The objectives of Task 19 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. Possibly recommend updates to standards that include comments from planners and operators.
- Find and recommend a method for estimating the effects of ice on production. A better method would reduce incorrect estimates and therefore the economic risks currently involved wind energy projects located in cold climates. As possible, verify the method on the basis of data from national projects.
- Clarify the significance of extra loading that ice and cold climate induce on wind turbine components and disseminate the results.
- 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 national activities of task participants are designed to provide new information on issues that are preventing cold climate development today. The results of these activities will enable improvements of the overall economy of wind energy projects and lower the risks involved in areas where low temperatures and atmospheric icing are frequent. The reduced risk would thereby reduce the cost of wind electricity produced in cold climates.

Participants in Task 19 are active in several international projects and co-operative efforts. Some take part in the European Union–funded COST727 action, which aims to improve the Europe-wide ice measurement network and to forecast atmospheric icing. This information directly benefits the work of Task 19.

The collaboration will continue to actively disseminate results through the Task 19 web site (linked at www.ieawind.org), and through conferences and seminars (2–6). At the end of the current task period, a final report will be published that describes updated state of the art technology and gives updated recommendations regarding the use of wind turbines at sites where winter conditions prevail for a significant time during the year. One important dimension of this work will be the initiation of conversation about whether cold climate issues should be recognized in future standards that set the limits for turbine design.

3.0 Progress in 2009

Two meetings were organized in 2009: the first in Bern, Switzerland hosted by Meteotes, and the second in December in Vienna, Austria hosted by Energiewerkstatt.

In 2009, participants released three key reports. *Recommendations for Wind Energy Projects in Cold Climates* includes information on available best practices, site measurement techniques, ways to estimate ice-induced production losses, key safety aspects, and technical solutions provided by wind turbine manufacturers. *The State-of-the-Art of Wind Energy in Cold Climates* finds that keeping turbine blades free from ice is essential. It provides information on indirect and direct icing measurements and an analysis of available icing models. The severity of icing depends heavily on local conditions. *A Final Report* on the term ending in 2009 was also published summarizing findings and results.

The need to continue the work of Task 19 in one way or another was expressed during 2008. The issue of low temperatures is mentioned in standards and recommendations; however, icing is rarely taken into account. Many projects are in the planning stage, but there is a lack of commercially available solutions, especially for ice detection and blade anti-icing and de-icing. The development of such solutions may not be a suitable topic for an IEA Wind Task, but pointing out the needs and recommending tools to compare the solutions are goals of Task 19. It was decided to propose a third term to the ExCo at the first meeting of 2009. As a result, a third three-year term was approved by the ExCo in April 2010.

The Task 19 web site has been updated and serves as an extranet among Task 19 participants.

4.0 Plans for 2010 and beyond

Final results of the task to be achieved by the end of the term include:

- Publishing an updated state-of-the-art report
- Publishing an updated recommendations report
- Completing a database of wind turbines in cold climates
- Completing a database of relevant reports
- Preparing a proposal for the extension of Task 19.

The activities will help solve the most common issues causing uncertainty for cold climate wind energy development. These task activities are intended to match well with the national activities of participants.

References

(1) T. Laakso, H. Holttinen, G. Ronsten, L. Tallhaug, R.Horbaty, I. Baring-Gould, A. Lacroix, E. Peltola, B. Tammelin. State of the Art of Wind Energy in Cold Climates. IEA Wind Annex 19, 53 p. http://arcticwind.vtt.fi, 2003 (date of access 31 January 2006).

(2) Jonas Wolff, Per Lundsager, Lars Tallhaug, Göran Ronsten, Ian Baring-Gould. Cold Climate Wind Energy Co-operation under the IEA. Proceedings of Boreas V, Levi, Finland, 2000.

(3) H. Holttinen, G. Ronsten, L. Tallhaug, P. Lundsager, R. Horbaty, I. Baring-Gould, A. Lacroix, E. Peltola, T. Laakso. The State of the Art of Wind Energy in Cold Climates. Proceedings of GWPC, Paris, France, 2002.

(4) E. Peltola, T. Laakso, G. Ronsten, L. Tallhaug, R. Horbaty, I. Baring-Gould, A. Lacroix. IEA Co-operation on Wind Turbines in Icing and Cold Climates. Proceedings of Boreas VI, Pyhätunturi, Finland, 2003.

(5) T. Laakso, E. Peltola, G. Ronsten, L. Tallhaug, R. Horbaty, I. Baring-Gould, A. Lacroix. Specific Recommendations for the Development of Wind Energy Projects in Cold Climates. Proceedings of EWEC, London, United Kingdom, 2004.

(6) E. Peltola, T. Laakso, G. Ronsten, L. Tallhaug, R. Horbaty, I. Baring-Gould, A. Lacroix. Specific Recommendations for the Development of Wind Energy Projects in Cold Climates. Proceedings of Boreas VII, Saariselkä, Finland, 2005.

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Task 23

1.0 Introduction

Recognizing the interest and challenges of offshore development of wind energy, IEA Wind Task 11 Base Technology Information Exchange sponsored a Topical Expert Meeting (TEM 43) in early 2004. This workshop on Critical Issues Regarding Offshore Technology and Deployment gathered 18 participants from six countries. Following this meeting, the IEA Wind ExCo approved Annex 23 (Task 23) Offshore Wind Technology and Deployment to the Implementing Agreement as a framework for holding additional focused workshops and developing research projects. The work would increase understanding of issues and technologies to advance the development of wind energy systems offshore. In 2009, 10 countries participated in this task (Table 1), and many research organizations in these countries shared their experiences and conducted the work.

Table 1 Task 23 participants

	Country	Institution
1	Denmark	Danish Energy Agency; Risø DTU (OA)
2	Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
3	Republic of Korea	Korean Institute of Research (KEMCO)
4	The Netherlands	Wea@Sea
5	Norway	ENOVA SF
6	Portugal	INETI
7	Spain	CENER
8	Sweden	Chalmers University
9	United Kingdom	Department of Trade and Industry
10	United States	U.S. Department of Energy; NREL (OA)

2.0 Objectives and Strategy

The overall objectives of Task 23 include the following:

- Sub-task 1, Experience with Critical Deployment Issues, led by Risø National Laboratory (Risø) in Denmark, organized workshops on critical research areas for offshore wind to identify R&D needs of interest to participating countries.
- Sub-task 2, Technical Research for Deeper Water, led by the National Renewable Energy Laboratory (NREL) in the United States, conducted R&D activities of common interest to participants to reduce costs and uncertainties.

3.0 Progress in 2009

3.1 Subtask 1: Experience with Critical Deployment Issues

When this IEA Wind Task began in 2005, the people and organizations involved in offshore wind energy were accumulating the first experiences with this technology and the critical issues of its deployment. From 2005 to 2009, Subtask 1 brought together more than 225 experts from 11 countries for 125 presentations during seven narrowly defined, highly technical meetings to share their experiences and plan new ways to cooperate. Although no official research efforts were begun under Task 23 Subtask 1, the workshops informed the experts who went on to design national, corporate, and institutional research programs. The invited experts included representatives from wind turbine manufacturers and developers; utility planning, grid operators, and regulatory bodies; national research institutes; engineering and design consultants; environmental planning and regulatory bodies; universities; and wind plant operators. Participants in the task selected three areas to explore: Ecological Issues and Regulations, Electrical System Integration of Offshore Wind, and External Conditions.

Under the topic of Ecological Issues and Regulations, one workshop was held: Offshore Wind Energy Deployment - Workshop on Ecology and Regulation was held February 28–29, 2008, Petten, the Netherlands.

Under the topic of Electrical System Integration of Offshore Wind, three workshops were held:

- *Grid Integration of Offshore Wind,* September 12–13, 2005, Manchester, UK.
- *Workshop/Round Table Discussion on Grid Integration of Offshore Wind*, June 18, 2007, London, UK.
- *Power Fluctuations from Offshore Wind Farms*, February 26, 2009, Roskilde, Denmark.

Under the topic External Conditions, the following workshops were held:

- *Workshop Programme on External Conditions, Layouts, and Design of Offshore Wind Farms* December 12–13, 2005, Roskilde, Denmark.
- *Workshop on Wake Modelling and Benchmarking Of Models*, September 7–9, 2006, Billund, Denmark.
- *IEA Task 23 Offshore Wind Energy Deployment - Workshop on Wake Effects*, February 25, 2009, Denmark.

The two final workshops for this subtask were held in 2009. The workshop on Power Fluctuations from Offshore Wind Farms, addressed key topics of Electrical System Integration and benfitted from the previous two workshops on this topic held in 2005 and 2007. The Workshop on Wake Effects addressed key topics of External Conditions and benefitted from two previous workshops in 2005 and 2006.

The final Technical Report will be published in 2010. The official records of these workshops contain valuable technical detail and are now available to any interested party via the Task 23 web pages hosted at www.ieawind.org. More than 125 presentations on topics ranging from aerodynamic modeling to benthic studies to wake effects can be found there for each of the seven workshops organized under the task.

3.2 Sub-task 2: Technical Research for Deeper Water

Sub-task 2 began in October 2004 and was intended to address technical issues associated with deeper-water implementation of offshore wind energy. In practice, however, the subtask turned into a working group known as the Offshore Code Comparison Collaborative (OC3), which verified design codes for shallow, transitional, and deep-water offshore wind turbine concepts. The group investigated different support structures in separate phases of the code comparison project:

- In Phase I, the NREL model of an offshore 5-MW wind turbine was installed on a monopile with a rigid foundation in 20 m of water.
- In Phase II, the foundation of the monopile from Phase I was made flexible by applying different models to represent the soil-pile interactions.
- In Phase III, the water depth was changed to 45 m and the monopile is swapped with a tripod substructure, which is one of the common space frame concepts proposed for offshore installations in water of intermediate depth.
- In Phase IV, the wind turbine was installed on a floating spar-buoy in deep water (320 m).

Phase IV was completed in 2009 and the final report will be published in 2010. In Phase IV of OC3, participants used an assortment of codes to model the coupled dynamic response of the NREL model of a 5-MW wind turbine installed on a deeply drafted, slender spar buoy with catenary mooring lines in 320 m of water. (Figure 1) Code predictions were compared from load-case simulations selected to test different model features. The comparisons have resulted in a greater understanding of offshore floating wind turbine dynamics and modeling techniques, and better knowledge of the validity of various approximations.

The code-to-code comparisons in Phases I through IV have agreed very well, in general. The key reasons for the differences and the other findings from Phases I through IV are discussed in the final report to be published on the Task 23 website (www.ieawind.org) in 2010. The verification activities performed in OC3 were important because the advancement of the offshore wind industry is closely tied to the development and accuracy of dynamics models. Not only have vital experiences and knowledge been exchanged among the project participants, but the lessons learned have helped identify deficiencies in existing codes and needed

Figure 1 Illustration of the NREL 5-MW wind turbine on the OC3-Hywind spar

improvements, which will be used to improve the accuracy of future predictions.

4.0 Plans for 2010 and Beyond

Work on Task 23 ended in December 2009. In 2010 the final Technical Reports will be published as two stand-alone documents at www.ieawind.org. Participants in both subtasks have discussed follow-on work and new Annex (Task) proposals are being considered.

A proposal to continue the work of OC3 participants was approved by the ExCo as Annex (Task) 30 Offshore Comparison of Dynamic Computer Codes and Models. Operating agents are the National Renewable Energy Laboratory, United States, and Fraunhofer IWES, Germany. The new annex will engage the current members of OC3 in further studies to benchmark at least two new coupled wind turbine and substructure systems that are relevant to the wind energy industry.

References

(1) 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.

(2) Passon, P., Kühn, M., Butterfield, S., Jonkman, J., Camp, T., and Larsen, T. J. "OC3—Benchmark Exercise of Aero-Elastic Offshore Wind Turbine Codes," Journal of Physics: Conference Series, The Second Conference on the Science of Making Torque From Wind, 28–31 August 2007, Copenhagen, Denmark [online journal], 012071, vol. 75, 2007. www.iop.org/EJ/article/1742-6596/75/1/012071/jpconf7_75_012071.pdf?request-id=8kI1Ig5u3BGgUobT2wi7Kg. NREL/CP-500-41930. Golden, CO: National Renewable Energy Laboratory.

(3) Jonkman, J., Butterfield, S., Passon, P., Larsen, T., Camp, T., Nichols, J., Azcona, J., and Martinez, A. "Offshore Code Comparison Collaboration within IEA Wind Annex XXIII: Phase II Results Regarding Monopile Foundation Modeling." 2007 European Offshore Wind Conference & Exhibition, 4–6 December 2007, Berlin, Germany [online proceedings], BT2.1. www.eow2007proceedings.info/allfiles2/206_Eow2007fullpaper.pdf. NREL/CP-500-42471. Golden, CO: National Renewable Energy Laboratory.

(4) Nichols, J., Camp, T., Jonkman, J., Butterfield, S., Larsen, T., Hansen, A., Azcona, J., Martinez, A., Munduate, X., Vorpahl, F., Kleinhansl, S., Kohlmeier, M., Kossel, T., Böker, C., and Kaufer, D. "Offshore Code Comparison Collaboration within IEA Wind Annex XXIII: Phase III Results Regarding Tripod Support Structure Modeling." 47th AIAA Aerospace Sciences Meeting and Exhibit, 5–8 January 2008, Orlando, Florida, AIAA Meeting Papers on Disc 14(1). CD-ROM. AIAA-2009-1038, Reston, VA: American Institute of Aeronautics and Astronautics, January 2009. NREL/CP-500-44810. Golden, CO: National Renewable Energy Laboratory.

(5) Jonkman J. Definition of the Floating System for Phase IV of OC3. NREL: Golden, CO, 2009 (to be published).

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Task 24

Integration of Wind and Hydropower Systems

1.0 Introduction

About 450 GW of hydropower capacity and approximately 115 GW (year end 2009) of wind power capacity is operating in the IEA Wind member countries. In many of these countries, a large amount of wind generation is being integrated into the electricity supply system. Because of the natural variability of wind power and the uncertainty in its prediction, the impact of integrating wind power into utility operations can increase generation reserves required and the need for flexible, rapidly responding generation resources. Since hydropower generally is quite flexible and able to provide reserves, many utilities are using these characteristics to help meet the balancing needs of wind power.

	Table 1 Task 24 participants	
	Country	Institution
1	Australia	Australia Wind Energy Association and Hydro Tasmania
2	Canada	Natural Resources Canada, Natural Resources Canada, Manitoba Hydro, and Hydro Québec
3	Finland	TEKES National Technology Agency in Finland and VTT
4	Norway	Norwegian Water Resources and Energy Directorate, Sintef Energy Research, and Statkraft Energy
5	Sweden	Swedish Energy Agency and KTH Swedish Institute of Technology
6	Switzerland	Swiss Federal Office of Energy and EW Ursern
7	United States	U.S. Department of Energy, National Renewable Energy Laboratory, Grant County Public Utility District, Sacramento Municipal Utility District, and Northern Arizona University

Questions then arise about the economics, overall benefit to the electrical system, impacts on hydropower operations, and more.

In light of these questions, attendees at an IEA Wind Topical Experts Meeting in 2003 began work to organize cooperative research on the integration of wind and hydropower technologies under the auspices of the IEA Wind agreement. Task 24 "Integration of Wind and Hydropower Systems" was approved by the ExCo in May 2004. This cooperative research effort (concluded in 2009), multiplied the experience and knowledge gained from many different hydro system configurations, in seven countries and in many different electricity markets (Table 1). In addition, the IEA Wind Task 24 cooperated with the IEA Hydropower Implementing Agreement and with IEA Wind Task 25 Power Systems with Large Amounts of Wind Power.

2.0 Objectives and Strategy

Task 24 was organized to conduct cooperative research concerning the generation, transmission, and economics of integrating wind and hydropower systems, and to provide a forum for information exchange.

The participants conducted three types of case studies: grid integration, hydro system impacts, and market and economics. While many case studies involved all of these topics, some studies only addressed one or two. Each case study addressed problem formulation and assumptions, analysis techniques, and results.

2.1 Grid Integration Case Studies

The wide variety of hydropower installations, reservoirs, operating constraints, and hydrologic conditions combined with the diverse characteristics of the numerous electrical grids (balancing areas) provided many combinations of wind, hydropower, balancing areas, and markets, and thus many possible solutions to issues that arise. Six of the seven countries participating in the Task contributed at least one grid integration case study ranging from small systems (<1,000 MW peak load), such as Grant County Public Utility in Washington State, USA, to large systems (>35,000 MW peak load) such as Hydro Québec. Hydropower facilities ranged from run-of-the-river with little storage capacity (a day or two), to very large hydro plants with multi-year storage capability.

2.2 Hydropower System Impact Case Studies

Integrating wind generation may require changes to hydropower operation to provide balancing, reserves, or energy storage. These changes may affect maintenance, revenue, water storage, and the ability of the hydro facility to meet its primary purposes. Integration with wind could also benefit the hydro system by increasing water storage or enhancing compliance with environmental regulations (e.g., fish passage), or creating new economic opportunities. Four of the seven countries contributed hydropower system impact case studies.

2.3 Market and Economic Case Studies

The economic feasibility of a given project may require new methods of scheduling and pricing that are advantageous to wind-hydro integration and permit better utilization of system resources. The market and economic case studies addressed the effects of today's market structures on wind-hydro system economics with the intention of identifying the most-effective market structures. Six of the seven participating countries contributed to market and economic case studies.

3.0 Progress in 2009

Task participants held six meetings to collaborate on methods for studying wind and hydropower integration and to share, interpret, and sometimes debate the methods and results related to specific case studies. To place the study results in a uniform context, a template for describing and interpreting participant case studies was developed.

The Task 24 Final Technical Report will be completed in 2010. It includes two stand-alone volumes outlined below. Volume introduces the objectives and issues to be addressed; describes the problems posed by wind integration, the relevant characteristics of wind power and hydro power; and discusses results and conclusions related to the task objectives. Volume II presents the methods used in the case studies, issues related to system flexibility, and differing methods of describing wind penetration. Then case study chapters provide a succinct description of the studies conducted by the participants and include references to related publications.

Volume I – Issues, Impacts, and Economics of Wind and Hydropower Integration

Executive summary

1. Background Information and Objectives of Task
2. Wind Energy – Overview
3. Hydro System Planning and Operation
4. Power System Operation and Balancing in Systems with Wind and Hydropower
5. Conclusions
6. References / Bibliography
7. Glossary

Volume II – Participant Case Studies

Abstract

1. Introduction
2. Australia – Hydro Tasmania Case Studies

Case Study 1: Large-scale wind integration to the Tasmanian system

Case Study 2: The costs of wind-firming service provided by a hydro plant

Case Study 3: Inertia support in a hydro, wind, and high-voltage direct current (HVDC) hybrid power system

3. Canada – Natural Resources Canada Case Study

RETScreen case study of a wind

Table 2 The Task established to	
•	Exchange knowledge, ideas, and experiences on the integration of wind and hydropower technologies within electricity supply systems.
•	Share information about grid integration; transmission issues; hydrological and hydropower impacts; markets and economics; and simplified modeling techniques.
•	Identify technically and economically feasible system configurations for integrating wind and hydropower, including the effects of market structure to identify the most effective market structures.
•	Develop case studies of wind and hydropower integration and create a library available on the web site (Task 24 at www.ieawind.org).

farm integrated into hydroelectric power system
4. Finland – VTT Case Study
Case Study 1: A case study focusing on the handling of wind power prediction errors for a single hydrothermal power producer in Finland
Case Study 2: A summary of the impacts of a wind- and hydro-dominated power system on the electricity markets and the characteristics of Nordic hydropower
5. Norway – Sintef Case Studies
Case Study 1: Wind Integration in Areas with Limited Power Transfer Capacity
Case Study 2: Wind Integration in a Regional Hydro-based Power System with Weak Interconnections
6. Sweden – KTH Case Study
Case Study 1: Balancing of wind power in one river
Case Study 2: Balancing of wind power in North Sweden
7. United States Case Studies
Case Study 1: Wind Integration in the Western Area Power Administration, Missouri River Basin
Case Study 2: Integration of Wind and Hydropower in the Grant County Public Utility District, Washington, United States
Case Study 3: Wind Integration Study for the Sacramento Municipal Utility District, California, United States
8. References / Bibliography
9. Glossary

As the breadth of the case studies indicate, integrating wind and hydropower can be quite complex. A summary of some key observations and conclusions from the work of the participants are provided below:

- Figure 1 shows a practical configuration for combining wind and hydropower in a balancing area. Wind and hydropower are system resources that help serve the load via the transmission grid; each is controlled by the transmission system operator (TSO). The incremental impacts of wind integration are addressed in the context of the entire system, with all of its load and generation resources, and not in isolation from them, (e.g., not one wind power plant balanced by one hydro plant to produce a flat output).
- The holistic impact of wind power on the system (e.g., a cost-benefit analysis directed toward the electricity customer and effect on transmission system reliability) must be considered, not just the enhanced balancing requirements due to wind power's variability and uncertainty. For example, wind power will enhance balancing requirements and incur an "integration" cost; however, the overall cost of electricity to the consumer may decrease due to wind energy displacing other higher cost generation resources.
- The setup and operation of the transmission system and balancing area authority will have a profound impact on its ability to integrate wind power and the integration costs incurred. TSOs can integrate wind power at lower costs where the transactions are frequent (committing units, buying and selling of electricity, ancillary services, and reserves).
- Transmission interconnections can limit wind and hydropower integration due to transmission constraints or congestion, or they can facilitate integration via power exchanges with neighboring systems. Larger balancing areas can more easily integrate wind and hydropower.
- Electrical systems can function within a liberalized electricity market, via a vertically integrated utility that participates with neighboring systems via bilateral transactions, or some combination of the two. Wind integration costs and impacts tend to be reduced in market systems, especially those with many market actors and flexible resources.
- The case study results were consistent with other wind integration studies and show that an efficient and liquid electricity market frequently dominates all other factors affecting the economics of integration. The perspective taken by the study is key for interpreting the economic consequences: for the overall benefit of the electric customer vs. a single actor in the market (e.g. a utility, a wind developer, etc.).
- The modeling assumptions and techniques can have a significant influence on the results. Thus, these should be well specified and understood when interpreting results and comparing different studies. Production cost models (PCM) simulate hourly operation of the power system. General PCM models (those not specifically developed for or by a hydropower-dominant utility) need improvements in how they model hydropower operation, water balances, and constraints, in order to better investigate the nuances of wind and hydro integration (e.g. the impact of enhanced system balancing requirements on hydro system constraints, or the ability to model the constraints, etc.). Virtually all PCM models require further improvement in how they handle wind power and wind power forecasts.
- Wind integration impacts and costs are minor at low wind penetration levels (~1%). As penetration levels increase to ~20%, impacts become more complex and costs increase. Above ~20%, changes in system operational practices are likely necessary to optimally integrate wind and hydropower (e.g. use of advanced wind forecasting models incorporated into system planning, etc.). Islanded or small power systems with weak interconnections may require attention in system planning because they more readily experience the effects of the enhanced variability in net load and increased reserve requirements caused by wind integration, including impacts on system inertia.
- Non-power constraints on the hydropower system can influence the ability to integrate wind and hydropower. Such constraints may include higher priority functions of the hydro facility that dictate how water is run through the generators, such as irrigation water deliveries, environmental regulation (e.g. fish passage), recreation, or flood control. While these

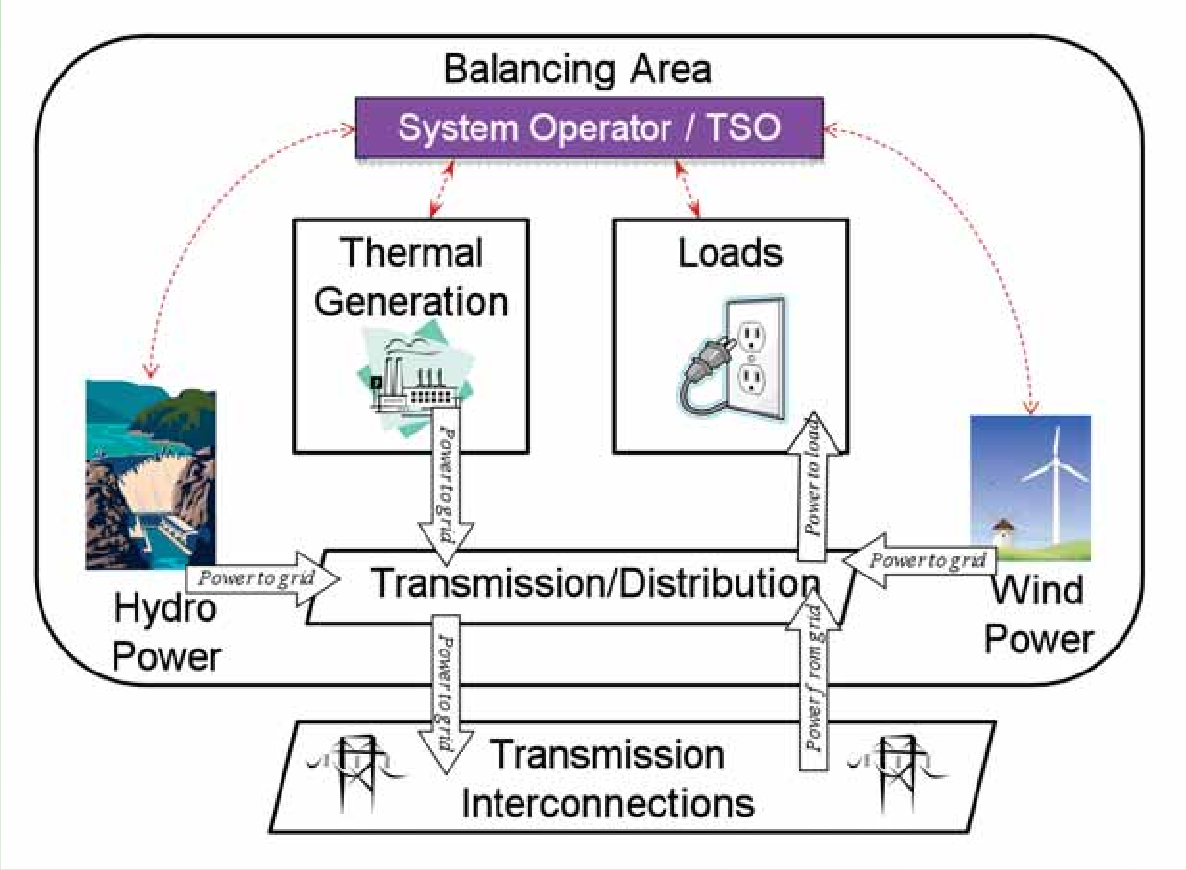

Figure 1 – A practical configuration for integrating wind and hydropower within an electrical balancing area.

non-power constraints are important, they frequently occur on time scales of system operation different than those related to wind/hydro integration. Thus they do not tend to be prohibitive and often may not significantly influence the wind and hydro integration, although at times they do reduce hydro system flexibility. Of the Task 24 participants, these constraints only played a significant role in hydro systems in the United States.

In summary, while hydropower systems possess special characteristics and operating constraints, the inherent flexibility of their generators and the potential for energy storage in their reservoirs make them well suited to integrate wind into the power system. As wind penetration increases, the agile hydro generation can address wind integration impacts and this service represents an economic opportunity for many hydro generators.

3.0 Plans for 2010 and Beyond

The work plan of the Task has been completed, with the only remaining activity being submission of the Task 24 Final Technical Report to the IEA Wind Implementing Agreement in 2010. Beyond the work of the task, participants have agreed to publish articles related to wind and hydropower integration in a special issue of the *Wind Engineering Journal*. This will occur during 2010.

Author: Thomas L. Acker, Ph.D., Northern Arizona University on behalf of NREL, United States

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 exists in the power system. To explore issues of wind power's effects on the wind 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 and Japan have joined (Table 1), and Italy will join for 2010 to 2011.

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% energy penetration), Spain and Portugal (14% to 15%), Ireland (12%), 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 operation 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 (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

	Country	Contracting Party; Organizations Coordinating Work; TSO is transmission system operator
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	Institute of Solar Energy Distribution Technology (ISET); TSO RWE
6	Ireland	University College Dublin (UCD); TSO Eirgrid
7	Italy	TSO Terna
8	Japan	National Institute of Advanced Industrial Science and Technology (AIST)
9	Netherlands	Energy Research Center of the Netherlands (ECN)
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	UK	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.		

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. This report, published in 2007, was updated as a final report of the 2006 to 2008 work and published in 2009. The task will end with developed guidelines on the recommended methodologies when estimating the system impacts and the costs of wind power integration. Also, best practice recommendations will be formulated on system operation practices and planning methodologies for high wind penetration.

3.0 Progress in 2009

The meetings organized by Task 25 have established an international forum for exchange of knowledge and experiences. The spring Task meeting in 2009 was organized in London, and hosted by Imperial College and UK National Grid. In the autumn meeting, hosted by ECN in Petten, the Netherlands, participating countries presented challenges of modeling wind power in integration studies followed by discussions.

Coordination with other relevant activities is an important part of the Task 25 effort. The meetings in 2007 were

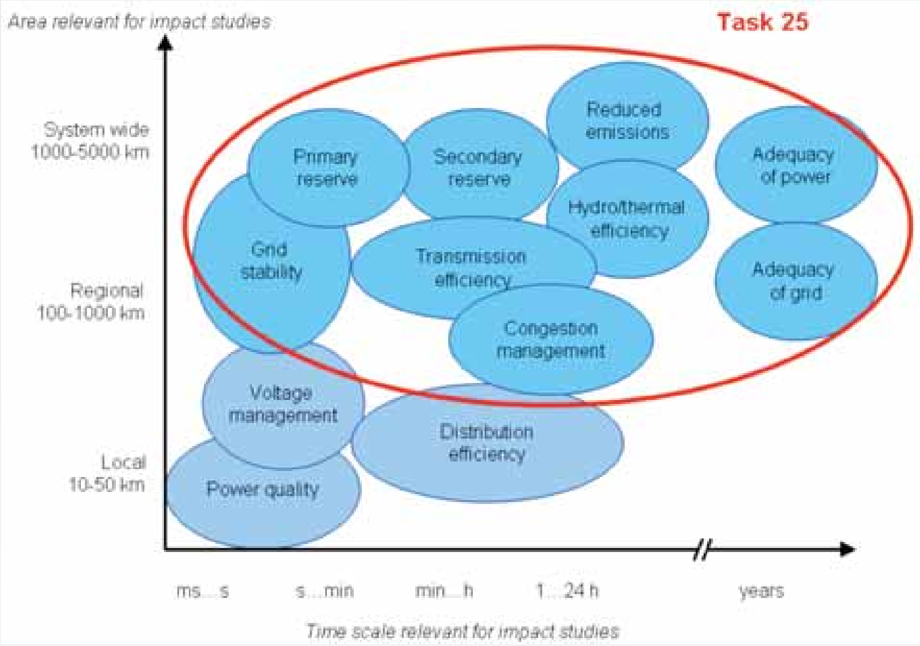

Figure 1 Impacts of wind power on power systems, divided into different time scales and size of area relevant for the studies. Primary reserve is denoted for reserves activated in seconds (frequency activated reserve; regulation) and secondary reserve is denoted for reserves activated in 5 to 15 minutes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

organized together with IEA Wind Task 24 Integration of Wind and Hydropower Systems. The system operators of Denmark, Germany, Ireland, Portugal, and the United Kingdom have joined the meetings organized so far. Links between TSO working groups at CIGRE and the European Transmission System Operators (ETSO) European Wind Integration Study (EWIS project) have been formed, and observers have been joining Task 25 meetings from 2008 to 2009. The IEA Secretariat 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 submitted to the Wind Energy Journal in November 2009, and it was decided at the fall meeting of 2009 to launch work on several joint articles. Task 25 sessions have been organized at several conferences: the 2007 European Wind Energy Conference (EWEC) in Milan, the 2008 EWEC in Brussels, and the Bremen wind integration workshop in 2009. Task 25 work and results were presented at several other meetings in 2009 by the Operating Agent and other representatives of Task 25: EU project SOLID-Der workshop in February 2009, IEA Secretariat Electricity Grid Coordination Meeting in February 2009, IEA Secretariat Grid Integration of Variable Resources (GIVAR) project kick-off meeting in February 2009, the March 2009 EWEC, and the Kassel Energy Symposium in September 2009. Work has also begun on a simplified assessment of wind integration effort and power system flexibility, in collaboration with the IEA Secretariat study on integrating renewable energy sources (GIVAR project).

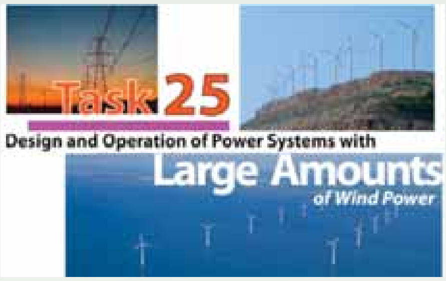

Figure 2 Task 25 Web site accessed from www.ieawind.org under Task Web Sites

The Task 25 web site has been established at http://www.ieawind.org under Task Web Sites (Figure 2). 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.

3.1 Results of the final report 2006 to 2008

The results of the final report of the first phase (2006 to 2008) can be used by the participating countries to show that claims are not correct that wind power requires large amounts of reserve power, and that integration costs do not erode away the benefits of wind power. The report finds that a substantial tolerance to variations is already built in to our power networks. This is why the impacts of wind power fluctuations can be further balanced through a variety of relatively easy and inexpensive measures for reasonably large penetrations (10% to 20% of electricity consumption). The impact of a large share of wind power can be controlled by appropriate grid-connection requirements, extension and enforcement of transmission networks, as well as integration of wind power production and production forecasts into system and market operation.

The report emphasizes the benefits of operating the power systems in a coordinated manner and/or with larger balancing areas. The aggregation benefits of a power system covering a large area help reduce wind power fluctuations and improve predictability. A large power system also has a larger amount of generation reserves available, and the increased regulation effort can be implemented cost-effectively. The transmission capacity between areas is crucial for utilizing the benefits arising from large production areas. An electricity market in which production forecasts can be updated a few hours ahead also helps in keeping down the forecast errors and thereby the costs of balance power.

The main results of the state-of-the-art report can be divided into three categories:

1) Additional costs arising from the balancing of wind power fluctuations. With wind power penetrations amounting to 10% to 20% of the gross electricity demand, the additional costs (per megawatt hour of wind power) arising from the balancing of wind power fluctuations are estimated to range between 1 to 4 €/MWh (Figure 3). This is less than 10% of the long-term market value of electricity.

2) Grid reinforcement needs due to wind power. Current wind power technology makes it possible for wind power plants to support the grid in the event of faults such as significant voltage drops and to participate in voltage regulation. Wind power plants are also able to limit their production fluctuations. The grid reinforcement needs due to wind power vary in different countries depending on how far from the consumption centers the wind power plants are constructed and how strong the existing grid is.

3) Capacity value of wind power, i.e. the ability of wind power to replace other power plant capacity. Even though wind power is mainly an energy resource that replaces fossil power generation, it can also be used for replacing existing power plant capacity. In areas where the overall wind penetration level is low, wind power can replace other capacity by its average power, typically 20% to 40% of the installed wind power capacity. However, when penetration levels are high (e.g. 30%) and in areas where the wind power production during peak demand is always low, wind power can only replace other capacity by 5% to 10% of the wind power capacity (Figure 5).

Figures 3 to 5 summarize the results from case studies reviewed in final report 2006 to 2008. They also illustrate the difficulties in comparing the results from existing studies. The range for the results is large due to different power systems in question and different methodologies applied in the studies. Comparison of the studies showed that the assumptions concerning the use of international transmission connections and the time scale of updating wind power forecasts had a major impact on the results.

4.0 Plans for 2010 and beyond

A meeting will take place in March in Toledo, Spain, hosted by University of Castilla la Mancha and the regional authority. Another meeting is planned for Montreal, Canada in conjunction with the 9th International Workshop on Large-Scale Integration of Wind Power into Power

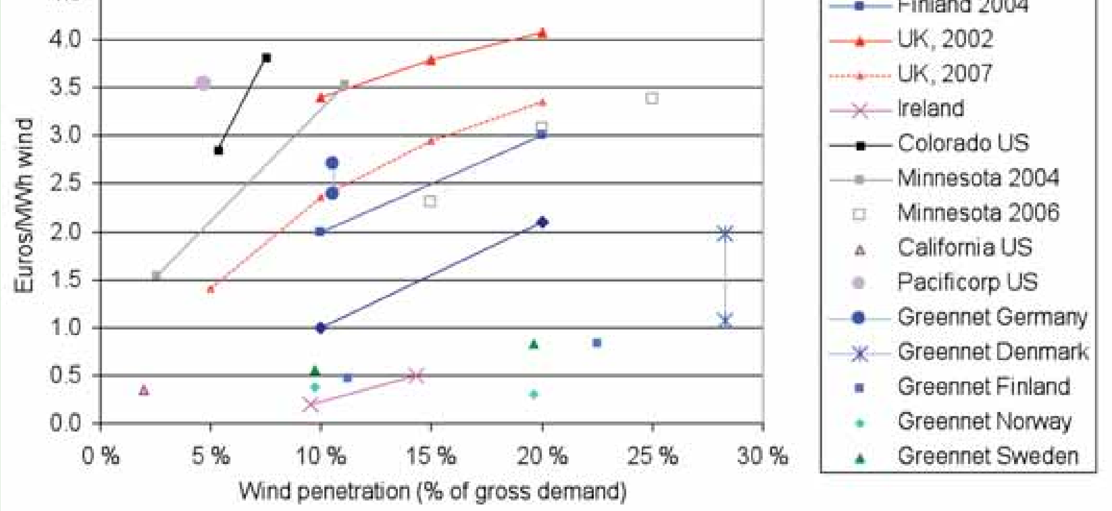

Figure 3 Results from estimates for the increase in balancing and operating costs due to wind power. The currency conversion used here is 1 € = 0.7 £ and 1 € = 1.3 USD.

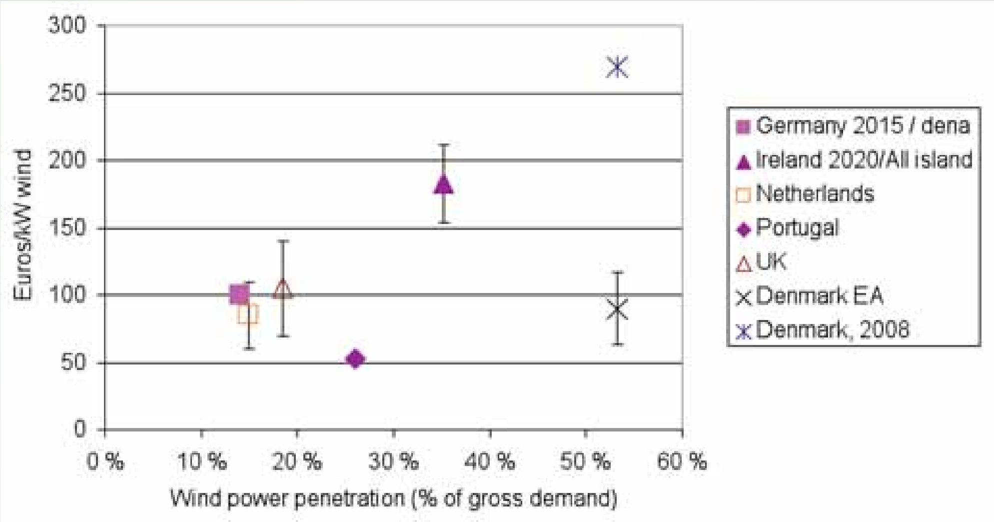

Figure 4 Results from studies on grid reinforcement costs due to wind power (for Denmark, the results are to reach from 20% to 50% penetration).

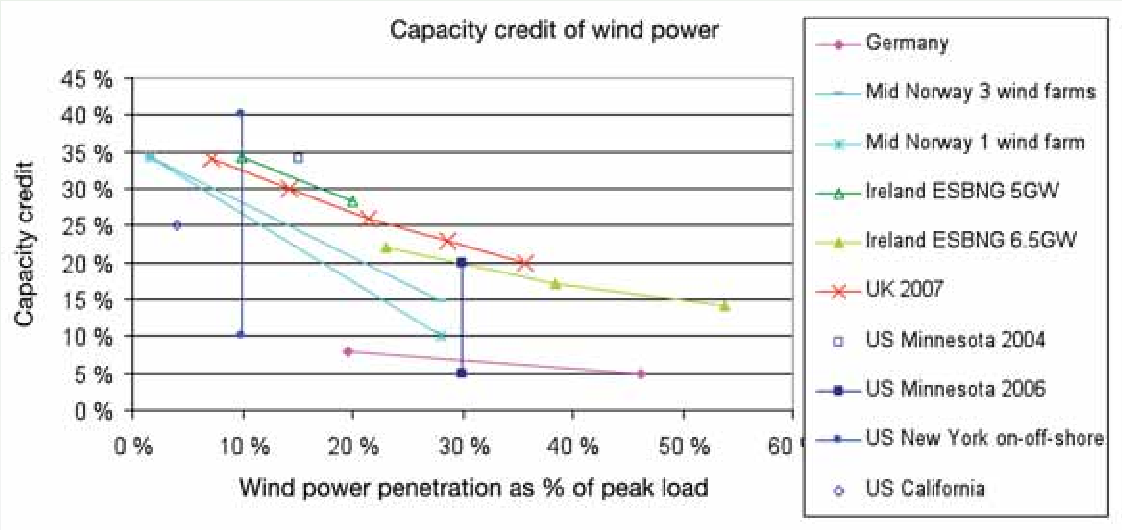

Figure 5 Results from studies on the capacity value (capacity credit) of wind power.

Systems. At the Transmission Networks for Offshore Wind Farms part, Task 25 will organize a session. Task 25 work and results will also be presented at several other meetings in 2010, such as a side event session at the 2010 EWEC.

The topic being addressed by Task 25 is growing exponentially in importance within the member countries and more broadly. There is a consensus that the work of the task has only just begun. During the second term, participants will expand into additional high penetration studies, address the important topic of cost/benefit analysis of wind power integration, and go deeper into the subject of modeling power systems with wind power. 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 as in collaboration with the IEA Secretariat GIVAR project. The library in the web pages of Task 25 will be complemented and updated. Journal articles will also be written about critical modeling issues in wind integration studies.

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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 MW 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 a nearly 50% increase in the investment cost of wind systems, up to approximately 1,900 USD/kW (1,319 €). 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 a new task. As wind is becoming an important source of electricity generation in many markets and competes with other technologies – notably natural gas and nuclear – 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 and impartial voice regarding the costs of wind systems, organizations without a clear understanding of wind systems are left to determine and publicize the costs of wind systems, often in error. These issues are exacerbated by the diversity of the wind portfolio and variations in international project development cost assumptions. The work undertaken in this task is also expected to provide a methodology for projecting future wind technology costs. Finally this task aims to form the basis for a more comprehensive analysis of 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, 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 International Energy Agency 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 the cost of wind energy and identification of major cost drivers; estimation of the future cost and performance of onshore and offshore wind projects; and assessment of methodologies and results for estimating the value of wind energy.

Providing transparency in the cost elements of wind projects among all participating countries will result in better understanding of the cost drivers of wind technology and the reasons for differences among participating countries. Development of a simple spreadsheet model that represents the major elements of wind project costs will result in a tool that could be used by IEA or others in estimating wind project costs. The model inputs and methodology will be clearly defined and

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 Center of the Netherlands (ECN)
5	Spain	The Spanish Wind Energy Association (AEE)
6	Sweden	Swedish Energy Agency, Vattenfall
7	Switzerland	Swiss Federal Office of Energy (SFOE)
8	United States	National Renewable Energy Laboratory (NREL), Lawrence Berkeley National Laboratory (LBNL)

documented. A representative set of input parameters specific to each participating country will be collected. This data should represent typical costs and project performance, for both onshore and offshore wind technology. Manufacturers, developers, and other wind industry participants should be engaged to obtain these representative costs. Methods such as surveys or interviews could be used. Based on this common set of data from each participating country, assumptions for a generic estimate of wind energy costs will be determined. Each participant will provide documentation of their representative cost data as well as quantify the differences between their country's cost structure and that of the generic model. A report will summarize these results and provide insight into the different cost drivers for each participating country.

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

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

3.0 Progress in 2009

In 2009, activities included 1) development of a transparent, discounted cash flow spreadsheet model to estimate the levelized cost of wind energy; 2) creation of a glossary of terms used in the model; 3) collection of representative cost and performance input data for wind projects installed in 2007 and 2008 for each participating country; and 4) analysis of each individual country's wind energy costs relative to a common reference.

A discounted cash flow spreadsheet model was developed based largely on a model in use by the Netherlands. A number of web-based meetings were held among all participants to identify model features that were necessary to represent country-specific cost of energy estimates, e.g. tax structures or incentives schemes. In parallel, a glossary of terms was developed in order to clearly define each model input.

Representative wind project cost data was collected by each participating country to represent the cost of projects installed in 2007 and 2008. Each participant used varying methods and sources to collect this data. Details differed among participating countries, but total installed capital cost, annual energy capture, operation and maintenance cost, finance parameters, and incentive schemes were 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 were drafted for inclusion in the work package report.

Web-based meetings were held nearly monthly throughout the year to maintain communication and progress. An in-person meeting was held in September in Stockholm, Sweden to assess progress. Initial comparison of cost elements among countries and development of the reference project were the primary outcomes of that meeting.

4.0 Plans for 2010 and beyond

The work for this task formally began in January 2009 and is expected to continue for three years until the end of 2011. During 2010, the primary activity will be directed toward completion of the work package 1 report. This report will include descriptions of the cost elements from each participating country as well as an analysis of the source of differences in cost among the countries. Assessment of methods and approaches used by the participating countries to project future cost and performance for wind technology will also begin in 2010. A meeting is planned for June 2010.

References:

(1) Wiser, R. and M. Bolinger (2009), 2008 Wind Technologies Market Report, DOE/GO 102009-2868.

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


Photo courtesy NREL

1.0 Introduction

With the high priority to develop clean energy sources, many countries are seeing rapid expansion of the small wind industry, especially companies supplying turbines for grid connected applications. Government incentives (feed-in tariffs, net metering, subsidies, etc.) require that small turbines be certified to assure safety and productivity. IEC standards exist for small wind turbines. However, very few wind turbines are certified against them because getting certified is difficult and costly. Only the largest suppliers can afford this process, so most offer their products without any certification. Some countries have developed national standards as a simplified path to the IEC standards, but these may require suppliers to meet different tests for each country.

The intention of IEA Wind Task 27 is to increase the use of common methodologies for testing small wind turbines. These tests should provide feedback and know-how to develop international standards in the area of quality and performance. The final outcome of the task will be the production and publication of an international sector guide, *Recommended Practice for Consumer Labeling of Small Wind Turbines.*

An additional problem facing governments and consumers is the lack of accredited test facilities to be used for certification of small wind turbines. In order to increase worldwide testing capabilities, an association of small wind testers will be developed as part of Task 27.

Task 27 will collect data, experiences, information from trials, and recommendations for small wind turbine standardization and provide it to interested parties in the IEA Wind member countries. All meetings and documents are available to organizations in the countries that participate in Task 27 and no fees are required to support the Operating Agent management of the task.

2.0 Objectives and Strategy

The following two subtasks were included in the Task 27 work plan.

Subtask A: Develop consumer labeling for small wind turbines (up to 200 m2 rotor swept area) in grid-tied and battery-connected applications. The following eight activities were defined and scheduled:

Activity A1 Identification of relevant existing testing standards, procedures, and methodologies
Activity A2 Identification of the tests required for labeling
Activity A3 Identification of potential third-party testers of small wind turbines and classification of rigour of test procedure
Activity A4 Recommendations for labeling reporting
Activity A5 Identification of the label display parameters
Activity A6 Publication requirement of summary test results
Activity A7 Pilot demonstration of consumer label
Activity A8 Understanding of legal implications and finalizing labelling procedure.

Subtask B: Peer reviewed testing and development of Small Wind Association of Testers (SWAT). The following six activities were defined and scheduled:

Activity B1 Initiate the new group of Small Wind Association of Testers (SWAT). Set up with annual

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	Denmark	Risø - DTU National Laboratory for Sustainable Research
4	Japan	National Institute of Advanced Industrial Science and Technology (AIST)
5	Spain	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT) (OA)
6	Sweden	Flexenclosure AB
7	United Kingdom	National Engineering Laboratory (TUV-NEL) Ampair Energy Limited
8	United States	National Renewable Energy Laboratory (NREL) Small Wind Certification Council (SWCC) Windward Engineering

meetings (or other web tools) international members' exchange, provide a website, blog, newsgroup

Activity B2 Develop peer reviewed task activities such as data analysis exchange, test protocol and methodology, promotion of small wind turbine trials, comparison of test results and strategies, relationships of anemometers. Validate each other's test results.

Activity B3 Develop testing and labeling strategies for other small wind turbine applications such as water pumping and water desalination

Activity B4 Develop test collaborative for urban building-integrated small wind turbines

Activity B5 Analyze urban test data for development of IEC urban small wind turbine

Activity B6 Dissemination activities

3.0 Progress in 2009

At the ExCo 61 meeting in 2008, the task received preliminary approval. At ExCo 64 in 2009, it received final approval. Five meetings were held in 2009 in conjunction with standards workshops of IEC (MT2) directed at improving IEC standards for small wind turbines. Many of the participants in Task 27 also work to develop IEC MT2 standards.

The first IEA Task 27-IEC MT2 Liaison meeting was held in Madrid, Spain, in February 2009. Starting with a draft proposal Consumer Labelling of Small Wind Turbines, a draft recommended practice for small wind turbine testing and evaluation, and other documents, participants outlined some activities for IEA Wind Task 27. They concluded that the task would define the state of art regarding small wind turbine testing and reporting and contribute to the development of quality labelling of small wind turbines.

The second IEA Task 27-IEC MT2 Liaison meeting was held in London, United Kingdom, in April 2009. In this meeting, labelling activities and testing services were identified. Participants reviewed test devices and mapped out the human resources needed to work on the specific activities within the task work plan. The cost was estimated to deploy an international quality label for small wind turbines, to promote regional test centres, and to run a label system secretariat. Participants identified these costs as an obstacle for their joining the effort.

The third IEA Task 27-IEC MT2 Liaison meeting was held in Wausau, Wisconsin and Boulder, Colorado, United States, in June 2009. It was suggested that mid-sized wind turbines be included in the label for small wind turbines and peer review testing was proposed. It was also proposed to develop an international test protocol for small wind turbines in the urban environment as an additional R&D activity within the task proposal.

The fourth IEA Task 27-IEC MT2 Liaison meeting was held in Toronto, Canada, in October 2009. During this meeting, the final proposal of the Task 27 Development and Deployment of Small Wind Turbine Labels for Consumers was issued. It was decided that participants would pay no fee for the services of the OA to manage the task. The OA presented this final task proposal at ExCo 64 in November 2009 and it was approved.

The fifth IEA Task 27-IEC MT2 Liaison meeting was held in Tokyo, Japan in December 2009 (Figure 3). This was the first official meeting after final approval of the task. Nineteen experts from six countries attended. It was decided that the future label will be used by the new IEC standard because the IEA Wind is not a certification body. Task 27 will develop guidelines or best practices. The group proposed some research in procedures to measure power curves at low and high turbulence test sites to illustrate the influence on energy production. All partners offered to share their data sets from small wind turbine tests. The parameters required for the study were defined:

Metrological – wind speed, wind direction, barometric pressure, relative air humidity, ambient air temperature, and precipitation.

Electrical – output voltage, output power, electric frequency, DC output voltage, DC output current, and DC output power.

Figure 1 Task 27 work schedule

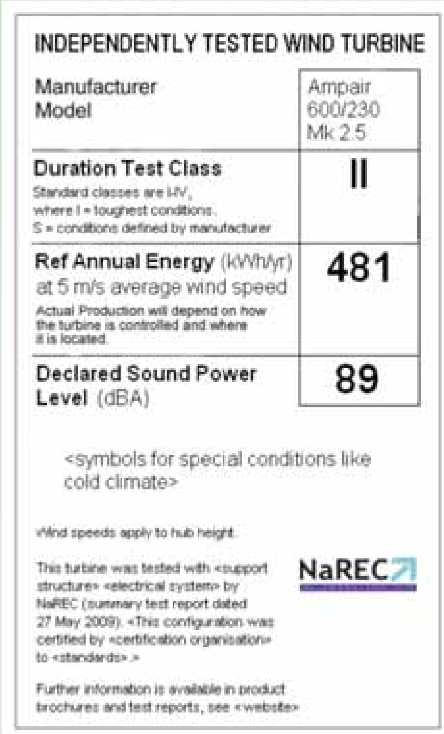

Figure 2 Draft label for small wind turbine consumers

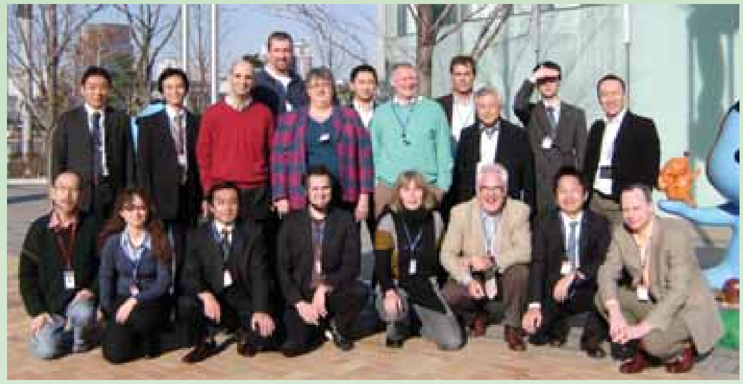

Figure 3 IEA Wind Task 27 meeting at AIST in Tokyo, Japan

4.0 Plans for 2010 and beyond

Four meetings were scheduled for 2010. The first meeting in March 2010, at Kaiser-Wilhelm-Koog, Germany, will address the IEA Wind label definition using the existing IEC standards. The group will need to add some points for urban turbines. This information could include classes or turbulence intensity behavior important for urban sites with high wind turbulence. Other discussion will be focused in the level of accreditation required for the test agency. The number of levels of testing must be defined as well. Finally, a new web site of the Small Wind Association of Testers (SWAT must be defined www.swat.org in order to have a Task 27 page linked with the main IEA Wind web site.).

The second meeting was proposed for TUV_NEL headquarters in Glasgow, United Kingdom, in July 2010. The main activity will be to start the draft report (Activities A2-A8); as well as activities for the Small Wind Association of Testers (Activities B2-B3).

The third meeting will take place in Perth (Australia) in December 2010. The main target will be the publication of requirements of summary test results.

In 2010, new partners from other IEA Wind countries are expected to join Task 27, including Germany, Italy, and the Republic of Korea. Although France is not currently a member of IEA Wind, several organizations there are interested in the work of Task 27.

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Task 28

Social Acceptance of Wind Energy Projects

1.0 Introduction

In 2009, many governments and organizations set new targets for CO_2 reductions, renewable energies in general, as well as specific targets for wind energy deployment. Two examples of these targets are the European Union's goal of 20% of electricity from renewables and 20% CO_2 reduction by 2010 (1) and the United States scenario of 20% wind contribution to U.S. electricity needs in 2030 (2). All these targets require many single projects to be carried out both onshore and offshore that necessitate hundreds of siting decisions and therefore hundreds of communities accepting a wind project nearby.

Wind projects do have an impact on landscapes, so we have to find ways to turn affected people into involved parties to get public support. Local visual and environmental effects have to be outweighed by benefits to the communities. Otherwise, social acceptance has the potential to become a powerful barrier for wind deployment.

Research and projects 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. While Denmark has one of the longest traditions of co-operatively owned wind farms, Japan may bring its expertise in generating additional benefits for the communities hosting the turbines. While Ireland and Canada know about the effects of wind parks on tourism, Norway has conducted actual research on communication between society and science, e.g. concerning bird risks with wind farms. 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 assist 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 this experience has 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 specific or partial objectives of this task are:

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 Tokyo
7	Netherlands	Netherlands Agency
8	Norway	Norwegian Water Resources and Energy Directorate; Enova SF; Norwegian University of Science and Technology, Centre for Energy and Society
9	Switzerland	Federal Department of the Environment, Transport, Energy and Communications, Swiss Federal Office of Energy; ENCO Energie-Consulting AG, Wind department
10	United States	US Department of Energy, Energy Efficiency and Renewable Energy, National Wind Technology Center

• Establishing an international forum for exchange of knowledge and experiences related to social acceptance and other societal issues of wind energy development. This network is composed of (1) a working group that meets twice each year and (2) support groups organized in each country in the form of national gatherings or conferences. Additionally, workshops at international conferences are getting feedback from the stakeholders (see "4.0 Plans for 2010 and beyond")
• Composing a "State of the Art Report" on the knowledge and results so far on social acceptance of wind energy projects, including an online library. This library is gathering papers, documentation of various kinds of projects, links, etc. from countries all over the world in their respective languages. The library will be accessible to the public.
• Establishing "Best 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.
• Establishing 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 2009

After starting activities in 2008, the working group took up its work in 2009. The following activities were accomplished:
• Kick-off meeting in Magdeburg, Germany (spring 2009): Discussion about work and contents including anticipated results, schedule, structure of activities, participation, and budget. Representatives presented on the current situation and discussions in their respective countries.
• Second meeting in Boulder, United States (autumn 2009): Further development of work and contents, finalization of structure of activities (Figure 2), preparations for State-of-the-Art report; country presentations for mutual update on ongoing activities.
• Second meeting in connection with first national gathering of U.S. experts: around 25 researchers, members of the wind community, and NGOs presented their projects and experiences. The organizational frame also set the possibilities for networking.
• IEA Wind Task 28 introduced additional discussions by web meetings; the first one was held in autumn 2009 with about 10 participants from North America, Europe, and Japan as preparation for the Boulder meeting.

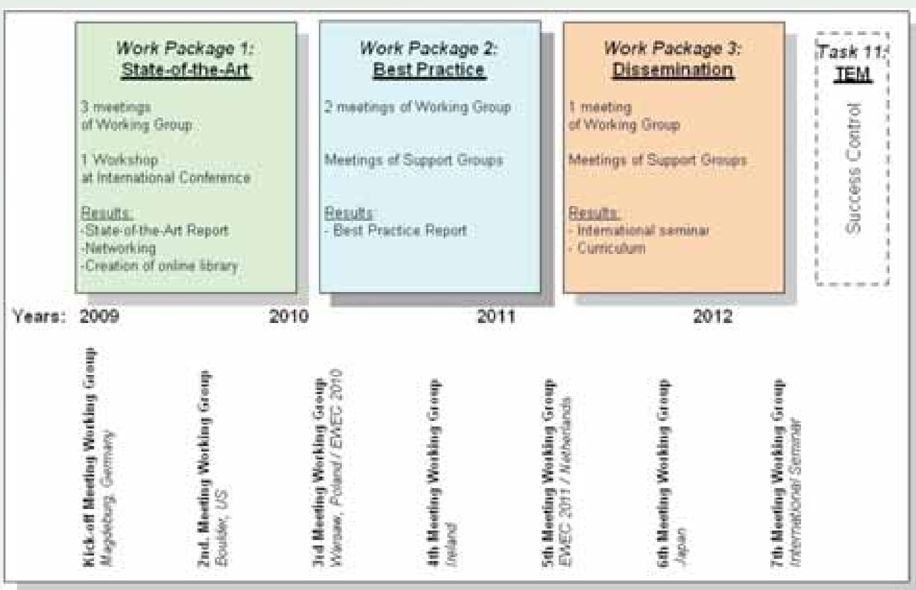

Figure 1 Schedule, work packages, and anticipated results of Task 28

• The web site www.socialacceptance.ch was expanded and regularly updated. A web database including about a hundred documents on the topic of social acceptance of wind energy is now available. All documents are presented with a classification following the structure of IEA Wind Task 28 activities (Figure 2) and an abstract highlighting the value of the content for social acceptance of wind energy projects. Resources come from more than a dozen countries and include documents in English, German, French, Japanese, Dutch, and Finnish, amongst others. While a part of the web site is only available for Task members, public documents are made accessible to the public.
• Work on the State-of-the-Art Report has started with the collection of information by each participating country. A template for country reports was worked out; the country reports will form the basis for the State-of-the-Art Report itself. The Operating Agent gathered additional documents from non-participating countries.
• An abstract for the 2010 European Wind Energy Conference and Exhibition (EWEC) was submitted to present the work of IEA Wind Task 28 during the session "Strategies to increase social acceptance," and preparations for a side event during the conference were launched (see also "4.0 Plans for 2010 and beyond").
• Contacts with non-participating countries such as the United Kingdom and Spain 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 (63 and 64).
• A report on the finances of IEA Wind Task 28 was executed.

4.0 Plans for 2010 and beyond

The end of 2010 should see the publication of the result of Work package 1, the State-of-the-Art Report. The Report will give an overview of actual knowledge on how to boost social acceptance and conclusions on what is still lacking and where IEA countries should invest in further activities. Work package 2 will process the information collected in the State-of-the-Art Report into Best Practices, which will be started in 2010. Work package 3 concentrates on dissemination of the

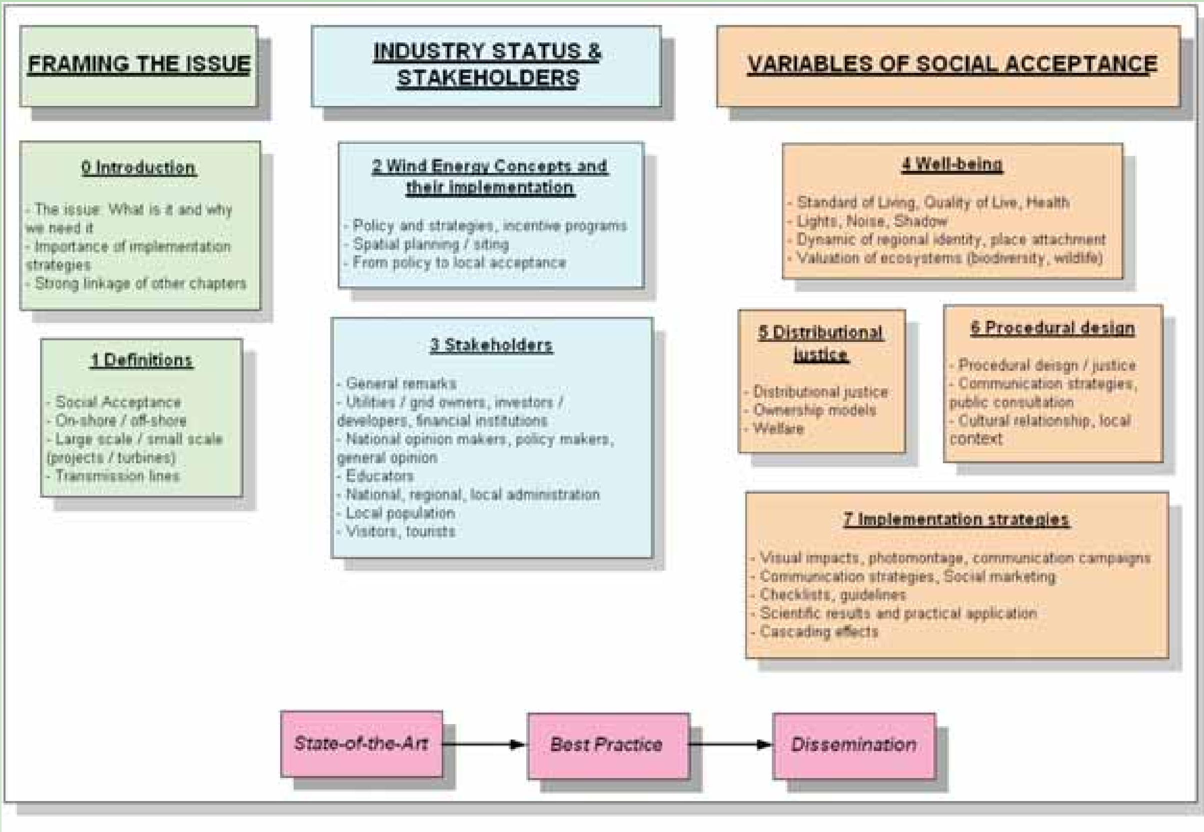

Figure 2 Structure of IEA Wind Task 28 activities

results, and dissemination is already taken into consideration at every meeting. Apart from publications and the website, an international seminar is being considered for 2011 or 2012.

The State-of-the-Art Report is the first step in IEA Wind Task 28 efforts to support the industry and authorities in the implementation of the renewable energy targets. To make this known to a broader public and to get stakeholder input on how this knowledge shall be further processed, IEA Wind Task 28 will be present at EWEC 2010 in Warsaw. Robert Horbaty will participate in the session "Strategies to increase social acceptance" with a presentation on the work of IEA Wind Task 28, and a side event will be held to discuss strategies with the wind industry and the interested public. Further information can be found at www.social-acceptance.ch.

Next meetings are proposed as follows:

- 3rd meeting of working group, spring 2010, in connection with EWEC 2010, in Warsaw, April 19th to 21st
- 4th meeting of working group, autumn 2010, in Ireland, in connection with an Irish event on Social Acceptance
- 5th meeting of working group, spring 2011, in Amsterdam, eventually in connection with EWEC 2011 in Brussels
- 6th meeting of working group, autumn 2011, in Japan.

Reference

Opening photos; http://www.juwi.de/typo3temp/pics/6bdf940e55.jpg

http://i.treehugger.com/wind_powered_kid.jpg

http://betterplan.squarespace.com/storage/kids.jpg

(1) Commission of the European Communities, Communication to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, 20 20 by 2020 – Europe's climate change opportunity. COM(2008) 30 final. Download from http://ec.europa.eu/commission_barroso/president/pdf/COM2008_030_en.pdf

(2) U.S. Department of Energy 20% Wind Energy by 2030 Report. Download from www.20percentwind.org.

Author: Robert Horbaty, ENCO AG, Switzerland.

Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models


Photo courtesy of ECN

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, amongst others, contribute to unknown responses, particularly at off-design conditions.

The availability of high quality measurements is considered to be the most important pre-requisite to gain insight into these uncertainties and to validate and improve aerodynamic wind turbine models. For this reason, the European Union project "MEXICO: Measurements and EXperiments In COntrolled conditions has been carried out (5). In this project, ten institutes from six countries co-operated in doing experiments on an instrumented, 3-bladed, 4.5-m diameter wind turbine placed in the 9.5 m2 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 (2). An obvious difference between the two types of experiments lies in the larger size of turbine diameter 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,

Table 1 Task 29 Participants

	Country	Contracting Party; Institution(s)
1	Canada	École de technologie supérieur, Montreal (ETS)
2	Denmark	RISO-DTU and DTU(MEK)
3	Germany	University of Stuttgart (IAG), University of Applied Sciences at Kiel, ForWind, Windguard
4	Japan	Mie University/National Institute of Advanced Industrial Science (Mie/AIST)
5	Korea	Korea Institute of Energy Research (KIER) and Korea Aerospace Research Institute (KARI)
6	The Netherlands	Energy Research Center of the Netherlands (ECN), Technical University of Delft (TUDelft), Suzlon Blade Technology (SBT), and the University of Twente
7	Norway	Institute for Energy Technology/Norwegian University of Science and Technology (IFE/NTNU)
8	Spain	CENER
9	Sweden	Royal Institute of Technology/University of Gotland (KTH/HGO)
10	USA	National Renewable Energy Laboratory (NREL)

* Technion in Israel is a subcontractor to Task 29.
More information on MEXNEX(T) can be found on www.mexnext.org

the flow field around the blade (i.e. the induction) is calculated, and second from that the loads are derived. Each of these steps has its own uncertainty (e.g. the second step may contain the uncertainty in airfoil characteristics). In conventional experimental programs, only blade loads are measured, therefore, it is not possible to distinguish between these two sources of discrepancies. The addition of flow field measurements should open up this possibility.

The MEXICO project database is still in a rather rudimentary form and only limited analyses have been 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 will take 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 where the following institutes participate.

2.0 Objectives and Strategy

The objective of the IEA Wind Task 29 MEXNEX(T) is to improve aerodynamic modes 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 x 9.5 m). This ratio of turbine diameter over tunnel size may make the wind tunnel situation not fully representative of the free stream situation. Therefore, tunnel effects 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, a deeper investigation of different phenomena will take place. 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 2009

In October 2009, the 2nd plenary meeting was held, attended by almost all participants. A large variety of subjects were presented and discussed, such as investigations on measurement quality and tunnel effects. Models were presented, and the measured rotating airfoil characteristics were presented in different ways using different angle of attack methods (or even without angle of attack methods). The rotating characteristics were also compared with 2-D measurements. Furthermore, PIV measurements in the wake have been analyzed (Figure 1), and a comparison was made between the observations from the NASA-Ames and MEXICO experiments. Moreover, the effects from airfoil imperfections were estimated, and the effects from Reynolds number and Mach number were discussed, among other topics.

It is worthwhile mentioning that the Korea Aerospace Research Institute (KARI) even built a scaled down model of the MEXICO rotor and measured its performance in their wind tunnel in comparison to the performance of the 'real' MEXICO turbine. A first (limited) comparison has already been made between some calculation results and measurements. A typical example of the comparison between calculated and measured results is shown in Figure 2. Note that this is a very preliminary result, which is the reason why the models have not been identified yet. It shows the comparison in axial velocity as function of radial position just behind the wind turbine. Generally speaking, a very good qualitative agreement is found, but most results over-predict the velocities.

Results from MEXNEX(T) obtained in 2009 have been presented in (3, 6, 8, 9, and 10).

4.0 Plans for 2010 and Beyond

A large number of activities are foreseen in 2010. In March 2010, all participants will supply their calculational results to the Operating Agent who will compare them with the measurements. This comparison will be discussed in June 2010 when the next plenary meeting of MEXNEX(T) is planned, and explanations will be sought for the differences between calculations and measurements. An interesting aspect of these comparisons will be to understand the relation between the differences in loads and the differences in underlying flow field. This goes together with the activities in WP4 (i.e. the in-depth investigation of phenomena). WP4 is divided into

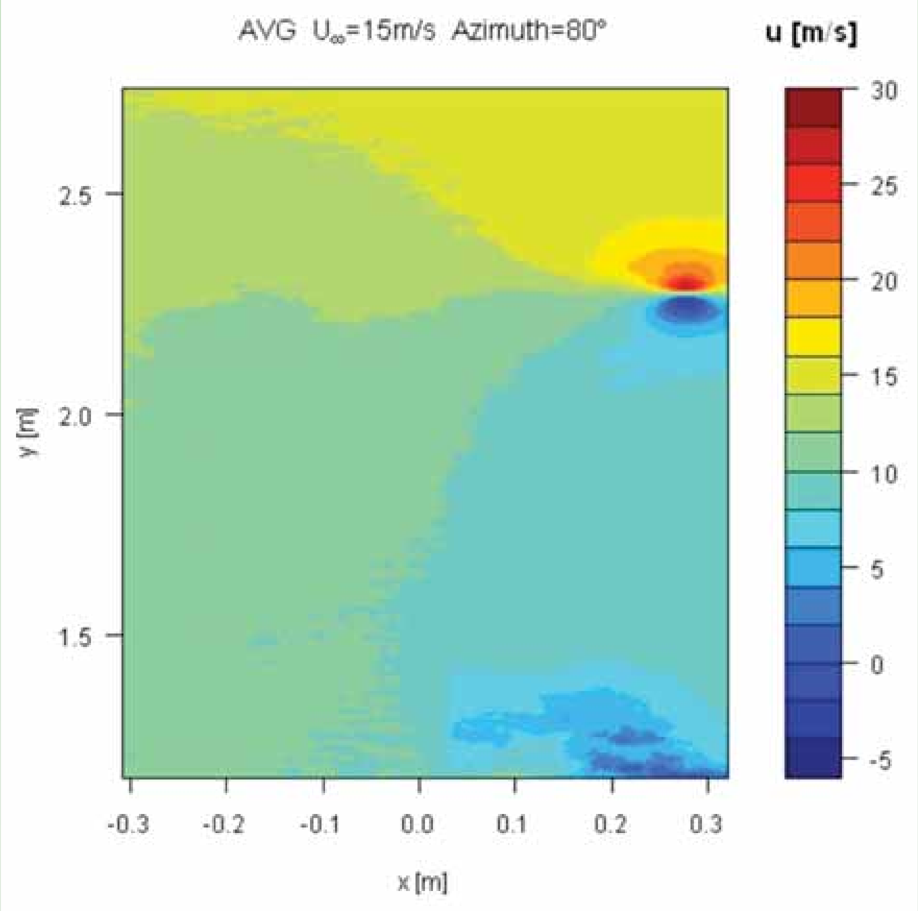

Figure 1 Measured axial velocity as function of radial position (y) and axial position (x), showing details of the flow field around the rotor plane

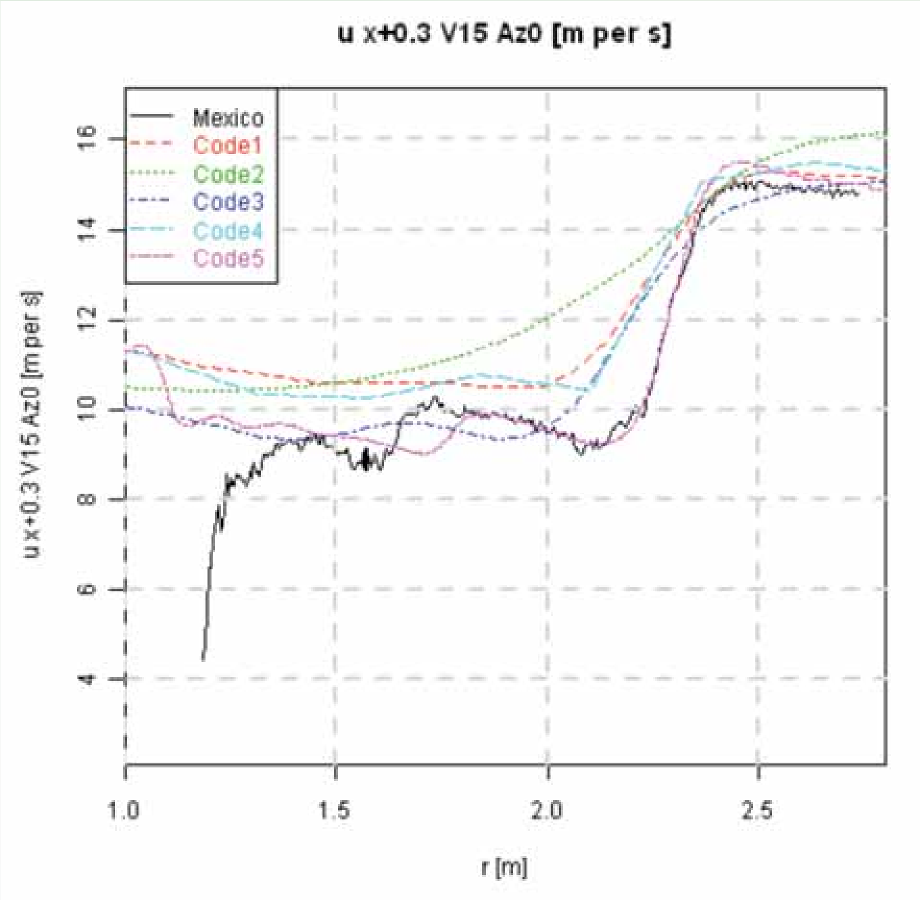

Figure 2 Comparison between calculated and measured velocities just behind the rotor plane

several subtasks for which task leaders have been appointed. These task leaders made detailed descriptions for the approach to be followed in their task. Results from many of these tasks are expected in 2010.

Activities are also foreseen in WP2 (tunnel effects). It is well known that tunnel effects for the present open jet configuration will be much less severe than the effects in a closed tunnel section where the tunnel effects are further reduced because of slits in the collector (4). On the other hand, the quantification of the (smaller) corrections is more difficult due to the shear layer between the tunnel flow and the outer flow, where the presence of the collector that 'captures' the wind turbine wake adds to the complexity. As such, standard tunnel correction methods cannot be applied and so detailed CFD analysis of the wind turbine and its wake with and without the tunnel geometry is required. First results from CFD analysis at design conditions indicate little tunnel disturbance (3), but the disturbances are expected to be more severe at high loading and yawed conditions.

Finally, it is worthwhile mentioning that a conference paper was approved for oral presentation at the European Wind Energy Conference (EWEC) in April 2010 (7) and seven oral presentations on MEXNEX(T) will be given at the European Academy of Wind Energy (EAWE) conference 'The science of Making Torque from the Wind' which will be held in June 2010 (11 to 16).

References

(1) J.G. Schepers et al. *Verification of European Wind Turbine Design Codes, VEWT-DC*. European Wind Energy Conference, EWEC, Copenhagen, July 2001.

(2) 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.

(3) A.K. Kuczaj. *Virtual Blade Model Simulations of the Mexico experiment*. NRG-21810/09.97106, NRG Petten, the Netherlands, November 2009.

(4) 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.

(5) 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.

(6) H. Snel, J.G. Schepers, and A. Siccama. *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*. To be presented at the European Wind Energy 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*, To be presented at '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*, To be presented at '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*, To be presented at 'The Science of Making Torque from the Wind', June 2010.

(14) S. Gomez-Iradi and X. Munduate. *A CFD Investigation of the Influence of Trip-Tape on the MEXICO Wind Turbine Blade Sections*, To be presented at 'The Science of Making Torque from the Wind', June 2010.

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

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

Photo Credit: Amber Taylor

Australia


Source: Roaring 40s

1.0 Overview

Australia is in a prime position to transition to a low carbon economy, courtesy of its abundant renewable energy resources, expanding population, stable political, and economic environment. Aided by world-class wind resources such as the Roaring Forties winds in Southern Australia, wind energy has already made a significant contribution to the country's clean energy mix. With the right policy settings it will continue to increase its market share of the nation's electricity supply.

The cornerstones of the federal government's commitment are the Carbon Pollution Reduction Scheme (CPRS) – an emissions trading scheme with medium and long-term emission reduction targets – and the national Renewable Energy Target. The CPRS has been defeated multiple times in the Australian Parliament and it is unknown whether it will be legislated in the near future.

The expanded Renewable Energy Target (RET) scheme was passed by federal parliament in August 2009. It mandates that 45,000 GWh, or 20% of Australia's electricity supply, will be sourced from renewable energy in 2020. This target is four times the previous mandatory renewable energy target (MRET) which was introduced in 2001.

At the close of 2009, Australia had 51 wind farms with a total operating wind capacity of 1,712 MW. Four new projects were commissioned in 2009 adding 406 MW of capacity to the Australian electricity grid. Another seven projects are under construction and are expected to add an additional 588 MW within the next few years. A further 12,000 MW of projects currently proposed for Australia are either in the evaluation phase or undergoing the development approval process.

Table 1 Key Statistics 2009: Australia	
Total installed wind generation	1,712 MW
New wind generation installed	406 MW
Total electrical output from wind	***4.284*** TWh
Wind generation as % of national electric demand	***1.6%***
Target:	The Mandatory Renewable Energy Target (MRET), 9,500 GWh from renewables by 2010, has been met. The expanded Renewable Energy Target, (45,000 GWh from renewables by 2020) commenced in 2010.
Bold italic indicates estimates.	

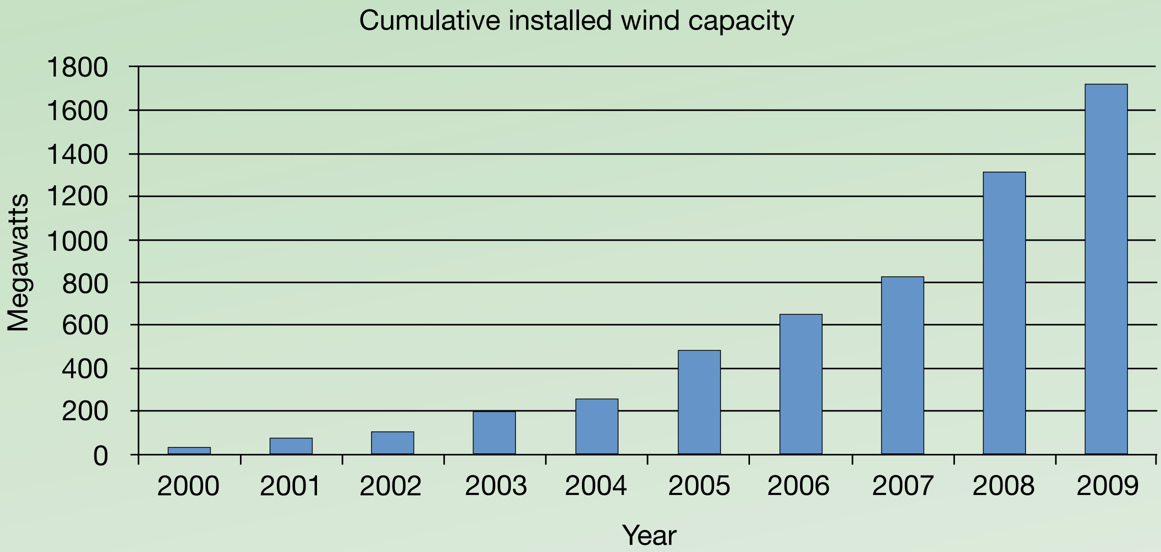

Figure 1 Cumulative installed wind capacity 2000-2009

2.0 National Objectives and Progress

2.1 National targets

The purpose of the national RET is to set aside a share of the electricity market to be filled by clean energy technologies ahead of a full price on greenhouse emissions. Its aim is to bridge the gap between the costs of renewable energy deployment and the price of black electricity. Renewable energy generation under the RET scheme creates renewable energy certificates (RECs) which must be surrendered each year by electricity retailers as prescribed by the RET legislation. The expanded RET commenced on 1 January 2010 with an initial annual target of 12,500 GWh which will be gradually increased until 2020. Since 2000, Australian cumulative installed wind capacity has greatly increased (See figure 1).

The Carbon Pollution Reduction Scheme (CPRS) is a cap-and-trade emissions trading scheme. The CPRS medium term national emissions reduction target will be 5% of 2000 emissions by 2020 unless an international agreement is brokered, in which case it could rise to 25% by 2020. The CPRS will provide a carbon price that will help to drive the development of the renewable energy sector in Australia. The CPRS legislation has been before the Australian Parliament three times, but without bipartisan support it has so far been rejected. While both sides of Australian politics are committed to reducing emissions, they are yet to agree on a method and with a possible looming Australian federal election in 2010 climate change will play a big part in policy positions.

2.2 Progress

At the close of 2009, there were 51 wind farms in Australia, with a total of 984 operating turbines. The total operating wind capacity was 1,712 MW. The estimated annual wind generation output in Australia from this 1,712 MW of installed capacity of wind energy is 4,284 GWh or 1.6% of national electrical demand.

Several new projects became fully operational throughout the year, adding capacity to the Australian electricity grid. These include Waubra (Acciona, 192 MW) and Portland Stage 3 Cape Nelson South (Pacific Hydro, 44 MW) in Victoria; and Capital Wind Farm (Infigen Energy, 141 MW) and Cullerin Range (Origin Energy, 30 MW) both in New South Wales. Another seven projects (Table 2) totaling 588 MW are under construction

Table 2 Wind farms under construction

Owner	Location	State	Expected Commission Year	Installed Capacity MW
AGL	Hallett Stage 2	South Australia	2010	71.4 MW
Pacific Hydro	Clements Gap	South Australia	2010	56.7 MW
Union Fenosa	Crookwell 2	New South Wales	2010	92.0 MW
Infigen Energy	Lake Bonney Stage 3	South Australia	2010	39.0 MW
AGL	Oaklands Hill	Victoria	2011	67.2 MW
Roaring 40's	Musselroe	Tasmania	2011	129.0 MW
AGL	Hallett Stage 4 (Nth Brown Hill)	South Australia	2012	132.3 MW

Table 3 Australian wind energy industry 2009 – environmental benefits	
Installed megawatts	1,712
Number of wind turbines	984
Average number of Australian households powered by wind energy	603,380
Number of wind energy projects (two or more turbines)	51
Annual greenhouse gas emissions displaced (tonnes CO_2/yr)	4,284,000
Equivalent number of cars taken off the road/yr	952,000
Note: All figures are estimates only, based on current available information obtained by the Clean Energy Council.	

Table 4 Wind farms offsetting desalination plants

Desalination Plant	Owner	Location	Commission Year	Installed Capacity MW
Victoria	AGL	Oaklands Hill	2011	68 MW
Sydney	Infigen Energy	Capital Wind Farm	2010	141 MW
South Australia	AGL	Hallett Wind farm projects	2008-2012	438 MW
Western Australia	Transfield Services / Griffin Energy	Emu Downs	2006	79 MW

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 renewable energy target, but South Australia has set its own renewable energy target of 33% by 2020 which provides an additional incentive for investment in the state. South Australia is the country's wind energy leader.

Green power schemes are becoming increasingly popular. 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. More than 900,000 domestic and commercial customers have taken up green power since its inception in 1997.

A number of 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 for wind farms. The scheme commences 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, doubt around the future of the CPRS and problems with the deployment of the recently legislated and expanded Renewable Energy Target is resulting in uncertainty within the wind industry. The industry was also affected by the global financial crisis which impacted upon lending practices and tolerance of risk by banks with respect to renewable energy projects.

Currently as a result of other support measures for domestic small scale technologies, there is an oversupply of RECs in the market which has caused the REC spot price to collapse. This is impacting the ability of wind project developers to finance their projects as they are unable to achieve long-term off-take contacts or Power Purchase Agreements at prices that will support debt financing. This in turn will delay the commissioning of large-scale wind farms down the track.

Currently the only large-scale wind farms being financially committed are those which have a guaranteed energy price through their energy offset of desalination plants (Table 4). Australia's ongoing water shortages have led to the building of large desalination plants for a number of Australia's capital cities. These commissioned and proposed desalination plants have a requirement to have their electricity use offset by wind power, providing the opportunity for a number of wind farms to progress with this assured income

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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).

More than 1,600 people are employed in the wind sector and this figure is expected to grow as more wind farms are implemented. The investment in wind power in 2009 was estimated at over 1 billion AUD. 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

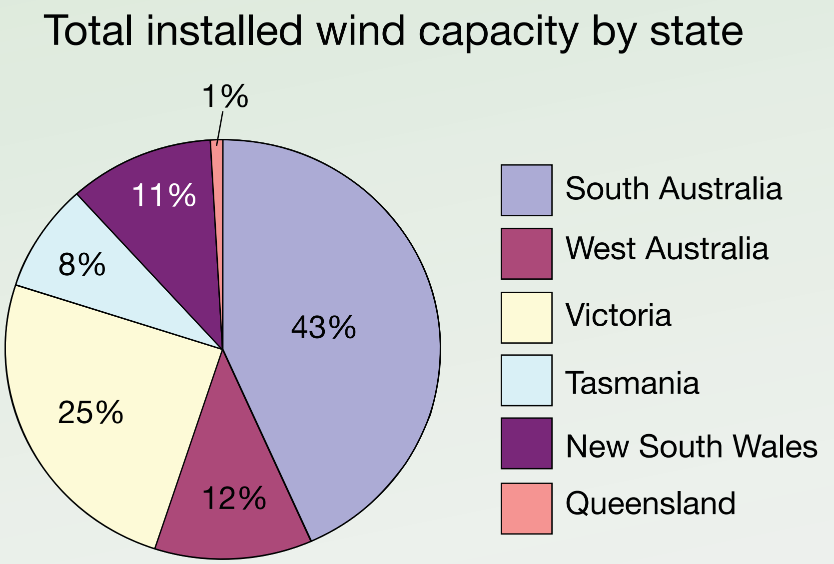

Figure 2 Installed wind capacity in Australia by state

construction. Wind turbines can also be an alternative source of income for farmers who host them.

3.2 Industry status

Many of the existing and proposed wind farms are owned by large electricity companies such as AGL, Origin Energy, Pacific Hydro, Acciona Energy, and Verve Energy. Other wind-specific companies include Infigen Energy and Roaring 40s. Investment and infrastructure funds such as Transfield Services Infrastructure Fund and Macquarie Capital Wind 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 Union Fenosa, Epuron, Wind Prospect, and Wind Farm Developments 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 Hepburn Community Wind Farm, Denmark Community Wind Farm, and Mt Barker wind farm.

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 Accion, Enercon, REpower, Suzlon, and Vestas. Vestas is the market leader in terms of installed capacity with Suzlon having the second highest portion of installed capacity in the market.

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, but there are proposals under evaluation for larger wind farms such as AGL's Macarthur Wind farm at 329 MW in Victoria and Epuron's proposal for Silverton Wind farm in New South Wales at over 1,000 MW. 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 40% of the national total. Currently there are 6,794 MW of wind farms under development which includes wind farms that have received all approvals or are in the process of seeking planning and environmental approvals (Table 5) and another 6,147 MW of capacity that are undergoing feasibility studies. All these proposed projects are onshore wind farms.

3.4 Wind energy costs

Wind turbine costs range from 1,584 to 2,112 AUD/kW (990 to 1,320 €/kW). Total installed costs range from 2,216 to 3,584 AUD/kW (1,385 to 2,240 €/kW).

Wind capacity totaling 1,712 MW was operating in Australia at the close of 2009. In addition, 588 MW were under construction, 6,794 MW were under development, and 6147 MW were under evaluation. If all of the existing and proposed projects are completed, a full 15,241 MW of wind will be in operation.

4.0 R, D&D Activities

The Australian Centre for Renewable Energy (ACRE) was established in 2009. Its purpose is to promote the development, commercialization, and deployment of renewable energy technologies. ACRE will be a one-stop shop for Australian renewable energy businesses and is responsible for the administration of programs such as the 300 million AUD Renewable Energy Demonstration Program and the 14 million AUD Wind Energy Forecasting Capability Program.

The Renewable Energy Demonstration Fund was launched in February 2009. It provides grants of 50 to 100 million AUD (up to one-third of eligible expenditure on the project) for funding to assist in demonstration of renewable energy for power generation on a commercial scale in Australia. While wind power is an eligible technology, it will not be a big recipient as it is already a well-established market sector in Australia. Rather, this investment is expected to provide great impetus for the early development of geothermal, solar thermal, bioenergy, and ocean generation projects.

The Wind Energy Forecasting Capability initiative (WEFC) provided funds to support the development and installation of software and systems for the effective forecasting of wind energy generation to address challenges created by wind energy's variability. WEFC funding concluded on 30 June 2009 although some work under the initiative will continue until 2010.

The Australian Wind Energy Forecasting System (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 expected to be in implemented in 2010. The WEFC has also funded a number of research and development projects to support AWEFS, including:

- an international benchmarking study to identify world's best practice wind energy forecasting systems
- studies of Australian weather patterns, their predictability, and their impact on wind energy generation
- further research into wind energy forecasting and electricity market integration of wind energy in Australia.

The state of New South Wales has established six renewable energy precincts across the state to streamline the planning and approval process for wind developers. Each precinct will have an advisory committee that can provide advice on development issues and enhance consultation with local government and communities. Coordinators of the committee have been appointed and the remaining committee members will be announced in 2010.

5.0 The Next Term

In October 2009 the Environment Protection and Heritage Council released its draft National Wind Farm Development Guidelines for public consultation. The draft was developed to address the need for greater consistency in the approach to wind farm developments. It focuses on the environmental and social areas of wind farm development, and it contains provisions with respect to community consultation, noise, shadow flicker, birds and bats, landscapes, and electromagnetic interference. A final draft is expected in 2010.

The Clean Energy Council is actively working with the federal government and Australia's other political parties to resolve the problems associated with the current design of the RET and to develop an effective solution that will increase investor certainty and drive the development of both large and small scale clean energy technologies. The RET is expected to unlock an estimated 20 billion AUD of investment by 2020 and, with investor certainty, the wind industry can remain a major contributor to the multi-billion dollar challenge of decarbonizing Australia's energy supply.

Author: Felicity Sands, Clean Energy Council, Australia.

1.0 Overview

After three years of stagnation of the wind power market in Austria, an amendment to the Green Electricity Act (GEA) finally took effect in October 2009. This amendment improves the climate for wind park planners and raises funds for new green electricity projects. Furthermore, a new feed-in tariff was fixed (0.097 €/kWh) for projects that apply for a purchase agreement until the end of 2010. The feed-in tariff is set by an ordinance of the Ministry for Economic Affairs and not fixed in the GEA itself. The tariff is applicable only for the year 2010; in 2011 a new tariff will be fixed bringing some uncertainty for investors. The purchase obligation is limited to a specific amount of capacity (depending on the available funds for new projects) so the number of installations for 2010 is somewhat uncertain. We expect 40 MW of new wind capacity in 2010, and 160 MW in 2011.

2.0 National Objectives and Progress

2.1 National targets

The GEA set 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 from 995 MW to approximately 1,700 MW wind capacity). The Austrian Wind Energy Association estimates that by 2020 an annual wind power potential of 7.3 TWh can be achieved (Figure 1).

2.2 Progress

At the end of 2009, 995 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_2 emissions every year.

Concerning the regional distribution of the installed wind capacity in Austria the most wind capacity has been installed in the Austrian province called Niederösterreich (541.3 MW) followed by Burgenland (369.2 MW), Steiermark (49.8 MW), Oberösterreich (26.4 MW), Wien (7.7 MW), and Kärnten (0.5 MW).

2.3 National incentive programs

The GEA (Ökostromgesetz) adopted in 2002 implements a feed-in system for RES including a purchase obligation for green electricity and a feed-in tariff to be set by Ministers. This law 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. New installations received a purchase obligation and a feed-in tariff only if they got a contract with the Ökostromabwicklungsstelle

Table 1 Key Statistics 2009: Austria	
Total installed wind generation	995 MW
New wind generation installed	0 MW
Total electrical output from wind	2.1 TWh
Wind generation as % of national electric demand	3%
Target:	Plus 700 MW by 2015.

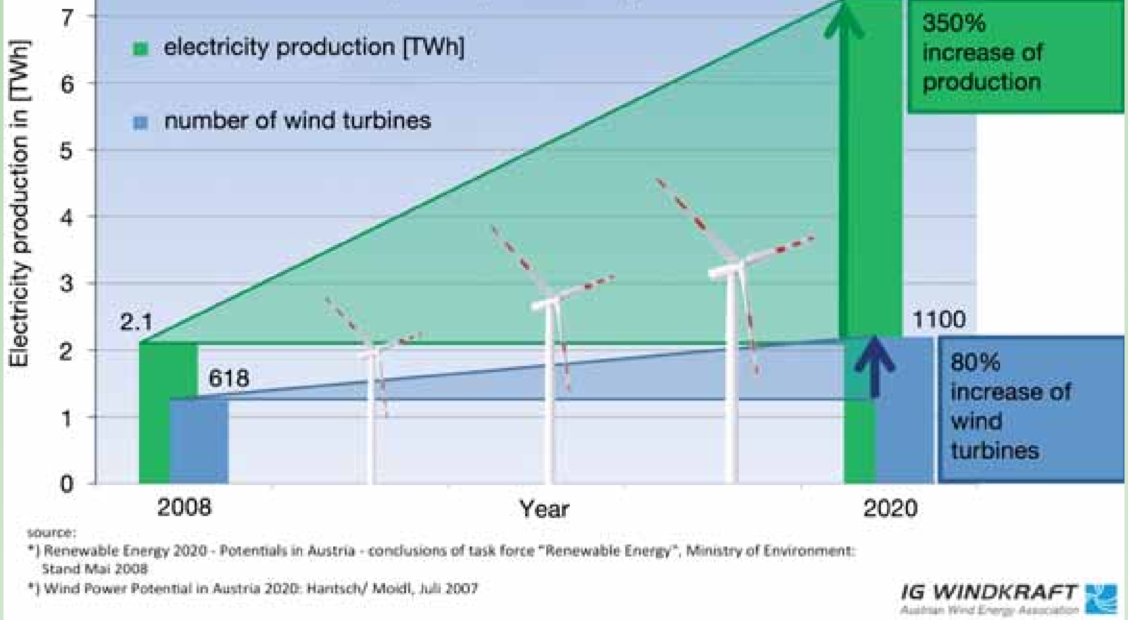

Figure 1 Wind power potential in Austria by 2020

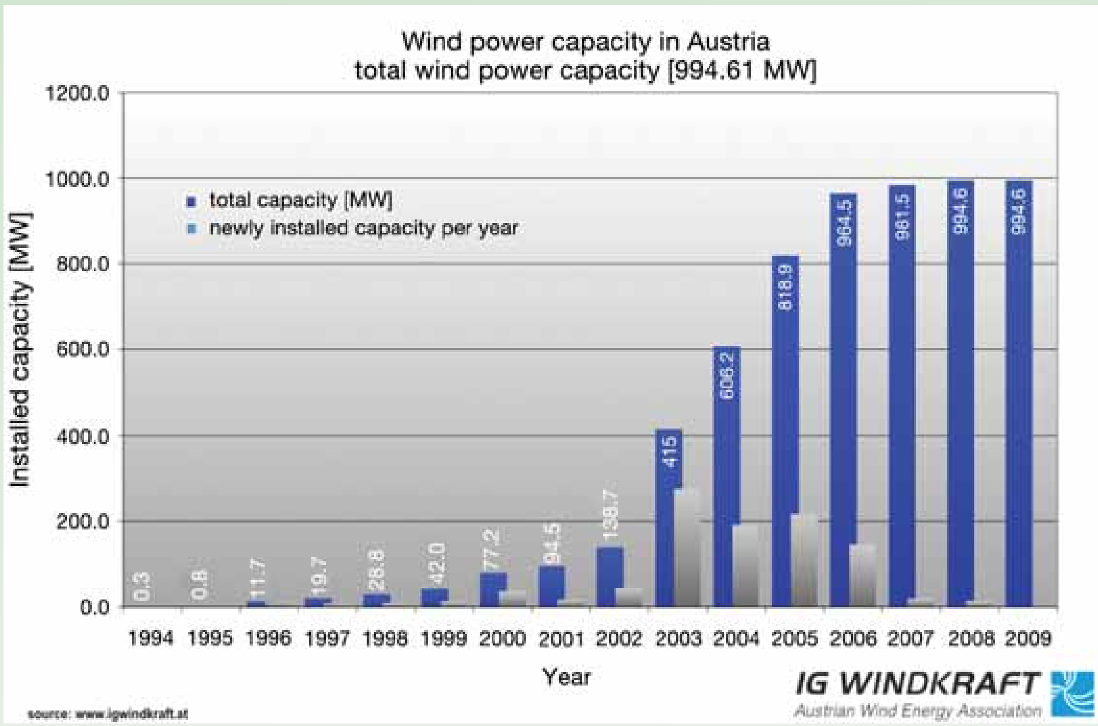

Figure 2 Total wind power capacity in Austria

(OeMAG). The OeMAG is the institution that buys green electricity at the feed-in tariff and sells it to electricity traders. The OeMAG has to give contracts to green electricity producers as long as there are enough funds for new projects. Applicants must submit all legal permissions to get money from these funds. In addition to a very low feed-in tariff (0.075 €/kWh) 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 entered 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 (0.097 €//kWh). This tariff is applicable for projects that apply for a purchase agreement until the end of 2010. These tariffs are granted for 13 years. The feed-in tariff is set by an ordinance of the Ministry for Economic Affairs and not fixed in the GEA itself. The tariff is applicable only for 2010, in 2011 a new tariff will be fixed. This again brings uncertainty for investors. The GEA set a new target of 15% RES without large hydro until 2015. It also set a specific target of adding 700 MW of wind power capacity by 2015 to reach about 1,700 MW wind capacity.

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. For 2010/2011 we expect the installation of 200 MW with a rising trend afterwards.

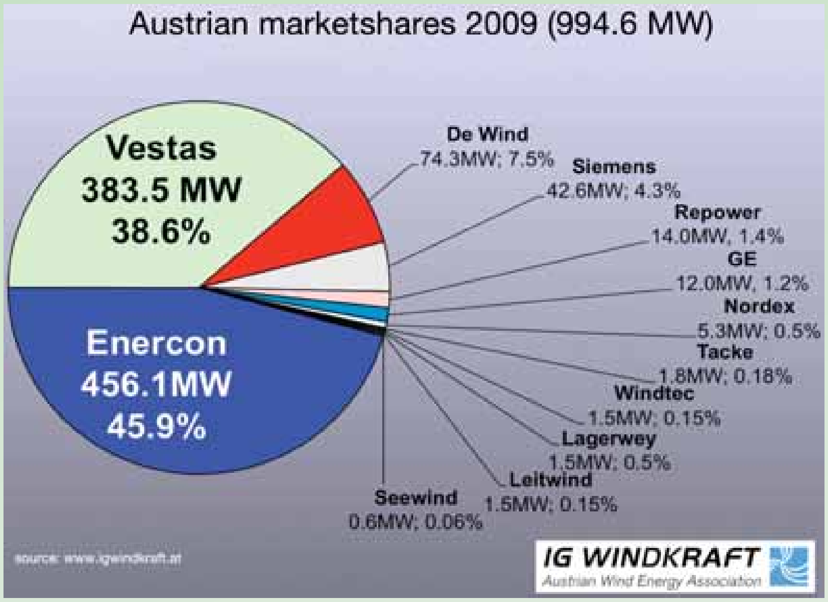

Figure 3 Market shares of wind turbine manufacturers in Austria

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. Due to the stagnation of wind power installations from 2006 to 2009 we cannot state any benefits in this sector apart from investments in planning of new wind parks. The annual turnover of operators of existing wind parks is about 200 million €.

Austrian companies supply components including wind turbine control systems, blade materials, generators, and wind turbine designs. Last year, the turnover of these companies rose by 20% to about 350 million €. The Austrian Wind Energy Association estimates that about 2,500 jobs have been created in the wind energy sector so far.

3.2 Industry status

Cooperatives own 40% of all existing wind turbines, and another 40% are owned by utilities. The rest are owned by private companies. The first wind turbines in Austria where built in 1994 when cooperatives or single wind turbines built by farmers were most common. With a more stable framework in the support system since 2000, but especially since 2003, utilities and other companies entered the market. Today the most active operators planning new wind projects are cooperatives and traditional electricity utilities. The Austrian operators are very active in the neighboring countries of Central and Eastern Europe, and some independent companies have also started businesses outside Europe.

Austrian component suppliers also serve the international wind turbine market. Bachmann electronic GmbH is a leading manufacturer of turbine control systems. About 35,000 MW of the world's wind capacity is equipped with Bachmann's control systems. Hexcel Composites GmbH develops and produces prepreg 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 Sonovel. Windtec develops customized wind turbine concepts and helps its customers to set up their own production. They are developing a 10-MW turbine.

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). Recently no new turbines have been installed. For 2010/2011 we expect wind parks at an average size of 20 MW to 50 MW, with Enercon E82 2.3-MW, Vestas V90 2-MW, and Repower MM92 turbines.

3.4 Wind energy costs

Table 2 shows estimated costs for wind energy project elements.

4.0 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

Table 2 Cost of new wind energy projects

Turbine costs	1,434 €/kW
Connection to grid and grid reinforcement	140 €/kW
Development costs	50 €/kW
O&M costs years 1 to 12	0.0236 €/kWh
O&M costs years 13 to 20	0.0356 €/kWh
Total investment cost	1,762 €/kW

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 geo-statistical approach. This calculation of the theoretical wind potential strives to estimate the feasible wind energy potential of the country. An open GIS 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 the Windatlas will be published at the end of 2010. Further information is available at www.windatlas.at.

Research funds have also been allocated to investigate the usability and economics of small wind turbines in urban areas to accommodate growing demand in this field. The following three 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.

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.

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. Beginning operation in 2006, the wind farm has three 2.3-MW turbines for an installed capacity of 11.5 MW. Operating at an elevation of 1,600 m the turbines face the risk of icing.

One option for de-icing or for preventing ice on the rotor blades is to heat them. This is done either by heating the surface of the blades by means of resistance heating or by heating and circulating the air inside the hollow space of the blades. At Moschkogel, all blades were equipped with surface heating systems. However, evaluations of the first two operational years revealed that the performance of this heating system was unsatisfactory. In 2008, all blades were replaced and equipped with an improved heating system based on warm air circulation. Operational data of 2008 and 2009 will be used by Energiewerkstatt to analyze monthly energy production of each turbine in ten minute increments of energy production and wind speed data. These data will be compared with the error codes of the turbines at operational stoppages. Based on this assessment and on comparison of the energy yields of the individual turbines, statistics about the reasons for stoppages can be established and production losses of individual turbines due to icing can be estimated. Additionally, the two different blade heating systems can be compared in terms of performance and cost effectiveness.

The Austrian company 'Energiewerkstatt Verein' is the coordinator of SEEWIND, one of the largest Research and Demonstration Projects carried out under the 6th 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 € to install one pilot wind turbine each in Bosnia Herzegovina, Croatia, and Serbia. The project began in May 2007 and will last four and a half years. Further information is available at 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 will be the amount of the feed-in tariff in 2011 and the ability to raise annual funds for projects. For 2010/2011 we expect the installation of 200 MW with a rising trend afterwards.

Authors: Ursula Nährer, Austrian Wind Energy Association; Andreas Krenn, Energiewerkstatt Verein; and Karin Hollaus, Federal Ministry of Transport, Innovation and Technology, Austria.

Canada

Credit: Jimmy Royer, NRCan

1.0 Overview

With a huge landmass, lengthy coastlines, and quality wind resources, Canada has enormous potential to generate electricity from wind. In 2009, Canada installed more than 900MW of new wind energy capacity, placing Canada in the top 10 worldwide for new installed capacity. It is estimated that new wind developments represented more than $2.2 billion in investment last year. Canada also achieved a new milestone in 2009 - wind-generated electricity is now produced in every province with the recent commissioning of Bear Mountain Wind Park in British Columbia. In total, Canada's wind energy capacity is more than 3,300 MW.

The Government of Canada continues to accelerate the growth of Canada's wind power sector through a range of mechanisms including the Clean Energy Fund and ecoENERGY for Renewable Power. Initiatives are also being employed in the provinces and territories. For example, Ontario's Green Energy Act enabled the creation of Canada's first comprehensive guaranteed pricing structure for renewable electricity production.

Canada completed its Wind Technology Road Map (an industry-led, government-supported initiative). The resulting long-term vision and action plan is designed to encourage the growth of domestic wind energy expertise, and the development of wind energy technology specifically relevant to Canada.

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: reliability of small wind turbines and certification standards; large wind turbines and offshore opportunities; cold climate research; adapting international codes and standards to the Canadian context; and, improving wind resource assessment and forecasting.

Canada is pursuing new wind development opportunities in the north, and offshore. Canada's northern and remote communities are currently monitoring their wind resources, with the hopes of developing wind energy projects. Enthusiasm for offshore wind is building momentum in Canada, and several offshore projects have either been proposed or are under development. Moreover, Canadian manufacturers are exploring opportunities, challenges and actions required to ensure Canada has a place in the growing global wind energy industry.

2.0 National Objectives and Progress

Canada's wind energy industry enjoyed a record breaking year. Over 900 MW of new wind energy capacity was installed in eight provinces, placing Canada in 9th place globally, in terms of new installed capacity for 2009.

As of December 2009, Canada's total wind energy capacity is more than 3,300 MW – a ten-fold increase in six years. Canada now produces enough wind generated electricity to power nearly one million Canadian homes. In Ontario alone, wind energy production rose by more than 60 per cent over the previous year, according to Ontario's Independent Electricity System Operator (IESO).

Table 1 Key Statistics 2009: Canada	
Total installed wind generation	***3,319 MW***
New wind generation installed	***950 MW***
Total electrical output from wind	***9,979 GWh/yr****
Wind generation as % of national electric demand	***1.85 %****
Target: n/a	n/a
(Estimated, source: CanWEA & NRCan)	

2.1 National targets

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

The Canadian Wind Energy Association (CanWEA) continues to pursue WindVision 2025, a strategic vision for wind energy development in Canada, released in 2008. CanWEA's vision sees wind energy supplying 20 percent of the country's demand by 2025, bringing total Canadian wind energy capacity to 55,000 MW.

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. The National Energy Board's recent publication "2009 Reference Case Scenario: Canadian Energy Demand and Supply to 2020" (download from www.neb-one.gc.ca) provides a forecast of Canada's electricity generation mix, by source.

Canada achieved a new milestone in 2009 - wind-generated electricity is now produced in every province with the recent commissioning of Bear Mountain Wind Park near Dawson Creek, B.C. Canada's wind energy capacity is roughly divided in thirds: one third in Ontario, one third in Alberta and Québec, and the remaining 1/3 in the rest of the provinces and territories. A graphical representation of Canada's installed wind energy capacity is shown in Figure 1.

The provinces see wind energy as an important source of new electricity generation and current provincial targets and initiatives could result in a further quadrupling of installed wind energy capacity in the next six years. A summary of provincial wind energy targets can be found on CanWEA's website at www.canwea.ca .

Wind energy has long been seen as a possibility for Canada's northern and remote communities to reduce the cost of diesel generated electricity, and to ensure a more sustainable energy supply. However, wind projects in Canada's North have had mixed success. Commercial wind turbines have been operating in the Yukon for over 15 years in extremely harsh icing conditions. Yet, wind-diesel projects in the NWT and Nunavut stopped operating after about a year. That being said, there are at least eight communities in the Canadian Arctic that are currently monitoring their wind resources, with the hopes of developing wind energy projects (1). Furthermore, CanWEA has been working with its Northern Caucus to create a federal Remote Community Wind Incentive Program (ReCWIP), specifically to assist wind energy development in the North.

2.3 National incentive programs

The Government of Canada continues to accelerate the growth of Canada's wind power sector through a range of mechanisms including:

- ecoENERGY for Renewable Power or ERP (www.ecoaction.gc.ca);
- accelerated Capital Cost Allowance (CCA) Class 43.1 and 43.2; and,
- Canadian Renewable and Conservation Expenses (CRCE).

The 2008 IEA Annual Report (section on Canada) describes the federal mechanisms in detail.

2.3.1 Other Examples of Incentives and Mechanisms in Canada

In Canada, initiatives are also being employed at the provincial level and by various organizations (Table 2):

2.4 Issues affecting growth

Canada's Wind Technology Roadmap (Wind TRM) process brought together over 100 representatives from industry, government and academia. Together, they identified barriers to achieving the Wind TRM vision such as:

- Challenges in securing broad action-oriented public support for wind energy;
- Challenges facing the Canadian industry in its efforts to establish a strong domestic wind energy manufacturing and services base;
- Challenges in human resources and skills development; and,
- Challenges in advancing R&D in wind.

3.0 Implementation

According to CanWEA, new wind developments represented more than $2.2 billion in investment last year. Furthermore, achieving WindVision 2025 will pay huge dividends to Canada by:

- Generating $79 billion of new investment;
- Creating at least 52,000 new full-time "green collar jobs", including many in rural communities (approximately half in manufacturing and a third in operations and servicing); and,
- Producing $165 million in new annual revenues for local governments in property taxes, and an equal amount in annual payments to landowners.

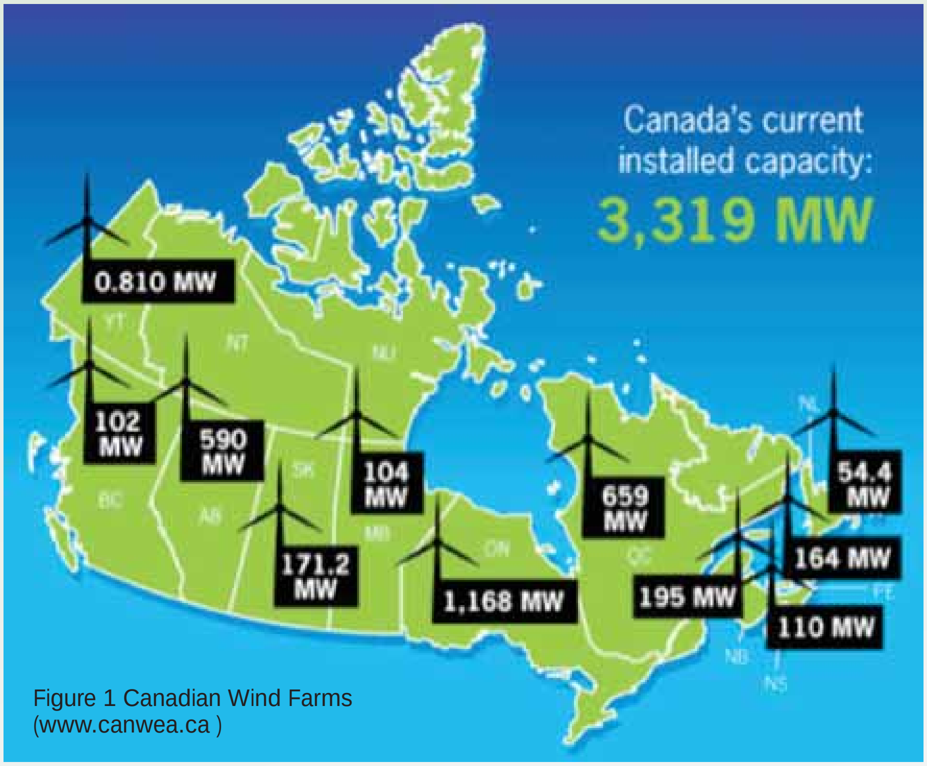

Figure 1 Canadian Wind Farms (www.canwea.ca)

Table 2 Incentives and mechanisms in Canada

Program Type	Where Offered	Examples
Enhanced feed-in tariff	Selected Provinces	NB Power Embedded Generation Program allows potential developers or IPPs to connect to distribution system. The generation unit may range from 100 kW to 3,000 kW. NB Power purchases the energy at a set 0.09445 CAD/kWh. Ontario's Feed-in-Tariff Program (FIT) pays participants a fixed-price (0.135 CAD/kWh) for electricity they generate; includes a stream called microFIT for projects of 10 kW or less. FIT and microFIT contracts are for 20 years.
Capital subsidies	NWT	NWT Alternative Energy Technologies Program (AETP) funds: 1) Community Renewable Energy Fund for up to one-half of project cost (max 50,000 CAD), for Aboriginal and community governments, agencies, and non-profits; 2) Medium Renewable Energy Fund for commercial businesses (max 15,000 CAD); 3) Small Renewable Energy Fund for residents (max 5,000 CAD).
Green electricity schemes	Selected Provinces	Bullfrog Power's electricity comes from wind/hydro facilities that have met Environment Canada's EcoLogoTM standard for low-impact renewable power. Enmax customers can redeem their EasyMax Rewards™ dollars toward Greenmax such that 5,000 kWh/yr of renewable energy is secured from an EcoLogoTM certified facility in Alberta.
Renewable Energy Standard (RES) or Renewable Portfolio Standard (RPS)	Selected Provinces	Nova Scotia's RES - by 2013, Nova Scotia will generate at least 18.5% of its electricity through renewable energy. Prince Edward Island RPS -15% by 2010, 30% by the year 2013.
Investment funds for wind energy	National	The Scotian WindFields: a network of eight community corporations in Nova Scotia that share ownership and invest equity in wind projects; PEI Energy Savings Bonds are sold December 2006-2011, interest rate fixed at 5%/yr for a 5-year period, maximum cumulative sales of 20 million CAD; Brookfield Renewable Power Fund, Macquarie Power & Infrastructure Income Fund, Innergex Power Income Fund, and Northland Power Income Fund own 1 to 3 wind farms each.
Net metering	Selected Provinces	NB Power Net Metering Program allows customers to generate their own electricity to offset consumption, generation units must not exceed 100 kW PEI Net Metering Program for small capacity renewable energy generators up to 100 kW; a new initiative focused on community rinks.
Electricity utility activities	Selected Provinces	SaskPower's Green Options Partners Program allows medium-sized clean power producers to generate and sell between 100 kW and 10 MW of electricity to SaskPower. Program cap - 50 MW; annual program cap - only 25 MW can be made up of wind power.
Sustainable building requirements	National - LEED®	The LEED® Canada for Commercial Interiors rating system awards organizations up to three points toward LEED certification for sourcing green electricity from Bullfrog Power to reduce the environmental footprint of their buildings.
Request for Proposal	Selected Provinces	Québec held 3 calls for wind power – 1,000 MW in 2003, 2,000 MW in 2005, 500 MW in 2009. British Columbia - Clean Power Call for up to 5,000 GWh/year of seasonal and hourly firm energy in 2008. Manitoba Hydro – called for new wind projects totaling up to 300 MW in 2007.

Adding 55,000 MW of wind generated capacity will also cut Canada's annual greenhouse gas emissions by 17 Megatonnes, replace up to 20 million litres of diesel fuel per year (in northern and remote communities), stabilize electricity prices, and strengthen Canada's electrical grids.

In January 2009, Ontario Power Authority (OPA) awarded 20-year contracts to 6 wind power projects, for a total of 492 MW. The projects are expected to be in service by the end of 2012. The OPA estimates that the economic impact of six successful projects will be as follows:

- Total investment: $1.32 billion
- Number of jobs created: About 2,200 direct and indirect jobs
- Annual combined lease payments to landowners hosting turbines: $3 million
- Total annual municipal tax revenues to host communities: $1 million.

3.1 Economic impact

The University of Moncton in New Brunswick recently completed a case study on the economic impact of a generic 100MW wind farm project in New Brunswick (2). Using publicly available financial data from a representative group of projects in Eastern Canada, it is estimated that a 100 MW wind farm requires a $200 million investment. Table 3 provides a summary of revenues and expenditures:

Table 3 Summary of revenues and expenditures for a generic 100-mw wind farm in New Brunswick	
Investment	
Total project investment	$200,000,000
Cost per MW	$2M/MW
Construction (in 2009)	
Provincial expenditures	$34,000,000
% of Provincial/ total investment	17%
Construction period	14 months
Direct labour	81 person years
Total employment (direct, indirect & induced)	225 person years
Total provincial revenues	$2,034,475
Operation & Maintenance	
Direct O&M employment	9 jobs/year
Total employment (direct, indirect & induced)	17 jobs/year
Provincial tax revenues	$934,852/year
Total Profits	**$200,000,000**

Based on the current costs to build, finance and operate a 100 MW wind farm in Eastern Canada, the study estimates that the owners of the 100 MW wind farm could accumulate profits of more than $200 million over life of the project (approximately 25 years). This does not take into consideration possible future revenues from carbon credits.

In a different study, GE Energy Financial Services concludes that investment in wind energy could yield a financial return for the Government of Canada (3). GE estimated the following costs and revenues from an average Canadian wind project financed in 2009: C$2500/kW project cost, 33 percent average lifetime capacity factor, 7.3 ¢/kWh revenue, and average O&M cost of C$30/kW per year.

3.1.1 Ownership

In Canada, wind farms are typically owned by independent power producers (IPPs), utilities, or income funds (CanWEA maintains a list of wind farm owners/operators, www.canwea.ca). Electricity generated is sold to utilities by means of a power purchase agreement (PPA) or, as in the case of deregulated markets such as in Alberta, it is sold on the spot market. In some jurisdictions, including in Québec and British Columbia, a call for tenders is issued so wind power producers must compete for contracts to sell power to utilities. The utilities can therefore obtain electricity at the best rate.

Community wind power is in its infancy in Canada, but in provinces like Ontario, Quebec, and New Brunswick, interest in community wind is growing. One such example is the 54 MW Pukwis Community Wind Park (www.pukwis.ca). The Wind Park is a joint venture between the Chippewas of Georgina Island First Nation and Windfall Ecology Centre. Collaboration on Pukwis began in 2003, and Pukwis Phase I (20 MW) is now ready to move from feasibility to construction. Examples of other wind energy cooperatives in Ontario include:

- WindShare Co-op in Toronto, ON - 600 kW, operational since 2002;
- Lakewind Power Co-op near Kincardine, ON - 10 x 2MW, submitted a FIT contract application;
- Positive Power Co-op on the north shore of Lake Erie, ON - 2 x 1.5MW, completing environmental assessments.

In the province of Québec, Val-Éo (www.val-eo.com) is a wind energy cooperative formed by landowners, municipalities and citizens. In 2007, Val-Éo submitted a 50MW project in response to Hydro Québec's call for tenders, but was not selected. Val-Éo is preparing for the next call for tender.

Lamèque Renewable Energy Co-operative initiated a wind energy project that is presently under development in New Brunswick. Acciona Energy Canada, and a local development partner Wind Dynamics, are constructing the 49.5 MW wind power facility on Lamèque Island. New Brunswick Power and Acciona have signed a 25-year power purchase agreement.

British Columbia's Bear Mountain Wind Park is wholly owned by AltaGas Income Trust. However, Peace Energy Cooperative (who initiated the project), retains an interest that will pay dividends for 25 years. Seven years ago, Peace Energy secured the rights to develop the wind resource and found a developer to undertake the project. The Cooperative has received a fee for its part in bringing the project to fruition.

3.1.2 Manufacturing

In February 2009, CanWEA held Canada's first-ever seminar on supply chain opportunities in Canada's growing wind energy industry. According to a panel of experts who spoke at the seminar, the North American supply chain for the wind industry is in its infancy. Original equipment manufacturers (OEMs) have to balance high transportation costs for imported goods with competitive pricing, because of barriers to entry for potential Canadian and North American component suppliers. The focus for the coming years will be to develop a North American supply chain that includes sourcing materials closer to home, simplifying supply chain processes, reducing lead times and reducing costs. AAER, a manufacturer of wind turbines (up to 2MW), sources 55% of its components in Canada.

In September 2009, the Canadian Manufacturers & Exporters (CME) and CanWEA announced a strategic partnership to "explore Canadian manufacturing opportunities in the growing global wind energy industry". The two national associations will partner to produce a co-branded market report that explores and outlines the opportunities, the challenges, and the actions required to "ensure Canada earns its share of new wind energy manufacturing and component production".

3.1.3 Applications

Canada's large land base provides many potential sites for onshore wind farms, and onshore sites are far cheaper to exploit than offshore sites. That being said, enthusiasm for offshore is building momentum and several offshore projects have either been proposed or are under development.

Canada's first offshore wind energy project is likely going to be Naikun Wind Energy Group Inc.'s project. NaiKun (www.naikun.ca) plans to develop a 396MW wind energy project off the northwest coast of British Columbia, in Hecate Straight. NaiKun's project has been granted a provincial Environmental Assessment Certificate from the British Columbia Environmental Assessment Office (EAO), and is under "active consideration" by BC Hydro (who recently provided an update on B.C.'s Clean Power Call).

Wind turbines built offshore in the Great Lakes have the potential to generate almost 21,000 MW of power, according to Trillium Power Wind Corp (www.trilliumpower.com). The wind developer has plans to build Trillium Power Wind 1 (TPW1) - a 142 turbine, 710 MW project, 17km to 28km from the shores of eastern Lake Ontario. Furthermore, Toronto Hydro, SouthPoint Wind and Canadian Hydro Developers (recently acquired by TransAlta) are also exploring development in the Great Lakes.

Canada has many remote and northern sites that require electricity including communities, industrial and remote communications sites. Hybrid wind-diesel systems reduce overall diesel fuel consumption, reduce the cost of electricity production and help to shelter communities from fuel price volatility. Ramea, an island off the coast of Newfoundland, hosts Canada's only operational wind-diesel system. A hydrogen storage component has since been added to the system, resulting in a unique wind-hydrogen-diesel system. The new system is undergoing performance monitoring and further R&D.

3.2 Operational details

Eleven wind farms were commissioned across seven provinces in 2009. Summary data follows:

- Installed capacity per wind farm: 6.6-197.8 MW
- Wind farm locations (provinces): ON, PE, NL, BC, AB, NB, QC
- Turbine manufacturers and models: Vestas V80, V82 and V90, Siemens SWT-2.3, Enercon E82, GE 1.5MW
- Turbine sizes: 1.5 -3 MW
- Average turbine size: 2MW
- Average estimated capacity factor: 34%

4.0 R, D&D Activities

4.1 National R, D&D efforts

Canada's federal departments and agencies in the energy domain are developing a consolidated approach to energy research, development, and demonstration (www.science.gc.ca). Science & Technology (S&T) performed in the energy domain is aimed at:

- improving the integration of intermittent renewable sources (like wind) and small-scale generation systems within the electrical grid;
- improving the economics and efficiency; and,
- reducing the environmental impacts of conversion of renewable energy to electricity.

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. Natural Resources Canada (NRCan) is one of several government departments active in wind energy R&D. NRCan's R&D priority areas include: small wind turbines, large wind turbines, codes and standards, and the Wind TRM. NRCan also works with other organizations on wind turbine standard development. Environment Canada maintains the Canadian Wind Energy Atlas, and conducts research on wind forecasting and wind resource assessment. Environment Canada's Canadian Wildlife Service (CWS) conducts research on the impact of wind turbines on wildlife. Health Canada supports the development of siting guidelines for wind farms. National Research Council conducts research on the aerodynamics of wind turbines and siting of wind farms in complex terrain.

The Small Wind Certification Council (SWCC) is an independent certification body. SWCC is attempting to address concerns about reliability, by providing a common North American standard for reporting small wind turbine energy and sound performance, as well as a labeling scheme to allow consumers to reliably predict and compare performance. NRCan continues to support this effort by working on technology improvements for small wind turbines including cold climate R&D of cold climate certification standards. Furthermore, NRCan is providing financial support to Saskatchewan Research Council (SRC) for performance assessment and reliability testing of small wind turbines installed in Saskatchewan, under the net metering program. This is a collaborative effort between SRC and WEICan.

Cold climates, offshore opportunities, wind integration and large wind turbine drive trains are areas of significant international interest that have important applications in Canada. Participation in the International Energy Agency Wind Implementing Agreement within this program is an important means of establishing international collaboration in cold climate research. Canada is laying the groundwork for offshore wind development on the Great Lakes through research on the behavior of offshore wind, and the tools that could be used to assess the wind resources, as well as through participation in projects that assess the impacts of offshore wind development. Toronto Hydro's wind research platform (anemometer) approximately 1.2 km offshore in Lake Ontario is being support, in part by NRCan. NRCan is also providing financial support to a Canadian company for development and demonstration of a permanent magnet generator for large wind turbines.

Codes and standards development focuses on adapting international standards to the Canadian climate and context. NRCan is an active member of the Canadian Standards Association (CSA) Technical Committee, and participates in the development of wind turbine standards, such as Small Wind Turbine Standard and Offshore Wind Turbine Standard. Environment Canada is working on incorporating cloud-to-ground lightning climatology and design icing conditions (that account for the different types of icing that occurs in Canada) into wind turbine standards. Canada continues to work on harmonizing Canadian standards with International Electrotechnical Commission (IEC) standards, which are being developed by 17 participating countries.

Canada's Wind TRM (www.windtrm.gc.ca) is an industry-led, government-supported initiative. NRCan's Wind R&D Team facilitated a series of stakeholder workshops with the objective of identifying key technology gaps and opportunities in wind energy, in Canada. A total of three workshops were held in 2009, with over 75 key players from industry and academia attending each workshop. The resulting action plan is designed to encourage the growth of domestic wind energy expertise, and the development of wind energy technology specifically relevant to Canada.

In May 2009, the Government of Canada announced a $1B CEF. The Fund (http://www.nrcan.gc.ca/eneene/index-eng.php) will provide $150 million over five years for clean energy R&D. It will also provide $850 million over five years for the demonstration of promising technologies, including renewable energy and clean energy systems demonstrations. The government issued a call for proposals in the fall of 2009, for "Renewable Energy and Clean Energy Systems Demonstration

Projects". Those that are selected for funding will be announced in 2010.

In Canada, there are a number of publicly funded organizations active in wind energy research:

- NSERC Wind Energy Strategic Network (WESNet) is a Canada wide multi-institutional and multi-disciplinary research network. During 2009, WESNet focused on implementing its research programs and enhancing research collaboration. Details on research in the four thematic areas can be found at www.wesnet.ca.
- Wind Energy Institute of Canada (WEICan) is a wind energy research and testing facility, located in the province of Prince Edward Island. In December of 2009, WEICan (www.weican.ca) announced that the Zephyr Airdolphin Z1000, manufactured in Japan, will undergo type testing leading to certification at WEICan's North Cape site. Two other turbines have already participated in the testing leading to certification program: Cleanfield's V3.5 and Raum Energy's 1.3 kW.
- The Wind Energy TechnoCentre (www.eolien.qc.ca) is a not-for-profit organization whose mission is to contribute to the development of an industrial wind energy network in Québec. The TechnoCentre has recently constructed a 4 MW wind farm at Site Nordique Expérimental en Éolien CORUS (SNEEC), in partnership with manufacturer REpower. The wind farm provides the TechnoCentre with a platform for offering a broader range of services to the wind power industry, specifically relevant to turbine performance and reliability in cold climates.

4.2 Collaborative research

Canada participates in Task 11, 19, 25 and 28 of the IEA Wind Implementing Agreement, as well as, in Technical Committee-88 (TC-88) of the International Electrotechnical Commission (IEC). Collaborative activity focuses on developing standards for on and offshore wind energy systems that meet the needs of Canada.

5.0 The Next Term

The Canadian wind energy industry will continue to mature and grow beyond 2010. Approximately 4,000 MW of new wind energy projects already have signed contracts, and are expected to be commissioned over the next few years. There will likely be a need for new transmission facilities to accommodate wind energy development in provinces such as Ontario and Alberta.

The provinces will make progress towards fulfilling renewable portfolio standards and targets. New power purchase agreements for wind energy projects are anticipated in several provinces. Many jurisdictions will also be working on strengthening their policy frameworks to support wind energy development. The real impact of Ontario's Green Energy Act will be felt in 2010, when the province signs its first contracts under the new feed-in-tariff program FIT.

Cost of generation remains the most important barrier to increasing wind deployment in Canada. Federal and provincial incentives will continue to have a significant impact on reducing cost. Canada's R&D efforts will also advance wind turbine technology and wind energy development in an effort to reduce the cost of wind generated electricity. R&D priority areas include: small wind turbines, large wind turbines, codes and standards, and methods and tools for wind resource assessment and forecasting.

Several of Canada's northern and remote communities are currently monitoring their wind resources, with the hopes of developing wind energy projects. Programs and initiatives that accelerate the adoption of wind energy technologies in the Canadian Arctic are under development. Expanding the use of wind-diesel technology and its application in northern communities would reduce overall diesel fuel consumption and reduce the cost of electricity production.

Enthusiasm for offshore wind is building momentum in Canada, and several offshore projects have either been proposed or are under development. Trillium Power Wind, Toronto Hydro, SouthPoint Wind and Canadian Hydro Developers (recently acquired by TransAlta) are all exploring development in the Great Lakes.

Canadian manufacturers will continue to explore opportunities, challenges and actions required to ensure Canada has a place in the growing global wind energy industry. The priority for the coming years will be to develop a North American supply chain that includes sourcing materials closer to home, simplifying supply chain processes, reducing lead times and reducing costs.

Canada's massive wind energy potential remains largely untapped – it ranks 11th in total installed wind energy capacity, and 18th in terms of the contribution of wind generated electricity to national electricity demand. By encouraging the growth of domestic wind energy expertise and the development of wind energy technology specifically relevant to the Canadian context, Canada can realize many benefits – to the economy, society and environment.

References and Notes:

(1) Government of NWT, 2007 Remote Community Wind Energy Conference Proceedings download http://www.enr.gov.nt.ca/_live/documents/documentManagerUpload/Wind_Energy_Conference_Proceedings_Report_March_2008.pdf

(2) University of Moncton, Economic Impact Assessment of a 100MW Wind Farm Project in New Brunswick download http://www.shearwind.com/media/pdf/eco_100mw_2009.pdf

(3) GE Financial Services, Study - Canada's ecoENERGY Investment in Renewables Pays Off for Taxpayers download http://www.geenergyfinancialservices.com/press_room/press_releases/ecoENERGYStudyFINAL.pdf

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Denmark's Horn's Rev 2

1.0 Overview

Initial statistics show that approximately 17.4% of Denmark's energy supply came from renewable sources in 2009, and the production from wind turbines alone corresponded to 19.3% of the domestic electricity supply. Another 20.3% of energy supplies came from natural gas, and 20.5% from coal. Dependence on oil has been about 40%.

Wind power capacity in Denmark has increased by 319 MW in 2009, bringing the total to 3,480 MW (Table 1). In 2009, 238 MW of offshore wind turbines were installed with three offshore wind farms connected to the grid: Horns Rev II, Avedøre Holme, and Sprogø. This is the highest amount of offshore turbines installed since 2002, which some see as proof the political initiatives are taking effect.

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 Feb2008 Agreement, defining among others, subsidies for renewable energy plants and access to offshore sites. Furthermore, initiatives that emphasize globalization and the improved use of renewable energy sources, including stronger support for energy research, development, and demonstration are continued through the energy policy introduced in 2006 which was based on the Strategy 2025, published June 2005, and later followed by A Visionary Danish Energy Policy 2025, published 19 January 2007.

2.0 National Objectives and Progress

2.1 National targets

Figures from the Danish Energy Agency show that the national target, of 20% of

Table 1 Key Statistics 2009: Denmark	
Total installed wind generation	3,480 MW
New wind generation installed*	319 MW
Total electrical output from wind	6.721 TWh
Wind generation as % of national electric demand**	19.3 %
Target***	Not specified for wind

* 351 MW installed; 33 MW removed
** In 2009 the wind index was 88%, thus wind generation as % of national electric demand is 22.1% corrected to normal wind index
*** Target for Renewable energy is 20% of gross energy consumption in 2011 and 30% in 2020

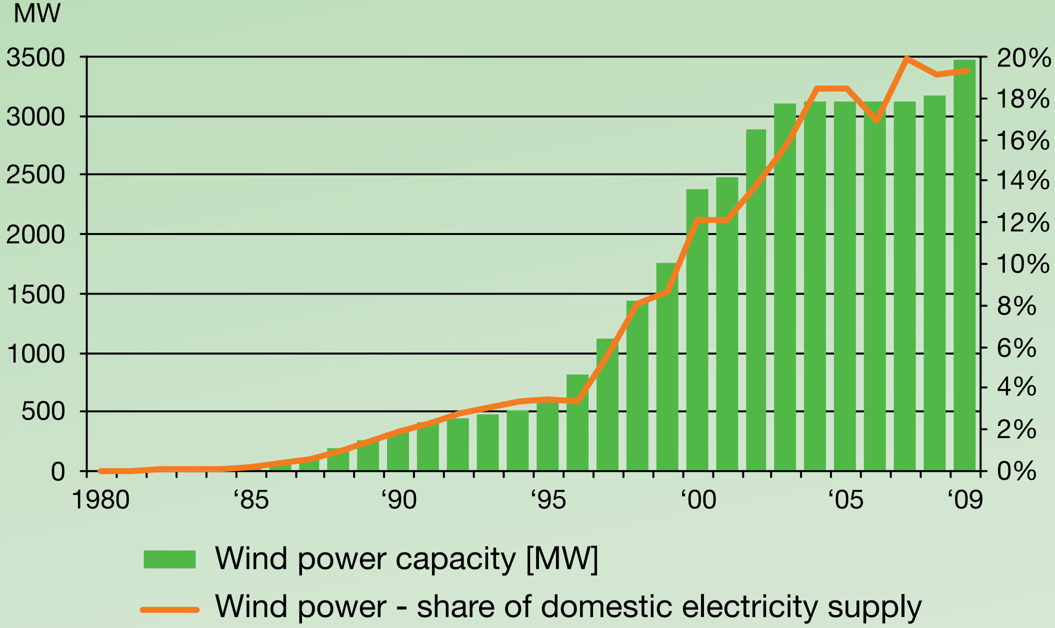

Figure 1 Danish wind power capacity and its share of domestic electricity supply (1)

gross energy consumption from renewable energy sources by 2011, is expected to be fulfilled. Wind power plays a major role in achieving this target. In April 2009, it was projected that 21.1% of energy in 2011 would come from renewable energy. 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 capacity of wind generation in Denmark increased by 319 MW in 2009, bringing the total up to 3,480 MW, and the total number of turbines to 5,108. Most of this takes place in west Denmark, with 78% of total capacity and 77% of total production there.

During 2009, 162 new wind turbines were installed, and 159 turbines were decommissioned. The average capacity of those installed in 2009 was 2.2 MW. A detailed history of installed capacity and production in Denmark can be downloaded at the Danish Energy Agency Web site (www.ens.dk) (1).

As shown in Table 1 and Figure 1, electricity from wind energy covered 19.3% (22.2% corrected to normal wind index) of the electricity consumption in Denmark in 2009 compared to 19.1% (100% wind index) in 2008. The total electricity production from wind energy in 2009 was 6,721 GWh, compared to 6,928 GWh in 2008: the slight reduction in power, even though the wind power capacity has increased in 2009, is due to a lower wind index.

In 2009, 116 MW of wind power were installed onshore, and 238 MW offshore. At the same time 34 MW have been decommissioned onshore. It is the first time since 2002 that there has there been such a high installation of onshore turbines. This is seen as an extremely positive development that will continue into and after 2010. It is interpreted as a sign that some of the political initiatives are beginning to take effect, and the municipalities are beginning to find their role in planning wind projects.

The environmental benefits due to the 2009 wind energy production, assuming coal is being substituted, results in 52.6% of Denmark's yearly CO_2 reduction obligation (1990-2010). More specifically (2): Saved coal: 2,441,852 tons (364 g/kWh); CO_2: 5,742,377 tons (856 g/kWh); SO_2: 1,811 tons (0.27 g/kWh); NOX 6,977 tons (1.04 g/kWh); Particles 201 (0.03 g/kWh); Cinder/Ash 362,253 tons (54 g/kWh).

2.3 National incentive programs

An act passed at the end of December 2008 (Law No. 1392 of 27/12/2008) aims to further promote the use of renewable energy in Denmark, in order to meet national and international targets (2). This is an implementation of the Feb2008 Agreement, described in detail in the *IEA Wind 2008 Annual Report*. In effect since 1 January 2009, this act encompasses:

- subsidies for wind turbines and other renewable energy generating plants
- schemes to foster the development of wind turbines (value of loss and buy legal systems, green system and guarantee fund)
- licensing to harness energy from water and wind on the sea
- connection and safety requirements for wind turbines
- regulation of electricity from proposed offshore wind turbines

2.4 Issues affecting growth

As of October 2009, a negative pricing scheme has been introduced into the Nordic Power Exchange (NordPool), with the minimum price for buying electricity set to - 1,650 DKK (-200 €) as compared to 0 DKK previously. In the announcement of the new pricing scheme (Nord Pool Spot) it is mentioned that a negative price floor has been in demand especially from participants trading in Elspot in the Danish bidding areas.

3.0 Implementation

3.1 Economic impact

The figures published in the latest report from the Danish Wind Turbine Industry 'Branchestatistik 2009' (4) are from 2008. There was an increase of about 26% in the national turnover to 53 billion DKK (7.1 billion €) in 2008, compared to 42.2 billion DKK (5.7 billion €) in 2007. The global turnover was increased by around

29%, from 65 billion DKK (8.7 billion €) in 2007 to 84 billion DKK (11.26 billion €) in 2008. The overall export in 2008 was 586 billion DKK (78.5 billion €), the wind energy industry covering 7.2% of the total Danish exports, and 70% of the exports in energy technologies. The wind turbine component manufacturers increased their exports in 2008 by 30%, due partly to a higher global focus.

The number of people employed within the wind energy sector in Denmark increased 20.9% in 2008 compared to 2007, making about 28,400 employees. As of mid-May 2009, publication of the aforementioned report, the number of employees dropped to 26,000, an increase of 11% from 2007. This reduction in employees is seen as a result of both the world economic crisis and the lower than expected market growth.

3.2 Industry status

The Danish Wind Industry Association's publication of its membership directory, 'Wind Power Hub – The Green Pages', 2009, lists Danish based companies 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 7% of the world market and Vestas Wind Systems A/S, the leading manufacturer with around 20% of the world market. The most important suppliers of major components for wind turbines are still LM Glasfiber A/S, a leading producer of composite blades for wind turbines; Mita Teknik A/S, kk-electronic A/S producers of controllers and communication systems; Svendborg Brakes A/S, a leading vendor of mechanical braking systems; and Skykon A/S Producers of towers.

Only one company, Gaia Wind Energy A/S (owned by Mita Teknik A/S), currently produces wind turbines for households, but several small companies are planning to produce or import micro-turbines. A number of Danish-based companies have started importing small turbines from abroad, including China, Germany, and Scotland.

3.3 Operational details

In 2009, 116 MW of wind power was installed onshore, and 237 MW offshore. It is the first time since 2002 that there has there been such a high installation of onshore turbines. The average capacity of turbines installed in 2009 was 2.2 MW. The largest onshore turbine installed in Denmark by the end of 2009 was the Siemens 3.6-MW turbine and the largest offshore wind farm is Horns Rev II with 91 turbines and installed capacity of 209 MW.

In September 2008, the Danish Energy Authority published the report: Havmøllehandlingsplan 2008 (Offshore wind action plan) (5), a follow-up to the April 2007 report: Future Offshore Wind Turbine Locations – 2025, reported in *IEA Wind 2008 Annual Report*. 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 2. Three offshore wind farms where connected to the grid in 2009: Horns Rev II, Avedøre Holme, and Sprogø. Roedsand II (207 MW) is under construction and will be finished before the end of 2010. Anholt (440 MW) is planned to be grid connected by 2012.

3.4 Wind energy costs

A report on wind energy costs in Denmark as of end of 2009 has been published under the EUDP 33033-0196 project (7). The data are based on statistics gathered from more than 250 operating turbines in Denmark with a capacity of 600 kW and up. All wind energy cost data presented herein is from this report. The database with price information is fairly large up to the year 2000 with around 1,000 wind energy projects. After the year 2000 some information is based on assessments. It is known that prices reached the bottom around 2002-03 with less than 7 million DKK/MW (0.94 million €) (6 million DKK/MW (0.8 million €) converted to 2009 prices) and have been increasing since.

3.4.1 Installed costs

Turbine cost has increased by 30% compared to 2003, including corrections for inflation. The energy production per installed MW has also increased, due to

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 (2009/10)	3 wind turbines, 10-13 MW
11. Sprogø (2009)	7 wind turbines, 21 MW

Planned Offshore Wind farms

12. Rødsand II (2010)	90 wind turbines, 207 MW
13. Anholt (2012)	400 MW

Figure 2 Existing offshore wind parks in Denmark

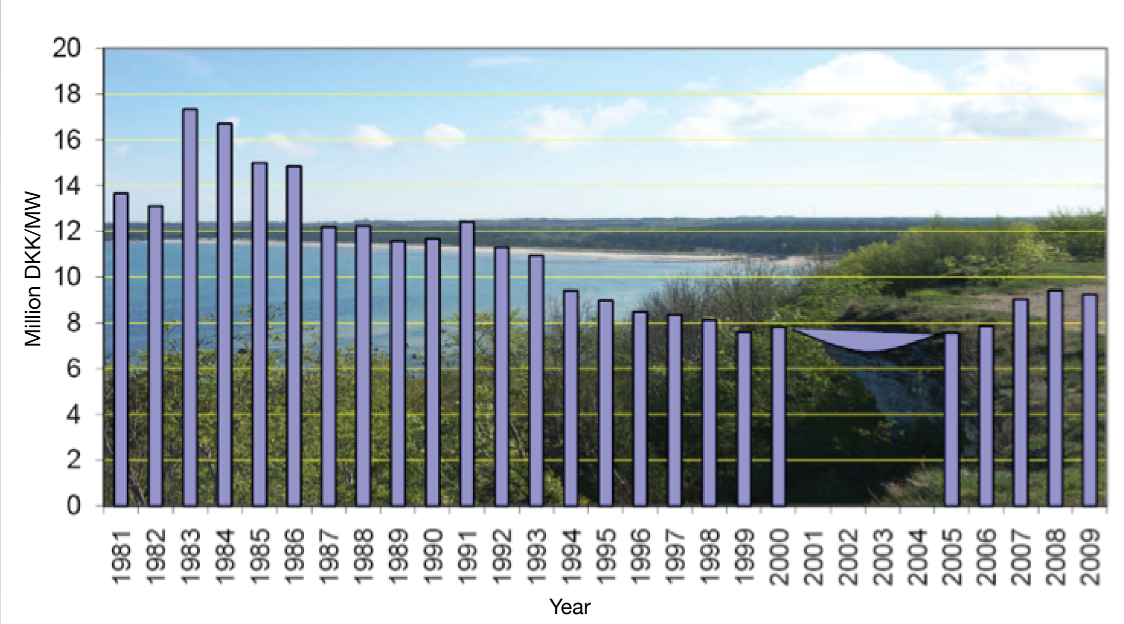

Figure 3 Wind turbine project costs in Denmark 1981-2009 (7).

increased hub heights and rotor diameters. Figure 3 shows the installed project cost of wind energy per MW, price referenced to 2009, from 1981 till 2009, for an on-shore project.

Costs for installing an onshore wind energy project are around 10 million DKK/MW (1.3 million €/ 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, i.e. 20 million DKK/ MW (2.68 million €/MW).

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 (0.02 €/kWh). O&M for an off-shore turbine it is up to 50% higher, but very dependent on the project.

The components of total O&M costs are as follows: repairs (21%); insurance (21%); service agreements (29%); administration (16%); land rent (12%); and other (1%). Many turbines have had gearbox problems after seven to ten years of operation, causing significant additional costs over and above the normal operating costs. A wind turbine gearbox is replaced on average four times in a turbine's lifetime and costs about 20% of the price of a wind turbine.

3.4.3 Cost of energy

The cost of wind electricity on shore, excluding risk factors and profit, was calculated to be 0.03 to 0.05 €/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 a large investor, like utilities. Private investors require 0.04-0.08 €/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 €/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

The yearly report 'Energy 2009' (8) publishes a summary of the research, demonstration, and new energy technology projects that receive funding. Figure 4. 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).

The programs are described in detail in the IEA Wind 2008 Annual Report.

Grants to wind energy projects supported in 2009 totaled 136 million DKK (18.2 million €). The most important projects are listed in Table 2. The funding was increased to about 850 million DKK (113.9 million €) in 2008, but decreased to 700 million DKK (93.8 million €) in 2009. 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.

4.1 Off-shore test facilities

Two demonstration wind farms are planned, one at Nissum Bredning, just off Rønland (Figure 2), with a space for up to 10 turbines, and one in the area near Frederikshavn with a view to build six demonstration turbines.

Nissum Bredning. In October 2009, the DEA (Danish Energy Agency) has reserved an area at Nissum Bredning, just off Rønland, for the research and development of wind turbines and it is expected that up to 10 turbines can be erected in the area. DEA has considered the applications received in relation to the number and size of turbines, planned experiments including replacement of the turbines, the testing of specific foundation types, demonstration value, local commitment, etc. In February 2010, the DEA decided to give Nissum Bredning Vindmøllelaug I/S and Nordvestjysk Elforsyning licence to do preliminary studies in the designated area. Feasibility studies handed in no later than 1 March 2011 will need to have an Environmental Impact Assessment (EIA), which the DEA will need to publish for public consultations.

Frederikshavn demonstration wind farm. DEA authorized NearshoreLAB in 2007 to carry out initial studies on the suitability of an area of sea 4 km east of the port of Frederikshavn in order to set up a demonstration wind farm. The DEA received in 2008 an application from Dong Energy, including an Environmental Impact Assessment (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 2011 and the installation of wind turbines in 2012-2015.

4.2 On-shore test facilities

National Test Centers: The need for a National Test Center for testing prototype wind turbines has long been identified. To supplement Høvsore, the Danish government, in September 2009, designated the area of Østerild Klitplantage, in the north-west of Jutland, as the location for testing wind turbines up to 250 m total height. It is hoped that the test center will be established in February 2010 and that the first wind turbines can be installed in the beginning of 2012. Furthermore an R&D Centre for Wind Turbine Components is in the construction phase. Initially, a test bed for a 200-300 kW drive train is being established, and work on the construction of the large-scale test bed is being initiated. This has been funded under last year's EUDP budget and is located at Risø-DTU.

4.3 Funded projects 2009

The following list presents the funded wind energy projects in Denmark for 2009.

4.4 Collaborative research

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

Denmark participates in the following IEA wind energy tasks:

- Task 29: MexNet: Analysis of WindTunnel Measurements; Participant: Risoe DTU, DTU-Mech
- Task 28: Social Acceptance of Wind Energy Projects; Participant: Danish Energy Agency
- Task 26: Cost of Wind Energy; Participants: DEA, Risø-DTU, EA Energy Analysis.
- Task 25: Power Systems with Large Amounts of Wind Power. Participants: Risø-DTU and energinet.dk (through 2011)
- Task 23: Offshore Wind Technology and Deployment; Operating agent: Risø-DTU, and NREL (USA). Denmark participation: Vestas, Siemens, Elsam, Carl Bro, DNV
- Task 11: Base Technology Information Exchange; Organized workshops, participants vary.

Risø DTU plays a leading role in the large European Union project called UpWind. With Risø DTU as the coordinator, 38 partners participate in the project, which started early in 2006. Funded under 7th FWP (Seventh Framework Programme), Denmark participates in:

- Marine renewable integrated application platform (MARINA PLATFORM) Coordinator: ACCIONA ENERGIA S.A. Danish participation: DTU.

Table 2 Wind Energy Projects Funded by Danish R&D Programs 2009

Project Title; Project Manager	Support; Total budget (DKK); Start/Completion date	Project description
Center for Numerical Wind turbine aerodynamics and atmospheric turbulence; DTU Mekanik	ENMI:32,035,000 Total: 53,036,000 2010/01–2015/12	Explore the interplay among wind turbines, rotor aerodynamics, their wake, the surrounding terrain, and atmospheric turbulence.
Nacelle based lidar for performance verification; Department of Wind Energy/Risø DTU	EUDP: 2,852,000 Total: 6,140,000 2010/01–2011/12	Develop and commercialize nacelle-based LIDAR technology for wind turbine power curve verification, replacing expensive and cumbersome meteorological masts, offshore and in complex terrain.
Detection of sub-surface damage in wind turbine gearboxes; Vestas Wind Systems A/S	EUDP: 1,904,000 Total: 3,982,000 2010/02–2012/01	Develop a technique to detect otherwise non-detectable sub-surface damage in wind turbine gearbox bearings, thereby increasing reliability and gearbox lifetimes.
DANAERO MW II; Risø DTU	EUDP: 3,918,000 Total: 6,134,000 2010/01–2011/12	Determine the influence of atmospheric and wake turbulence on the performance, loads, and stability of large turbines.
Optimisation of vortex generators for wind turbine blades; DTU Mekanik	EUDP: 3,825,000 Total: 5,686,000 2010/04–2013/04	Optimise vortex generators on wind turbine blades to suppress the separation at the inner section of the wing, and also increase the lift to drag ratio to increase blade efficiency further out towards the tip.
Processes and software for manufacturing and characterization of industrial multi-functioning surfaces; Image Metrology A/S.	HTF: 7,600,000 Total: 14,000,000 2010/01–2013/12	Design surfaces to increase the lifetime of mechanical parts, for example, wind turbine gearboxes.

Table continued on page 72

Integration of wind lidars into wind turbines; Risø DTU	HTF: 12,500,000 Total: 25,000,000 2010/01–2012/12	Use lidars to 'see' the wind before it hits the blades, so turbines can optimize their position and adjust the wing position for efficient operation and longer wind turbine lifetime.
Development of measurement methods for low-noise profile design and validation; Department of Wind Energy/Risø DTU	EUDP: 4,300,000 Total: 6,333,000 2010/01–2011/12	Develop a measurement method to evaluate the noise from the wing profiles in an industrial wind tunnel. Validate engineering noise models to design low-noise wind turbine blades.
International network for the analysis of electricity grid systems with a high wind turbine capacity. IEA Annex 25 – Phase 2; Risø DTU	EUDP: 252,000 Total: 252,000 2009/01–2011/12	Establish a forum for the exchange of knowledge and experiences regarding electricity systems with a high integration of wind energy.
Proactive participation of wind turbines in the electricity market; Energy Systems Department, EMD International A/S.	PSO: 762,000 Total: 1,338,000 2009/06–2010/12	Introduce wind turbines to the Elbas market and the power regulation market wherein the cost of balancing is expected to be reduced.
Radar(at)Sea; DTU Informatik	PSO: 5,427,000 Total: 8,252,000 2009/01–2012/12	Develop for more accurate wind prognosis within a 5 minute to a few hours range using LAWR (Local Area Weather Radar) to detect incoming fronts and their movement up to 60km away.
Calculation of extreme wind atlases using mesoscale modeling; Risø DTU	PSO: 2,960,000 Total: 4,397,000 2009/01–2012/03	Use mesoscale models to determine the extreme wind and import the data into the WAsP software for wind turbine manufacturers and for the placement of the wind turbines.
DEWEPS; WEPROG ApS	PSO: 1,300,000 Total: 3,506,000 2009/01–2011/06	Apply a fundamentally different formulation of the physics in the atmospheric boundary layer, i.e. Bergmann's balance of preserved sizes in their steady-state formulation.
Autonomous aerial sensors for wind power meteorology; Risø DTU	PSO: 2,500,000 Total: 4,278,000 2009/01–2011/03	Meteorological mini-sensors placed in, for example, small model airplanes is a fast developing area. This project will give an overview of existing mini-sensors and test their applicability through testing at Risø's test station at Høvsøre.
Improvement of wind farm performance with spinder anemomentry; Risø DTU	EUDP: 2,321,000 Total: 4,645,000 2009/09–2011/09	Wind turbines might not yaw effectively into the wind due to problems with the nacelle anemometry, resulting in estimated losses of 1-3% in flat terrain and offshore and up to 5% in complex terrain. Risø DTU has developed an innovative concept, spinder anemometry, which can determine yaw errors with accuracy.
Aeroelastic optimization of MW wind turbines; Risø DTU	EUDP: 6,113,000 Total: 6,113,000 2009/09–2011/08	Develop, demonstrate, and implement work tools, models, and components in the design process for aero-elastic optimization of MW turbines.
Demonstration of new blade designs using industrial process modeling; Risø DTU	EUDP: 5,482,000 Total: 11,453,000 2009/06–2011/06	Understand how imperfections in the structure of the blade are formed and evolve, and design and fabricate a new wing using new structural solutions and using simulation tools. The project ends with a full-scale test that demonstrates the strength of the wing.
Offshore Wind Dynamics; Risø DTU	1,366,000; 2,350,530; 3rd quarter 2010	Apply a fundamentally different formulation of the physics in the atmospheric boundary layer, i.e. Bergmann's balance of preserved sizes in their steady-state formulation.
Shadow Effects of Large Wind Farms; Risø DTU	2,446,000; 4,892,000; 4th quarter 2009	Develop a meteorological software tool for large wind farm planning. The project is based on data from previous projects on large wind farm shadow effects. The existing tools have proven too optimistic.
Main Electrical Wind Turbine Components; DTU Electrical Engineering	4,000,000; 6,943,000; 2nd quarter 2011	Prepare common guidelines under calls, during planning, design, and in connection with a risk analysis of wind turbine systems.
Aero-Hydro-Elastic Simulation Platform for Floating Systems; Risø DTU	2,679,000; 3,137,000; 4th quarter 2009	Study floating platforms for wind turbines, wave power systems, and the relationship between wind and wave power. The project basis is the existing wave-wind power plant 'Poseidon's Organ.'

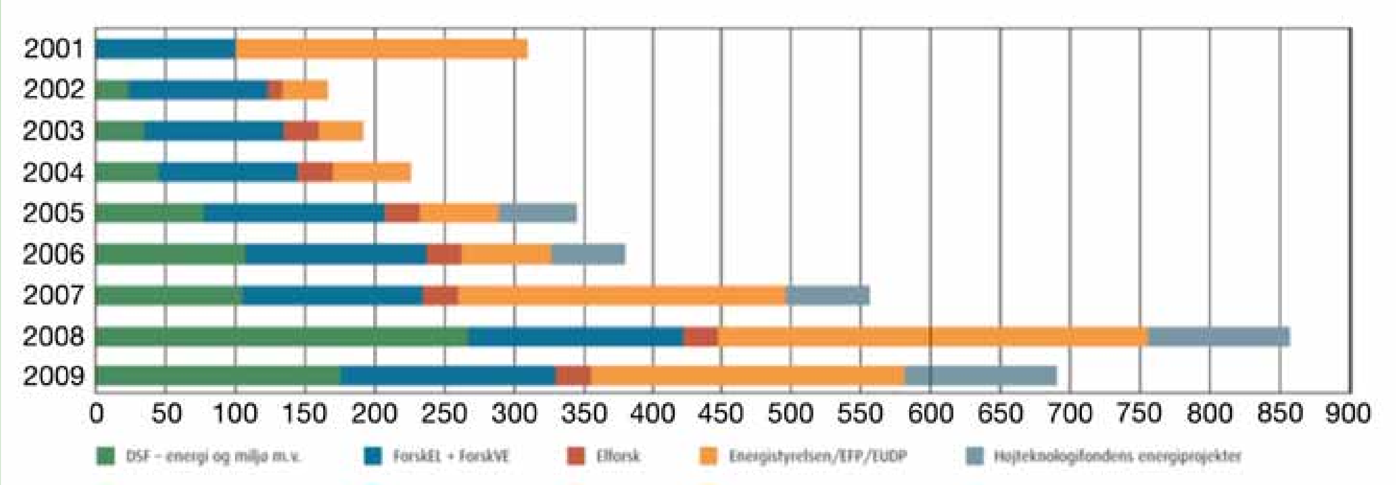

Figure 4 Funding for energy research and technological development, million DKK (8)

- Multi-scale data assimilation, advanced wind modeling and forecasting with emphasis to extreme weather situations for a secure large-scale wind power integration. (SAFEWIND) Coordinator: Association Pour La Recherche Et Le Developpement Des Methodes Et Processus Industriels – ARMINES Danish participation: Energinet and DTU.
- Northern seas wind index database (NORSEWIND) Coordinator: Oldbaum Services Limited Danish participation: DTU and Dong energy.
- Reliability research to optimize wind energy systems design, operation and maintenance: tools, proof of concepts, guidelines & methodologies for a new generation (RELIAWIND) Coordinator: Gamesa Innovation and Technology S.L. Danish participation: Lm Glasfiber A/S.

The Top-level Research Initiative was initiated in 2008, and is a common energy research program involving Nordisk Energy Research, Nordic Innovation Centre, and NordForsk. Its goal is to increase international cooperation both within the EU and beyond. It has six working areas, one of which is the sub-program Integration of Large-scale Wind Power. A call within this sub-program was launched in October 2009 with approximately 30 million NOK (3.6 million €) is allocated to the call. Relevant topics are grid integration, power and energy aspects, energy market aspects, operation and maintenance, arctic and offshore wind energy and new initiatives and methods.

5.0 The Next Term

In 2010, the new 207-MW offshore wind farm at Roedsand owned by E.ON will be finished and connected to the grid. The wind farm consists of 90 2.3-MW Siemens wind turbines. The next offshore project planned is the Anholt farm at 400 MW in Kattegat. The tendering period ends 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 € for the grid connections to land. On land, the higher installation rates compared to previous years are expected to continue.

References:

(1) The Danish Energy Agency Web site (www.ens.dk).

(2) http://www.vindstat.dk/

(3) https://www.retsinformation.dk/

(4) 'Branchestatistik2009', Published by Vindmølleindustrien, Publication date: May 2009, Language: Danish

(5) 'Havmøllehandlingsplan 2008' , Published by Danish Energy Agency (DEA) , Publication date: 19.11.2008, Language: Danish, ISBN: 8778447631

(6) 'Frederikshavn Demonstrationsvinmøller' August 2008, Dong Energy.

(7) Nielsen, P. et.al., 'Vindmøllers Økonomi', UEDP projekt 33033-0196, Publication date: February 2010

(8) 'Energi 2009: Forskning, Udvikling, Demonstration', Language: Danish, electronic version can be downloaded from: http://www.energinet.dk/da/menu/Forskning/ForskEL-programmet/Energiforskningsrapporter/Energi+2009.htm.

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1.0 Introduction

Europe has historically been and continues to be one of the world's strongest markets for wind energy development. In 2009, the European Union (EU) saw another record year with installations of almost 10.163 GW, thereby reaffirming its status as a leading wind energy market (1). Industry statistics released by the European Wind Energy Association (EWEA) show that in 2009, cumulative wind capacity increased by 16% to reach a level of 74.767 GW; this was up from 64.719 GW at the end of 2008 (Figure 1). This 10.163 GW of new wind power capacity represents a wind turbine manufacturing turnover of some 13 billion €, of which 1.5 billion € is from offshore wind investments.

1.1 Overall capacity increases

Over the last ten years, cumulative wind energy installations in the EU have increased by an average of 23%/yr. The overall market growth in 2009 was 16%. Looking beyond Europe, the global market for wind turbines grew by 31% last year to a total of 158 GW.

In the EU, wind power continues to be one of the most popular electricity generating technologies for expanding capacity. Since 2000, almost 212 GW of new electricity generating capacity has been installed in the EU. During that time, the installed wind capacity has increased almost eight times from 9.7 to 74.8 GW. Over these last eight years, according to figures from Platts PowerVision and EWEA, new gas installations totalled 103 GW, while wind energy installations totalled more than 65.6 GW. This represents 31% of the total new generation installations over the period between 2000 and 2009 (Figure 2).

In 2009 alone, wind power installations accounted for 39% of new power installations in Europe and grew more than any other power-generating technology. Wind energy now represents 9% of the total EU installed power capacity (Figure 3). Total wind power capacity installed by the end of 2009 will produce 163 TWh, or 4.8 % of EU power demand in an average wind year, and will avoid about 106 million tons of CO_2 annually. In 2000, less than 0.9% of EU electricity demand was met by wind power. In 2008, 20% of Denmark's electricity came from wind, 12% in Spain, and 7% in Germany.

The 2009 capacity increase was driven by Italy, Germany, and Spain, together representing 54% of the total. Italy added 1,114 MW to reach 4,850 MW; France installed 1,088 MW for a total of 4,492 MW; and the UK added 1,077 MW to get to 4,051 MW. The new Member States of the EU performed well and increased their installed wind capacity by 41%, with Poland, the most successful, reaching a total of 725 MW.

The slow pace of development in some European countries can be explained by a mixture of slow administrative processes, problems with grid access, and legislative uncertainty. The figures demonstrate the existence of continuous barriers to wind energy development. One critical element for a massive and sustained expansion of wind energy in all countries of the EU is the swift and rapid implementation of the European directive for the promotion of renewable energy sources. The objective is to have 20% of renewable energy in the European energy mix in 2020, which could represent 35% of European electricity coming from renewable sources.

1.2 Offshore wind

Offshore wind, seen as a key market for European expansion, is now taking off. By 2009, the industry had developed 39 projects in nine countries, many of them large scale and fully commercial, with a total capacity of around 2,063 MW (Figure 4). At the end of 2009, offshore wind farm installations represented nearly 2.8% of the total installed wind power capacity.

The short-term prospects for offshore wind are promising, with several projects planned to be connected to the grid in 2010. Around 1,000 MW are expected to be installed during 2010, with more than 10 projects being completed. The installations expected in 2010 should amount to more than a 75% market growth compared to 2009 installations.

Prospects for the next decade look bright. Currently 16 offshore wind parks are under construction in Europe. Another 53 installations have been fully consented, totalling more than 16,000 MW (Figure 5). At the end of 2009, EWEA performed a survey amongst its members and identified a total project pipeline of 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 European Union 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.

In terms of electricity consumption, renewable sources should provide about 35% of the EU's electricity by 2020, and wind energy is set to contribute the most - nearly 35% of all the power coming from renewable sources. The directive legally obliges each EU member state to

	Installed 2008	End 2008	Installed 2009	End 2009
EU Capacity (MW)				
Austria	14	995	0	995
Belgium	135	415	149	563
Bulgaria	63	120	57	177
Cyprus	0	0	0	0
Czech Republic	34	150	44	192
Denmark	60	3,163	334	3,465
Estonia	19	78	64	142
Finland	33	143	4	146
France	950	3,404	1,088	4,492
Germany	1665	23,903	1,917	25,777
Greece	114	985	102	1,087
Hungary	62	127	74	201
Ireland	232	1,027	233	1,260
Italy	1010	3,736	1,114	4,850
Latvia	0	27	2	28
Lithuania	3	54	37	91
Luxembourg	0	35	0	35
Malta	0	0	0	0
Netherlands	500	2,225	39	2,229
Poland	268	544	181	725
Portugal	712	2,862	673	3,535
Romania	3	11	3	14
Slovakia	0	3	0	3
Slovenia	0	0	0	0
Spain	1558	16,689	2,459	19,149
Sweden	262	1,048	512	1,560
United Kingdom	569	2,974	1,077	4,051
Total EU-27	**8,268**	**64,719**	**10,163**	**74,767**
Total EU-15	**7,815**	**63,604**	**9,702**	**73,194**
Total EU-12	**453**	**1,115**	**461**	**1,574**
Of which offshore and near shore	374	1,479	582	2,061

European Union: 74,767 MW
Candidate Countries: 829 MW
EFTA: 449 MW
Total Europe: 76,152 MW

	Installed 2008	End 2008	Installed 2009	End 2009
Candidate Countries (MW)				
Croatia	1	18	10	28
FYROM*	0	0	0	0
Turkey	311	458	343	801
Total	**312**	**476**	**353**	**829**
EFTA (MW)				
Iceland	0	0	0	0
Liechtenstein	0	0	0	0
Norway	103	429	2	431
Switzerland	2	14	4	18
Total	**105**	**443**	**6**	**449**
Other (MW)				
Faroe Islands	0	4	0	4
Ukraine	1	90	4	94
Russia	0	9	0	9
Total	**1**	**103**	**4**	**107**
Total Europe	**8,686**	**65,741**	**10,526**	**76,152**

*FYROM – Former Yugoslav Republic of Macedonia
Note: Due to previous year adjustments, 114.77 MW of project de-commissioning, re-powering and rounding of figures, the total 2009 end-of-year cumulative capacity is not exactly equivalent to the sum of the 2008 end-of-year total plus the 2009 additions.

Figure 1 Wind power installed in Europe by end of 2009. Source: European Wind Energy Association (EWEA)

ensure that its 2020 target is met and to outline the 'appropriate measures' it will take do so in a National Renewable Energy Action Plan (NREAP) to be submitted by 30 June 2010 to the EC.

The NREAPs will set out how each EU country is to meet its overall national target, including sector targets for shares of renewable energy for transport, electricity, and heating/cooling. The NREAPs will also describe how member states will tackle administrative and grid barriers. If they fall significantly short of their interim trajectory over any two-year period, member states will have to submit an amended NREAP stating how they will make up for the shortfall.

Every two years member states will submit 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 directive in order to help countries achieve their targets in a cost-effective way without undermining market stability. For example,

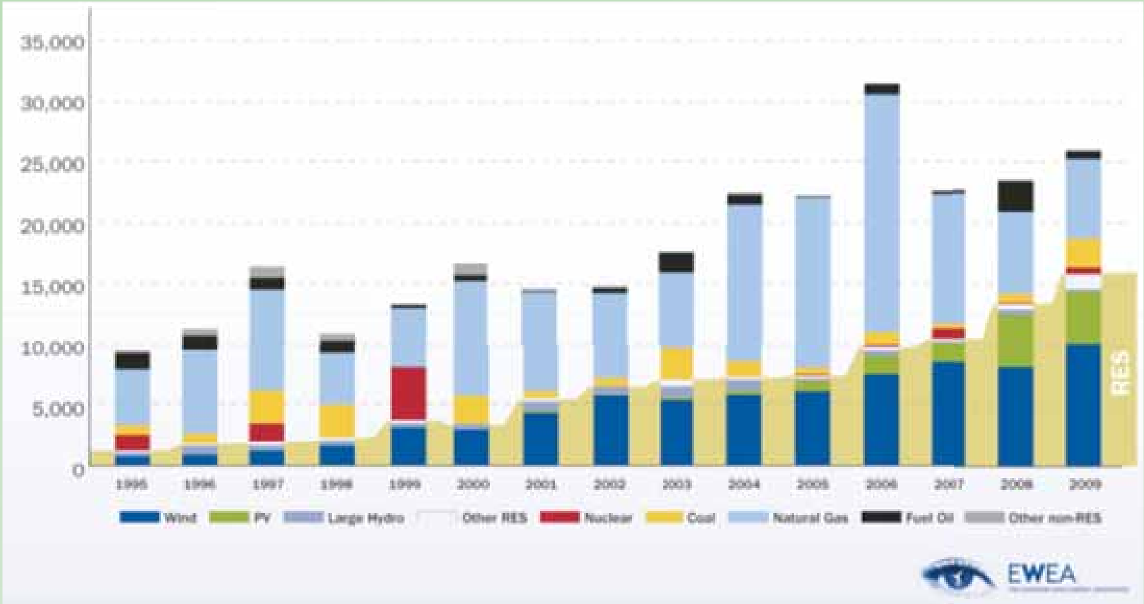


Figure 2 New electricity generating capacity in the EU from 1995 to 2009. Source: EWEA

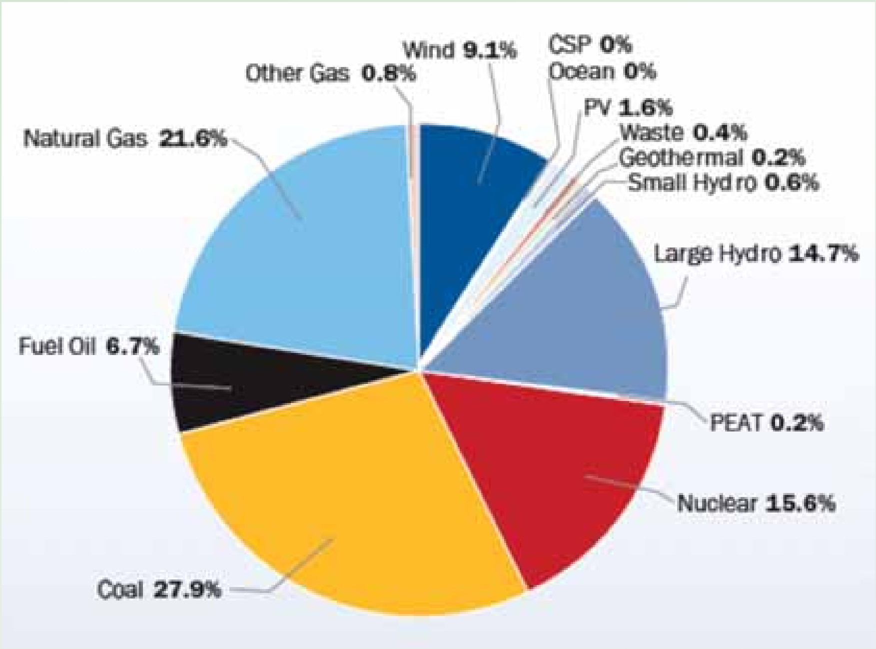


Figure 3 EU power capacity mix in 2009. Source: EWEA

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.

Under certain conditions, member states will be able to help meet their national electricity sector target with imports from non-EU countries. The electricity will have to be produced by a newly constructed installation that became operational after the directive enters into force, or by the increased capacity of an installation that was refurbished after the directive enters into force, and the electricity must be consumed within the EU community.

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 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 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

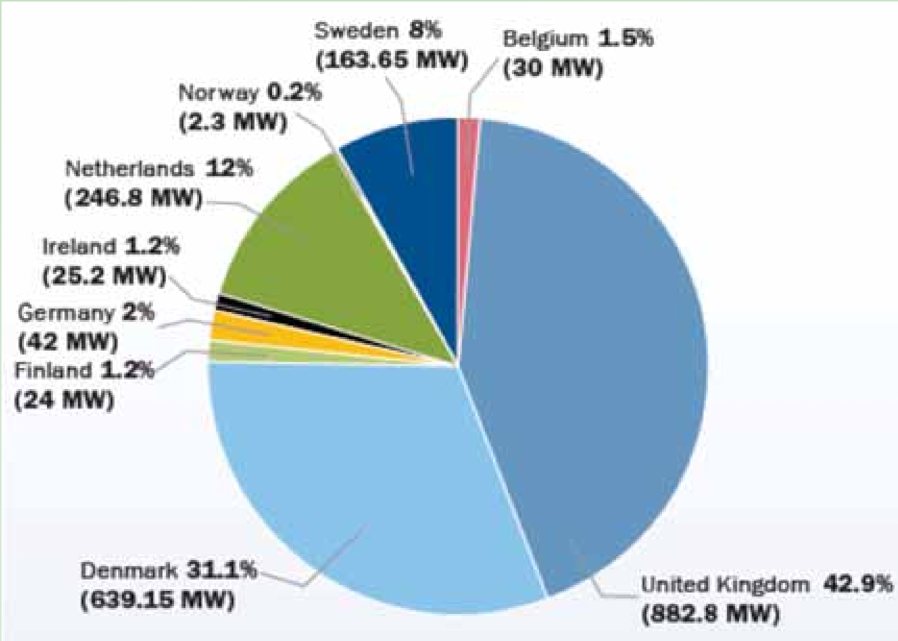
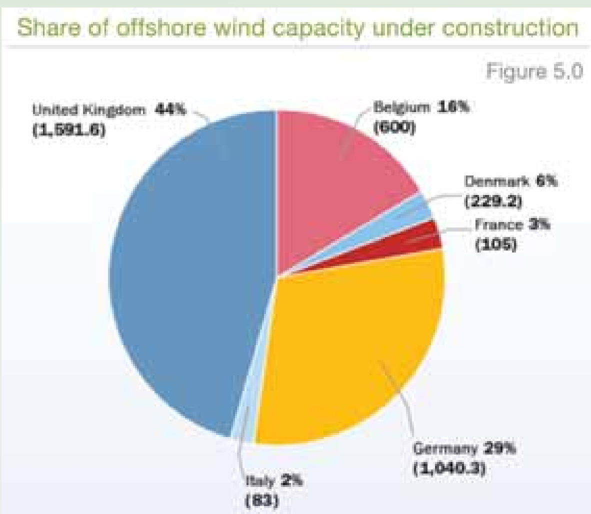


Figure 4 Offshore wind power installed by the end of 2009 by Member States of the EU. Source: EWEA



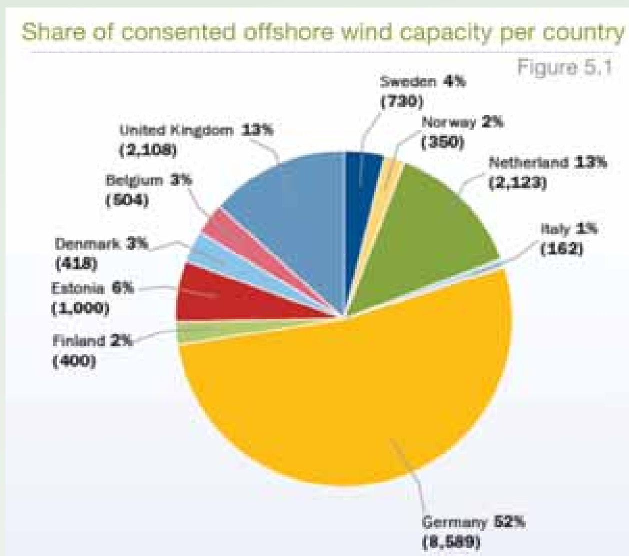


Figure 5 Consented and under construction offshore wind capacity, representing respectively 17.6 GW and 3.5 GW. Source: EWEA

Energy Directive of 2009 when it expires at the end of 2020.

3.0 R, D&D Wind Energy Projects

In 2009, 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 2009, two FP6 projects POW'WOW and UPWIND, as well as three FP7 projects, RELIAWIND, PROTEST, and SAFEWIND, continued their activities.

POW'WOW, which stands for Prediction Of Waves, Wakes and Offshore Wind was a 42-month coordination action that started in October 2005 with the aim to coordinate activities in the fields of short-term forecasting of wind power, offshore wind and wave resource prediction, and estimation of offshore wakes in large wind farms. The purpose of the POW'WOW project is to spread the knowledge gained in these fields among the partners and colleagues, and to start work on some roadmaps for the future. Several workshops were held and the project finished at the end of March 2009, but the website is still active at powwow.risoe.dk.

UPWIND, which stands for Integrated Wind Turbine Design (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 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.

The 2009 call for proposals brought two cross-cutting topics about platforms for deep water offshore multipurpose renewable energy (wind/wave/ocean). Several proposals were received by 25 November 2009 and are being evaluated.

3.2 DG TREN activities

The two projects discussed below represent demonstration actions funded within the Seventh Framework Programme (FP7- 2008 Call) of the EU and managed by the DG ENER.

WINGY-PRO: The aim of this project is to demonstrate the first ever large size transversal flux generator in an existing wind turbine. A determining factor for increasing the profitability of an offshore wind farm is the installation of wind turbines with a significantly high power capacity and low weight. Until now, the designs of large capacity turbines for offshore applications have been up scaling of the existing smaller models. This has led to the construction of wind turbines with huge physical dimensions. Consequently, the weight of the turbines have increased considerably, and the material-resistance of the blades have been taken almost to its limits (rotor blades can reach a length of up to 61 m). These large dimension and weight have a negative influence on the economic efficiency of those offshore applications, because of the high costs for the foundation, transportation, and installation of the wind turbines.

The objective of the project is to carry out the design and development of an improved generator technique through the transverse flux generator (TFG) with permanent magnets in the rotor. There are single-, two- or multi-phase machines, depending on the number of independent stator windings, which are mounted axially on the machine shaft. This technique has been known in the electro-field for years, but due to its strong vibrations and high noise emissions, it has been hardly used. Nowadays however, thanks to new and innovative manufacturing methods and to the development in modern micro-processing controls, the TFG can be used in practical applications.

NIMO: The energy output from wind turbines has increased dramatically over the past thirty years from 50 kW to 6 MW, while 10-12 MW turbines are in the design stage. The greater energy yield achieved means that the number of turbines needed to produce a given amount of energy has been reduced significantly. Over the same period, the tower height and rotor diameter of turbines have doubled, leading to much more complex construction, maintenance and inspection procedures, particularly when off-shore turbines are concerned. Under normal operation schedules wind turbines have an average annual maintenance expenditure of ~2% of the original turbine investment. However, unpredictable failure of certain wind turbine components (blades, tower, gearbox, generator, brakes, yaw system, etc.) can lead to substantially higher maintenance costs and reduced availability of turbines. To increase the competitiveness of wind energy in comparison to other power generation technologies, significant and measurable improvements in the availability, reliability, and lifetime of wind turbines need to be achieved in the foreseeable future. NIMO seeks to practically eliminate catastrophic failures and minimize the need for corrective maintenance by developing and successfully implementing an integrated condition monitoring system for the continuous evaluation of wind turbines. NIMO should advance existing state-of-the-art condition monitoring technology used in wind turbines by delivering an advanced system which will be able to reliably evaluate the condition of critical structural components, rotating parts and braking mechanisms.

3.3 Future R&D projects

New FP7 projects to start in 2010 will address deep-offshore multipurpose renewable energy platforms (MARINA Platform and ORECCA), the demonstration of innovative multi-MW machines, and wind mapping for offshore applications.

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, the European Industrial Initiatives will be 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.

The *European Wind Industrial Initiative*, which should be launched in 2010, has the objective to make wind one of the cheapest sources of electricity and to enable a smooth and effective integration of massive amounts of wind electricity into the grid. To achieve this, special efforts will be dedicated to greatly increase the power generation capacity of the largest wind turbines (from 5-6 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 Industrial Initiative will integrate the following elements:

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

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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 objective is to identify and prioritize areas for increased innovation, new and existing research, and development tasks.

Historically, the principal 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, as defined by the Steering Committee in 2007. TPWind is composed of four technical working groups responsible for building a Strategic Research Agenda, two working groups responsible for building a Market Deployment Strategy, the Finance Group responsible for exploring and proposing funding mechanisms, and the Mirror Group gathering representatives from national governments. The platform is lead by a Steering Committee of 25 members, representing a balance between industry and research, and between European countries. Altogether, this represents a group of 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

In 2008, TPWind published the Strategic Research Agenda for the wind energy sector. This document proposes an integrated vision towards 2020 and beyond, in terms of R&D, market and policy developments. TPWind has also been involved in the Strategic Energy Technology Plan (see Section 3.4), and proposed the European Wind Initiative in June 2009 to the European Commission and the member states. This large-scale R, D&D plan has a budget of 6 billion € over the 2010-2020 period. This plan was approved by the public authorities, and published in November 2009 by the European Commission in the Communication on Investing in the Development of Low-Carbon Technologies (4). Since December 2009, TPWind has been preparing the launch of the European Wind Initiative and it will be released in June 2010 in partnership with the European Commission and committed member states.

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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 standardisation, 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.

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Finland

Photo: Lentokuva Vallas

1.0 Overview

In Finland, 31% of electricity generation was by renewables in 2009. Finland's generating capacity is diverse. In 2009, 28% of gross demand was produced by nuclear, 15% by hydropower, 30% from combined heat and power (coal, gas, biomass, and peat) and 11% 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 10% in Finland. About 15% of electricity was imported, mainly from Russia, so the renewable share of gross electricity demand in Finland was 25%. Demand is dominated by energy-intensive industry and decreased 7% to about 81 TWh due to economic recession.

The national energy strategy foresees biomass as providing most of the increase in renewables. The hydropower resource has potential for only about 1 TWh/yr more. This makes wind power the second largest source of new renewables in Finland, with 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 (2,000 to 3,000 MW) and an anticipated feed-in tariff system has led to a rush for the best sites. At the beginning of 2010, there were 1,400 to 2,200 MW of wind power projects in various phases of planning onshore, and 4,000 to 5,800 MW of announced projects offshore. At the end of 2009, only 147 MW were installed, producing about 0.3 TWh, or 0.3% of gross demand in Finland.

A feed-in premium with a guaranteed price of 83.5 €/MWh could begin late in 2010, with an increased tariff of 105.3 €/MWh until the end of 2015 (max 3 years). The difference between the guaranteed price and spot price of electricity will be paid to the producers as a premium. In 2009, investment subsidies were given to roughly 60 MW.

Wind power technology exports from Finland amount to about 1 billion €. Wind turbine 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 (2,000 to 3,000 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

In 2009, two new turbines (1 MW and 3 MW WinWinD) as well as one second-hand turbine (600 kW) were installed.

Table 1 Key Statistics 2009: Finland	
Total installed wind generation	147 MW
New wind generation installed	4 MW
Total electrical output from wind	0.28 TWh
Wind generation as % of national electric demand	0.3%
Target:	6 TWh/yr (2,000 to 3,000 MW) in 2020

One 18-year-old 200-kW turbine was taken out of operation in 2009. The net increase was 4 MW, bringing the total capacity to 147 MW at the end of 2009 (Figure 1) (4% growth from the previous year). Two 16-year-old 300-kW turbines that were standing since 2007 were taken out of the statistics.

Although the wind resource was lower than average during 2009, the total wind energy production in 2009 increased by 6% compared to 2008. The production of 276 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 carbon dioxide savings per year.

There were 118 wind turbines in operation in Finland at the end of 2009 (Figure 2). The average wind turbine size is 1,240 kW. About 42% of the capacity originates from Finland, 35% from Denmark, 19% from Germany and 4% from the Netherlands. The size of the installed capacity ranges from 75 kW to 3 MW. The three turbines installed in 2009 were 600-kW, 1-MW, and 3-MW turbines.

In 2010, 12 MW (four 3-MW WinWinD) in Hamina and 9.2 MW (four 2.3-MW Siemens) in Raahe are under construction and 28.8 MW (eight 3.6-MW Siemens) in Torino will be built in the summer. One pilot offshore turbine is to be built in 2010 in Pori.

The Åland islands between Finland and Sweden constitute an autonomous region with its own legislation, budget, and energy policy. Wind energy covered 20% of electricity consumption in 2009 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 €/MWh is 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 €/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 new incentive program, a market-based feed-in premium, has been drafted and will be processed by parliament in autumn 2010. A guaranteed price of 83.5 €/MWh has been proposed 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 currently the plan is to recover the cost by electricity taxes. An increased level of 105.3 €/MWh is proposed until the end of 2015 (max 3 years). A three-month average spot price has been proposed as 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. A special subsidy for offshore wind power will still be considered. If the impacts of emission trading continue to raise electricity market prices, this will reduce the payments for this subsidy.

To help reduce uncertainty when estimating the production potential of the

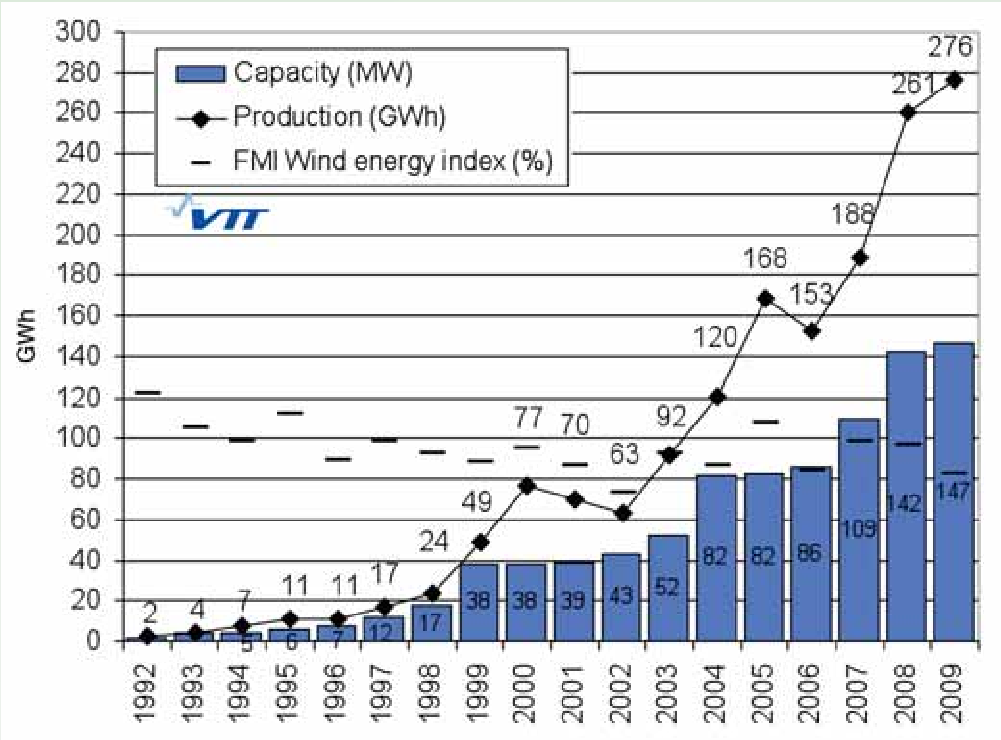


Figure 1 Wind power capacity and production. FMI Wind energy index is calculated from Finnish Meteorological Institute (FMI) wind-speed measurements converted to wind power production, 100% is average production from 1987 to 2001.

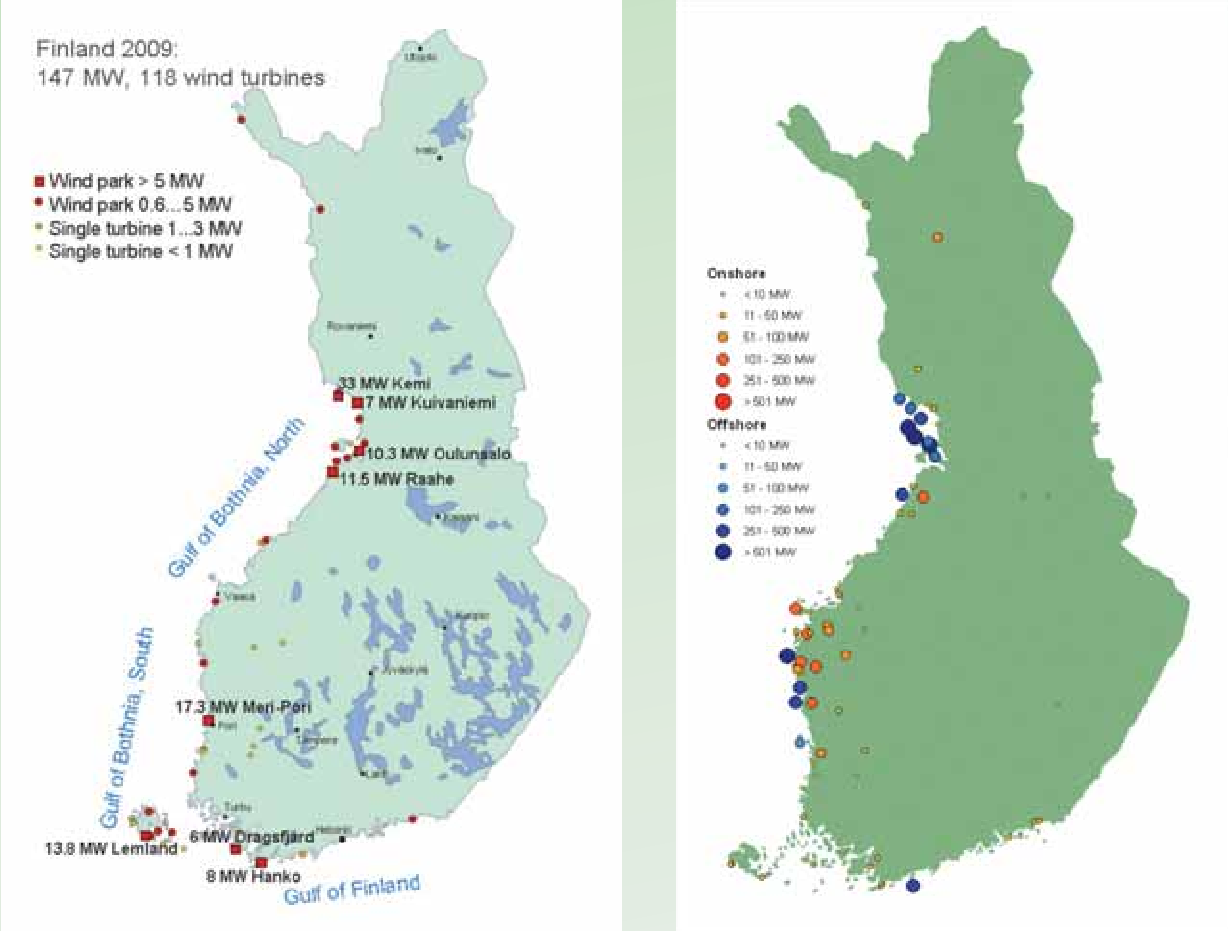


Figure 2 Wind turbines operating in Finland by end of 2009 (left); Wind power projects published at the end of 2009 (right).

taller multi-megawatt machines in the forested coastal areas of Finland, a new wind atlas was made by FMI with government budget 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 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 has 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 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 (2,000 to 3,000 MW) and the anticipated feed-in tariff system has led to a rush for the best sites. At the beginning of 2010, there are a total of 1,400 to 2,200 MW of wind power projects in various phases of planning onshore, and 4,000 to 5,800 MW of announced projects offshore. 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 initiated to mitigate the impacts.

3.0 Implementation

3.1 Economical 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 technology in Finland, employing more than 3,000 people, with an economic turnover of about 1 billion €/yr. They updated their road map for wind power technology in 2009. Maintaining current market share in global wind power markets means increasing economic turnover to a level of 3 billion €/yr in 2020. However, there is the potential to raise technology exports to a level of 12 to 14 billion €/yr in 2020 by increasing the global market share. Employment in the wind power sector in Finland could increase to 14,000 to 36,000 man-years in 2020.

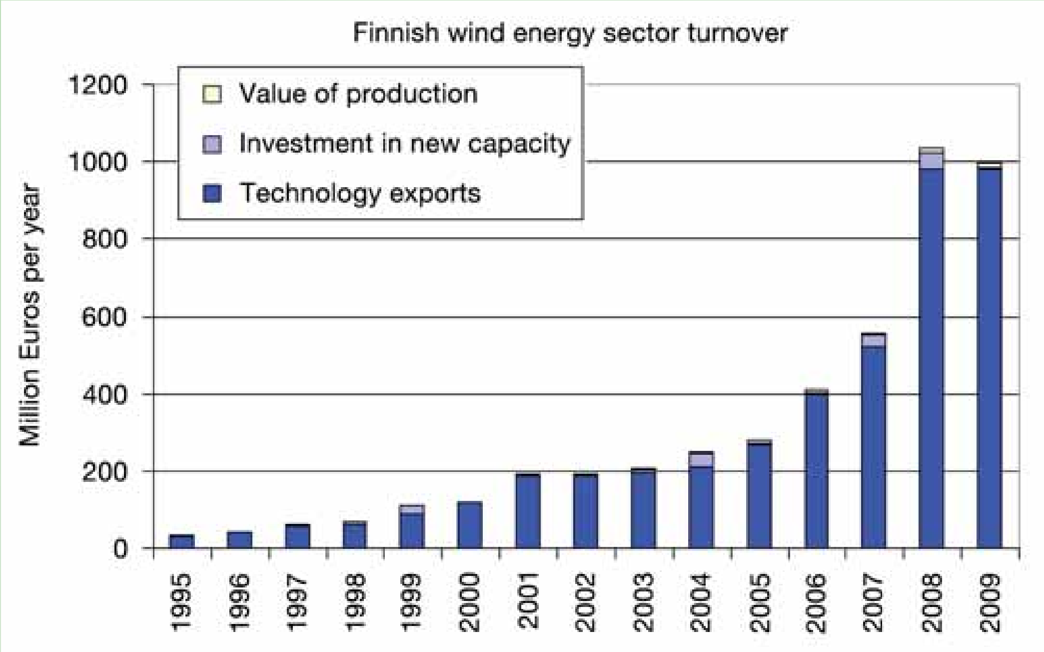


Figure 3 Finnish wind sector turnover: wind power technology exports, investments, and production turnover. Turnover from electricity production sales was estimated from the average spot market price.

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 2009, WinWinD had installed 245 MW in seven different countries including Estonia, France, Portugal, and Sweden. WinWinD has manufactured 42% (61 MW) of the installed wind power capacity in Finland (Figure 4). In 2009, the number of employees grew to 779 (273 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 pilot that is especially designed for offshore applications. The plan is to erect it in 2011.

Several industrial enterprises have developed important businesses as suppliers of major components for wind turbines. For example, Moventas (previously Metso Drives) 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, there have been a lot of new customers for 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- they 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 Båtskär. In 2007 to 2008, ten 3-MW WinWinD turbines were erected in Kemi Ajos. Eight of these turbines (24 MW) are offshore (opening photo). Two more offshore projects are in the permitting process (90-100 MW near Pori and 400 MW at Suurhiekka near Oulu). Environmental impact analyses have been started for several offshore wind farms. An offshore demonstration will need funding to be realized.

3.3 Operational details

The average capacity factor of wind turbines operating in Finland was 20% in 2009 due to the less than average wind index (production index was 75 to 92% in different coastal areas in Finland). In the 2000's, the average capacity factor has been 17 to 24%. As reported in previous IEA Wind Annual 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.

The average availability of wind turbines operating in Finland was 91% in 2009 (93 to 96% in 2001 to 2008). Of the 94 turbines reporting, there were two turbines with less than 70% availability in 2009 due to a computer breakdown and a yaw system failure. They were not operating for most of the year.

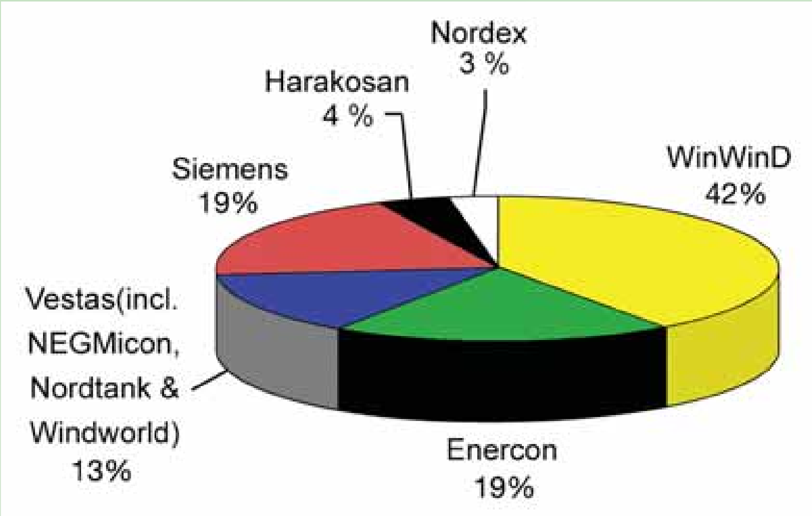


Figure 4 Market shares of turbine manufacturers in Finland as a percentage of total capacity at the end of 2009 (147 MW)

3.4 Wind energy costs

On coastal sites in Finland, the cost of wind energy production is estimated to be about 60 to 80 €/MWh without subsidies (2,100 to 2,400 h/a, 1,300 to 1,400 €/kW investment cost, 20 years, 7% internal rate of return, 26 to 28 €/kW,a O&M cost, and 2 €/MWh balancing cost). The estimated cost of offshore production could exceed 100 €/MWh. The average spot price in the electricity market Nordpool was 37 €/MWh in 2009 (51 €/MWh in 2008). Wind power still needs subsidies to compete even on the best available sites. The planned feed-in guaranteed price of 83.5 €/MWh for 12 years (105.3 €/MWh for the first three years but only until the end of 2015) is expected to start for 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

Tekes, the Finnish Funding Agency for Technology and Innovation, 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 579 million € in R&D projects in 2009. Tekes is the main source of funding for Finnish co-operation with IEA.

Since 1999, Finland has not had a 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. Tekes funding for wind power has significantly increased in the last five years (Figure 5). Tekes invested over 12 million € in wind power R&D projects in 2009. There were 36 ongoing wind power R&D projects in 2009; 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.

In the updated Technology Road Map of Wind Technology Industries in Finland, a clear need to increase R&D funding in wind technology is seen. This is necessary both to stay competitive with growing and competent global markets, and to reach the national goals set for wind power. A new research program for wind is currently under preparation, and stresses a strong industry involvement, with 50% of the R&D work to be carried out in industries (CLEEN WIPO program).

WinWinD developed an ice prevention system for its 3-MW turbines in 2009, in collaboration with VTT. The first turbines were erected in Swedish Lapland, Uljabouda in September, 2009.

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. Labkotec invested in the development of a new ice detector model. The product will have an integrated web server which allows a remote access over the Internet and thus reduces O&M costs. The new ice detector is commercially available during the first half of 2010. Industrial collaboration in the development of reliable and cost-efficient solutions for drive trains for future wind turbines continued. Several technical universities also carry out R&D projects related especially to electrical components and networks (Lappeenranta, Tampere, Vaasa, and Aalto).

4.2 Collaborative research

VTT has been active in several international collaborative 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 is coordinating the COST collaboration "Measuring and Forecasting Atmospheric Icing of Structures."

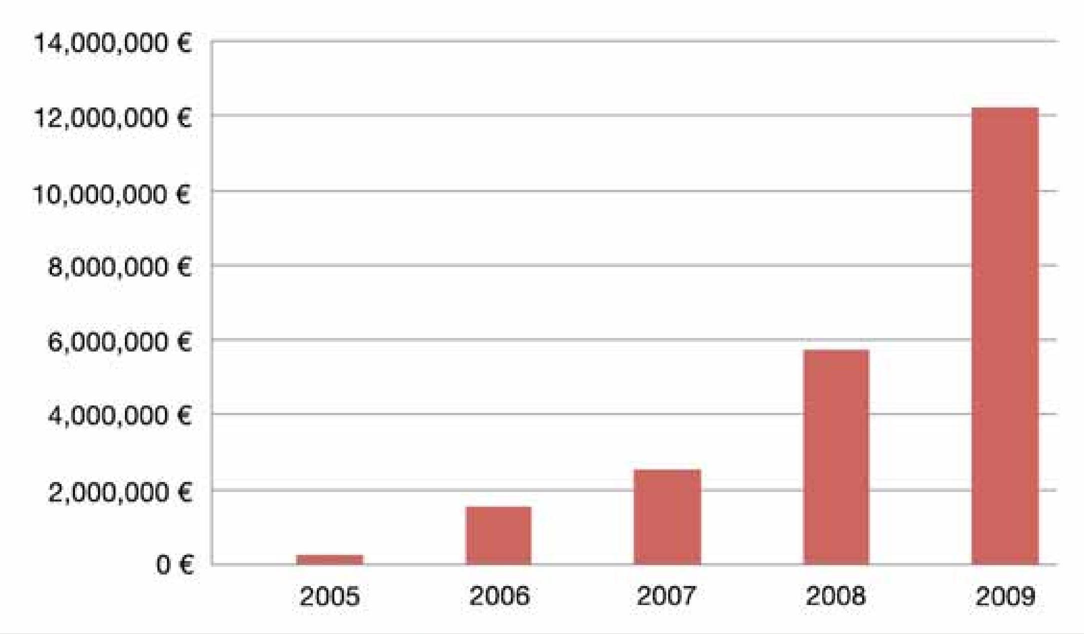


Figure 5 Tekes funding for wind power R&D projects in the last five years

Nordic Energy Research has two projects related to wind energy: VTT is participating in a grid integration project; and VTT and FMI are participating in a project investigating how climate change affects renewable energies.

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

- Task 11 Base Technology Information Exchange (VTT)
- Task 19 Wind Energy in Cold Climates (operating agent, VTT/Pöyry)
- Task 24 Integration of Wind and Hydropower Systems (VTT)
- Task 25 Power Systems with Large Amounts of Wind Power (operating agent, VTT)
- Task 28 Social Acceptance of Wind Energy Projects (Wpd Finland and Motiva).

5.0 The Next Term

Approximately 25 to 50 MW of new capacity is anticipated for 2010. There are a huge number of projects that are planned, under feasibility studies, or have just been proposed: 1,400 to 2,200 MW onshore and 4,000 to 5,800 MW offshore. A list of wind turbine projects in Finland can be found at http://www.vtt.fi/proj/windenergystatistics. A radar study needs to be initiated for some projects to get building permits. Most projects are also waiting for the new feed-in system to start in late 2010 or the beginning of 2011.

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 and Esa Peltola, VTT Technical Research Centre of Finland, Finland.

Germany

1.0 Overview

In 2009, wind power generation accounted for 6.5% of Germany's gross electricity consumption (1). The share of wind energy did not grow in 2009 because of a weak meteorological wind year (2008's wind power share was 6.6%); however wind energy is an important addition to conventional energy technologies. At the end of 2009, Germany had a total of 21,164 wind turbines installed with an output of 25,777 MW (compared with 23,902 MW at the end of 2008, as shown in Figure 1). The produced electrical energy from wind amounted to 37.5 TWh, compared to 40.4 TWh in 2008. Assuming that 2009 would have been a average supply of wind in relation to long-term wind data one could expect a theoretical energy output of 41.5 TWh (1).

Although investment in Germany's economy decreased by 12.5% in 2009 because of the world economic crises, the renewable energy sector increased its investment by 20%. Investment in the wind energy in Germany was 2.65 billion € (1) and has proven to be a stabilizing factor of the economy. About 90,000 people in Germany were

Table 1 Key Statistics 2009: Germany	
Total installed wind generation	25,777 MW
New wind generation installed	1,880 MW
Total electrical output from wind	37.5 TWh
Wind generation as % of national electric demand	6.5%
Target: Electricity from renewable energies(3)	30% by 2020

employed in the wind power sector in 2009.

Electricity from wind energy has in the medium term the largest potential among renewable energies in Germany for meeting the 30% goal for electricity from renewable energies set by the federal government. An important share of electricity from wind will need to be produced by offshore wind farms. A very important step for Germany on this technological path was the construction of the offshore test site alpha ventus in 2009. Alpha ventus was planned as a test site for the modern 5-MW turbine class under harsh marine conditions. In order to maximize the experience and knowledge from alpha ventus for future offshore wind projects and turbine development at a high scientific and technological level, the Federal Environmental Ministry launched the accompanying RAVE (Research at Alpha VEntus) research initiative. So far, they have spent 36 million € on 25 research projects.

Another important event in 2009 in Germany's wind energy research was the formation of the Institute for Wind Energy and Energy System Technologies (IWES) at the Fraunhofer-Gesellschaft. IWES will be a focal point for wind energy research in Germany networked with other important research institutions in Germany, Europe, and worldwide.

2.0 National Objectives and Progress

2.1 National targets

Germany pledged to the European Union that it will produce 18% of its overall energy requirements from renewable sources by 2020. Today the share is 10%. For the electrical energy sector, where the share of renewables was 16% by end of 2009, the goal is even more ambitious: 30% from renewables by 2020.

2.2 Progress

In 2009, the financial crisis did not seem to have a visible impact on the installation figures with even more capacity installed than in the previous year (1,665 MW installed in 2008 vs. 1,916 MW in 2009). Development in 2010 therefore promises to be interesting, particularly concerning offshore installations. The advanced planning underway at the end of 2009 for 300 to 400 MW offshore will have a positive effect on these figures, provided there are no delays due to bad weather or lack of availability of offshore installation equipment (2).

2.3 National Incentive Programs

The amendment of the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG) came in to force in January 2009. It turns out to be the main stimulation for the German wind market and it especially will accelerate offshore development in Germany. A more detailed description of the onshore and offshore remuneration conditions and principles can be found in the IEA Wind 2008 Annual Report (4).

According to information from turbine manufacturers, 76 wind turbines with a total installed power of 36.7 MW were decommissioned in 2009 (repowering in 2008 was 32.9 MW). In their place were installed 55 turbines with a total installed power of 136.2 MW (2). For such repowering, the EEG guaranties an extra payment of 0.005 €/kWh to the basic tariff of 0.092 €/kWh. Repowering has become a growing factor of wind energy implementation in Germany.

3.0 Implementation

3.1 Industry Status

Compared to 2008, market shares of turbine manufacturers have shown only minor changes. The wind turbine manufacturer Multibrid is a newcomer in the market with a share of 1.6%. Two significant shifts in market shares have been the increase of Enercon and the decrease of Vestas. Enercon claimed a market share of 60%, while the market share of Vestas fell from 31.6% to 19.5%. The three leading manufacturers on the German market for turbines installed in 2009 were Enercon, Vestas, and REpower Systems (Table 2).

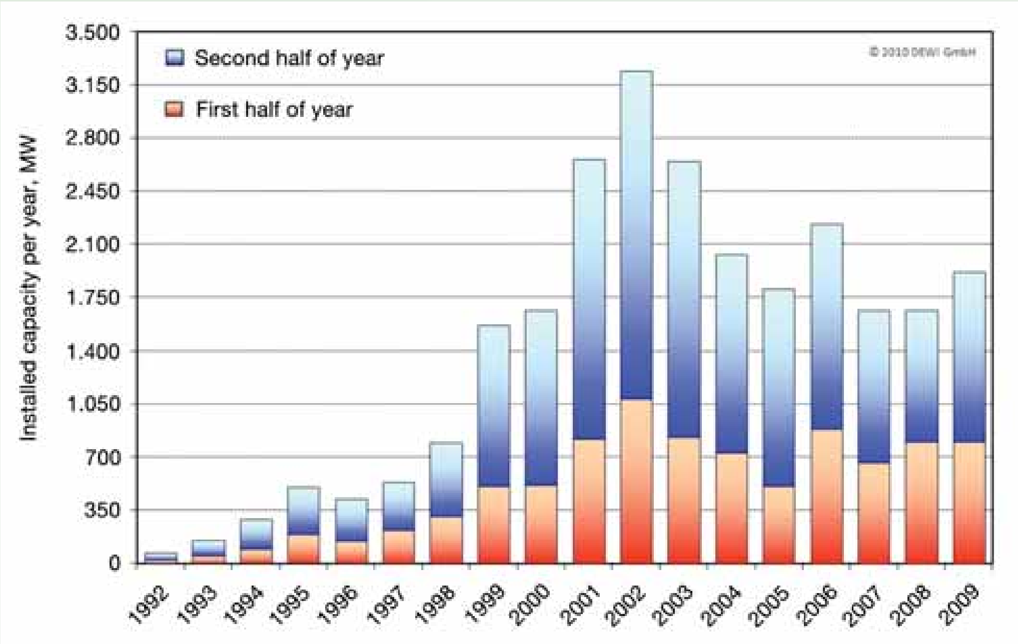


Figure 1 Long-term development of the installed power capacity of wind energy in Germany. Copyright: DEWI Magazine

Table 2 Leading manufacturers of turbines installed in 2009		
Company	Market share 2008 (%)	Market share 2009 (%)
Enercon	51.6	60.4
Vestas	31.6	19.5
REpower Systems	5.6	8.8

3.2 Operational Details

The major development of 2009 was the commissioning of Germany's first offshore wind park "alpha ventus" in the North Sea (45 km north of the island Borkum). This major event finally took place after years of delay and after 29 offshore projects with 1,894 turbines had been approved by the Federal and State Authorities since 2001. The alpha ventus park is the first step of the German wind industry into the water.

Alpha ventus is not only a conventional wind farm but also a test site for 5-MW offshore turbines. It consists of six Areva Multibrid M5000 turbines mounted on tripod foundations and six REpower 5M turbines on jacket foundations in 30 m water depth. The 12 wind turbines were placed in a grid-like formation with distances of approximately 800 m between each turbine. Four rows form a rectangle having a total surface area of 4 km2 – about the size of 500 football pitches. With its total capacity of 60 MW, a yearly energy yield of approximately 220 GW hours is expected, which is equivalent to the power consumption of around 50,000 households. The external conditions at this site have been investigated by the FINO 1 research platform since 2003 (5).

The construction started in the sea in the middle of April 2009. By 1 June 2009 the first milestone was reached when the six tripod foundations had been anchored. During the pile-driving of one of the tripods, scientists of the University Hannover tested a bubble curtain as a damping system to reduce sound emissions caused by the ramming of the piles. The implementation of the acoustic damping system was a challenge due to time restrictions and logistic requirements. Despite an incomplete operation, caused by a failure of a part of the system, a sound reduction effect was detected of about 12 dB in the direction of the sea current. On 15 July 2009 Germany's first offshore turbine, a M5000 in deep water and far away from the coast, was completed (Figure 2).

During the construction of the remaining five M5000s, the construction of the six jacket foundations for the 5M turbines started in June 2009. This process used the world's largest crane ship Thialf as a platform. The last 5M (Figure 3) was completed on 16 November 2009 (6). The wind farm can be seen by a web cam from the FINO 1 research platform which is located 405 m from the first turbine (for more information visit http://www.alpha-ventus.de/index.php?id=84#c47).

4.0 R, D&D Activities

4.1 Offshore Wind Research Programme RAVE

In order to maximize the experience and knowledge gained from alpha ventus at a high scientific and technological level, the Federal Environmental Ministry launched the accompanying RAVE research initiative. Under this initiative 25 projects have so far been supported at the cost of 36 million €. Industries, universities, and other research organizations are working closely in a research network, which has greatly enhanced the cooperation amongst German wind energy researchers. The results of RAVE will contribute considerably towards ensuring that future wind farms can be planned on a new scientific and technological knowledge base. The main focuses are reducing costs, increasing efficiency, advancing the availability of wind turbines, improving the technology for developing offshore wind energy, ensuring ecologically responsible application, as well as technologically optimizing turbines with regard to their environmental impact.

The RAVE research initiative consists of a variety of topics and projects in connection with the installation and operation of alpha ventus. In order to provide all participating research projects with detailed data, the test site is equipped with comprehensive measurement instrumentation. At two turbines next to research platform FINO 1 about 1,200 sensors are installed. As part of the RAVE initiative, the participating institutes and companies have so far set up projects on the following topics:

- Realization of joint measurements and data management
- Analysis of loads, modeling, and further development of the different components of offshore wind turbines
- Measuring loads on offshore foundations and structures
- Further development of LIDAR wind measuring techniques
- Grid integration of offshore wind energy
- Monitoring of offshore wind energy utilization in Germany – "Offshore WMEP"
- Measurement of operating noise and modeling of sound propagation between the tower and water
- Ecological and oceanographic research and social acceptance (7 and 8).

Figure 2 The first offshore wind turbine of alpha ventus with the transformer station in the background. ©alpha ventus picture library

Figure 3 Repower 5M on a jacket foundation at alpha ventus ©alpha ventus picture library

4.2 New research institute — IWES

The new wind energy research institute IWES was founded on 1 January 2009. It consists of the former Fraunhofer Center für Windenergie und Meerestechnik CWMT in Bremerhaven, and the Kassel Institut für Solare Energieversorgungstechnik ISET. Furthermore, Fraunhofer IWES will establish two Fraunhofer project groups in Hanover and Oldenburg. The Institute is networked among other national and international partners especially with the ForWind wind energy competence group of the Universities of Bremen, Hannover, and Oldenburg. Presently, 240 scientists, appointees, and students are employed at the IWES. Main research topics include:

- Engineering and operation of wind energy turbines and parks
- Investigation, development and test of components: rotor, drive train, and foundations
- Fluid elasticity and dynamics
- Offshore site condition assessment for wind and ocean energy technology
- Control and system integration of decentralized energy converters and storages
- Energy management and grid operation
- Energy supply structures and systems analysis.

IWES facilities incorporated a test center for rotor blades of up to 70 m in length (Figure 4) and another future center for rotor blades of up to 90 m in length is under construction. This allows IWES to test the statics and dynamics of current and next-generation rotor blades and their components, thus contributing to their optimization. Closely linked with experimental and numerical procedures a variety of activities are scheduled, such as the development of new test methods, endurance tests, and tests of new construction methods (9).

4.3 New turbines

A 'BARD VM' wind turbine was tested in 2009 under near-shore conditions at a location in the Jade Bay near Wilhelmshaven. The turbine (Figure 5) is mounted on BARD's own developed tripile foundation. The near-shore wind turbine, which has a rated power of 5 MW, is about 400 m from the coast line. The aim is to test the whole design of the turbine including the foundation. BARD will use 80 turbines of this type for BARD's first offshore wind farm in the North Sea. The transformer station was installed in June 2009 and construction of the wind farm started in March 2010.

Figure 4 Opening ceremony of the IWES rotor blade test center in Bremerhaven, April 2009. Photo: IWES

Figure 5 BARD VM at Hooksiel (Germany). Source: Gert Heider, PtJ

Another new turbine developer is Schuler Pressen GmbH & Co. KG, Göppingen (Schuler). As a market leader in molding presses for automobile production, Schuler has much experience in the technical management and transformation of large loads and forces, as is the case also in wind energy converters. Schuler developed a 2.7-MW direct-drive turbine with a permanent magnet synchronic generator. The turbine was especially designed for inland locations with middle wind potentials and possesses low operational sound emissions. A frequency converter and transformer are mounted in the tower base so that the nacelle weight could be minimized. The first prototype will be installed in 2010 (11). Furthermore, the Federal Ministry for the Environment (BMU) funded Schuler's development of the basic design of a 6.5-MW offshore turbine.

4.4 R&D budget of the federal government

In 2009, the BMU funded 45 new projects with a total of 28.2 million €. The budget for wind energy research and development has been significantly growing over the last years (Figure 6). A main focus of the research is the development

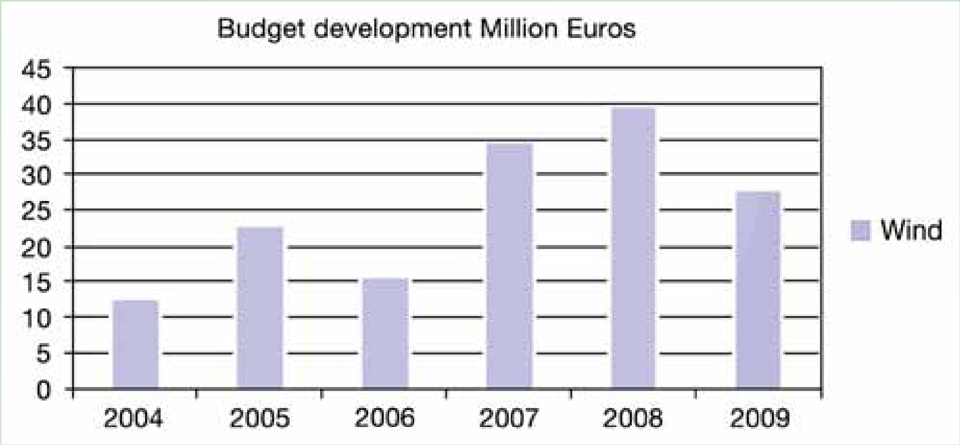


Figure 6 Budget development for wind energy research since 2004

of technologies for offshore wind energy deployment. More detailed information about the whole spectrum of wind energy research funded by BMU will be given in the brochure INNOVATION THROUGH RESEARCH 2009 Annual Report on Research Funding in the Renewable Energies Sector (10).

References and Notes

(1) Development of renewable energies in Germany in 2009. State as of 18th March 2010. Preliminary data of the German Federal Environmental Ministry on the basis of information of the Working Group Renewable Energies Statistics (AGEE-Stat).

(2) Wind Energy Use in Germany, DEWI Magazine NO. 36, February 2010

(3) Target for electricity from renewable energy. There is no special wind energy target.

(4) Chapter 17 Germany, IEA Wind Annual Report 2008, p. 145

(5) Update Fino1-Platform: Analyses of Data until June 2009, DEWI Magazine No. 35, p.69; http://www.dewi.de/dewi/fileadmin/pdf/publications/Magazin_35/12.pdf

(6) http://www.alpha-ventus.de

(7) RAVE-The Research Initiative at the first German Offshore Wind Farm, 2nd revised version 2010, in press

(8) http://rave.iset.uni-kassel.de

(9) http://www.iwes.fraunhofer.de

(10) http://www.bmu.de/erneuerbare/energien/doc/1235.php

(11) Ein Neuer aus Südwest, Erneuerbare Energien, Nr. 3 2010, p. 32-33

Authors: Joachim Kutscher, Forschungszentrum Juelich GmbH, PtJ; Ralf Christmann, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Germany.

Greece

Photo courtesy of CRES

1.0 Overview

During 2009, there were only a small number of installations because of the delay of the license procedures, which is still a major barrier on the development of renewable energy sources in Greece. In 2009, 87 wind turbines were installed, increasing the total installed power from 993 MW in 2008 to 1,109.04 MW.

The new Greek government, which was elected in October 2009, has acknowledged the importance of renewable energy sources and set new national policy for their development. In this regard, a new law has been proposed and is under elaboration, with the main goal to simplify and accelerate the licensing procedures. Regarding R, D&D, the Ministry of Environment, Energy and Climatic Change continues to support and promote all renewable energy activities in the country. New projects regarding offshore wind parks and wind desalination will come into force.

2.0 National Objectives and Progress

2.1 National targets

The Greek government sets as a binding national target the 20% contribution of RES to gross electricity consumption, by 2020. The new government proposed and set under public consultation a new law for the acceleration of RES development. The proposed law aims to accelerate licensing procedures and to reduce administrative burdens on the renewable energy sector. The new 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. Moreover, the law introduces discounts in the electricity bills of local communities and a different tariff regime for new RES installations (except for photovoltaic and solar thermal plants). It provides a 20% higher tariff to

Table 1 Key Statistics 2009: Greece	
Total installed wind generation	1,109 MW
New wind generation installed	115.75 MW
Total electrical output from wind	2.547 TWh
Wind generation as % of national electric demand	4.4%
Target:	10.7%

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 Islands Interconnections by ceasing the operation of the local conventional plants and minimizing local pollution. According to the new law, an individual Entity for the Service of Investors on RES projects under the standards of "one-stop service" (one-stop-shop) will be established.

Finally, the proposed new law suggests 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 €/MWh for the interconnected areas and 99.45 €/MWh for the non- interconnected islands. For wind projects of less than 50 kW, it proposes a feed-in-tariff of 250 €/MWh. The new law will come into force in 2010.

2.2 Progress

The progress in wind power capacity has been slow compared with other European countries. In 2009, the installed capacity reached 1,109 MW, showing an increase over the previous year of 12%. In 11 separate projects, a total of 87 wind energy conversion systems, with an installed capacity of approximately 115 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.

The energy produced from wind turbines during 2009 was approximately 2,550 GWh, and corresponds to 4.4% 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 Operational Program for Competitiveness (OPC), 2000-2006 and the Law for Development 3299/04 as amended with Article 37 of Law 3522/2006. In 2008, the Greek Ministry of Economy and Finance announced a new program entitled National Strategic Development Plan (NSDP), 2007-2013, which is the continuation of the OPC. The NSDP raises resources from the Fourth Framework Programme to reinforce the investment activities of the private sector and strengthen 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 is expected to be issued the first half of 2010.

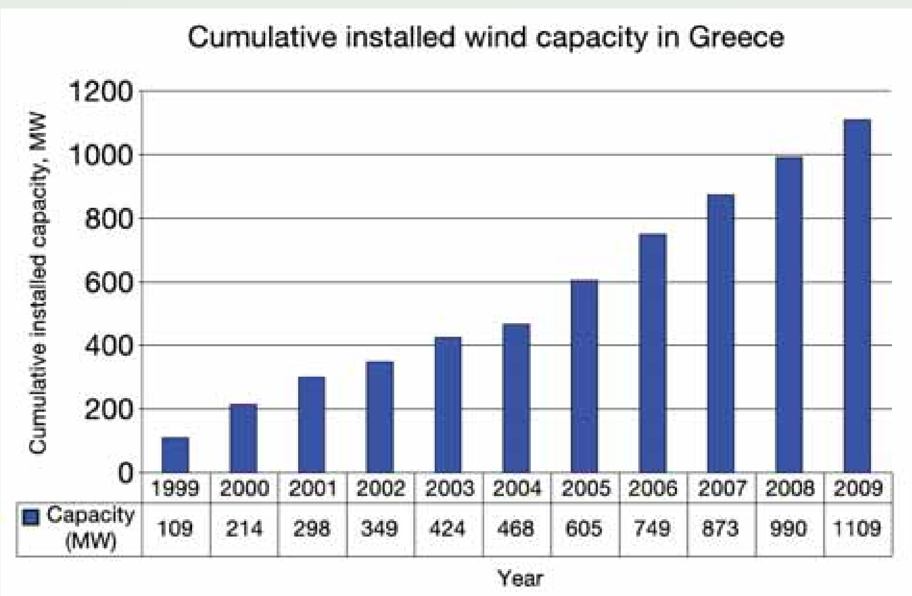


Figure 1 Cumulative installed wind capacity in Greece

3.0 Implementation

3.1 Economic impact

Wind energy represents an enormous opportunity to attract foreign investments into Greece and is also a challenge for the country's business world. In the last decade, interest has increased among, mainly, construction companies and individual investors for wind energy-related projects. 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 in mainly underdeveloped areas. An expanding network of highly experienced engineering firms has been created and is currently working on all phases of the development of new wind energy projects. The distribution of installed wind farms throughout Greece is depicted in Figure 3.

3.2 Industry status

A significant share of the wind projects is owned by six important construction companies. Small investors are active as well, however most of the time, the ownership structure is not known. No significant domestic manufacturing developments occurred in 2009 apart from the continuing involvement of the Greek steel industry in wind turbine tower manufacturing. The market share of wind turbine manufacturers is depicted in Figures 4 and 5.

During 2008 and 2009, two wind desalination plants were installed and began operation in the islands of Milos and Symi. Both projects were financed by

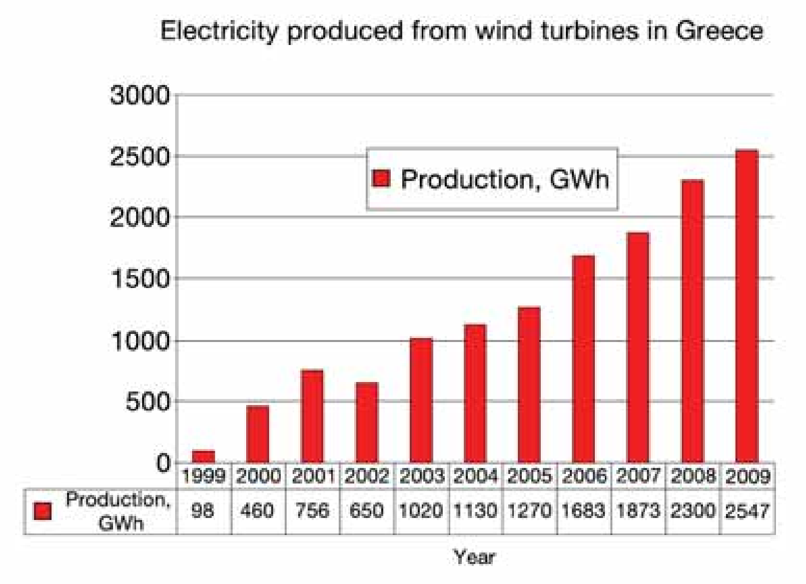


Figure 2 Electricity produced from wind turbines in Greece

Figure 3 Installed wind farms distribution in Greece (MW)

the Operational Programme for Competitiveness, Measure 6.3 of the Greek Ministry of Development (now called Ministry of Environment, Energy and Climatic Change). The Milos project has 850 kW of grid-connected wind turbines to cover the energy consumed by a Reverse Osmosis (RO) unit for seawater desalination. In 2009, the unit increased its capacity from 2,000 m3/day to 3,600 m3/day of potable water. This production is sufficient to cover the water needs of the island. The second project has an autonomous Mechanical Vapor Compression (MVC) seawater desalination unit in combination with a wind turbine of 800 kW nominal power. The desalination plant has a yearly production capacity of 90,000 m3 of high purity water.

3.3 Operational details

During 2009, four large wind farms were installed, having capacities in the range of 18 MW to 28 MW each. The average capacity of the wind turbines installed in 2009 was 1,330 kW, while the average capacity of all the wind turbines operating in the country was 873 kW. No major events leading to extensive wind farm outages have been reported. The malfunctions reported are mainly related to gearbox failure and lightning strikes.

3.4 Wind energy costs

The total cost of wind power projects depends on the turbine type, project size, and site accessibility. This cost ranges from 1,100 to 1,400 €/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 €/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 in the field of wind energy in Greece 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

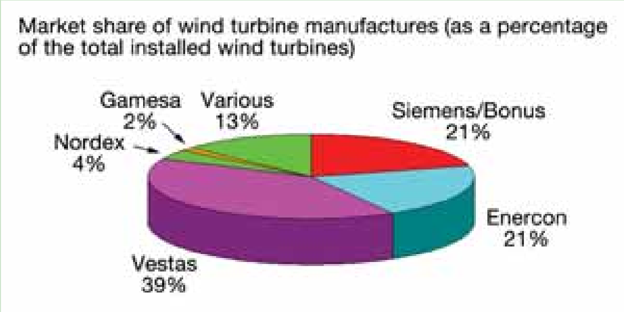


Figure 4 Market-share of wind turbine manufacturers (as a percentage of total installed wind turbines)

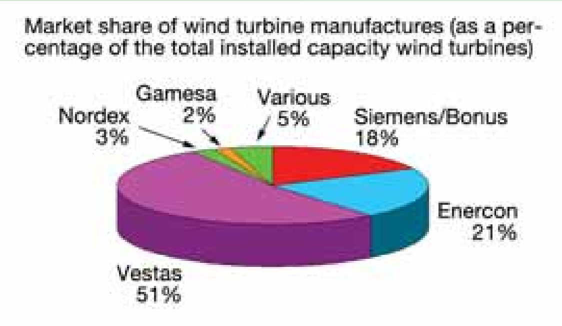


Figure 5 Market-share of wind turbine manufacturers (as a percentage of total installed capacity of wind turbines)

integration. The main actors in this field are the Centre for Renewable Energy Sources and Saving (CRES), the National Technical University of Athens (NTUA), and the University of Patras. Among the above mentioned organizations there is strong and long-standing collaboration for national and EU projects for the development and optimization of wind energy technology.

5.0 The Next Term

The new law for the acceleration 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 begin a new opening of the wind energy market.

Concerning the use of wind energy for water production through desalination, the announcement of several support programs, (small projects for the private sector; small hotels, resorts, etc., and large projects for Municipalities of the islands) are expected within the coming year. With the implementation of the new law for the acceleration of RES and with the coming financial support programs, the Greek government will lay the foundation for the fulfillment of the national RES objectives.

Authors: Kyriakos Rossis, Eftihia Tzen; CRES, Greece

Ireland

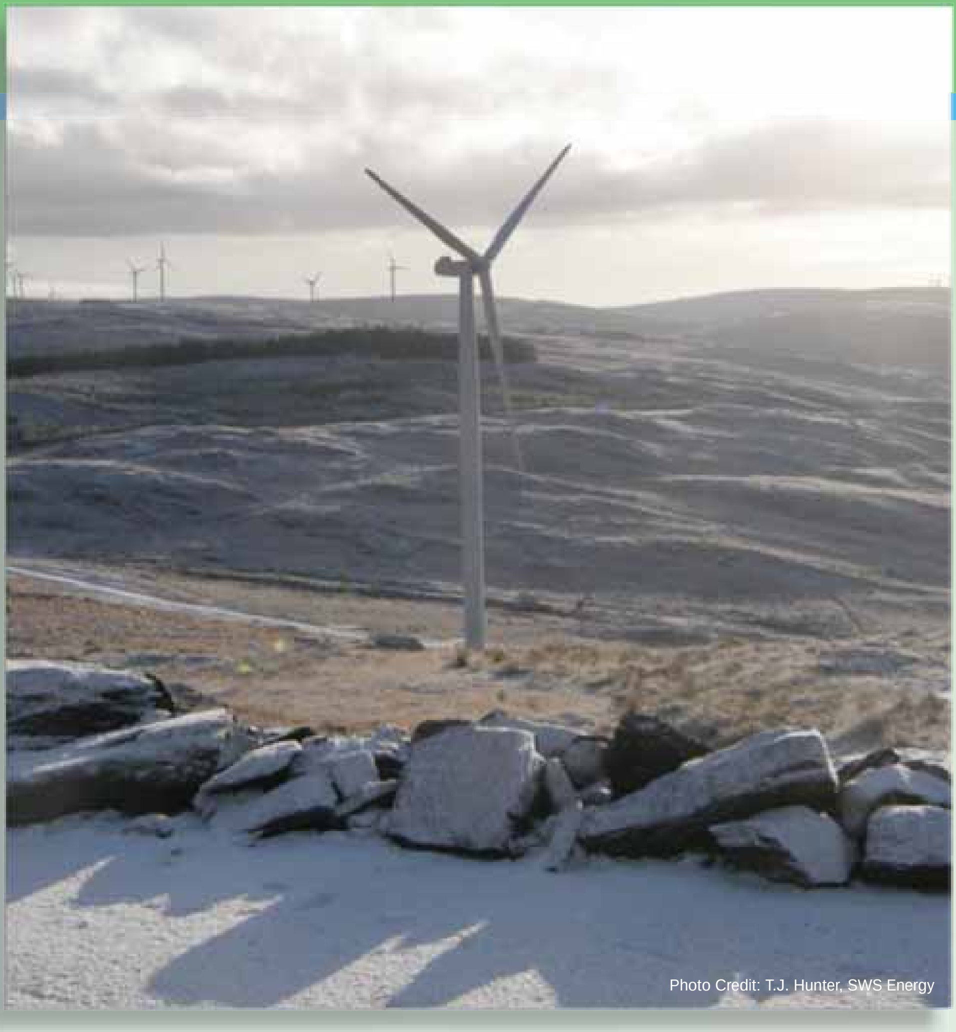


Photo Credit: T.J. Hunter, SWS Energy

1.0 Overview

Wind energy's contribution to Ireland's electricity supply continues to rise as record capacity is added (Figure 1). Ireland is on course to achieve its national target for RES-E contribution to electricity demand in 2010 (15%). Wind energy is expected to meet approximately 10.5% of 2010 electricity demand, or 70% of renewable electricity supply. By December 2009, a total of 85 wind farms were connected to the electricity system, bringing the total installed capacity for wind to 1,264 MW. Wind farm connection rates have been maintained above 200 MW for the second year with 237 MW connecting in 2009, a slight increase on 2008, and a new record for additions of wind capacity in Ireland.

A new quarter-hourly record for the amount of electricity generated by Ireland's wind farms was also achieved. The output of Ireland's wind farms reached its 2009 peak of 1,064 MW on 24 October with enough power generated at that time to supply over 600,000 homes. At times towards the end of 2009, the amount of wind power on the system was meeting 45% of the national electricity demand with no issues reported by EirGrid, the Irish transmission system operator. This is remarkable given the small isolated nature of Ireland's electricity grid.

Despite increases in wind power output, the average emission factor for electricity generation was 554kg CO_2/MWh in 2008. The increase in wind output was offset by a recovery in peat fired generation output after outages in 2007. The average emission factor for 2009 was 530kg CO_2/MWh. Wind energy accounted for 63% of renewable sourced electricity in 2008 and 73% in 2009. Reduction in the

Table 1 Key Statistics 2009: Ireland	
Total installed wind generation	1,264 MW
New wind generation installed	237 MW
Total electrical output from wind	2.955 TWh
Wind generation as % of national electric demand	10.5%
RES-E Target 2010: RES-E Target 2020:	15% 40%

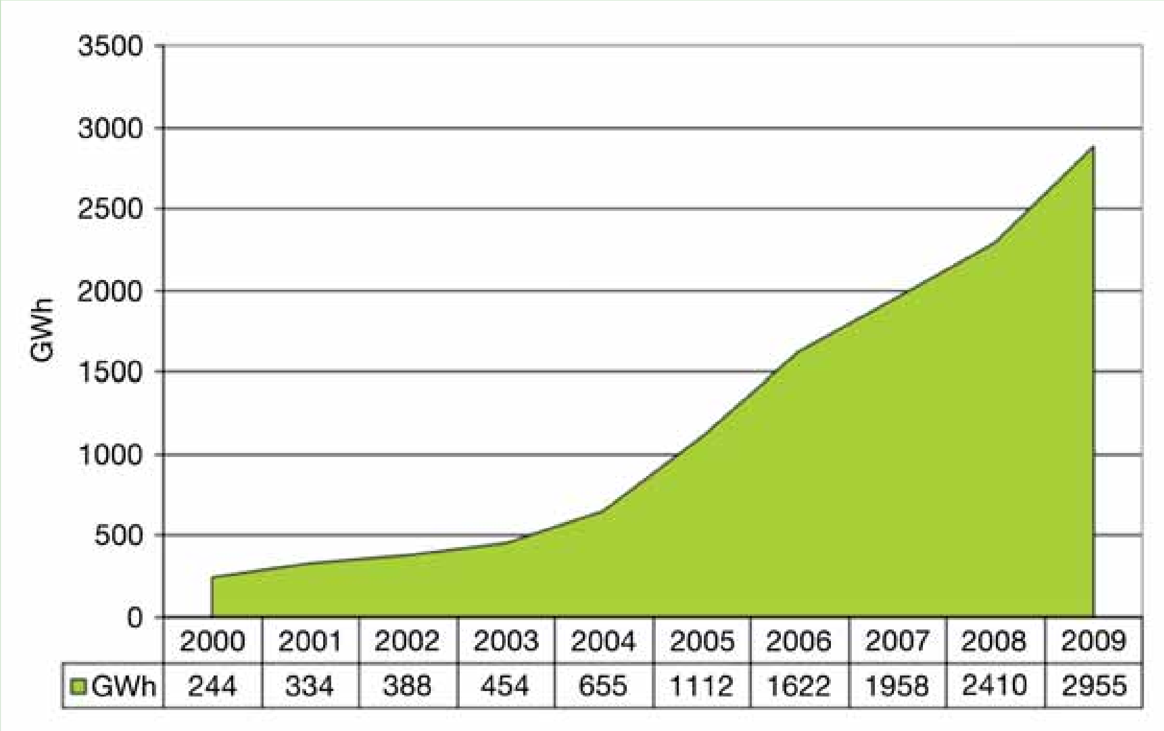


Figure 1 Wind-sourced electricity in Ireland, 2000–2009. Source: EirGrid.

reliance on imported sources of energy is a key benefit of indigenous sources such as wind as Ireland is already nearly 90% reliant on imported energy.

2.0 National Objectives and Progress

2.1 National targets and progress

Ireland's target is to supply 15% of electricity demand from renewable sources during 2010, a target which is expected to be achieved. Wind has contributed, and will continue to contribute, the vast majority of the required additional renewable generation. Added to other renewable generation stock, an estimated 1,350 MW of wind capacity is required to meet the target for 2010. An indicator of future wind power capacity additions is the queue of planned wind farms awaiting grid connections. Planned wind farms with connection contracts totaled 1,412.3 MW at the end of 2008 and total 1,257.5 MW at the end of 2009. The reduction in planned capacity additions reflects the connection of contracted sites and the lag between the last tranche of connection offers (known as Gate 2) and the current, Gate 3.

The term Gate is used to describe the overall process by which each tranche of grid capacity is assigned. As the system for allocating renewable capacity in Ireland is primarily based on a date-order queue system each round of capacity is allocated to those applicants in the connection queue prior to gate closure. The Commission for Energy Regulation (CER) directs the system operators on the process and on the total capacity to be allocated in each Gate. Not all applicants in the queue at gate closure receive offers however as the capacity of the completed applications exceeds the required capacity. The successful applicants are taken from the applicant queue via a group processing approach (GPA), which is discussed later in this section.

Figures from the TSO show that the capacity factor for the wind had been falling over the past number of years reaching a low point in 2007 of 29.1% (Table 2). It appears to have recovered during 2008 and 2009 but further study is required to understand the longer term forces on the capacity factor and determine if the longer term trend is up or down.

As outlined in the Irish government's 2007 Energy White Paper, Ireland had aimed to supply 33% of its electricity demand from renewable sources by 2020. This is one element which will contribute to the overall national target in EU Directive 2009/28/EC of 16% of total final energy consumption from renewable energy for 2020. The 33% target for RES-E was increased voluntarily to 40% in 2008. It can be seen from the figures for current connection applicants (c11,000 MW), sites

Table 2 Capacity additions and capacity factor 2002-2009, 2009 CF provisional. Source: EirGrid

	2002	2003	2004	2005	2006	2007	2008	2009
Capacity Factor	34.1%	34.7%	33.4%	32.5%	31.4%	29.1%	31.7%	31.3%
Capacity Additions (MW)	12.7	75.5	127.5	174.7	231.8	48.2	207.7	237

contracted for connection (1,257.5 MW), and wind farms already connected (1,264 MW) that the wind industry is capable of providing the generation required as long as conducive conditions persist and the system operators can execute planned network upgrades required for renewable generator connections. Approximately 290 MW of new renewable capacity is required each year from 2010 to 2020 if the target is to be met. The capacity additions for each year since 2002 are shown in Table 2.

Those wishing to connect to the grid join an applicant queue once their application is "deemed complete." They are then part of the Group Processing Approach (GPA) and are included in the Grid Development Strategy (GDS). In January 2010 the transmission system operator published the results for the Gate 3 firm access schedule. The dates were the result of running the Incremental Transfer Capability ITC program within the GDS. ITC was the methodology adopted by the system operators to assess the capability of the grid to accommodate applicants on a firm basis. Further details of the GPA and ITC are provided in the *IEA Wind 2008 Annual Report*.

Non-Gate 3 applicants or other applicants who qualify for consideration outside of the GPA may be eligible to receive connection offers sooner if they meet the criteria set out in the CER Direction CER/09/099: Treatment of small, renewable and low carbon generators outside of the group processing approach.

Until this change all renewable generators (<500kW) were subject to the GPA which is effectively a queue system. The new approach differentiates between wind and non-wind renewable generators. However applications by non-wind renewable generators with a capacity less than 5 MW will be processed outside of the queue and interaction studies will not be carried out. Only auto production wind sites, where the generator (up to 5 MW) is installed on an industrial site to predominantly supply in-house demand, will be included in this new arrangement. Wind sites with a direct connection to the grid will not be included and will be subject to the full GPA.

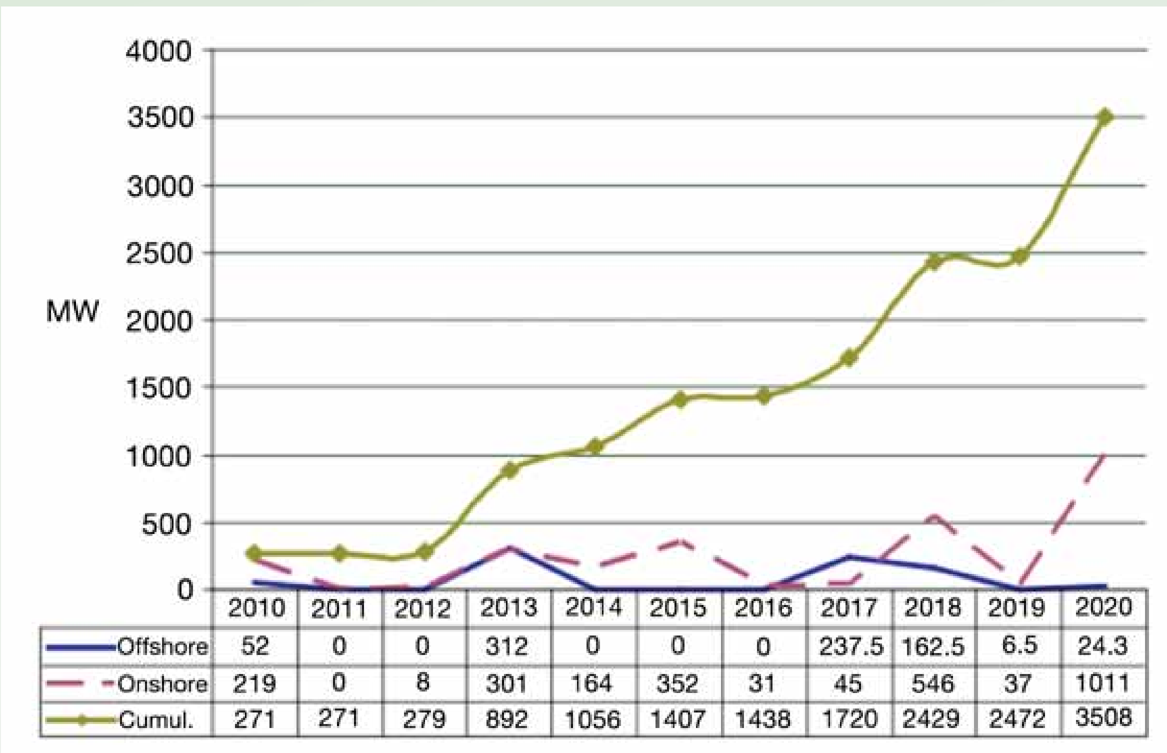
Non-wind renewable generator applicants with a capacity greater than 5 MW will also be processed outside of the GPA but will be subject to interaction studies before being assessed for wider public interest benefits on a case by case basis. Public benefits acceptable include diversity of fuel mix, predictability and power system support, environmental benefits and research or innovation.

The East-West 500 MW HVDC (High Voltage Direct Current) Interconnector project has progressed significantly in 2009 and remains on course to be completed by 2012. It is hoped that the 260-km long interconnector will assist in the deployment of high levels of wind generation and provide generators with greater access to the U.K. electricity market, BETTA. It will have sufficient capacity to satisfy more than 10% of a typical day's peak demand. The European Commission announced a contribution of 110 million € toward the strategic infrastructure as part of its Investing today for tomorrow's energy economic development plan.

Further studies are underway by the transmission system operator focusing on further interconnection to the UK and France with a view to making Ireland a renewable energy exporter.

2.2 National incentive programs

The Renewable Energy Feed-in Tariff (REFIT) is the form of support mechanism employed in Ireland, initially with the aim of meeting the 2010 targets for renewable energy. Different levels of REFIT exist for different renewable technologies to promote diversity in the generation portfolio. At January 2010, the value of REFIT for large-scale wind was 66.35 €/MWh. A wind farm with an installed capacity greater than 5 MW is deemed to be large scale for the purposes of REFIT. Please refer to the IEA Wind 2008 Annual Report for more details on REFIT.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Offshore	52	0	0	312	0	0	0	237.5	162.5	6.5	24.3
Onshore	219	0	8	301	164	352	31	45	546	37	1011
Cumul.	271	271	279	892	1056	1407	1438	1720	2429	2472	3508

Figure 2 Gate 3 scheduled firm access quantities 2010 - 2020

In 2009, the Department of Communications, Energy, and Natural Resources announced details of a REFIT specific to offshore wind at 140 €/MWh as part of REFIT II. Gate 3 includes 785 MW of offshore connection applicants. The details of the offshore REFIT will be finalised in the first half of 2010.

The Business Expansion Scheme (BES) allows individual investors to obtain income tax relief on investments in wind energy in each tax year. There is no tax advantage for the company in receipt of the BES, but securing this funding may enhance their ability to attract other external funding.

In 2008, the Irish Government introduced an Accelerated Capital Allowances scheme for companies investing in energy efficient technologies. Under this scheme, corporations investing in qualifying wind turbines may now fully depreciate the investment for tax purposes in the first year (www.seai.ie/aca).

2.3 Issues affecting growth

As is the case internationally, the affects of the credit crunch are being felt by developers. Access to finance is a cause for growing concern within the sector. Adding to the concerns about the cost of finance is the continued uncertainty with respect to variable transmission loss adjustment factors and delayed firm access to the grid. Generators are unlikely to find that the sourcing of finance is made easier by the fact that connections will be non-firm and the level of constraint they can expect is unknown. The 3,900 MW of Gate 3 connections will be loaded towards 2020 rather than front loaded, which will mean the industry will not be ramping up to maximum capacity for a number of years and will likely see a sharp fall in opportunities beyond 2022.

In the micro and small wind sectors, unlike many European countries, there is no government supported feed-in tariff available to incentivize investment by individuals. Electricity Supply Board (ESB) Networks and Customer Supply now offer a combined tariff up to a maximum 0.19 €/kWh, with some restrictions. The micro-generation sector is currently not expanding at a rate that would make a significant contribution to electricity demand.

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 €/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 €/yr. The value of civil and construction costs to the local economies is approximately 30 million €/yr.

Development of wind farms in Ireland has been undertaken by a wide range of individuals and organizations. The recent trend has been towards consolidation and an increasing proportion of the added capacity is by large utilities. Factors such as economies of scale and access to finance are thought to be driving this trend although small projects in good sites remain viable and bankable. Approximately 1,500 people are directly employed by wind energy companies in Ireland. The future O&M needs of the sector will be the key driver of the increase in local employment as capacity is added towards meeting our targets. Assuming such costs are of the order of 1.5% of capital costs it is estimated that O&M is worth approximately 20 million €/yr to the economy.

3.2 Industry status

In 2009, another major consolidation took place when semi-state utility Bord Gáis purchased SWS Energy. SWS Energy operated 179 MW of wind capacity and had approximately 460 MW of new projects at various stages of development at the time of the purchase. BG intends to invest 700 million € in wind projects in the next five years to create 250 jobs as a result.

Nordex SE has established a firmer footing in Ireland with the establishment of two service offices in 2009. The German manufacturer has also founded Nordex Energy Ireland Ltd. and by the end of 2010 will open two more offices.

3.3 Operational details

The single electricity market (SEM) has been live for more than two years. Northern Ireland and the Republic of Ireland trade most of their electricity through a gross pool operated by the SEM operator; please see previous IEA annual reports for more details.

The SEM Committee continues to develop a position on the treatment of wind and other intermittent generation in the SEM (SEM/09/073). The aim is to promote discussion on a market of increasing wind penetration with the goal of dealing with issues in a timely manner. Issues such as the process to secure economic dispatch, firm access, calculation of the average system marginal price, constraint compensation, and capacity payments will be further developed in 2010.

A relatively small number of developers connected the majority of the additional capacity in 2009. Much of the additional capacity (35%) consisted of extensions to six existing wind farms. The average size of a turbine was 1.9 MW in 2007, 1.65 MW in 2008, and rose sharply to 2.2 MW in 2009. There were 105 turbines installed in 11 wind farms.

Five turbine manufacturers' turbines were installed during 2009; Vestas (52%), GE (16%), Nordex (14%), Siemens (14%), Enercon (4%).

3.4 Wind energy costs

Current total capital costs are in the range of 1.6 to 2 million €/MW installed for wind developments in the 10 MW range. Turbine costs have fallen and currently range between 900,000 and 1,000,000 €/MW, depending on the size of the turbine and the project. The trend in costs has turned downward as global demand for turbines and raw materials moderates. A typical cost for connection would be in the range of 150,000 to 300,000 €/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%).

Contestability at distribution level is currently under final consultation and its implementation should lead to reduced connection costs for developers (CER/09/193). Contestability is where a contractor other than the transmission or distribution system owner can be engaged to build a connection.

Regarding the market value of wind energy, following on from the technical All-island Grid Study (AIGS), the regulators undertook a study to assess the possible impacts of high penetrations of wind on the SEM in 2020 (SEM/09/002). Details of the study were outlined in the IEA Wind 2008 Annual Report. At a high level, the study resulted in the following findings when analysing the impact of wind on the market:

- Wholesale market prices are significantly lower with high wind penetration,
- Economic benefits are sensitive to fuel and carbon prices,
- A mixed portfolio of plant including CCGT (Closed Cycle Gas Turbine), OCGT (Open Cycle Gas Turbine) and wind provides the best carbon reduction,

- Incentives may be required for all forms of new generation into the future,
- The SEM design appears to be robust, but continued review will be required to facilitate the changes expected in the next decade.

Generally, a market with more renewable energy will have a lower average System Marginal Price than one with little renewable energy. This is due to the lower marginal production cost of renewable energy such as wind relative to conventional generation units.

4.0 R, D&D Activities

Several R, D&D projects continue during 2010 and beyond. These, along with a national smart metering pilot and smart grid demonstrations, will assist the deployment of wind at all scales. The abstracts of a selection of academic research papers will be published with this text at www.seai.ie/wind.

4.1 National R, D&D efforts

4.1.1 Wind auto production

In May, Wind Energy Direct Ltd. completed Ireland's first large-scale industrial site wind energy installation at Munster Joinery in North Cork. The SEAI-supported demonstration project includes two Enercon E82 2-MW turbines and the project built on experience gained during other SEAI-supported projects in other settings such as the Dundalk I.T. campus turbine.

4.1.2 TSO facilitation of renewables

The AIGS concluded that up to 42% of renewable generation could be accommodated on the power system given the required infrastructure and an investigation into the underlying technical aspects of a power system with large amounts of variable generation sources. As there have been periods of 40% wind during 2009 it is clear that the power system can sustain such levels of penetration for short periods at least. It is thought however that the characteristics and behavior of the power system with large amounts of variable generation sources for sustained periods will be fundamentally different to the power system of today.

EirGrid and SONI are conducting a series of technical studies which have the objective of increasing our understanding of the power system with levels of renewable generation, particularly wind power, as forecast in 2020. This, according to the TSO, "will help set standards which are appropriate to the needs of the future power system and to develop operational practices which will ensure the continued security and stability of the power system."

4.1.3 Wind with Storage

In August 2005, the Centre for Renewable Energy at Dundalk Inst. of Technology (CREDIT) installed the world's first large-scale turbine on a college campus. The 850-kW V52 turbine supplies half of the college's power needs. In 2009, a 125-kW/500-kWh ZBB flow battery was added to complement the intermittent generator. The benefits of behind the meter storage, or demand side management, to a system with large amounts of wind power are often stated and the facility will be used to test and model the interactions and potential. Specific research includes: Operational Evaluation of a Flow Battery in Conjunction with Wind Autoproduction and Grid Ancillary Services Provided by Distributed Electricity Storage - A Case Study. Also at CREDIT is a small-scale wind turbine test site which complements the centres turbine and rotor design activities. Other research topics include investigations into over-speed regulation by blade deformation.

4.1.4 Smart networks for island communities

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. It is hoped that the methods developed in this study may also serve to inform the development of the energy system for the whole of Ireland (www.seai.ie/aran).

4.1.5 Micro-generation field trials

Interest in domestic power generation was increased when the largest electricity supplier announced an offer of 0.09 €/kWh to its domestic customers for exported electricity. This was on top of a 0.10 €/kWh ESB Networks offering for the first 3,000 kW exported.

The major R, D&D activity at the smaller scales, SEAI's field trials, will continue 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 budget for the study of 2 million € which includes a market study on the potential for the sector, and a report on the commercial arrangements for micro-generation. The program will assess the performance of the technologies and inform future

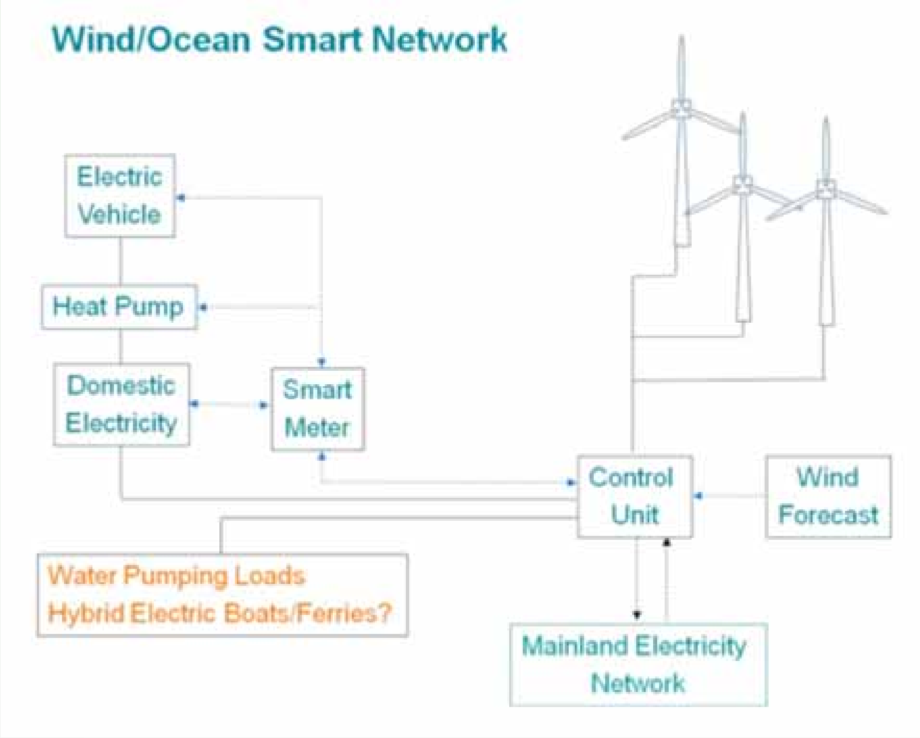


Figure 3 Schematic of Wind/Ocean Smart Energy System

decisions on possible incentives, tariffs, or deployment programs.

To protect customers and prescribe best practices, turbine suppliers and manufacturers applying for inclusion in the field trails were required to supply equipment that conforms to the appropriate European standards (EN 61400-2/11/12), as was the case with the associated inverters (EN50438).

Installers were required to undergo wind theory and practical manufacturer training. SEAI has worked with the relevant authorities to deliver a national training standard for PV and micro-wind under the supervision of FETAC. The first candidates will enrol in the course later in 2010.

4.2 Collaborative research

Ireland will continue its participation in two of IEA Wind's annexes. Namely, Task 28 - The Social Acceptance of Wind Energy Projects: Winning Hearts and Minds and Task 25 - Power Systems with Large Amounts of Wind Power. Ireland will continue to contribute research beneficial to the international wind community. Dublin will host the next meeting of the Task 28 working group in September 2010.

ESB Networks and EPRI (The Electric Power Research Institute) have formed a three-year alliance focused on the R&D and demonstration of a number of the key innovations in the Smart Grid strategy. The Smart Grid is seen as a key tool in increasing wind energy penetration of all scales. ESBN have become the Sixth EPRI Smart Grid Demonstration host site. Cooperative project areas relevant to wind energy include: Smart green circuit and smart grid demonstration projects; Electric vehicles infrastructure and standardization; Cluster stations resulting in fewer transformers; Voltage/VAr control; and Use of voltage regulators to limit voltage rise. ESB Networks Smart Grid project will be carried out on a collaborative basis between ESBN, EPRI and University College Dublin.

Electricity Research Centre (ERC), University College Dublin, is engaged in research on a variety of topics relating to wind energy. In the short time-scales, research on the effect of wind power on voltage stability and system frequency control is ongoing. In the hourly time-frame, the work concentrates on the effect of wind on cycling of conventional plant and the need for storage at very high penetrations of wind power (>50%). In a longer time frame, research which assesses system flexibility continues (both in a simplified general approach and more detailed quantification) for dealing with increased variability and incorporating the need for flexibility into portfolio planning. Optimal planning of the transmission network is being examined for future transmission expansion. Work is also in progress on the effect of wind power on the distribution network and the controls that could be employed here (http://erc.ucd.ie).

The FP5 project ANEMOS identified new research priorities and challenges for the future in the arena of short-term wind power forecasting for a wide range of end-user requirements. One of the main challenges is to integrate efficiently wind power forecasts and their uncertainty into the daily practice of power system management and trading of wind generation. The aim of the follow-up FP6 project ANEMOS+ is to develop wide research and demonstration activities towards this direction. The project is carried out by 21 partners from eight Member States.

References:

Opening photo: Inchincoosh Windfarm near Kilgarvan, Kerry.

Lists of connected and contracted generators, Lists of completed applications,
http://www.eirgrid.com/customers/

SEAI EPPSU Energy in Ireland 2009 Report, http://www.seai.ie/Publications/Statistics_Publications/EPSSU_Publications/Energy_in_Ireland_2009.pdf

Delivering a Sustainable Energy Future for Ireland, Department of Communications, Energy and Natural Resources, www.dcmnr.gov.ie/Energy/Energy+Planning+Division/Energy+White+Paper.htm.

2009 Carbon Budget, www.environ.ie/en/Publications/Environment/Atmosphere/PublicationsDocuments/FileDownLoad,18677,en.doc

East West Interconnector updates, www.interconnector.ie

TSO Studies on Facilitation of Renewables, http://www.eirgrid.com/renewables/facilitationofrenewables/

Department of Communications, Energy and Natural Resources, "Terms and Conditions of REFIT,"
http://www.dcenr.gov.ie/Energy/Sustainable+and+Renewable+Energy+Division/Sustainable+and+Renewable+Energy+Division.htm

Information on the microgeneration pilot, http://www.seai.ie/Grants/Microgenpilot/

All-Island Grid Study
www.dcmnr.gov.ie/Energy/Latest+News/All-Island+Grid+Study+Published.htm

Irish Wind Energy Association, www.iwea.com

IWEA Deloitte Report on Jobs and Investment in Irish Wind Energy,
http://www.iwea.com/index.cfm?page=viewnews&id=55

Centre for Renewable Energy at Dundalk Institute of Technology, http://ww2.dkit.ie/research/credit

Electricity Research Centre, University College Dublin, http://erc.ucd.ie/#/front.swf

Sustainable Energy Research Group, University College Cork, www.ucc.ie/en/serg

CER/08/260 Direction on Criteria for Gate 3 Renewable Generators,
www.cer.ie/GetAttachment.aspx?id=54270766-56dc-4ddf-b0a1-d3be66a23df1

SEM/09/002 Impact of High Levels of Wind Penetration in 2020 on the SEM,
www.allislandproject.org/en/modelling-group-minutes-presentations.aspx?article=7e445962-3abe-4224-90a4-82adc6038b91

CER/09/193 Proposed Decision on Contestability for Distribution and Transmission Level Connections,
http://www.cer.ie/en/electricity-distribution-network-current-consultations.aspx?article=37848dee-ee81-4187-a3e7-33a8ea052f93

Author: Martin McCarthy, Renewable Energy Information Office, Sustainable Energy Authority of Ireland, Ireland.

Italy

Photo courtesy Nordex Italia

1.0 Overview

Installation of new wind farms in Italy continued at a brisk pace in 2009. Total online grid-connected wind capacity reached 4,850 MW at the end of the year, with an increase of 1,114 MW over 2008. As usual, the largest developments took place in the southern regions, particularly in Sicily, Apulia, Calabria, Campania, and Sardinia. The 652 new wind turbines deployed in 2009 had an average capacity of 1,715 kW and brought the total wind turbines on line to 4,237, with an overall average capacity of 1,144 kW. All plants are onshore, and are mostly at hill or mountain sites. The 2009 production from wind farms is estimated at 6.5 TWh, which is about 2% 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 wind investors an average price around 67 €/MWh in 2009. The additional income from the sale of TGCs was nearly 88 €/MWh. Owners of wind plants between 1 kW and 200 kW can opt for other schemes: either a fixed feed-in tariff of 300 €/MWh or exchange (net-metering) contracts.

The main issues affecting growth came from lengthy procedures for

Table 1 Key Statistics 2009: Italy	
Total installed wind generation	4,850 MW
New wind generation installed	1,114 MW
Total electrical output from wind	***6.5 TWh****
Wind generation as % of national electric demand	***2%****
Formal wind target from 1999 RES White paper	2,500 MW or 5 TWh by 2008-2012
Maximum wind potential according to the 2007 Position Paper of the Italian Government:	12,000 MW or 22.6 TWh by 2020
RES target according to Directive 2009/28/EC:	17% of total primary energy consumption from RES by 2020
*Provisional data	

permitting and grid connection and from wind production curtailments ordered by the TSO. New regulations on these matters and others (ancillary services) have been issued by the regulatory authority AEEG.

Most new turbines were supplied by foreign manufacturers. Vestas has production and management facilities in Italy. The Italian manufacturers are currently Leitwind (1.5-MW turbines), Moncada (850-kW machines), and 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 ERSE (formerly CESI RICERCA) under contract to the Italian government in the interest of Italy's electricity system, some Universities (Bologna, Genoa, Naples, Trento), the Polytechnics of Milan and Turin, and other companies (BlueH etc.).

2.0 National Objectives and Progress

2.1 National targets

Italy's official wind energy target was set by the White Paper for Valorisation of Renewable Energy Sources in 1999 and provided for wind generating capacity of 2,500 MW and annual wind energy production of 5 TWh/yr to be attained in 2008-2010. This target has already been greatly exceeded, especially as far as capacity is concerned.

In September 2007, however, a new target was set by the position paper issued by the Italian government in response to the new RES goal of the plan of action "An Energy Policy for Europe" of the European Union (20% of total EU primary energy consumption from RES by 2020). This position paper has indicated a total theoretical potential of 12 GW (ten onshore and two offshore) available by 2020, which could produce 22.6 TWh/yr. European Directive 2009/28 EC on RES promotion, issued on 23 April 2009, has given Italy a binding national RES target equaling 17% of overall primary energy consumption from RES. It is now up to the Italian government to lay down a RES action plan sharing this target among the various sectors by June 2010, and the electricity sector should obviously play a major part.

2.2 Progress

Progress continued in 2009 when (Figure 1) total online grid-connected wind capacity reached 4,850 MW. This increase of 1,114 MW over 2008 is the largest growth ever in absolute terms (as a percentage, the growth was 30%, against 37% in 2008). As usual, the largest developments took place in southern regions, particularly in Sicily, Apulia, Calabria, Campania, and Sardinia. The five regions with the highest wind capacities include: Apulia (1,158 MW), Sicily (1,116 MW), Campania (809 MW), Sardinia (586 MW) and Calabria (398 MW) (Figure 2).

Provisional figures from Terna (the Italian Transmission System Operator) indicate a 2009 production of about 11.4 TWh from wind, photovoltaic, and geothermal plants combined. The production from wind farms alone could provisionally be put at about 6.5 TWh, which would equal about 2% of total electricity demand on the Italian system (total consumption plus grid losses).

Total electricity demand in 2009 (316.8 TWh) showed a 6.7% drop from 2008, as a consequence of the ongoing economic crisis and also (hopefully) of better end-use efficiency. According to Terna's provisional data, 86% of the 2009 demand was met by domestic production and 14% by imports. Gross domestic production came from thermal plants (78%, mostly gas-fired and, to a lesser extent, burning oil, coal, and biomass), hydropower (18%, including pumped-storage plants), and other sources including wind (4%).

2.3 National incentive programs

In 2009, the schemes for supporting deployment of RES in Italy were mostly the same as in the previous year. Apart from the old CIP 6/92 system based on feed-in tariffs, which has gradually been expiring, the main scheme is based on a RES quota obligation and the issuing of TGCs. Producers or importers of electricity from non-renewable sources exceeding 100 MWh must feed into the Italian grid a quota of RES electricity calculated as a percentage of their electricity from conventional sources in the previous year. In 2009, the quota rose to 4.55% compared to 2008.

Obliged operators have to prove compliance by returning to GSE (Manager of Energy Services - the body in charge of running RES support schemes) a corresponding number of TGCs, either from their own plants or bought from other RES electricity producers. Now TGCs are granted to certified RES plants (the so-called IAFR plants) for a period of 15 years if they started operations after 31 December 2007 and for a period of 12 years if older). TGCs are valid for three years.

Since 2006, the TGC offer has somehow exceeded demand and this has pulled down the TGC trading price. On average it was nearly 88 €/MWh in 2009

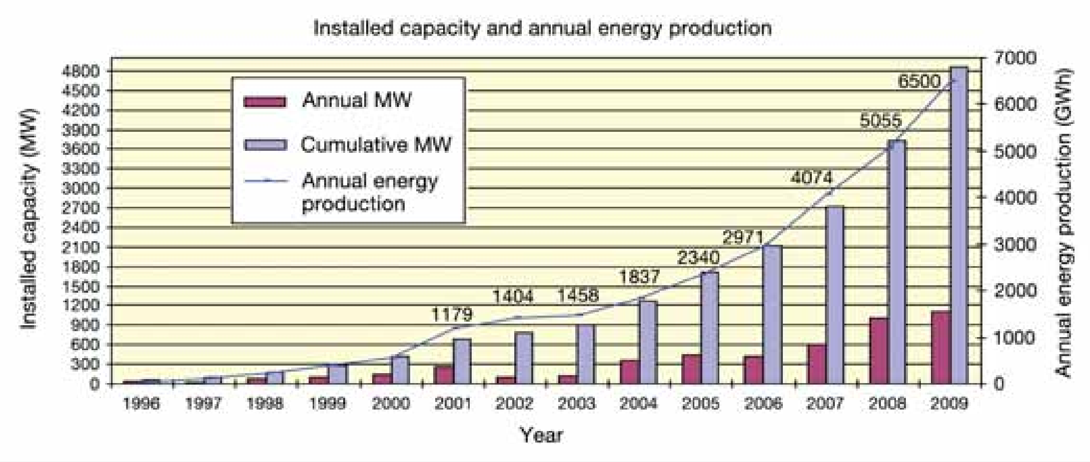


Figure 1 Installed capacity and annual energy production 1996 to 2009

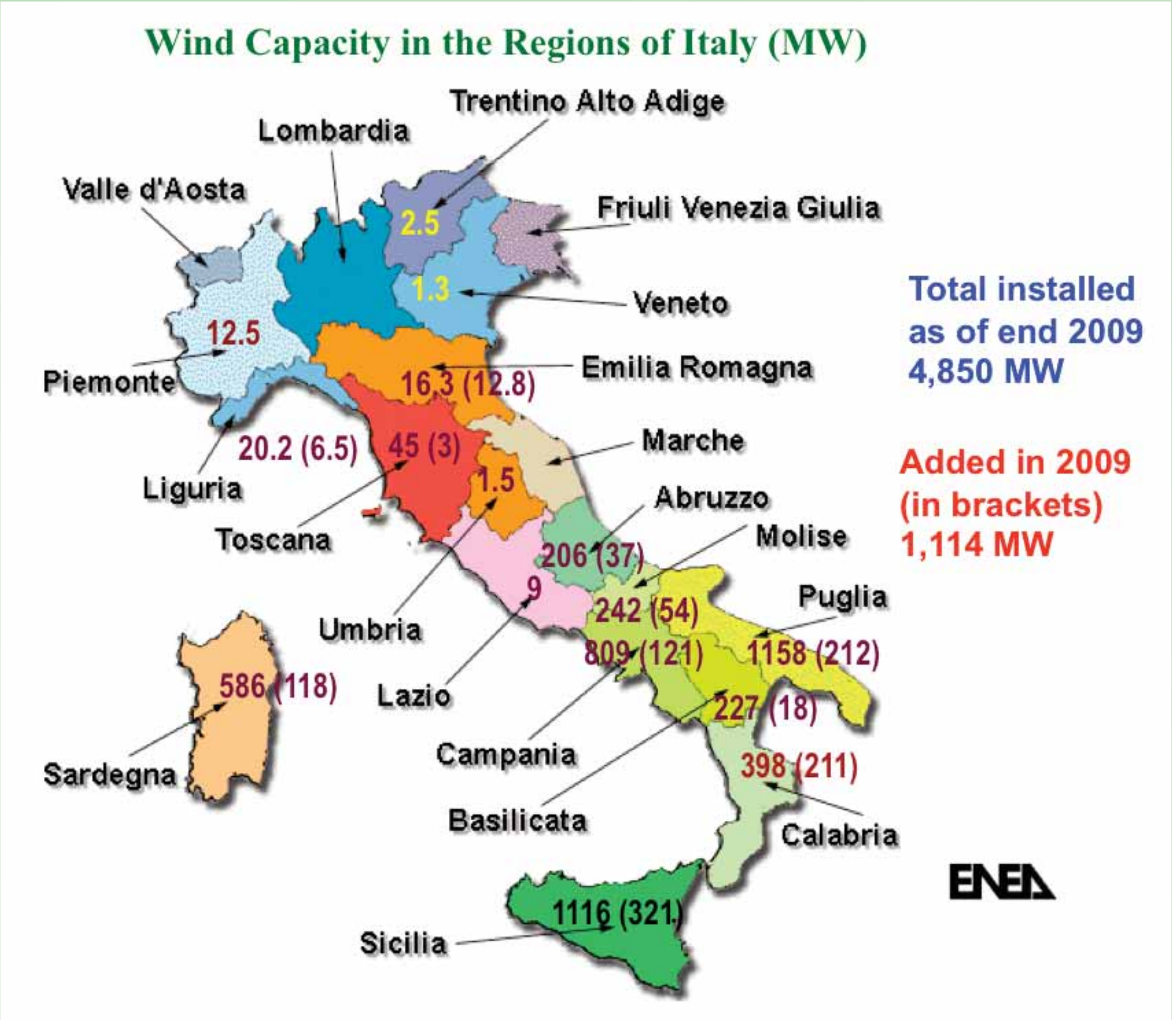


Figure 2 Wind capacity in the regions of Italy in MW (wind capacities added in 2009 are indicated in brackets)

trading. GSE, too, sold its own TGCs at a price fixed by law of 88.66 €/MWh in 2009. This revenue from TGC sales adds to the income from energy production (commonly sold straight to GSE), which yielded an average price of 67 €/MWh in 2009. RES plants can get a number of TGCs equaling the number of produced MWh multiplied by a coefficient depending on technology, specifically 1 for onshore wind and 1.5 for offshore wind (raised from 1.1 to 1.5 by Law No. 99 of 23 July 2009).

The TGC scheme is clearly less suited for smaller wind plants, which have therefore been given the option to choose between this and two other schemes by Law No. 244 of 24 December 2007 and the subsequent Decree of 18 December 2008. Specifically, a wind plant between 1 kW and 200 kW capacity, which has come on stream after 31 December 2007 is entitled to a fixed comprehensive feed-in tariff for the energy it feeds into the grid during the first 15 years of operation. The tariff is currently 300 €/MWh. In this case the owners also have to file an application with GSE to obtain the IAFR qualification. This provision could open new market prospects to small wind systems (their deployment has so far been poor in Italy). The third option is the possibility for owners of wind 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). This possibility has been extended to RES plants from 1 kW up to 200 kW capacity, provided that they have come into operation after 31 December 2007. In this case, TGCs can also be obtained. A procedure with GSE has to be entered into for this option as well.

2.4 Issues affecting growth

Any undertaking in Italy must follow the rules of physical planning authorities for land development, such as the Regional Energy and Environment Plans (PEAR). There is, however, a lack of nation-wide guidelines for location of wind farms, and so the various regional or local authorities have ended up issuing their own regulations, with technically and legally heterogeneous approaches. Wind energy investors have long complained of uncertainties ensuing from such different and sometimes unclear and lengthy procedures, which can easily bring about delays that are not financially acceptable, especially to small companies. Some speeding-up of permitting procedures may come from the long-awaited National Guidelines for the Single Authorization, currently being worked out jointly by the state government and the regions. Sharing of the targets and ensuing burdens imposed by national RES engagements among the regions may also bring about faster permitting procedures.

Other major delays have been caused by long wait times generally needed for connection to the grid, which has mainly been due to wind plants being located in areas where the existing electricity grid is rather weak, among other factors. Terna, the Italian TSO, has been tackling two important issues for guaranteeing wind operators full access to the grid. The first is construction of new lines and substations, which take a long time (two to three years and sometimes longer) to come in operation, as these infrastructures have to undergo lengthy permitting processes as well. The second issue stems from the fact that, in 2008 and 2009, Terna sometimes obliged wind operators to shut down their wind farms because of temporary overloads occurring on electrical lines in Apulia, Campania, Basilicata, and Sardinia. Around 500 GWh of wind production was lost in this way during the last year, and this prompted AEEG (the Italian Regulatory Authority for Electricity and Gas) to take action in order to avoid undue damages both to wind investors and to the electrical system at large. Since 1 January 2009, grid-connection of new generating plants has been regulated by Deliberation ARG/elt 99/08 (the so-called TICA, Integrated Text of Active Connections) issued by AEEG on 23 July 2008. This document has streamlined into a single text the technical and economic conditions for connecting generating plants to grids at all voltages. It provides for special, more favorable terms for RES and CHP (Combined Heat and Power) plants, with a view to speeding up their connection and alleviating costs to investors. Wind farms above 6 MW capacity are to be connected to the high voltage grid (in Italy this is typically 132 kV or 150 kV networks), which is managed by Terna.

Terna has been investing heavily (over 500 million € planned) on new grid infrastructures to accommodate increasing wind capacities without affecting existing networks. This aim is also pursued by building dedicated substations ("collecting plants") through which wind generated power can be fed straight from 150 kV lines into the very high voltage (380 kV) system. Moreover, some major links currently being built for general purposes (e.g. the SAPEI d.c. cable between Sardinia and the mainland, the a.c. cable between Sicily and Calabria, and some mainland links) will contribute to improving transport of wind power.

The curtailments of wind production ordered by Terna as a consequence of planned work or the occurrence of temporary bottlenecks on the grid have raised quite some discussion on how producers should be indemnified, all the more so because in principle, according to the law, RES plants should have priority in dispatching.

Another issue has been the request that wind farms be equipped like other conventional generating plants to provide the system with ancillary services, such as power output modulation, output power ramp control at cut-in, grid fault ride-through capability, contribution to frequency and voltage regulation, etc. AEEG Deliberation ARG/elt 98/08 of 23 July 2008 allowed Terna to require new wind farms to provide these ancillary services. AEEG Deliberation ARG/elt 5/10 of 25 January 2010 has confirmed this and also stated that plants already in operation, or at an advanced design stage, as of 25 July 2008 may be fitted out for these purposes on a voluntary basis (if so, they obviously have some economic advantage).

Further regulations under AEEG Deliberation ARG/elt 5/10 of 25 January 2010 on dispatching of non-programmable RES power plants, have entrusted GSE with the task of calculating wind production losses caused by dispatching orders by means of forecasting models based on inputs from anemometers at reference plants, and how Terna must pay producers accordingly. Lastly, AEEG Deliberation ARG/elt 4/10 of 25 January 2010 has charged GSE with acquiring wind data and making production forecasts with regard to smaller wind farms (less than 10 MVA) which are generally not liable to dispatching orders.

In the last few years, Terna and GSE have been developing their own wind production forecasting models for better dispatching of all generating plants in the system and better bidding of wind farm production on the day-ahead market (see the *IEA Wind 2008 Annual Report*).

3.0 Implementation

3.1 Economic impact

The 652 new wind turbines (1,114 MW) put in operation in 2009 and the relevant civil and electrical engineering infrastructures brought about a turnover of approximately 2 billion €, including wind turbines and components made at factories in Italy and delivered to foreign countries. The best effect is the growing number of employees in the wind sector. As stated in the *IEA Wind 2008 Annual Report*, ANEV (the National Wind Energy Association) estimated a total of more than 18,000 people working in the wind energy sector, of which over 5,000 were working directly in the industry and the rest in ancillary jobs (studies, infrastructures, O&M, etc.). The same estimate holds, more or less, for 2009 as well.

Regarding future prospects, it is worth recalling the study jointly carried out by ANEV and UIL (a national trade union) in 2008. This study estimated that by 2020, if the full wind potential was realized of 16,200 MW, some 66,000 people would be employed in Italy's wind sector, including indirect employment.

3.2 Industry status

As in previous years, foreign manufacturers supplied most of the new wind turbines set up in Italy (Figure 3). In 2009, Vestas (Denmark) with 336 MW and Enercon (Germany) with 207 MW provided the largest capacities, followed by Nordex (Germany) with 167 MW, Gamesa (Spain) with 153 MW, GE Wind

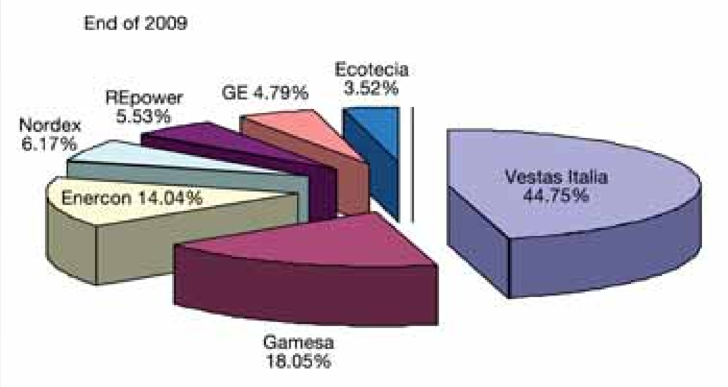


Figure 3 Market shares of wind turbine manufacturers in Italy at the end of 2009 (as percentages of total online capacity)

Figure 4 Leitwind 1.5-MW LTW77 wind turbine with panoramic platform installed on Grouse Mountain near Vancouver, Canada (courtesy of Leitwind)

(USA) with 76 MW, REpower (Germany) with 70 MW, and Ecotècnia (Spain) with 50 MW. It should be pointed out, however, that the Vestas group has set a major establishment in Italy since 1998. Vestas Italy now runs two commercial offices based in Taranto (Apulia Region) and in Rome. These offices are responsible for the sale, installation, and operations assistance of wind turbines over an area comprising various countries of North Africa and Southern Balkans (including Albania, Egypt, Libya, and Jordan). 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. In addition, two 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 2009, this company installed some of its 1.5-MW units in Italy. The company also installed its first wind turbines in France and, most recently, a unit near Vancouver in Canada (Figure 4). Previously, Leitwind had installed turbines in Italy, Austria, Bulgaria, and India. The Leitner line includes the LTW70 (1.7 MW and 70-m rotor diameter), LTW77 (1.5 MW or 1.0 MW, 77-m), and LTW80 (1.5 MW, 80-m). All models feature a three-blade, variable-speed rotor, no gearbox, and a 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. Leitwind has estimated that during the three-year period from 2009 to 2011, their annual turnover outside of Italy may reach 170 million €.

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. Other projects for wind farms in Tunisia, Mozambique, etc. are being considered.

The situation of electricity producers from wind in Italy as of the end of 2009 is shown in Figure 5 in order of percentage of overall installed capacity. The highest capacities are owned by International Power (11.3%) and the IVPC group (8.8%). The former is a well-known multi-national power producer, the latter is an Italian developer of very long standing, which has actually been the pioneer of wind farming in Italy since 1993. In addition to setting up and running its own wind farms, the IVPC group also manages and maintains wind farms for third parties. Other substantial capacity shares are held by the wind developer FRI-EL (8.6%) and by subsidiaries of some large electricity utilities, such as Enel WindPower (8.5%), Edens - Edison Energie Speciali (7.4%), and E.ON Italia (5.8%), which has taken over the former Endesa Italia.

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, 25 kW), Blue Mini Power (horizontal-axis, 20 kW), Ropatec (vertical-axis, up to 20 kW), Layer Electronics (horizontal-axis, up to 10 kW), etc. Further horizontal-axis machines in the range of 50-80 kW capacity have been developed by ARIA, Terom, Eolart, Klimeko, etc.

3.3 Operational details

In 2009, 652 new wind turbines were deployed in Italy, totaling 1,114 MW. Their average capacity was 1,715 kW, confirming the increased use of large-sized machines Italy, despite sites where terrain is often rough and access difficult. A total of 4,237 wind turbines are on line, corresponding to 4,850 MW and an overall average capacity of 1,144 kW per unit (Figure 6). All plants are based on land, mostly at hill or mountain sites. A number of applications for offshore projects have been submitted, but none of them have obtained permits yet.

Several wind farms completed in 2009 have a capacity of 20 MW or more. The record capacity is at the Monte Grighine plant built by Greentech/EDF in Sardinia: 99 MW with 43 Nordex machines. Among the largest plants are also those of Isola Capo Rizzuto in Calabria (96 MW), Salemi in Sicily (62 MW), Regalbuto in Sicily (50 MW), and San Sostene in calabria (42 MW).

Assuming the production of 6.5 TWh from wind in 2009 (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

The cost figures provided in the *IEA Wind 2008 Annual Report* could more or less be confirmed. As a typical example, the average installed plant cost of a land-based wind farm at a site of medium complexity, with15 km of roads and 12 km of electric line for connection to the high-voltage grid, could be put at around 1,740 €/kW. This cost is generally subdivided as follows: about 70% for turbines and their installation and commissioning, and 30% for the other items. Among the latter, development, namely site qualification, design, administrative procedures, etc. take a substantial part (nearly half). The sale of energy production (commonly sold straight to GSE) yielded an average price of 67 €/MWh in 2009. The additional income from the sale of TGCs was, on average, nearly 88 €/MWh in the 2009 trading. As stated earlier, owners of wind plants between 1 kW and 200 kW can also opt for either a fixed tariff of 300 €/MWh for energy fed into the grid (clearly better suited for them) or exchange (net-metering) contracts. In the latter case, their income equals the avoided price of the electricity they would have bought as customers, which is rather variable, but could be put on average at 200 €/MWh.

4.0 R, D&D Activities

4.1 National R, D&D efforts

In Italy, there has been no national R, D&D program running on wind energy, but this topic has been the subject of activities carried out by different entities. ERSE S.p.A. (new corporate style of the former CESI RICERCA since 29 April 2009) has continued to work on research programs under contract to the Italian government in the interest of Italy's whole electricity system. The financial engagement of ERSE on wind energy research was about 2 million € in 2009 and the 2010 and 2011 budgets are nearly as much.

The work of ERSE on wind energy led to a new, interactive Wind Atlas of Italy (http://atlanteeolico.erse-web.it) and to studies such as Italy's onshore and offshore wind potential, technologies of floating wind systems, and environmental compatibility issues. The work carried out in 2009 follows.

A more accurate investigation of offshore wind potential was undertaken using wind and sea depth maps, as well as system costs and other factors a GIS based tool was developed for this purpose. At the same time, wind measuring campaigns were conducted at a few stations set up both on land (Tuscany) and at sites representative of offshore conditions on the Pianosa and Ischia islands, in the Adriatic and Tyrrhenian sea, respectively. These measurements were conducted to fine-tune the Wind Atlas in areas of higher uncertainty.

A methodology was developed for better assessing the onshore wind capacity that can be installed in a given area, taking into account its main technical aspects (wind, slopes, land cover, etc.). This methodology was validated by applying it to sample areas of Italy.

A survey was carried out on small wind systems available on the Italian market to gather information about their technologies, costs, reliability, and performance for the benefit of prospective purchasers.

In view of increasing penetration of wind farms into the electrical system, research was started to go deeper into control issues of wind turbines and their operating strategies.

After the feasibility study on a floating wind system consisting of a TLP (Tension Leg Platform) structure with a 6-MW turbine, a study was started on a control system capable of stabilizing such a system even under critical working conditions that might lead to instability (e.g. strong winds).

Some research was also carried out on wind farm production forecasting. With the help of the utility Enel, the possibility of forecasting wind production

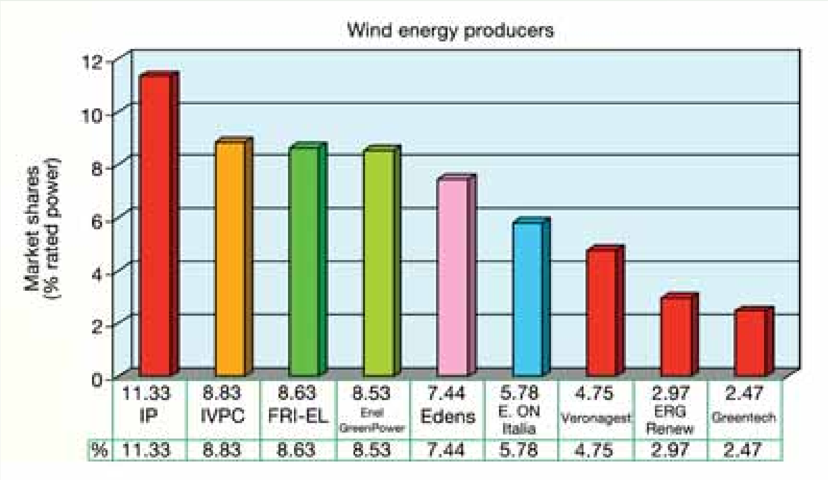


Figure 5 The main electricity producers from wind in Italy at the end of 2009 (as percentages of total online capacity)

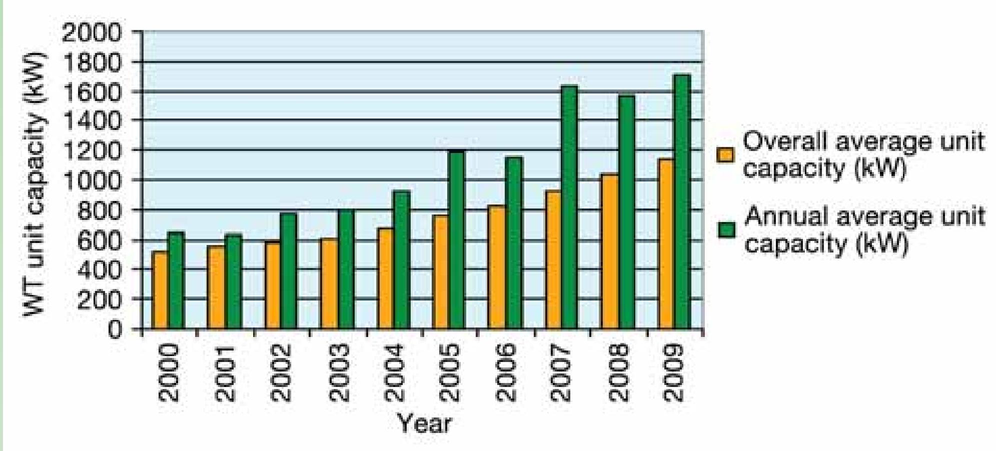
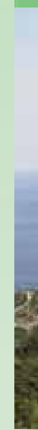


Figure 6 Trend of wind turbines capacity



by limited-area meteorological models (LAM) was investigated.

For determining environmental compatibility, a new section of the Wind Atlas was implemented that provides information on areas that are restricted for nature or landscape protection, and other constraints. Then a software application was developed for 3-D rendering of visual impact of wind farms on a given area. On this basis, a software tool based on a set of indicators for use by decision makers in evaluating the visual impact of wind farm projects was then developed and tested on sample cases.

Further research work has been carried out by universities on specific subjects. The University of Trento has been running its own test field in a mountain environment to test and characterize small wind turbines ranging from 1.5 kW to 20 kW (test results are available on http://www.eolicotrento.ing.unitn.it). The Polytechnic of Milan, through its Aerospace Engineering Department, has been working with industry, particularly concerning wind turbine aero elastic modeling and control system design. The department has also been performing tests in their wind tunnel. The University of Naples has been conducting research on anemometers and small-sized wind turbines also by wind tunnel tests. As for offshore wind farms, work has been under way at the University of Bologna, which has a special interest in foundations, and at the Physics Department of the University of Genoa for assessment of offshore wind resources. Feasibility studies have been carried out on offshore wind farms in Sicily jointly by the University of Catania and ENEA.

A floating wind system with an 80-kW turbine mounted on a TLP floater was tested by the BlueH company for a few months some 20 km off Tricase (Apulia) in 100 to 110-m deep waters. Another prototype with a 2.5-MW turbine will be tested at the same site. In addition, a consortium led by BlueH including companies and research centers has been granted funds by the Italian government under the "Industria 2015" program for developing a 3.5-MW system of the same concept.

Lastly, mention should also be made of some research and experiments on kite wind generators, carried out by KiteGen with the help of Sequoia Automation and the Polytechnic of Turin.

4.2 Collaborative research

Within the framework of the IEA Wind Implementing Agreement, ERSE has continued participating in Task 11 Base Technology Information Exchange, and Terna (Italian TSO) has been taking steps to join in the second term of Task 25 Power Systems with Large Amounts of Wind Power. The Department of Aerospace Engineering of the University of Naples has shown intrest in joining Task 27 Development of Small Wind Turbine Labels for Comsumers. ENEA, Enel, the University of Florence, APER (Renewable Energy Producers Association), CSM SpA, and others have taken part in the European Wind Energy Technology Platform (TPWind) set up by the European Commission. The Italian government has been consulting with ERSE, the University of Rome 3, and others with a view to defining the position of Italy with regard to the European Wind Initiative (EWI) proposed by the European Commission in its SET-Plan.

5.0 The Next Term

According to Terna (Italian TSO), on the basis of financial engagements taken by wind investors for connecting their planned wind farms to the grid, total installed capacity could well reach 6,000 MW by the end of 2010 and likely 9,600 MW in 2013 to 2014. Estimations of exploitable potential have been made by various entities: ERSE in 2006 estimated up to 12,000 MW onshore plus 1,000 MW to 2,500 MW offshore between 5 km and 40 km from the coastline (up to 6,500 MW including waters deeper than 60 m); the government's 2007 Position Paper set a potential of 12,000 MW (10,000 onshore and 2,000 offshore) to be reached by 2020; and the wind energy association ANEV calculated 16,200 MW exploitable by 2020. From this, it could be inferred that a considerable part of Italy's best onshore potential has already been exploited with the 4,850 MW capacity installed so far (end of 2009). Many of the remaining onshore sites are likely to be exploited at increasing costs.

A different perspective could be opened if offshore installations, none of which is operating in Italy yet, were to come on stream, but current offshore technologies look unfit for the deep waters that are often found where offshore wind resources are best. For offshore wind farms to give a substantial contribution to electricity production from RES, it is advisable to devote more efforts and resources to technologies of floating wind systems.

Authors: Claudio Casale, ERSE and Luciano Pirazzi, ENEA, Italy.

1.0 Overview

At the end of 2009, the total wind power apacity in Japan was 2,056 MW (1,609 turbines) with an annual net increase of 176 MW. The national target of Japan is 3,000 MW by 2010 (2008 to 2012), for which we are now two thirds of the way (Table 1). On 22 September 2009, Prime Minister Yukio Hatoyama declared at the United Nations Summit that as a mid-term goal, Japan will aim to reduce GHG emissions 25% by 2020, as compared to the 1990 level. A condition of this goal, however, is the establishment of a fair and effective international framework with the participation of all major economies. 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. The portion of the national budget allocated for wind energy development by the government was 22.7 billion JPY (0.17 billion €), mostly as subsidies. New generic R&D started and offshore development progressed with the building of two offshore meteorology masts. However, wind energy deployment in 2009 did not show big progress for several reasons: a load map for wind was not settled, the grid-connection issue still stands in the way, some local citizens' groups started campaigns against wind, and the new building code delayed wind power development.

2.0 National Objectives and Progress

Currently, the national policy remains unchanged and mainly consists of wind power development promotion by subsidies, wind technology R&D development, and by Renewable Portfolio Standards (since 2003). A total of 22.7 billion JPY (0.17 billion €) was allocated to 58 wind projects as subsidies under the New Energy Development Supports program in 2009. After a new green house gas (GHG) emissions target (25% reduction by 2020) was proposed last September, the role of wind energy is under consideration by the government.

2.1 National targets

The national target for wind power development that would contribute to decreased GHG emissions is 3,000 MW installed capacity by 2010, which will be rather difficult to achieve. A new target for 2020 or in the range of next few decades is now being discussed.

2.2 Progress

The cumulative wind power capacity was 2,056 MW (1,609 turbine units) with 176 MW of annual net increase (increase ratio: 9.4%). Figure 1 shows the history of wind power development in Japan. Wind power generation in 2009 was 3,137 GWh/yr and the contribution of wind power to the national energy demand accounted for 0.37%.

2.3 National incentive programs

The most important incentive program is the New Energy Development Supports subsidy program, which represents 97% of the national wind energy budget conducted by the Ministry of Economy, Trade and Technology (METI). Other incentive

Table 1 Key Statistics 2009: Japan	
Total installed wind generation	2,056 MW[1]
New wind generation installed	176 MW[2]
Total electrical output from wind	3.138 TWh[3]
Wind generation as % of national electric demand	0.37%[4]
Target:	3,000 MW by 2010[5]

1. Statistics at the end of December 2009, based on grid-connected wind plants
2. New capacity (178 MW) minus decommissioned capacity (2 MW)
3. Estimated based on home page data, Japanese Renewables Portfolio Standard System, METI
4. Electric power demand in 2009 was 846.1 TWh (Data: home page of the Federation of Electric Power Companies of Japan)
5. In the period of 2008 to 2012

programs include: R&D of Next-generation Wind Power Generation Technology, R&D of Offshore Wind Power Generation Technology, and the wind technology standards program (Table 2). R&D programs are directed by the New Energy and Industrial Technology Development Organization (NEDO) and then contracted to research institutes or universities.

In addition to the subsidy and R&D programs, renewable portfolio standards (RPS) are in place to increase wind energy development. The RPS target was set as 12.2 TWh for fiscal year 2009, which corresponds to about 1.44% of national electricity demand. The target increases yearly and is 16.0 TWh for fiscal year 2014—about 1.63% of electricity demand.

2.4 Issues affecting growth

Since a considerable number of wind turbines have been damaged by typhoons and lightning hits, a national committee has investigated all turbine failures for the last six years. The average chance of failure (defined as a wind turbine generator stopping operation more than three days) is 0.15 times per year per unit. This means that one turbine will have 3 times of failure during its 20-year lifetime. Concerning natural hazards, 182 failures were caused by lightning hits, and 35 failures were caused by typhoons, storms, and turbulent flows.

These statistics suggest that the southwest part of Japan needs IEC S-class wind turbines that can survive extreme winds and severe lightning strikes. Regarding extreme wind speed, IEC S-class is defined as three seconds averaged wind speed above 70 m/s. Regarding lightning strength, Japan defines S-class as a lightning strike with current up to 20 MJ/Ω of specific energy, which requires a charge capacity of 600 Coulombs.

To encourage investment in S-class turbines, the government provides an incentive scheme such that the subsidy rate is 1/3x0.9 for 1-S class turbines (designed against either of extreme wind or lightning strike) and 2-S class turbines (designed against both), instead of the usual 1/3x0.8 of initial cost for normal turbine. In spite of such efforts, judging from the annual growth rate of wind power capacity shown in Figure 1, the growth curve is quite liner. This trend suggests that a considerable contribution of wind generation to the ambitious national GHG reduction target is still a long way off.

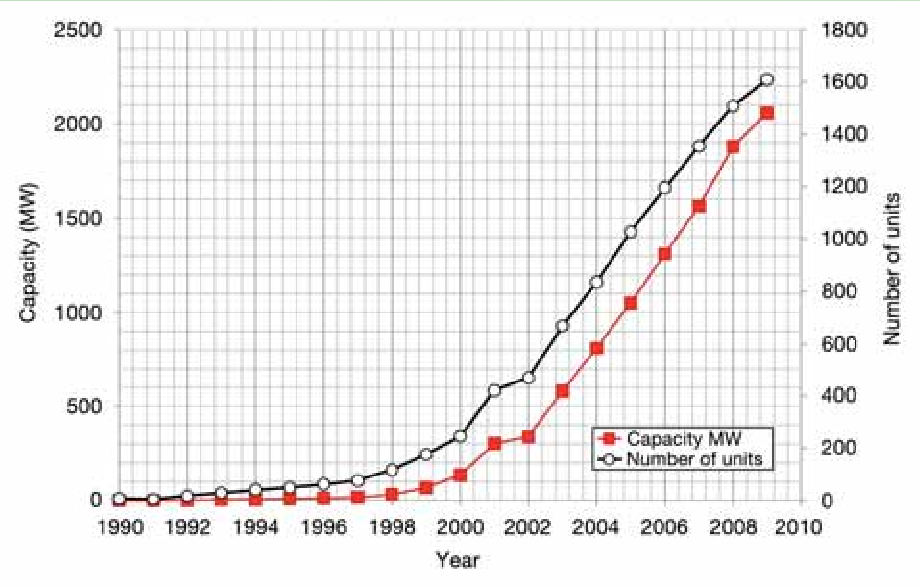


Figure 1 History of wind power development in Japan through December 2009

One advance in incentives for renewables was the government introduction of a feed-in tariff system. However, this first feed-in tariff focuses only on solar photovoltaic (PV) systems. The generated electricity shall be purchased at 48 JPY/kWh (0.36 €/kWh). Citizens buy electricity for their domestic use at around 24 JPY/kWh (0.18 €/kWh), so this is a good incentive to install PV systems. On the other hand, electric power companies announced the purchase price of 12 JPY/kWh (0.09 €/kWh) for electricity generated by domestic use of small wind turbine generators.

3.0 Implementation

Although Japan experienced rather slow progress, the contribution of the wind power developments to the national economy is increasing as considered below.

3.1 Economic impact

The sum of the subsidies provided to the wind power developers by the government in 2009 (from April 2009 to March 2010) was about 22.7 billion JPY (0.17 billion €). Considering the rate of the subsidy is 30%, it can be estimated that 76 billion JPY (0.57 billion €) 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 wind is estimated at approximately 400 billion JPY (3 billion €), which corresponds to about 6,000 jobs. Figure 2 shows the recent growth of wind industrial statistics.

3.2 Industry status

There are three Japanese wind turbine manufacturers that produce turbines above 1 MW: Mitsubishi Heavy Industries, Ltd. (MHI), The Japan Steel Works, Ltd. (JSW), and Fuji Heavy Industries Ltd. (FHI) & Hitachi Ltd. (Hitachi). The relatively new manufacturers, JSW and FHI & Hitachi, grew to supply 32 units and 10 units respectively in the home market. MHI made a considerable contribution to U.S. market. As a result, these three companies supplied 986 MW of capacity (570 units) worldwide and 95 MW (47 units) in the domestic market in 2009 (domestic share was 10%). Additionally, these three companies have around a 50% share in the Japanese market from 2005-2009, if the plants under construction are included. This analysis calculates an economic contribution of more than 100 billion JPY (0.751 billion €) from wind turbine manufacturers.

Additionally, Japanese machinery and electric manufactures supplied a considerable number of turbine components such as bearings, generators, and power devices, worldwide. They are making an effort to expand their business rapidly. For bearing companies, NTN has purchased French SNR, and JTEKT. NSK are expanding their production lines. For electric machinery companies, Hitachi organized a "Renewable Energy & Smart Grid

Table 2 National incentive programs in 2009

Project Name	Category	Operating Institutions	Budget FY 2009 (MJPY) (Apr. 2009-Mar. 2010)
R&D of Next generation wind power generation technology	R&D	METI/NEDO/TEPCO, CTC, JEMA, etc.	439
Generic R&D			98
Lightning Protection			231
Failure investigation			17
Wind turbine sounds			93
R&D of offshore wind power generation technology	R&D	METI/NEDO/TEPCO, J-Power, etc.	247
Offshore			255
Ocean energy			22
New energy development supports	Subsidy	METI/New Energy Promotion Council	22,669
Infrastructure technology for wind	Standard	METI/NEDO/JEMA	12
Total			23,355

AIST National Institute of Advanced Industrial Science and Technology
CTC ITOCHU Techno-Solutiions Corp.
JEMA Japan Electrical Manufacturer's Association
TEPCO Tokyo Electric Company

Division" in May 2009 and announced plans to expand its new energy business from its current 25 billion JPY (0.19 billion €) to 200 billion JPY (1.5 billion €) by 2015. Toshiba, Fuji Electric, and Meidensya are also following Hitachi.

Commercial offshore development has been quite slow. Japan has two near-shore wind 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 Setana Town since 2003. The other is a 10-MW plant (five Vestas 2-MW units) that is 50 m offshore of Sakata Port, Akita, and operated by Summit Wind Power Sakata since 2003. A remarkable new plant is now under construction 40 m offshore of Kamisu, Ibaraki (Figiure 3). It is the first open-sea 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.

Komai Tekko Inc. has developed a 300-kW mid-scale wind turbine that is designed as an IEC S-class wind turbine with Iref (turbulence intensity) of 18%. One unit was erected in 2009 at the test field of the Instituto de Investigaciones Electricas in Mexico as a research machine. In Japan, five of the Komai 300-kW turbines are being planned for introduction on a small island. Such a mid-scale turbine has good market potential because it is easy to transport and build in mountainous areas as well as on small islands, and it has less visual impact.

Zephyr Corporation developed a small, 1-kW wind turbine. Zephyr supplied 500 units domestically and 500 units abroad in 2009. Zephyr is active in R&D and field testing to co-operate with domestic and foreign national institutes such as AIST in Japan, CIEMAT in Spain, and CanWEA in Canada.

3.3 Operational details

A remarkable wind farm installed in 2009 is the Shin Izumo Wind Farm in Izumo city, Shimane Prefecture (opening photo). Developed by Shin Izumo Windfarm Corporation (a subsidiary of Eurus Energy Holdings Co.), it is the largest wind farm in Japan with 24 Vestas V90 3.0-MW turbines, and a total capacity of 78 MW.

3.4 Wind energy costs

Under the co-operative investigation by METI, NEDO, the Japanese Wind Power Association (JWPA), the Japan Wind Energy Association (JWEA), the Wind Power Developers Association (WPDA), and the Global Wind Energy Council (GWEC-Japan), the average economic values/costs are estimated as follows:

- Turbine cost
  200,000 JPY/kW (1,502 €/kW)
- Installed project cost
  300,000 JPY/kW (2,253 €/kW)
- COE
  11.0 JPY/kWh (0.07885 €/kWh)
- Wind electricity purchase price 7 to 9 JPY/kWh (0.052 to 0.068 €/kWh)
- O&M costs
  6,000 JPY/kW/unit/yr (45 €/kW/unit/yr)
- Subsidy
  1/3x(0.8, 0.9, 1.0) of project cost

4.0 R, D&D Activities

Of the total national wind energy budget of 23,355 million JPY (175.4 million €) for 2009, 686 million JPY (5.15 million €) (2.9%) was the R&D related budget, as shown in Table 2.

4.1 National R, D&D efforts

The national R&D program has following structure:

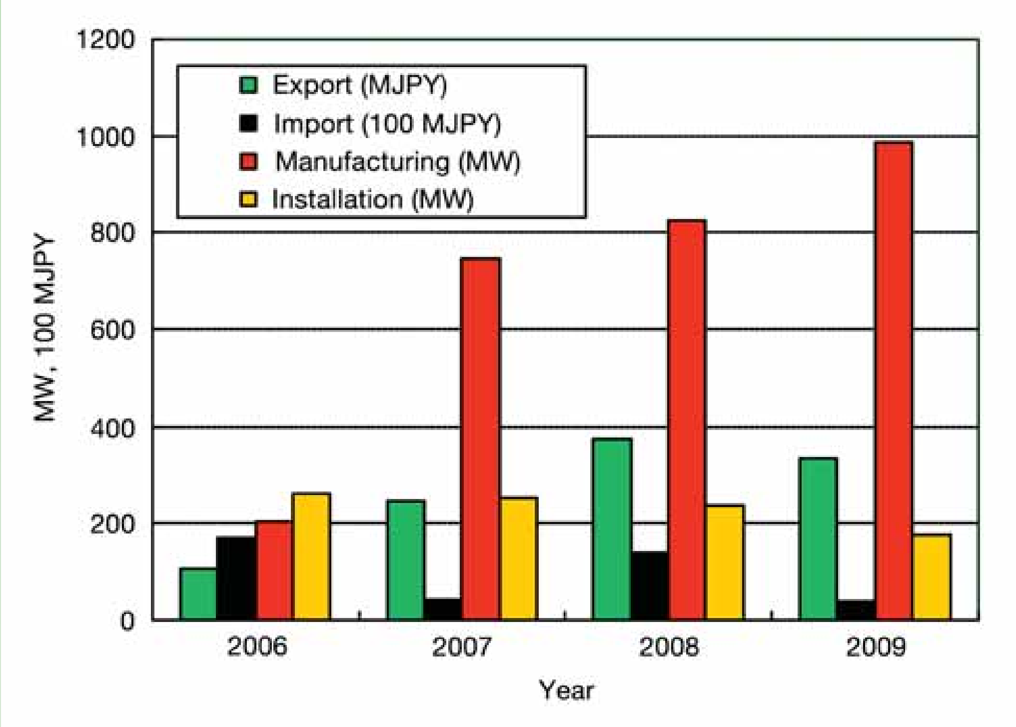


Figure 2 Recent wind industrial statistics

A. Research and Development of Next-generation Wind Power Generation Technology (2008 to 2012)

- A1 Generic R&D; main target fields are basic turbine technology that will survive the severe Japanese external conditions
- A2 Lightning Protection; measurements and creating lightning map
- A3 Failure Investigation; statistical survey and publication
- A4 Wind Turbine Sounds.

B. Research and Development of Offshore Wind Power Generation Technology (2008 to 2013)

- B1 Offshore Wind; construction of two offshore measurement towers
- B2 Ocean Energy.

Concerning A1, in 2009, an enormous amount of wind data that was measured under the NEDO Field Test Program at 418 sites from 1995 to 2008 was statistically re-analyzed. The intent was to clarify the characteristics of Japanese wind conditions, which are severely affected by typhoons and highly turbulent flows in complex terrain. One of the remarkable findings is that between 1/4 and 1/2 of the wind plant sites might suffer from higher turbulence intensity than IEC standard classes. It is very important to understand the structure of the high turbulence intensity map, and to classify standards accordingly for turbine construction in Japan. As IEC 61400-1 covers no practical indication on S-class definitions, some new ideas obtained from this work would be useful in designing and operating wind turbines in complex terrain, not only in Japan but also worldwide.

Another main target of the next-generation wind power generic R&D program is to develop advanced remote sensing technology that enables measurement of wind flow fields around a MW-class wind turbine in complex terrain. This technology is conducted by field measurements, but also supported by wind tunnel testing and CFD (Computational Fluid Dynamics). This technology will provide much more reliable siting techniques as well as wind performance measurements and evaluation.

Wind turbines failures caused by lightning hits are extremely significant, and accounted for 168 out of 219 nature-oriented failures (77%) in the past 5 years. Thus, R&D on lightning protection (A2) is also being pushed forward to find effective measures based on measurements against lightning strikes.

The Failure Investigation Program (A3) is designed to investigate all the failures/accidents of wind turbines in Japan and to improve their availability by identifying the failure sources and resolving technical measures. The failure reports will contribute to creating J-class wind technology (technology especially for Japanese severe conditions) when combined with other national activities such as A1, A2, and wind turbine standards.

In 2009, the Offshore Wind Technology Project (B) moved forward to the offshore wind/ocean measurements phase. Two offshore sites were selected, one at Choshi and one at Hibiki-nada. The Choshi site is 3 km from the coast line of Choshi city, Chiba prefecture. The site faces the Pacific Ocean, where a 78-m meteorological mast with 6 stages and 18 anemometers is under construction at a water depth of 11 to 12 m. The research team is made up of scientists from the Tokyo Electric Power Company and the University of Tokyo. The Hibiki-nada site is 1.7 km from coast line in the Hibiki open sea between the mainland and Kyushu Island in Fukuoka city, Fukuoka prefecture, where a 86-m meteorological mast with 6 stages and 18 anemometers is under construction at a water depth of 14 m. This site has a higher chance of typhoon attacks. The research team is made up of scientists from J-Power, Port & Airport Research Institute, and Itochu Techno-Solutions Corporation. The

Fiigure 3 The 14-MW offshore wind plant a Kamisu, Ibaraki.

research period is from 2009 to 2013 and demonstration plants will be developed after 2013.

4.2 Collaborative research

A generic R&D budget was revived in 2008 after several years of stagnation. Thereby, broader IEA Wind R&D collaborative activities became achievable, and Japan has joined Task 11 Base Technology Information Exchange, Task 25 Power Systems With Large Amounts of Wind Power, Task 27 Consumer Labeling of Small Wind Turbines, Task 28 Social Acceptance of Wind Energy Projects, and Task 29 MEXNEX(T) Aerodynamics.

Small wind turbine technology has progressed and is expected to contribute to the wind power market. This conforms to foreign trends such as in Spain, Sweden, the United Kingdom, the United States, and others. Therefore, Japan has joined in Task 27 Consumer Labeling of Small Wind Turbines and has offered to host the fifth IEA/IEC Liaison meeting on the topic in Tokyo. The backgrounds are quite similar among the countries in that although small turbines have been developed, social environments are very primitive. A kind of common consensus is to create reliable markets for small wind turbines with a consumer labeling system for safety, performance, and social impact within each country.

As should be clear from the present report, Japan has some severe natural conditions. From a technical aspect, a higher level of international standards is necessary to supply wind turbines, whether domestic or imported, that are tougher against natural hazards. Therefore, international collaboration on IEC standards is very important to combine national R&D activities as well as IEA Wind research. With a considerable amount of measured data all over Japan, a revision proposal for IEC 61400-1was sent to IEC Technical Committee 88.

5.0 The Next Term

Wind power development in Japan is just in a break. The national target of 3,000 MW by 2010 is not likely to be attained. The present R&D projects will continue for the next 4 to 5 years, which will create advanced wind technologies including offshore technology. Further, the new ambitious target of a 25% reduction of GHG emissions by 2020 that was proposed by the new government will break through the current slump in wind power development if proper and fair measures are provided in the national politics and economics.

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Korea, Republic of

Photo courtesy of Acciona

1.0 Overview

The cumulative installed wind power in The Republic of Korea was 304 MW in 2008 and 392 MW in 2009, increasing by 29% over one year. An RPS proposal for new and renewable energy is to be approved by the Congress. The utility firms prefer wind energy, which is considered to be the most cost-effective among all new and renewable sources.

Until the end of 2008, the government had focused on localizing the manufacturing of wind turbine systems. In 2009, the government concentrated on the localization of components to secure the supply chain. To provide a track record in the field for local development, a wind farm demonstration project is to be finalized by the end of 2015, and 300 MW of wind power will be installed on the shores of the west coast of Korea.

2.0 National Objectives and Progress

The first locally manufactured turbines were installed in Korea in 2009 and installed capacity of wind turbines increased 29%, despite the financial crisis. Due to the drastic increase in oil prices late in 2008, the average system marginal price of electricity was 122.63 KRW/kWh (0.0735 €/kWh), compared to 105.04 KRW (0.0630 €/kWh) in 2009, which means wind energy is comparable in economics with the existing LNG (Liquefied Natural Gas) sources in Korea.

2.1 National targets

The national target is for wind power to reach 7.3 GW by 2030 as stipulated in the Third National Energy Plan 2030, sharing about 12.6% among the new and renewables. At the end of 2008, it was reported that the energy from new and renewable energy accounted for 2.43% of total energy consumption, which is should reach 11% by 2030.

2.2 Progress

Many of the wind turbines installed in 2009 were imported, such as Vestas (Denmark), but 8.4 MW of new capacity was from locally manufactured wind turbines. Korean manufactured turbines accounted for 2.4% of the capacity installed in 2009.

Table 1 Key Statistics 2008: Korea	
Total installed wind generation	392 MW
New wind generation installed	88 MW
Total electrical output from wind	.678 TWh
Wind generation as % of national electric demand	0.15%
Target:	7.3 GW by 2030

Table 2 Total installed wind capacity in Korea										
Year	~2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
Capacity (MW)	7.9	4.7	5.4	50	30	77	18	111	88	392
Electrical Output (GWh)	25	15	23	38	125	234	371	421	678	

The largest wind farm completed in 2009 was the Youngyang wind farm, which is equipped with 41 units of 1.5-MW Acciona wind turbines and represents 61.5 MW of power capacity (opening photo).

2.3 National incentive programs

The government subsidizes part of the installation costs of the NRE (New and Renewable Energy) facilities to enhance deployment and to relieve the end user's cost burden. For wind energy, the government subsidizes 50% of the installation cost for wind turbines for demonstrations or for private use of turbines smaller than 10 kW.

Other incentive programs are as follows:

- Million Green Homes Program: In order to help build a favorable investment environment in residential areas, the government has been expanding the existing 100,000 solar roof program to diversify and optimize renewable energy use. The aim is to have one million green homes by 2020.
- Green requirement to public buildings: New construction, expansion, or remodeling of public buildings that have a floor area which exceeds 3,000 square meters are required to invest more than 5% of their total construction expenses in installation of new or renewable energy systems.
- Feed-in Tariff: The standard price will be adjusted annually reflecting the change of the NRE market and economic feasibility of NRE. Concerning wind energy, the feed-in tariff was 107.22 KRW/kWh (0.0643 €/kWh) as a flat rate for 15 years in 2009. For newly installed wind farms, it is planned to decrease by 2% every year.
- RPA (Renewable Portfolio Agreement): Large Public Utilities agreed with the Korean government to invest $737 million KRW (0.442 million €) in NRE between 2006 and 2008, and plan to transform to RPS in 2012 after the second agreement period (2009-2011).

In addition, Loan & Tax Deduction, Local Government NRE Deployment Program, and others are available as national incentive programs.

2.4 Issues affecting growth

Korean manufactured MW-scale wind turbines need to become approved by certifying authorities to build a track record. Testing offshore turbines will help achieve this goal. Therefore, the government set out to create an offshore test bed with a total capacity of 100 MW by 2012 along the shore of Shinan in the Jeonlabukdo province. To encourage wind projects for the utility companies, the RPS is subject to be enacted in 2010 and will come into effect in 2012. As a result, the demand by utility firms for large wind farms which are economically efficient will rise. This, in turn, created the need for a feasibility study on 5 GW of offshore wind on the west coast.

3.0 Implementation

3.1 Economic impact

At the end of 2009, in addition to the existing MW-scale wind turbine manufacturers, it was found that more than 100 companies had entered into the small wind turbine business. This resulted in the need for wind turbine experts, and in response, the government supports the programs that train these experts. Due to the dramatic increase in the wind energy industry, the statistics on workers associated with wind industry including the supply chain is unclear.

3.2 Industry status

In 2009, Daewoo Shipbuilding & Marine Engineering (DSME) acquired DeWind; and STX was taken over Harakosan. There are now nine Korean manufacturers of MW-scale wind turbines.

3.3 Operational details

More than ten units of 3-MW Vestas turbines were installed in Jeju island, bringing the average turbine size up to 2.5 MW in 2009. In addition to importing turbines, the effort to develop a domestic industry continues.

The first 3-MW offshore wind turbine by Doosan Heavy Industries was erected in the national test bed situated in Jeju island in October of 2009. After commissioning, it reached rated power successfully. Once Doosan succeeds in having their offshore wind turbine certified, the development of offshore wind farms will be realized to the fullest degree.

The 2.0-MW wind turbine with doubly-fed induction generator (DFIG) developed by Hyosung has already been certified by DEWI-OCC. The 2.0-MW wind turbine with permanent magnet synchronous generators (PMSG) by Unison, the 1.65-MW wind turbine by Hyundai Heavy Industries and the 3.0-MW wind turbine by Doosan Heavy Industries are undergoing field tests for type certification.

3.4 Wind energy costs

So far, most of the wind turbines have been imported from overseas. This has created additional costs for developers accrued from the change in the exchange rates and logistics. Due to the short history of well-developed business models based on private capital, there are not enough statistics available to break down the costs.

4.0 R, D&D Activities

4.1 National R, D&D efforts

The government sponsored project budget increased by a great margin in 2004 and 2006, and again showed a noticeable increase in 2009 compared to previous

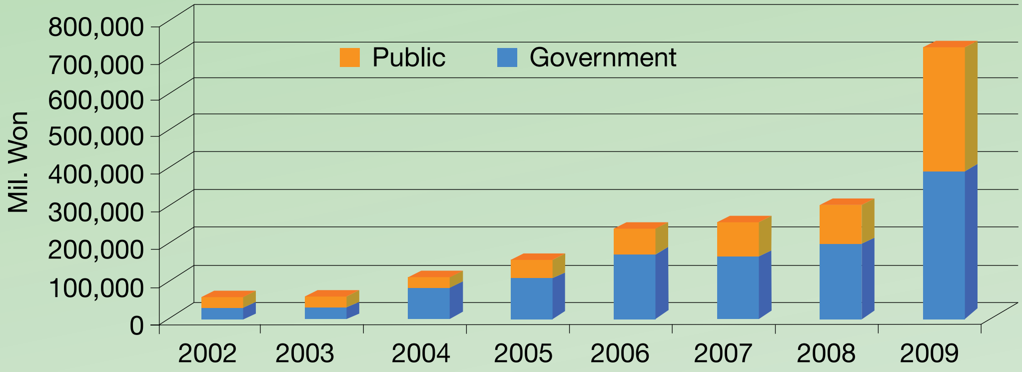

Figure 1 The budget trend of government sponsored R,D&D

years (Figure 1). By the end of 2008, the government was focusing on domestic manufacturing of wind turbines. However, as of 2009, the government has been concentrating on local production of components to secure the supply chain. Consequently, to support the domestic manufacturers government sponsored projects have started regarding 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.

In response to the demand for national test sites, in 2009 a second test bed was completed in Jeju Island for two 3-MW onshore wind turbines. The prototype 3-MW wind turbine by Doosan Heavy Industries is undergoing a type test. For the time being, the feasibility study is in progress on development of a 100-MW offshore wind farm by 2012 on the west coast.

5.0 The Next Term

In 2010, an additional 300 MW of wind power is to be installed and the RPS will be also enacted. As a result, wind energy is expected to make rapid progress in 2010. Furthermore, it is highly likely that the government will support the development of offshore foundations, including the floating type, so as to vitalize the development of offshore wind farms.

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1.0 Overview

During 2009, 261 new wind turbines were commissioned in México, bringing the total wind generation capacity to 415 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 two IPP (Independent Power Producer) 100-MW wind power plants and also issued a call for bid for another three IPP 100-MW projects.

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. It is estimated that full implementation of technologically and economically feasible projects would lead to the construction of 10,000 MW of wind generation capacity. Mexico's largest wind energy resource is found in the Isthmus of Tehuantepec in the state of Oaxaca (Figure 1). Average annual wind speeds in this region range from 7 m/s to 10 m/s, measured 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.

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 will 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 Mexico and are owned and operated by the CFE.
- Parques Ecológicos was the first privately owned wind energy plant in Mexico, (the main investor is Iberdrola Renovables). It 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 electricity demand.
- Eléctrica del Valle de México (opening photo) has the largest wind turbines installed in Mexico, 27 2.5-MW turbines Clipper Windpower.
- La Rumorosa 1 is the first wind energy project for public municipal lightning.
- 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), and is the first small wind energy power producer in Mexico.
- 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/kW that will be granted by GEF through the World Bank.

Table 1 Key Statistics 2009: Mexico	
Total installed wind generation	415 MW
New wind generation installed	330.4 MW
Total electrical output from wind	***.500 TWh***
Wind generation as % of national electric demand	***0.25***
Target:	2.5 GW by the end of 2012 3% of 2013 national electric demand
Bold italic indicates an estimate.	

2.2.1 Contribution to electrical demand

Official information from wind power plants constructed during 2009 is not available yet. It was estimated that wind generation was 500 GWh, which means around 0.25% of national electric demand.

2.2.2 Environmental benefits

Potential reduction of CO_2 emissions for the year 2010 is 873,862 t, assuming the capacity already commissioned by the end of 2009 operates at 40%, and considering a mitigation rate of 0.6 t CO_2 per each wind generated MWh.

2.3 National incentive programs

The Law for the Use of Renewable Energy and Financing of Energy Transition is a sound signal from the government of México regarding both political will and commitment for implementing energy diversification toward sustainable development. The main elements of the strategy in the law include: presenting strategic goals; creating a Special Program for Renewable Energy; creating a green fund; providing access to the grid; recognizing external costs; recognizing capacity credit; encouraging technical standards for interconnection and infrastructure for electricity transmission; providing support for industrial development; and providing support for research and development. Some of the regulatory instruments for this law have already been issued while others are still under development. The existing incentives are:

- Model agreement for the interconnection of renewable energy power plants to the national electrical grid (2001), allows administrative interchange of electricity among billing periods
- Accelerated depreciation (up to 100% in one year) (2004)
- Recognition of certain capacity credit for self-supply projects.

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.

Figure 1 Wind generating capacity installed in Mexico as of December 2009

3.0 Implementation

3.1 Economic impact

By the end of 2009, it was estimated that the total investment in the construction of wind power plants is around 850 million USD. Assuming that around 80% of this amount corresponds to the cost of the wind turbines, the rest, around 166 million USD, 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 manufactures Acciona Windpower and Gamesa Eólica are leading the Mexican wind turbine market, but other prestigious companies like Clipper Windpower, Vestas, and Siemens have been awarded important contracts.

CEMEX 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 electricity consumers under the creation of self-supply consortiums. With the support of the federal government, the government of the state of Baja California is leading the implementation of a 10-MW wind energy project for public municipal lighting. This project will be commissioned in early 2010.

The Mexican company Potencia Industrial S.A. de C.V. is manufacturing PM electric generators for Clipper Windpower. More than 200 Mexican companies have the capacity to manufacture some parts required for wind turbines and wind power plants. 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 Mexico.

3.3 Operational details

During 2008, the combined electricity production from CFE's wind power plants, La Venta I (1.3 MW) and La Venta II (83.3 MW), was around 254 GWh. The facilities operated at an annual capacity factor of 34%, according to the manager of the wind power plants. It was expected that the capacity factor of La Venta II would exceed 40%; however, there were some constraints regarding the availability of the transmission line and some of the wind

Figure 2 La Venta II 83.3-MW wind farm in the Isthmus of Tehuantepec, Mexico

Table 2 Progress on wind generation capacity

Wind power station	No. WT	WT (KW)	WT Manuf.	Capacity (MW)	Status by the end of 2009	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	Constructed	POSS	2010	OAX
Certe-IIE F1	1	300	Komai	0.3	Constructed	FGOB	2010	OAX
E. Valle de México	27	2,500	Clipper	67.5	Constructed	POSS	2010	OAX
La Rumorosa I	5	2,000	Gamesa	10.0	Constructed	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
DEMSA	45	2,000	Gamesa	90.0	U. Construction	POSS	2011	OAX
Oaxaca II				102.0	Call for bids	IPP	2011	OAX
Oaxaca III				102.0	Call for bids	IPP	2011	OAX
Oaxaca IV				102.0	Call for bids	IPP	2011	OAX
Fuerza Eólica				30.0	Not initiated	POSS	2012	OAX
Eoliatec Istmo 1				22.0	Not initiated	POSS	2012	OAX
Eoliatec Pacífico				160.5	Not initiated	POSS	2012	OAX
Eoliacetc Istmo 2				142.4	Not initiated	POSS	2012	OAX
Gamesa Energía				288.0	Not initiated	POSS	2012	OAX
Vientos del Istmo				180.0	Not initiated	POSS	2012	OAX
Energía Alterna				215.9	Not initiated	POSS	2012	OAX
Unión Fenosa				227.5	Not initiated	POSS	2012	OAX
Fuerza Eólica 2				50	Not initiated	POSS	2012	OAX
Accumulated				**2,570.75**				

(1) FGOB=Federal Government, SGOB= State Government, POSS= Private owned self-supply, IPP= Independent Power Producer, IIE = Instituto de Investigaciones Eléctricas

(2) Commissioning year

turbines. Operational details for the new privately owned wind power plants are not yet available. It is expected that the major indicators would be released by late 2010.

3.4 Wind energy costs

Investment cost for installed wind energy projects in the Isthmus of Tehuantepec are around 2,000 USD/KW (1,388 €/kW). In that region, the levelized generation price over a 20-year period is around 0.065 USD/KWh (0.045 €/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.

Figure 3 The Wind Energy Technology Center operated by the IIE

4.2 Collaborative research

The IIE is participates in IEA Wind Task 11 Base Technology Information Exchange.

5.0 The Next Term

During 2010, at least five wind power plants accumulating 207 MW will be commissioned, and the implementation of wind energy in other states will begin, particularly in Baja California and Tamaulipas. In addition, at least five projects totaling 498 MW will start construction and be commissioned during 2011. This will bring the total generation capacity to at least 1,120 MW by the end of 2011. It is expected that, triggered by the commissioning of the wind energy 2,000-MW electrical transmission line, several other privately owned projects will start construction in 2010 or early 2011 to be commissioned by the end of 2012. It is anticipated that by the end of 2012, the total wind generation capacity will be around 2,500 MW.

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Courtesy Jaap 't Hooft, Agentschap NL

1.0 Overview

The total installed wind capacity reached 2,216 MW in 2009. Wind power generated 4,589 GWh of electricity or 4.0% of the total electricity consumption of 114 TWh (Table 1). The Netherlands government further increased its ambition level for wind energy. This implies an installed wind capacity of about 6 GW on land and 6 GW offshore in 2020.

2.0 National Objectives and Progress

2.1 National targets

The national target for electricity is 9% of total electricity consumption from renewable electricity in 2010. As part of the program "Schoon en Zuinig", the government has the ambition for the Netherlands to achieve energy savings of 2% per year, a share of renewable energy of 20% in 2020, and a reduction of greenhouse gas emissions of 30% in 2020 as compared to 1990. Until 2020, the government expects a considerable share of wind energy in the growth of renewable energy to come.

2.1.1 Wind on land

Present government ambition foresees to double the capacity for wind on land by 2011 (compared to 2007) and free the way to increase the capacity after 2011 to 6,000 MW installed on land. For the short term, solutions are being worked out for frequent bottlenecks in the implementation of wind energy on land in the Netherlands. This includes new regulations on noise and safety, radar disturbance, and further active project support on a local and regional level.

Additionally, the National Coordination Mechanism came into force as part of the Electricity Law as from 1 March 2009. This Mechanism allows for well-coordinated permitting and decision taking by governments at different levels and applies to larger energy-related projects, including wind farm projects over 100 MW. A similar mechanism at the Province level for smaller wind energy initiatives (5 to 100 MW) is under preparation for early 2010.

For the long term, the Ministry of Housing, Spatial Planning and the Environment (VROM) prepared a draft vision for spatial planning of 6,000 MW in 2020, in cooperation with various parties involved. The perspective includes ten

Table 1 Key Statistics 2009: The Netherlands	
Total installed wind generation	2,216 MW
New wind generation installed	67 MW
Total electrical output from wind	4.589 TWh
Wind generation as % of national electric demand	4%
Target:	9% Renewable Electricity in 2010
Ambition 2020:	12,000 MW wind generation installed

concentration areas for wind energy as well general directives for combinations of wind energy and other functions. It will be subject of further discussion in 2010.

2.1.2 Wind offshore (second round)

To reach the ambition of committing 450 MW offshore wind power in the present government 2008-2011 timeframe the ministries of Economic Affairs, Water Management and Environment published a strategy in June 2008. For a more detailed explanation of the scenario see the *IEA Wind 2008 Annual Report*. As part of a package to combat the effects of the economic crisis, the present government raised their ambition level from 450 to approximately 950 MW increasing the subsidy available to 4.5 billion €.

By the end of 2009, a total of 12 building permits for a total of 3,250 MW were granted to initiators (Figure 3). A tender for the SDE (*stimulering duurzame energie)* subsidy was opened and will be closed on March 1, 2010. Parties having acquired a building permit can submit a bid for the requested level of production subsidy. After a correction for the distance of the project to the shore, the proposals will be ranked according to the corrected price levels. The SDE budget allocated is expected to allow for two or three wind farms with an installed capacity of approximately 950 MW. Construction of these wind farms is expected to start in 2012-2013 and needs to be completed within five years after granting the subsidy.

2.1.3 Wind offshore (third round)

To reach the Netherlands' ambition of 20% renewable energy in 2020, the government is aiming at 6 GW of offshore wind capacity. To reach this target, the government wants to allocate locations for the further development of wind energy offshore. Preparations for the issue of locations were announced in June 2008 with an outline for a new policy for wind offshore. The third round is fundamentally different from earlier Dutch developments because the government designates so-called wind areas. These areas will be reserved for wind energy and the government commits itself to grant SDE subsidies for offshore wind energy only in these areas. Further details are described in the *IEA Wind 2008 Annual Report*.

The Ministry of Economic Affairs has investigated options for issuing areas for development of wind energy. This has led to two options for the issue of locations, i.e. larger areas (concessions) or smaller areas of 200 to 300 MW each within the wind areas offshore (more in line with the present approach). In both options, the Minister expressed the intention to establish close links between issuing of locations and granting of the subsidies.

A Task Force on Offshore Wind Energy was established by the Minister of Economic Affairs in May 2009. The Task Force will advise the Minister on the financial base for offshore wind energy and on preferred ways of cooperation between public and private sectors, with the aim to reach the target of 6,000 MW offshore wind in 2020. The advice is expected to be issued in April 2010.

The Ministry of Economic Affairs commissioned a study for the cost of an offshore electricity grid to accommodate 6,000 MW of wind power in 2020. Based on the results of this study, the Minister expressed the intention to award the Dutch TSO TenneT a legal role for development and management of the Dutch offshore electricity grid. Awaiting further clarity on related cost structures, the Minister has requested TenneT to continue preparations for such a future legal role (1).

The Ministry of Economic Affairs is actively participating in the North Seas Countries' Offshore Grid Initiative. This Initiative started with the Political Declaration signed 7 December 2009 by the Ministers of nine North Seas Countries (2). Its objective is to achieve a coordinated effort in the development of offshore electricity infrastructure and a compatible political and regulatory basis for long term development of offshore electricity infrastructure, involving all relevant stakeholders.

2.2 Progress (3)

The production of all renewable electricity increased from 7.5% of the total electricity consumption in 2008 to 9% in 2009, meeting the 2010 target for renewable electricity production. The increase was due to a combination of lower electricity consumption (approximately 5%) and growth in the production of wind electricity and electricity from biomass.

Wind generation as a share of national electricity consumption increased from 3.6% in 2008 to 4.0% in 2009. This is due to above mentioned decrease of the national electricity consumption on one hand and higher production of wind generated electricity (from 4,260 GWh in 2008 to 4,589 in 2009) on the other hand. Offshore wind generation counted for 16% of the total wind generation in 2009 (Figure 1). The total installed wind generation increased by 67 MW from 2,149 MW end of 2008 to 2,216 MW end of 2009 (Figure 2). On land, a total capacity of 101.4 MW was installed while 106 turbines with a total capacity of 34.8 MW were decommissioned.

In 2009, the production of wind electricity increased with almost 8% which is larger than expectations based on wind conditions and increased capacity. The improved operational efficiency is due to the relatively large increase of installed generation in 2008. The newly installed turbines had only partial operation during 2008.

2.3 National incentive programs

Two incentive programs relevant for wind energy projects exist in the Netherlands: The SDE production subsidy and the EIA tax incentive on investment. The EIA is a tax incentive scheme for investments in energy savings and renewable energy, 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

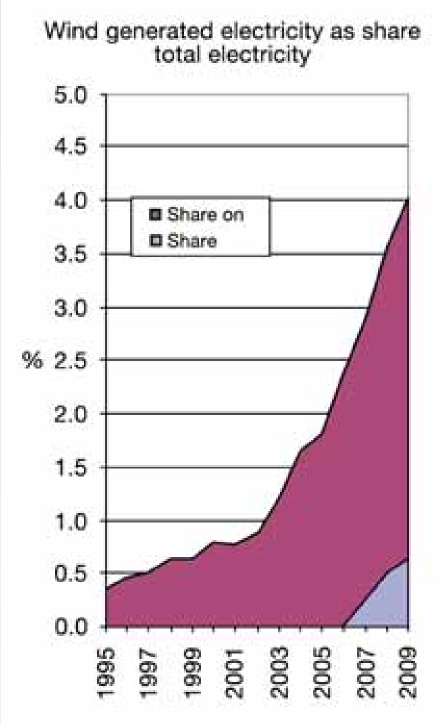

Figure 1 Wind generated electricity as share of total electricity demand (1995-2009)

the base subsidy tariff with the average market price of electricity. The IEA Wind 2007 Annual Report describes the SDE mechanism.

A structural change announced in 2009 is the modification of the financing mechanism for the SDE. A so-called SDE-charge will be added to the electricity and gas charges. This will reinforce the financing base for SDE moving it out of the yearly government budget discussions.

The annual assessment of ECN (Energy research Centre of the Netherlands) and KEMA (formerly Keuring Electrotechnisch Materieel Arnhem) the costs for renewable energy projects in the Netherlands was published in September 2009 (4). As a result of the assessment, a slight adjustment took place of the base subsidy tariff for SDE on land, from 94 to 96 €/MWh.

The Minister of Economic Affairs announced two new categories for the SDE to accommodate developments in turbine technology and to support the development of the large Noordoostpolder project.

The first category concerns turbines of at least 6 MW on land. The SDE base subsidy amounts 96 €/MWh for a maximum of 3,095 full-load-hours per year during 15 years. The second –only temporary- category is for turbines with a capacity between 3 and 5 MW placed in waters under municipal jurisdiction and has an SDE base subsidy of 121 €/MWh for a maximum of 3,118 full-load-hours per year during 15 years. Both categories only apply for projects of over 100MW. For the second round of offshore wind projects a tender within the SDE support scheme is organised (5).

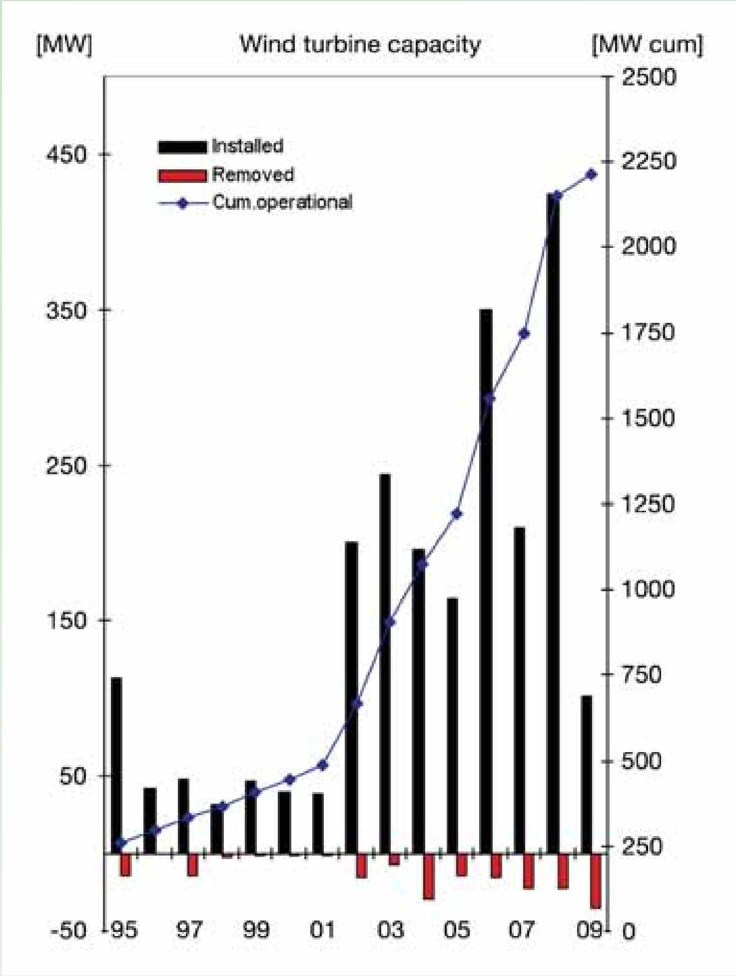

Figure 2 Installed, removed, and cumulative wind turbine capacity in the Netherlands

2.4 Issues affecting growth

Wind capacity on land shows a strong decrease in growth since the introduction of the SDE in 2008 (Figure 2), leading to an almost complete standstill in the second half of 2009 with 0.85 MW installed (6). This may be the result of various factors, including:

- changing financial requirements as a result of the economic crisis,
- limited progress in permitting of large-scale initiatives,
- increasing complexity of new projects involving up scaling and existing interests with turbine owners,
- speculation by project owners, counting on more attractive SDE base tariff, and
- possibly less attractive aspects of the SDE scheme as compared to the former MEP subsidy scheme.

Discussions concerning the structure and level of the SDE subsidy concentrate on regional differences in wind regime (the Minister decided not to include regional differentiation following an advice of ECN and KEMA), the mechanism and effect of the SDE full-load-hours methodology (which will be part of the SDE evaluation scheduled for 2010), and on additional project cost as a result of the increasing complexity of projects (e.g., compensation cost for owners of affected turbines, or cost of financial participation).

The growth of wind capacity offshore is presently limited by the amount of subsidy in the present second round for SDE subsidy. The planned elaboration of the mechanisms for the third round will enable further growth.

3.0 Implementation

3.1 Economic impact

Total investment in wind energy installations in the Netherlands for 2009 can be estimated at 52 million €, assuming an average investment cost for land-based wind of 1,325 €/kW for the 39 MW installed. The total investment in wind energy installations from 1995 to 2009, not corrected for inflation, is estimated at some 3,000 million €.

3.2 Industry status

3.2.1 Offshore developments

The Ministry of Transport and Public Works (V&W) granted a total of 12 construction permits for a maximum 3,250 MW (Figure 3). These initiators have the possibility to participate in the SDE tender for the second round.

In 2009, several developments took place with the commercial parties involved, of which the most prominent

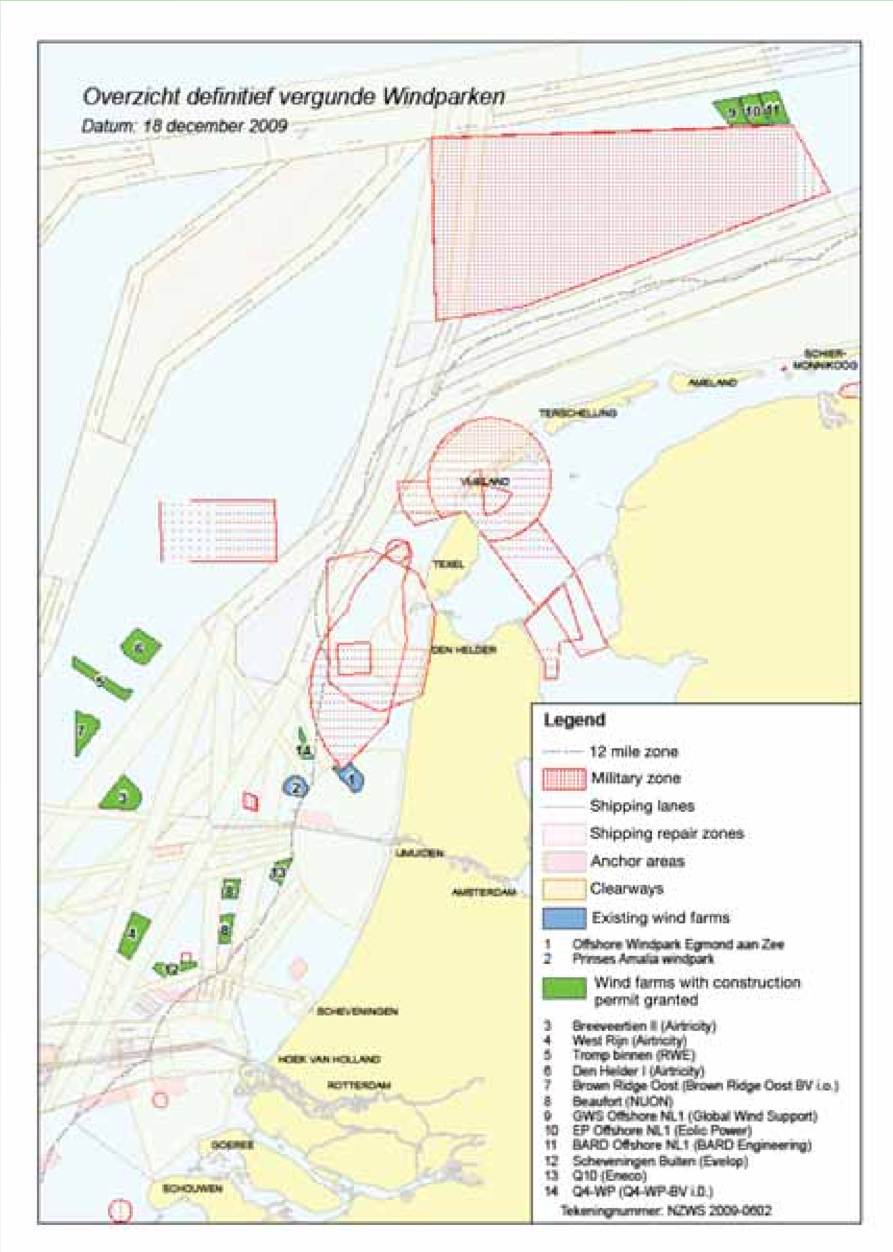

Figure 3 Overview of wind farms with construction permit granted

were the bankruptcy of Econcern N.V., of which important parts including project developer Evelop were taken over by energy company Eneco, and the sales of energy company Nuon to Vattenfall and energy company Essent to RWE.

3.2.2 Onshore developments

Major developments on land include two wind farms in the province of Flevoland, Zuidlob and Noordoostpolder.

The wind farm Zuidlob is a 108-MW wind project in the southern part of the province of Flevoland, based on joined forces of over 60 farmers and a project developer. The 36-turbine project is approaching the final permitting stage after the publication of a "Rijksinpassingsplan" in 2009. At the end of 2009, radar issues appeared to be the major bottleneck with the Ministry of Defense objecting because of national safety.

The wind farm Noordoostpolder has a long history with various projects joining forces. This resulted in an environmental impact study that was published for public consultation end of 2009. The "Rijksinpassingsplan" for the planned 80 to 100 large turbines is expected in early 2010. Part of the wind farm will be built in the IJsselmeer and construction of the 429-MW project is planned for 2012/2013.

3.2.3 Manufacturers and suppliers

In August 2009, Dutch wind turbine manufacturer DarwinD was taken over by Chinese XEMC after the bankruptcy of Darwind's shareholder Econcern. The development of the 5-MW direct-drive turbine for offshore conditions continued and two prototypes are planned for 2010 (7).

Dutch wind turbine manufacturer 2-B Energy is developing a new design for a large dedicated offshore wind turbine. The innovative wind power plant concept includes a 2-bladed rotor, a truss tower support structure, and a direct current power export system. The prototype begins operation during the first half of 2011 (8).

The first prototype of the 2-MW direct-drive turbine of Lagerwey Wind BV (L82 2.0) was erected in December 2009. This turbine is being developed as part of a production and sales license to Reliance ADA Group of India (9).

3.3 Operational details (10)

The average generation capacity per installed turbine slightly decreased to 1,982 kW in 2009. This is mainly due to the large number of relatively small turbines E52 Vestas turbines installed in a number of projects. From the total 51 turbines installed, 29 have a capacity of 2 MW and over. Of the new wind turbines installed in 2009, the Vestas share was 50% and the Enercon share amounted 40%, while Nordex and Siemens shared the remainder.

4.0 R, D&D Activities

4.1 National R, D&D efforts

4.1.1 R, D&D priorities and budget

No changes in research priorities concerning wind energy took place in 2009. For a complete description of the Netherlands research priorities refer to the IEA Wind 2007 Annual Report. National government allocations for wind energy R, D&D in 2009 amount to approximately 10 million €, mainly for offshore wind energy. This includes base finance of ECN and TU Delft of approximately 4.5 million €.

4.1.2 Energy Innovation Agenda

The Innovatieagenda Energie (Energy Innovation Agenda) was formulated in 2008 and the Ministry of Economic

Affairs allocated 438 million € for the period 2008-2012 to speed up the large-impact innovation processes for the transition to a sustainable energy supply. As part of this Agenda, a tender was organised to support the development of offshore wind turbines larger than 4 MW and/or related support structures. The tender will close in early 2010 and 9 million € will be available to support two or three projects (11).

In September 2009, the FLOW (Far and Large Offshore Wind) proposal was presented to 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 and 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. At the end of 2009, the possibilities for a governmental contribution were under discussion (12).

Under the same Energy Innovation Agenda, a support program for wind on land has been under discussion in 2009. The program will support innovative project development approaches, with a focus on complex up scaling and participation issues, and it will be launched early 2010.

4.1.3 Offshore electricity grid

In addition to the study of a Dutch offshore electricity grid referred to in section 2.1, a research and development project is under way called North Sea Transnational Grid (NSTG). ECN and TU Delft intend to determine optimal technical solutions for an international offshore electricity grid. This high-capacity grid should be able to connect all future wind farms in the Northern part of the North Sea. The project partners closely cooperate with IEA Wind Task 25.

As part of a package of 15 energy projects for European economic recovery, the project Cobra Cable was announced at the end of 2009. The project by Dutch TSO TenneT B.V. and Danish Energinet.dk invest in innovative designs for direct connection of offshore wind farms and the modular start of the North Sea Grid related to a large capacity interconnector between the Netherlands and Denmark. The EU supports this project with maximum 86.54 million €.

4.1.4 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 2009. The MEP-NSW covers two areas: 1. Technology and economics and 2. Environment and public opinion. All reports and data (except other data below) are freely available (13). Results were presented at the European Offshore Wind Energy Conference 2009, Stockholm.

A series of half-year reports with analyses of wind climate characteristics at the 116 m high meteorological mast are being produced. The updates for 2009 are now available including the associated 10-min average wind measurements of the site at three heights of the meteorological mast. Also, two reports on the long term wind characteristics are available. Wave and current data are integrated in the files of the 10-min average wind measurements of the site. A report with a description of the relation of wind, wave and current characteristics is available.

In the Operations Report 2008, NoordzeeWind gives an account of the second year of operation of the wind farm. It contains data of the availability of the wind farm and its energy production, losses and downtime per subsystem. It also contains a complete overview of all data and reports delivered by NoordzeeWind on behalf of the MEP-NSW in 2008. NoordzeeWind's conclusion is that the wind farm, having generated 315 GWh with an average wind speed of 9.25 m/s, has performed acceptable showing an availability of 76%.

Other data have been collected during 2009 on the following subjects: corrosion and lightning; dynamics of turbines, aero-elastic stability; scour protection; electricity production, disruptions, failure data, availability, maintenance and reliability; power quality, grid stability and power forecasts; wind turbine P-V curve and wake effects. ECN, Delft Technical University and Germanischer Lloyd amongst others have started several projects with some of these data under a non-disclosure agreement with NoordzeeWind.

The aim of the environmental research is to determine the impact of the wind farm on the living environment, concentrating on the effects:

- on birds,
- of noise on animal sea life, and
- on sub-aquatic life and the refuge function.

During construction of the wind farm and in the operational phase, surveys were executed on behalf of NoordzeeWind. Work through 2009 included surveys on local birds, flight path and large scale bird movements; surveys on the occurrence of porpoises; surveys at the behavior of individual fish and what scale and periods they use the wind farm; and surveys at the colonization of underwater man-made structures. The research is ongoing. In 2010, the first overall conclusions will be drawn. The results of the surveys through 2009 are available (14).

The Dutch government is using the results of the monitoring program at the OWEZ and the lessons learnt to define a longer-term environmental monitoring program in order to support the realization of the 6 GW offshore wind energy target of the Netherlands.

The public opinion monitoring program also contains research on the perception of the wind farm by people visiting the beaches and living or working in the area. The research has been completed and results are available (14).

4.1.5 Results of the We@Sea program

In December 2009, the main results of the We@Sea program were presented during a two-day-congress in Den Helder. Presentations and discussions took place for the research lines: Scenario's and Integration; Offshore Wind Energy Technology; Spatial Planning and Environmental Aspects; Energy Transport and Distribution; Energy Market and Financing; Installation, Operations and Maintenance. Presentations and papers can be found on the website (14).

4.1.6 Offshore port sustainable energy North Sea (Heden)

Ten Dutch parties involved in the development of offshore wind energy (15) took the initiative to develop the concept of artificial offshore ports in the North Sea to facilitate the construction, exploitation, and maintenance of far offshore wind farms in the North Sea. Available port capacity on the mainland is limited. In an offshore port island containing a service harbour, parts of the wind turbines can be shipped in, assembled, tested, and transported to the foundations. This will allow construction at a greater pace. Repairs can be faster,

Figure 4 Impression of Heden (offshore port sustainable energy North Sea)

leading to increased production, as the artificial offshore port is an island with a hotel and spare part facilities. In addition, the offshore port island may be part of the future offshore electrical infrastructure. Synergy with planned UK and German projects will be possible. The island will have a diameter of about 1,000 m and consist of landing sites, sites for storage and assembly and commissioning wind turbines, hotel, substation, etc. (Figure 4). The required investment for the civil infrastructure is estimated at 1,000 million €. The association Heden (Haveneiland duurzame energie North Sea; Offshore port sustainable energy North Sea) was established to investigate and develop the prospects for such an island. Heden has also initiated the procedures to obtain building permits from the Ministry of Transport and Public Works (V&W) with the submission of environmental impact assessments for three different locations (16).

4.1.7 New projects on control systems

In 2009, two different projects started for the development of innovative control systems for wind turbines. The Dutch company DotX Control Solutions, in collaboration with ECN, VWEC Wind Energy Consult and Mitsubishi Power Systems Europe, is following an integrated approach based on the principles of non-linear predictive control for the development of a new control system.

XEMC-Darwind, also supported by ECN, will use an innovative approach with partially scaled components (so-called hardware-in-the-loop) to develop a control system. This allows for fast and high-quality development of the improved control system for XEMC-Darwind's 5-MW offshore wind turbine presently under development. Both projects were awarded under the EOS short-term R&D program.

4.1.8 Open Jet Facility at Delft University

Delft University officially opened its new wind tunnel the Open Jet Facility OJF. The octagonal jet has a maximum test section flow velocity of 30 m/s with an installed power of 500 kW. The test section (height 6 m, width 6.5 m, length 13.5 m) is for a typical rotor model diameter of 1.8 m. One of the first larger experiments will be the testing of the flexible Smart Dynamic Rotor and associated controls in the framework of the EU UpWind project

4.2 Collaborative research

As of 2008, 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 AERotortechniek are also participating in this Task. The Netherlands participation in this task is important to further strengthen the knowledge that ECN and Delft Technical University have in this research area.

Participation in the IEA Wind tasks is a cost-effective way to conduct research. On average, each euro spent in the Netherlands on research gives access to five euro value of research spent in the other participating countries.

5.0 The Next Term

The following policy developments in 2010 are expected.

- Elaboration of the long-term perspective towards 6,000 MW on land in 2020
- Further elaboration of planning for the development offshore locations, grid at sea, and support levels and mechanisms after 2011

• Evaluation of the SDE support scheme
• Evaluation of the "Schoon en Zuinig" program

Based on the amounts for the SDE subsidy allocated for 2010, the expected installed capacity will be between 335 and 500 MW on land. The SDE subsidy for a total of approximately 950 MW is expected to be awarded in 2010. Construction of this capacity will only take place in 2012/2013.

References and notes:

(1) Letter Minister to Parliament – 12-06-2009: http://parlis.nl/pdf/kamerstukken/KST132219.pdf (in Dutch)

(2) Initially, these were Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Sweden and the United Kingdom, followed by Norway early 2010.

(3) Sources: CBS http://www.cbs.nl/nl-NL/menu/themas/industrie-energie/publicaties/artikelen/archief/2009/2009-2707-wm.htm and Wind Service Holland, http://home.wxs.nl/~windsh/nwturtab09.html (both in Dutch). The installed estimated capacity end of 2008 as stated in the 2008 IEA Wind Energy Annual Report (2,214 MW) was corrected to 2,149 MW as a result of different criteria with CBS and WSH.

(4) http://www.ecn.nl/docs/library/report/2009/e09058.pdf (in Dutch)

(5) More details on the tender can be found on www.agentschapnl.nl/sde/Wind_op_zee/index.asp. (in Dutch)

(6) http://home.kpn.nl/windsh/wsh.html (in Dutch)

(7) Darwind: http://xemc-darwind.org/index.php?option=com_content&task=view&id=165&Itemid=25

(8) http://www.flow-windpark.nl/downloads/090901_Press_release_FLOW_ENG.pdf (9) http://www.renewableenergyworld.com/rea/news/article/2009/01/sudhindra-rao-ceo-of-global-wind-power-54343 and http://www.lagerweywind.nl/

(10) Wind Service Holland, http://home.wxs.nl/~windsh/nwturtab09.html (in Dutch). Figures are based on the WSH estimated growth of 39 MW in 2009 plus part of the December 2008 installations (62 MW) that was assigned to 2009 according to CBS criteria.

(11) See http://www.agentschapnl.nl/eos/financiele_steun/innovatieagenda_energie/wind_op_zee/index.asp (in Dutch)

(12) See also http://www.flow-windpark.nl/

(13) See http://www.agentschapnl.nl/offshorewindenergy/owez_wind_farm_monitoring/index.asp and www.offshorewind.nl

(14) For conference papers and presentations: http://www.we-at-sea.org/index.php?keuze=e&nummer=69#anchor; research results: http://www.we-at-sea.org/index.php?keuze=r0

(15) Participants in HEDEN: TNO Delft, ATO den Helder, TenneT TSO bv, Royal Haskoning, Grontmij Nederland BV, Van Oord Nederland, Lievense B.V., Eneco, Ballast Nedam, ECN.

(16) http://www.haveneilandopzee.nl/. For the start of the permit (Wbr) procedure with three environmental impact documents, see http://www.haveneilandopzee.nl/docs/StartnotitieIJmuiden(Engels).pdf; http://www.haveneilandopzee.nl/docs/StartnotitieNorthEastFriesland.pdf and http://www.haveneilandopzee.nl/docs/StartnotitieNorthclayland(Engels).pdf

Authors: Quirin W.M. Sluijs and Jaap L. 't Hooft, NL Agency NL Energy and Climate Change, The Netherlands.

Norway

Photo credit: Øyvind Hagen, Statoil

1.0 Overview

The installation of new wind power capacity in Norway has been low during the past year. In 2009, the net capacity installed was 2 MW. Total production of wind power was 980 GWh compared to 917 GWh last year. Wind generation constitutes 0.8% 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 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 2009 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 105% of the national electrical demand in 2009. About 0.8% of the renewable supply came from wind power, which saw the net installed capacity increase by 2 MW, with 2.3 MW of new wind generation installed, and 0.3 MW removed. Since electricity production in Norway mainly

Table 1 Key Statistics 2009: Norway	
Total installed wind generation	431 MW
New wind generation installed	2.3 MW
Total electrical output from wind	0.98 TWh
Wind generation as % of national electric demand	0.8 %
Target:	No target for wind power

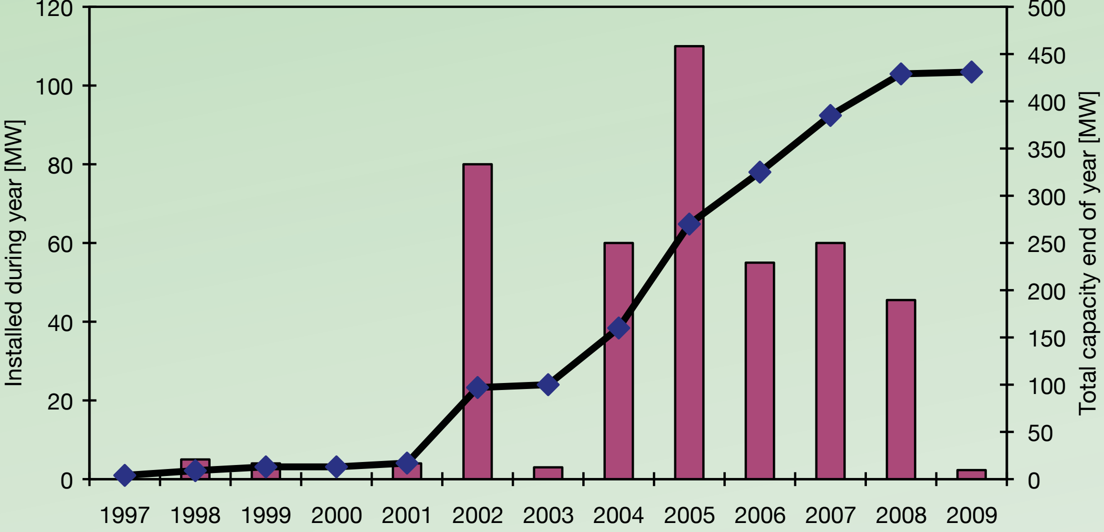

Figure 1 Installed wind power capacity in Norway.

comes from hydropower, the share of renewable energy varies considerably from one year to the next. It turns out that 2009 was a rather wet year resulting in excess power production available for export. Since most of the electricity produced in Norway is already based on renewable energy, the national environmental benefits of wind power are insignificant since new wind power capacity only contributes to excess power for export to the European market.

2.3 National incentive programs

For renewable power production, the support system is 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 program will continue to 2011. Enova provided grants to four wind power projects in 2009. The energy companies received a combined 1.1 billion NOK (132 million €) for wind parks with an annual production of 450 GWh. Since 2001, Enova has signed contracts with energy utilities for 14 wind power projects. The projects represent an estimated 1.6 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.

In addition to the ongoing Wind Power Program, the Norwegian government has come to an agreement with the Swedish government for a common green electricity market. The new green electricity market is expected to open during 2012. It is expected that the new market will be a sufficient incentive to spur new investment in wind energy.

Figure 2 Location of wind power installations

2.4 Issues affecting growth

The low increase of wind power capacity during the last years (Figure 1) is due to an inconclusive and insufficient support regime.

The forward price on the Nord Pool (Nordic electricity market place), by the end of January 2010 was 390 NOK/MWh (45 €/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 2).

3.0 Implementation

3.1 Economic impact

Some of the Norwegian industry takes part in component production for wind energy systems, e.g. wind turbine blades and nacelles. Companies with experience from the offshore oil industry (OEWC Tower and Aker Solutions) have widened their scope of interest and engagement to the offshore wind industry. The companies offer offshore wind turbine substructure solutions like Jacket Quattropod and Tripod.

3.2 Industry status

Production of wind power is dispersed among several energy companies, some of which are small local utilities. The largest wind power projects are operated by big national energy companies (Statkraft and Statoil). These companies are also engaged in projects in foreign countries where the economic conditions for wind power development are better. 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 €/MW). Annual maintenance is reported to be between 0.12 and 0.22 NOK/kWh (0.014 to 0.026 €/kWh), with an average cost of 0.14 NOK/kWh (0.017 €/kWh). Estimates of production costs from sites with good wind conditions (33% capacity factor) suggest a production cost of about 530 NOK/MWh (64 €/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 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 €) annually over a five-year period with the possibility of receiving an extension of funding up to eight years. Two of the CEERs are focusing on offshore wind energy: the Research Center for Offshore Wind Technology (NOWITECH) at SINTEF Energy Research and the Norwegian Center for Offshore Wind Energy (NORCOWE) at Christian Michelsen Research. A third CEER, the Center for Environmental Design of Renewable Energy (CEDREN) is working on issues such as integration of wind energy.

The governmental research program for sustainable energy is called RENERGI. Its budget for wind energy R&D in 2009 was 26.2 million NOK (3 million €), which is more than twice the budget in 2008. The following wind energy R&D projects were approved for funding in 2009:

- Deep-sea offshore wind turbine technology. This program combines wind technology know-how with offshore industry experience to develop deep sea (+30 m) offshore wind farms.
- Innovative foundation structure for offshore wind turbines. The base of the project is the verification of a numerical simulation of the jacket foundation by full scale measurements.
- Future offshore wind turbines. The project will develop a generator and control system that enable the design of a 10-MW turbine solution that is lighter than today's 3.5-MW turbines, with lower operating and maintenance costs, and with a minimum of 30% reduction in cost per megawatt of installed capacity.
- Research, development, numerical modeling, and testing of Njord concept for offshore wind turbines. The concept is characterized by directing the thrust forces from the turbine down from the nacelle, where they occur, to the sea floor.
- Development of a floating wind energy converter for deep water.
- Development of models for offshore wind and turbulence conditions and the calculation of loads on fixed and floating offshore wind turbines.
- Research-related aspects of the design, installation, and delivery execution of multiple types of foundations for offshore wind turbines.
- Hydrostatic drive for use in an offshore wind turbine or tidal turbine.
- Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway. The main focus of this project is to obtain biological and ecological knowledge on wind turbines and bird behaviors. The project results will significantly increase knowledge about how wind power may affect birds adversely in coastal areas of Norway.

In 2001, in order to assist the development of wind energy in Norway, SINTEF Energy Research, the Institute for Energy Technology (IFE), and the University of Trondheim (NTNU) formed a joint initiative to develop a test station for wind turbines on the Midwestern coast of Norway. The test site (VIVA AS) was opened in the summer of 2005 and is now operating. A new 900-kW test turbine has been erected in order to try out the new hydraulic concept of ChapDrive AS. For more information: www.vivawind.no.

ChapDrive AS is a new company with the aim to develop a system for hydraulic transmission of wind power. The object of the system is to move the gearbox and the generator down to ground level to reduce the weight at the top of the tower. A pilot project has been in successful operation on a 225-kW wind turbine at the VIVA AS test facility. An upgraded version on a 900-kW wind turbine was put into operation in June 2009. A 5-MW version is planned.

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 2010. Upscaling the design for 3-MW to 8-MW turbines is also ongoing with support from the Norwegian Research Council.

The world's first full-scale floating wind turbine (Hywind concept developed by Statoil) is operational (opening photo the world's first full-scale floating wind turbine.) Statoil is testing the wind turbine over a two-year period. Statoil is investing around 400 million NOK (48 million €) in the construction and further development of the pilot and in research and development related to the wind turbine concept. Enova SF has granted 59 million NOK (7 million €) in support for the project. 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. The country's wind resources estimate figures will be revised after the new investigation.

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 2009, three development projects totaling 40 MW were under construction, and they are expected to come into operation within one or two years. Additionally, it is expected that Enova will launch a new round of investment subsidies in January 2010 with a total budget of 1 billion NOK (120 million €).

Authors: Knut Hofstad, Norwegian Water Resources and Energy Directorate; Espen Borgir Christophersen, Enova, Norway.

Portugal

Photo credit: Pedro Correia

1.0 Overview

In 2009, the electricity consumption in Portugal was 49.9 TWh, which represents a reduction of 1.4% in demand, the first decrease since 1981. By the end of December 2009, Portugal had a renewable energy capacity of 9,093 MW, which represents 51% of the total installed capacity (1). The energy generation by the renewable power plants during this year corresponded to 33% of the generated electricity.

The Portuguese wind sector has been growing steadily in the past decade, and in 2009 the country surpassed 3.5 GW of installed wind capacity. Moreover, the wind-generated electricity in Portugal represented 15% of the country's electricity consumption, which is one of the highest wind penetrations in the world (Table 1).

This was a record year not only in terms of yearly wind generation, but also in terms of the technical operation of a power system with a high amount of wind power. In 2009, the Portuguese power systems experienced extremely high wind production, namely an instantaneous power penetration of 70%, on 15 November 2009, during the no-load hours with no operational problems to be reported (1).

2.0 National Objectives and Progress

2.1 National targets

Within the European directive 2001/77/CE, Portugal set national targets for the installation of 3,750 MW of wind capacity by the end of 2010 (2).

Table 1 Key Statistics 2009: Portugal	
Total installed wind generation	3,616 MW
New wind generation installed	797 MW
Total electrical output from wind	7.492 TWh
Wind generation as % of national electric demand	15%
Target:	3,750 MW by 2010 5,100 MW by 2013

This target was nearly accomplished at the end of 2009, with 3,616 MW already installed and commissioned. The remaining capacity that will allow the fulfillment of the wind power contribution to the directive is already under construction. This goal was reviewed in 2005 (3), and the Portuguese government set the new national target at 5,100 MW by the end of 2013.

In July 2007, the European Union country leaders decided to reduce greenhouse gas emissions by 20%, to increase the use of renewable energy systems by 20%, and to increase energy efficiency by 20% by the end of 2020. In accordance with the European Agenda for Energy and Economy defined in the European Strategic Energy Technological Plan (SET-PLAN) 'Towards a low carbon future' (4), new measures for the renewable and wind sectors are being studied in Portugal and many other European countries, although no new wind capacity targets with published during 2009.

2.2 Progress

During 2009, Portugal installed the record value of 797 MW of new wind capacity, which brought the total capacity to 3,616 MW (5). This capacity is distributed among 195 wind parks and 1,879 wind turbines across the country, with a strong concentration in the interior center and north of the country, as well as a relevant capacity in the windy region just northern of Lisbon.

The wind capacity produced 7,492 GWh in 2009 according to the national transmission system operator REN (1), and corresponded to 15% of the Portuguese electricity production and 40% of the renewable generation. Figure 1 represents the installed and accumulated capacity and the wind energy production as a percentage of the national demand.

In Portugal during 2009, the operating wind parks verified a mean annual production of 2,230 hours at rated power. The wind power production by classes of NEPs (number of hours at full capacity) ranged from 7% of the wind power plants above 2,750 NEPs, 46% between 2,250 and 2,750, 39% in the interval from 1,750 to 2,250, and the remaining 8% with a low production below 1,750 NEPs.

In the last year, the energy production from renewable energies was slightly lower than in 2008 for hydropower and biomass, but higher for wind and photovoltaic systems. The annual evolution of the wind contribution in the renewable energy production has consistently increased in the last decade. In 2009, the contribution of wind generation was 40%, almost that of traditional hydropower generation (47% of the total renewable generation). Other contributions came from biomass (12%) and PV systems, already contributing with 0.9% of total renewable production in 2009.

2.3 National incentive programs

There are not specific incentive programs in Portugal for capital investment or tax reduction. The governmental support to wind generation is officially defined by the existence of a "green tariff" that includes the conventional generation avoided costs, as well as the environmental contribution of the renewable energies. Although recent contracts for the purchasing of energy from wind power plants set tariffs much lower (in the order of 75 €/MWh), the mean tariff value practiced in Portugal during 2009 was 93.7 €/MWh (6), since most operating capacity was licensed under previous legislation.

Portugal has a great commitment toward micro-generation, and implemented a procedure in 2007 where the interested consumers can apply over the internet to become "domestic generators." The evolution of the program has shown growth in the PV domestic micro-generation plants much more than in small wind turbine generation plants, a fact partially explained by the high solar resource of the country and the added difficulties with the characterization of the urban resource in constructed areas. The governmental initiative "Renováveis na Hora" (Renewables in the hour) was a major success, and 2009 witnessed 7,286 domestic applications for connection of micro-generation systems with a total capacity of 25.9 MW. From those

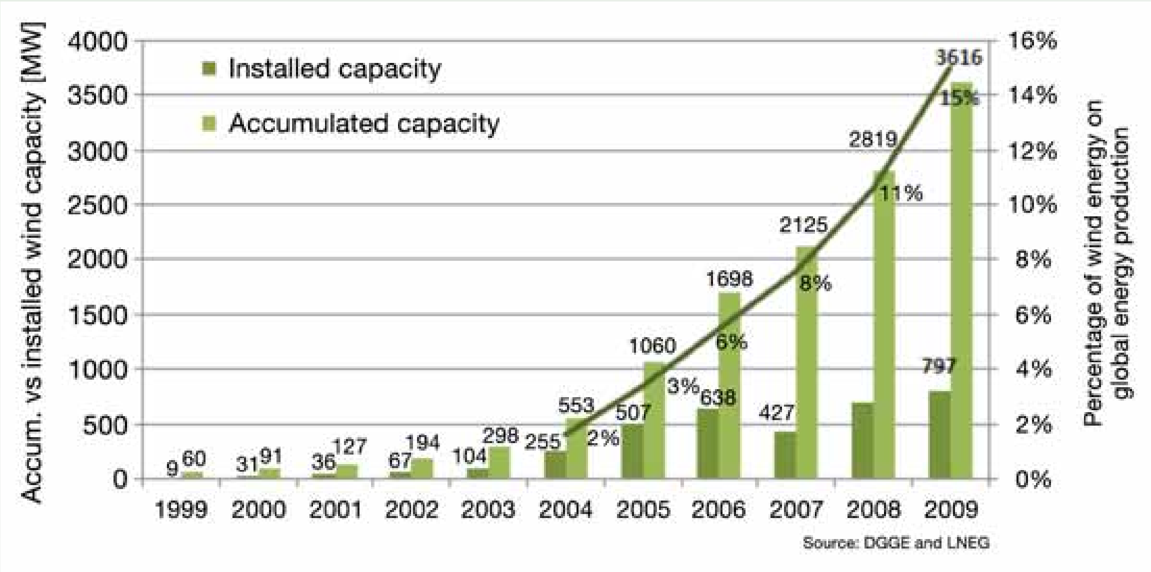

Figure 1 Installed versus accumulated wind capacity and percentage of wind energy in the consumption

applications, 2,506 with a capacity of 8.9 MW are already in the inspections phase.

2.4 Issues affecting growth

No major issues affected the growth of the Portuguese wind sector. Not only there is a strong national commitment to fulfill both the 2010 and 1013 targets, but the fact that Portugal is exceeding the emissions accorded under the Kyoto Protocol ratification will probably lead to an increase of those targets and the reinforcement of those commitments.

An energy index on the evolution of the tendency of the national CO_2 emissions during the implementation period of the Kyoto protocol (2008 to 2012) started to be published in 2009 – the E.Value Index (7). This index is computed by establishing the monthly relation of CO_2/energy referring to December 2007 (base 1000). The most relevant sectors for the fulfillment of the Kyoto protocol in Portugal are the energy and transports area, and these are covered by the E.Value Index represented in Figure 2.

Portugal has installed and is operating a high capacity of both wind power and run-of-river hydropower stations. These electricity sources share the common technical characteristic of being mainly non-controllable power stations – the technical term being non-dispatchable - by the transmission system operator (TSO). This requires the power mix to have a certain amount of controllable sources in order to be able to balance the total sources of generation and the total consumption. In power 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 that should never exceed the no-load consumption added by a reserve value of conventional controllable power. During the winter of 2009 this limit was reached in a sequence of very wet and windy days, when the power system reached the limiting instantiations penetration of 70% wind power (Figure 3). This constitutes a record in such a peripheral European country, with a limited interconnection capacity to its neighbor countries (1,000 to 1,800 MW with Spain). Although no technical problems for the power system operation were reported, the occurrence of this design and technical parameter so soon in the progress toward the country objectives and with only 3,616 MW of wind power installed, is expected to introduce a limitation on the growth rate of wind power deployment in the next years in Portugal.

3.0 Implementation

3.1 Economic impact

The record amount of wind capacity installed in 2009 (797 MW), together with the wind industry already settled in Portugal has created an estimated 2,500 jobs. Despite the worldwide economic difficulties, this newly installed capacity represents a private investment by wind power plant developers of over 900 million €. The wind generated electrical energy produced an income of 700 million € for these wind utilities. The continuing increase in the creation of small companies for the assessment and installation of micro-generation systems has also contributed to the economic impact of this sector.

The indirect economic impact of the wind deployment is difficult to assess, but there are a large number of companies, from the construction area to the steel industry, that have a great share of the activity and turnover in the wind sector, and are thus overcoming the actual global economic crisis with a minimized impact.

3.2 Industry status

In 2007, the technological complex of the German company Enercon GmbH, a member of the wind energy consortium Eólicas de Portugal, SA., began construction in the north of Portugal (Viana do Castelo). In 2009, this industrial complex reached its full production potential, and the country passed from an importer of wind technology to an exporter. In the industrial complex in Viana do Castelo, Enercon manufactures almost all components of its model E82, as well as components for other models, including the novel concrete towers.

During 2009, Enercon, reinforced its leading position in Portugal with a of 44% share of the Spanish market, followed by Vestas (17%), Gamesa (12%), and Nordez (10%). The remaining share is divided by Repower (5%), GE Wind (3%), Ecotecnia (3%), Suzlon (2%), and Izar Bonus (2%) (8).

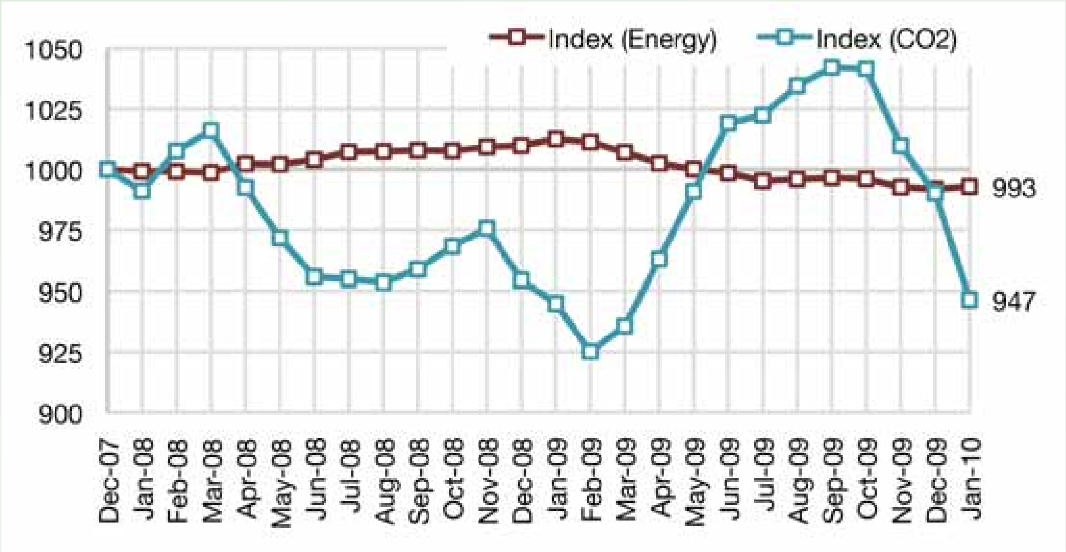

Figure 2 Energy E.Value Index for Portugal (7) Source: www.evalue.pt

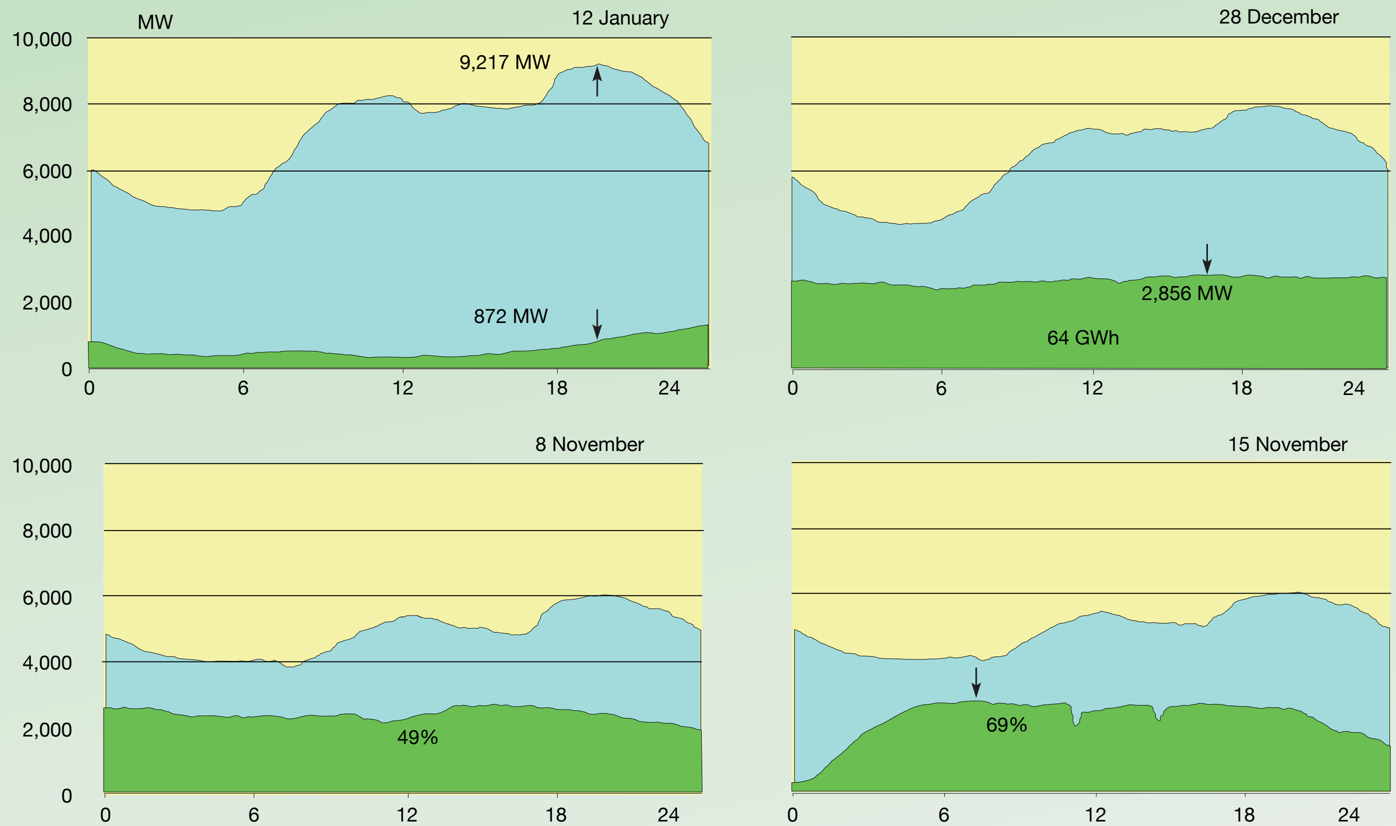

Figure 3 Occurrence of record wind power penetration and energy generation during 2009

3.3 Operational details

The installation of large wind parks marked wind deployment in 2009, a tendency in this country for several years now. Wind parks with more than 50 MW accounted for 44%, and 47% of wind parks had between 10 and 50 MW. As a part of the national plan to maximize the penetration of wind in the energy mix, the first management center for wind generation installed in Oporto - having 1,200 MW of dispersed wind power connected - started its final phase of tests toward full operation during 2009.

Figure 4 shows the wind and production indexes in the last ten years. These values were obtained for the two typical regions where wind turbines are operating in Portugal: coastal and mountainous. The wind and production indexes were computed based on reference wind data from anemometric stations installed in these two regions.

Data from the Portuguese TSO (1) indicated that the overall wind generation index in 2009 was 1.03, thus revealing an unexpected similarity to the typical coastal behavior, although most of the operating capacity is installed the mountains of the interior.

3.4 Wind energy costs

During 2009, the average cost per kilowatt installed in Portugal laid between 950 and 1,300 €/kW, excluding grid connection and land contracting. In Portugal, the majority of the wind turbines are installed in complex terrain in mountainous regions, which has the higher wind resource. This fact increases slightly the installation costs due to the difficulties associated with the construction of connection lines and the difficulties in transporting the components. The mean tariff paid to wind energy utilities during 2009 was 93.7 €/kWh for large wind power plants and 432.3 €/MWh for the micro wind turbines in domestic applications.

4.0 R, D&D Activities

4.1 National R, D&D efforts

Initiatives to deploy the offshore wind power sector in Portugal started to appear in 2009. This was mainly driven by the exhaustion of windy onshore sites without severe environmental classification. The offshore wind resource, especially in deep waters (40 m to 200 m) is vast in Portugal, with all of the Atlantic coast north of Lisbon showing very favorable conditions for this wind power application. Although generally considered as a difficult coast to deploy offshore wind, the Portuguese continental shelf has a smooth slope until 200 m of depth and only sinks quickly in the first 25 m. Thus, Portugal has some areas with medium depths (until 40 m of depth) with the potential to deploy up to 2,500 MW, and an immense wind potential for deeper waters where fixed structures are economically not feasible and floating wind technology may be applied when available.

During 2009, the Portuguese energy utility, Energias de Portugal (EDP), announced an agreement with the U.S. company Principle Power, Inc., to develop and install the floating deep water offshore structure, WindFloat (Figure 5) designed by Marine Innovation &

Technology (http://www.marineitech.com) and owned by Principle Power, Inc. (9) in a wind power project off the coast of Portugal.

4.2 Collaborative research

There are several companies interested in deploying the Portuguese offshore wind potential these days. Some of them are already performing preliminary offshore wind resource assessments (e.g. Martifer). To contribute to the area of offshore wind deployment, the National Laboratory of Energy and Geology (LNEG) is involved in the Norsewind EC project, which aims to develop and validate methodologies for the assessment of wind resources in the ocean. Within this project, LNEG is operating a LIDAR in the offshore Atlantic islet of Berlengas and running mesoscale models with experimental data assimilation for detailed offshore wind resource mapping.

Other R&D institutions and Portuguese companies are actively participating in several European and national wind energy projects. Some of these projects include the involvement of INESC-Porto with the EC project 'Twenties' for high penetration of renewables, and the participation of the Portuguese TSO in the Project WindGrid. The Instituto de Soldadura e Qualidade (ISQ) and A. Silva Matos are also participating in several projects in the area of failures and condition assessment of existing structural and aerodynamic components in order to contribute to the use of advanced new materials and production techniques (EC projects NIMO and Safetower, and the Portuguese Quadro de Referência Estratégico Nacional (QREN) project Phasewind).

LNEG also participates with other Portuguese R&D entities, the Institute of Mechanical Engineering (IDMEC), Centro de Estudos em Economia da Energia, dos Transportes e do Ambiente (CEEETA), and the Wave Energy Center (WavEC) in the Foundation for Science and Technology (FCT) project RoadMap. This project aims to identify all the requirements and constrains (logistic, economical, technical/scientific, and technological) for the marine energy sector deployment and will create a road map for this sector. The results obtained from this project will have an important role in the development of the offshore renewable energy sector in Portugal.

Finally, LNEG represents Portugal and participates actively in the Wind Energy Program of the European Energy Research Alliance (EERA), a collaborative European platform for governmental laboratories and universities, where UoP is also represented.

5.0 The Next Term

A deep offshore wind power project using WindFloat technology is prepared to manufacture and install a 2-MW prototype off the coast of Portugal for testing.

The official announcement of the rising of the Portuguese wind power targets is expected during 2010, together with plans to mitigate its potential technical impact in the national power system operation and to optimize the integration of a large amount renewable generation in the Iberian electricity market, MIBEL.

References:

(1) REN, Rede Eléctrica Nacional; A Energia Eólica em Portugal 2009. Download from http://www.centro-deinformacao.ren.pt/PT/publicacoes/EnergiaEolica/A%20Energia%20E%C3%B3lica%20em%20Portugal%20-%202009.pdf/

(2) Official resolution RCM - 63/2003, 28 April 2003, Diário da República, no 98, 2stserie-B, pp. 2722-2731. Download from http://www.dre.pt/pdf1s/2003/04/098B00/27222731.pdf

(3) Official resolution RCM - 169/2005, 24 October 2005, Diário da República, no 204, 1stserie-B, pp. 6168-6176. Download from http://www.dre.pt/pdf1sdip/2005/10/204B00/61686176.

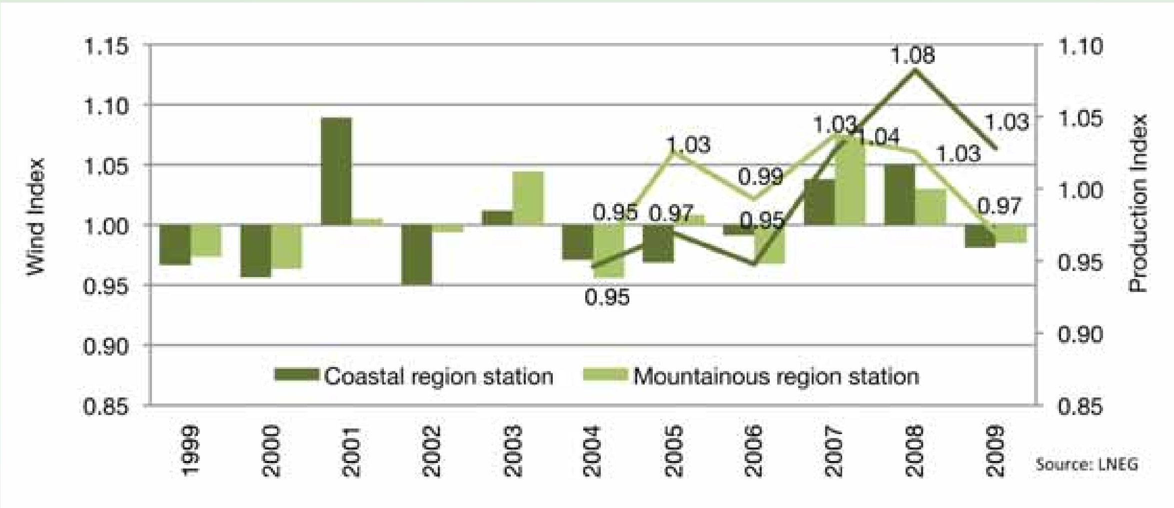

Figure 4 Production and wind indexes in a coastal and in a mountainous region of Portugal

Figure 5 The WindFloat structure

PDF

(4) COM(2007) 723 final; 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 Technological Plan (SET-PLAN) 'Towards a low carbon future'. Commission of the European Communities, Brussels, 22 November 2007. Download from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0723:FIN:EN:PDF

(5) DGEG, Direcção Geral de Energia e Geologia; Renováveis – Estatísticas Rápidas, Novembro/Dezembro 2009, Nº57/58, 31 March 2010. Download from http://www.dgge.pt/

(6) ERSE, Entidade Reguladora dos Serviços Energéticos, 18 February 2010. Download from

http://www.erse.pt/pt/imprensa/noticias/2010/Paginas/DebatesobreenergiaeolicapermitiutrocadeexperienciasentrePortugaleBrasil.aspx

(7) E.Value, 1 March 2010. Download from http://www.evalue.pt

(8) INEGI, Instituto de Engenharia Mecânica e Gestão Industrial; Parques Eólicos em Portugal (December 2009), 11 February 2010. Download from http://www.inegi.up.pt

(9) Principle Renewable Energy Delivered, WindFloat, Principle Power, 31 March 2010. Download from http://www.principlepowerinc.com/images/PrinciplePowerWindFloatBrochure.pdf/

Authors: Ana Estanqueiro, Liliana Madeira, and Teresa Simões, LNEG – Laboratório Nacional de Energia e Geologia, Portugal.

Spain

Photo credit: Jake Abbot

1.0 Overview

Installed wind capacity in Spain reached 19,149 MW in 2009 with the addition of 2,460 MW, according to the Spanish Wind Energy Association's Wind Observatory. Such growth was not expected after the 1,585-MW increase in 2008 in which companies made a big effort to keep the planned number of wind farms after spectacular wind capacity growth in previous years. The 19,149 MW of capacity establishes Spain as the fourth country in the world in terms of installed capacity and will allow the 2010 objective (20,155 MW set by the Renewable Energies Plan 2005–2010) to be reached. The total electricity produced from wind in Spain in 2009 reached 36,188 GWh.

The addition of 2,459.44 MW in 2009 is an increase of 14.74%, the second largest in absolute terms in the history of wind energy in Spain. This increase is only overtaken by 2007 (3,519 MW and 30%), although 2004 was the biggest in percentage terms at 37% (2,291 MW). However, the creation of the new mandatory Pre-allocation Register by the Spanish central government will operate as a bottle neck to future wind energy sector deployment.

Electrical energy demand in 2009 was 251.30 TWh, a decrease of 4.47% from 2008. Wind energy met 14.39% of this demand and was the third largest contributing technology in 2009. Other big contributors to the system were gas combined-cycle power plants (31% of total demand) and nuclear power plants (21%). Figure 1 shows how power demand was supplied by different sources and technologies in Spain during 2009.

Wind energy is a driving force for industrial development in Spain. In 2009, investment was more than 2,250 million €, 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 creation of the Register of Pre-Assignment by the Spanish government. This slowdown has resulted in the loss of thousands of jobs and development. In 2010, according to sector forecasts, the industry will only install about 1,000 MW, the lowest figure since 2000.

According to the "Macroeconomic Study on the Impact of the Wind Energy Sector in Spain," the number of jobs related to wind power has declined during 2009 by 35% reaching less than 26,000. Of this total, the number of direct jobs in operation and maintenance of wind farms, manufacturing, assembly, research, and development is estimated at more than 16,000 (22% less than 2008). The number of indirect jobs (linked mainly to components) is estimated to be more than 8,000 (almost 50% less than 2008).

Finally, it is important to point out the significant efforts of the industrial sector and the system operators to implement the new Grid Code (P.O.12.3). Due to their coordinated efforts, the impact of wind energy on system operation is smaller than expected. The regulatory systems

Table 1 Key Statistics 2009: Spain	
Total installed wind generation	19,149 MW
New wind generation installed	2,459 MW
Total electrical output from wind	36.188 TWh
Wind generation as % of national electric demand	14.39%
Target:	20,155 MW by 2010
Sources: REEand AEE	

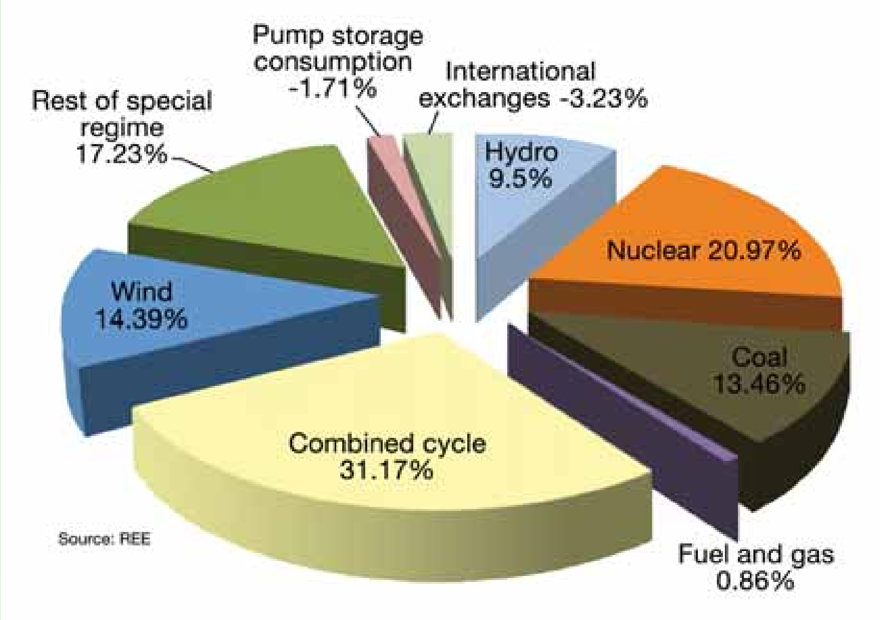

Figure 1 Electricity generation mix in Spain, 2009

have been able to regulate and optimize system management at very low cost.

2.0 National Objectives and Progress

2.1 National targets

The present objectives for 2010 for the promotion of renewable energies are contained in the Spanish Renewable Energy Plan 2005–2010 (PER) (1). This plan is a revision of the previous version completed in 2002. The aim of this revision was to maintain the commitment to meet at least 12% of total energy use from renewable sources by 2010. It also incorporates other indicative targets (29.4% of electricity generated from renewable sources and 5.75% of transport fuel from biofuels).

For the wind energy sector, the PER objective implies reaching a capacity of 20,155 MW by the end of 2010. The 2,460 MW installed in 2009 confirms that the sector is strong. The installed wind power in Spain during 2009 implies a growth rate of 14.74%. It is expected that this growth will be not maintained or probably will decrease in the next year, and will just reach the total of 20,155 MW fixed as the objective according to PER. Figure 2 shows the annual cumulative wind capacity and the PER objectives for 2005 to 2010.

Wind energy is still considered a strong sector and its continuous growth has created the expectation of new targets for the next term. There is consensus for fixing a new target of 40,000 MW by 2020. The majority of the Autonomous Regions (that are responsible for regulating wind installations) have plans for reaching 41,000 MW between 2010 and 2020. Local governments see the need for this on the basis of energy production, local resource use, industrial development, and job creation in their zones. The industrial sector participating in the AEE has established a new objective of 40,000 MW for 2020 (2). It is conducting studies and developing strategies to reach that goal. Finally, the management and planning of the new Spanish target is designed to fulfill the new European Union objectives established during 2007—to supply 20% of the primary energy with renewable sources by 2020. Due to the solidity of the wind sector, it is likely that an important amount of the renewable objective will be covered by wind energy.

2.2 Progress

The total electrical generation capacity in the Spanish mainland generation system increased more than 2,682 MW during 2009 and reached a total of 92,152 MW according to the data of Red Eléctrica de España (the Spanish Transmission System Operator [TSO]) (3). Wind power and gas combined cycle are the technologies that contributed to this growth.

With more than 19,149 MW of wind power installed, there are nowadays more than 18,400 turbines operating in Spain. They are grouped among 850 wind farms.

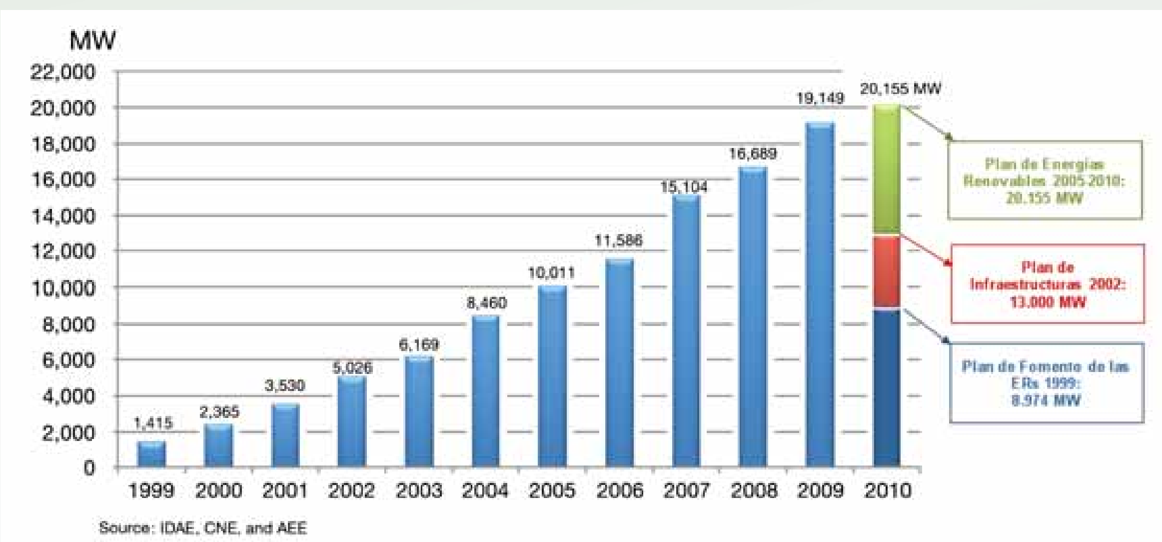

Figure 2 Wind farms in operation and objectives for 2010

The average size of an installed wind farm in 2008 was 26 MW. Wind energy is present in fifteen of the seventeen Autonomous Communities. Castilla–Leon has the most installed power among them. The region's capacity breakdown shows that Castilla–Leon keeps its leadership with 3,882.72 MW (548.68 MW added in 2009). The biggest growth in absolute terms is in Andalucía, with 1,077.46 MW; that amount put the region in fourth place with 2,840.07 MW, after of Castilla-La Mancha which has 3,699.61 MW, and Galicia which had 3,231.81 MW.

In percentages, Andalucía has experienced the biggest growth, with 61.13%. With the 1.077 MW installed in 2009, it has reached 2,840.07 MW. Andalucía is followed by Comunidad Valenciana, which grew 41.56%, adding 289.75 MW to reach a total of 986.99 MW. The third is Catalonia with a growth of 25.06% adding 105.10 MW. 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. 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_2 emissions by about 22 million tons just during 2009. Furthermore, wind generation has saved up to 7 million tons of conventional fuels. Wind production has supplied the electrical consumption of more than 11.5 million households.

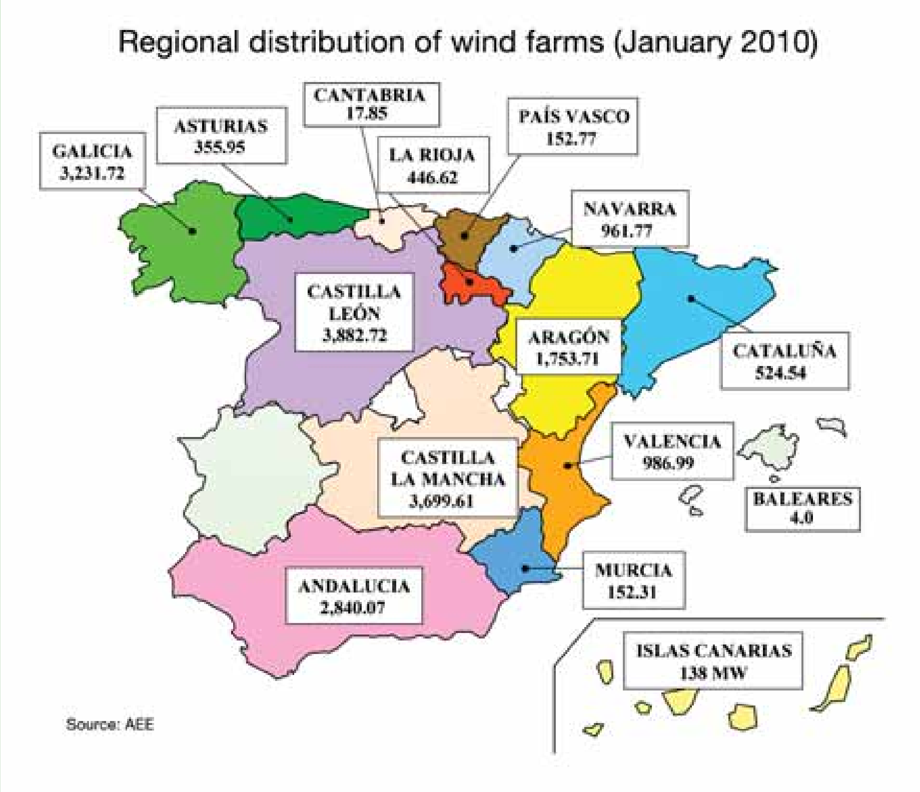

Figure 3 Wind energy capacity distributions by Autonomous Communities (MW)

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 Renewable Energy Plan, including midterm objectives for each technology (PER 2005–2010), and the tariff scheme are guaranteed until the fulfillment of targets.
- 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.
- 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 2009, the value was 78.183 €/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 2009 are reference premium 31.27 €/MWh, lower limit 76.098 €/MWh, and upper limit 90.692 €/MWh.

The feed-in scheme will be valid until fulfillment of the PER objective (20,155 MW) in 2010. An additional 2,000 MW are considered for repowering wind farms built before December 2001, and an extra bonus of 7 €/MWh is considered. By comparison, during 2009, the average electricity price reached 64.43 €/MWh.

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 2009. Also, a new mandatory instrument called "Pre-allocation Register" aims to define the 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 thousands of jobs have been lost. Development in 2010 may be as low as 1,000 MW, the lowest figure since 2000.

3.0 Implementation

3.1 Economic impact

The number of installations during 2009 demonstrates the maturity of the wind industry, which has been able to increase despite worldwide difficulties with financial crisis and deployment of the Pre-allocation Register in Spain. Installing and operating wind plants to cover 14.39% of the Spanish electrical demand implies a huge accomplishment by the developers and manufacturers.

3.2 Industry status

In 2009, there was a tendency to consolidate holdings. The largest companies had accumulated the farms they put into the network and some companies were being acquired by others. Nevertheless, new agents also appeared in the Spanish market as promoters and manufacturers. In 2009, 74.5% of the Spanish wind market was covered by the top-ten developers compared to 77% in 2008.

In the ranking of wind farm owners, Iberdrola Renewables, the largest Spanish utility, has the largest accumulated capacity (4,882 MW) thanks to the addition in 2009 of 341.45 MW. Acciona Energy is still in second place with an accumulated capacity of 3,996.82 MW with bigger new capacity (359.60 MW). Several other organizations have installed wind power capacity during 2009. Figure 4 shows the percentage of new capacity supplied by each developer.

Gamesa installed more than 34% of the new capacity in 2009 (845.15 MW), according to the AEE's Wind Observatory, with more than 10,334.67 MW (including the subsidiary company Made), which consolidates its leadership among manufacturers. Vestas, the second largest manufacturer, installed more than 23.32% of new capacity in 2009, adding 573.71 MW. Figure 5 shows the distribution of accumulated wind capacity by manufacturer.

Among new technological developments are two 3-MW-rated power wind turbines under test by Alston-Ecotécnia and Acciona Wind Power, another being designed by MTorres, and a brand-new 5-MW wind turbine from Gamesa is under test.

In relation to small wind, 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 wind turbine prototypes in the range from 150 kW to 300 kW.

3.3 Operational details

The number of wind turbines in Spain increased by more than 890 in 2008, and the total number of turbines is more than 18,400 units. The average size of a wind turbine installed in 2008 was 1.85 MW.

Wind turbines operating in Spain show important seasonal behavior. Total electricity generated by wind farms was more than 31,100 GWh, and the equivalent hours at rated power were slightly higher than 2,000 hours for all of the wind farms. On 18 April 2008, new historic highs in wind power were recorded: 10,879 MW of instantaneous power, 10,727 MWh of hourly wind power, and 213,169 MWh of daily wind power (28.2% of the electrical demand for that day). On 24 November 2009, wind power production supplied 43% of total demand.

Regulations for the grid code have been completed successfully. Every wind farm is assigned to a control center and only 30% of wind capacity installed has not complied with low voltage ride-trough 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 2009 in Spain was about 1,250 €/kW.

4.0 R, D&D Activities

4.1 National R&D efforts

The new National R&D plan developed in 2008 has been progressing in 2009. This 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. There are also another R&D programs promoted by the Autonomous Communities for wind energy research activity at regional level.

The ongoing PER (Renewable Energies Plan) 2005–2010 is making an exhaustive analysis of the technological innovation required to achieve its objectives. In the case of wind energy, the priority for

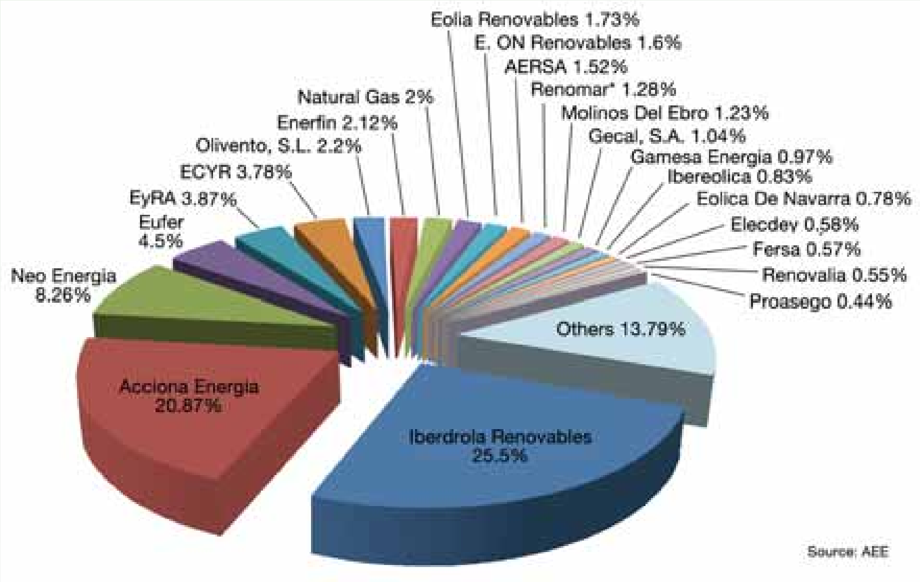

Figure 4 Installed wind capacity by developer at the end of 2009

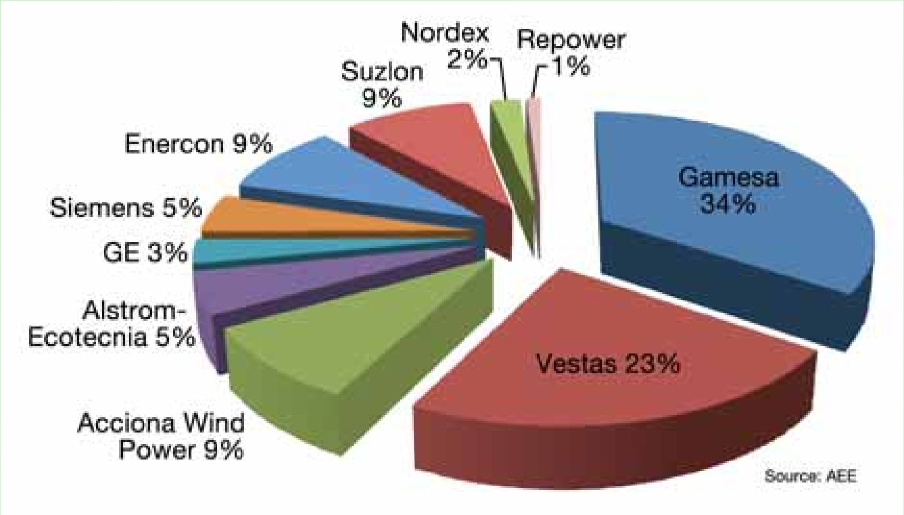

Figure 5 Installed wind capacity in 2009 by manufacturer

the Spanish manufacturers is to make efforts leading toward the following goals:

- Develop advanced systems to control the quality of the power fed into the grid,
- Develop wind turbines with unit power outputs of more than 2 MW,
- Adapt high-capacity wind turbines to the more demanding technical requirements of offshore applications, and
- Implement demonstrations of offshore wind farms.
- Within the basic research activity drive by the General Sub-direction for Research projects of the Science and Innovation Ministry, many projects have been proposed for the different Subprograms of the National R&D Plan:
- Subprogram of fundamental research projects (not oriented).
- Subprogram of fundamental research projects oriented to knowledge transfer.
- Subprogram of complementary actions for non-oriented fundamental research projects.
- Assistance for development and reinforcement to Results Research Transfer Offices.

It is important to highlight that most of the projects presented in this solicitation were focused on grid integration and control subjects. During 2009, the following projects and lead institutions were approved:

- Robust control modeling and simulation for advanced wind turbines in order to improve their efficiency: Basque country University
- Advanced solutions for global integration of wind farms in the electrical network: Basque country University
- Instruments for risk analysis in wind farms: University of Castilla-La Mancha.
- Study of the voltage sags in the stability of wind energy generators: Catalonia Polytechnic University
- Wind energy generation systems and grid code requirements: University of Vigo.
- Studies of integration of electrical and mechanical models for DFIG and PMSG wind turbines: University of Castilla-LA Mancha
- Development of a test bench for voltage and frequency disturbances test in wind turbines connected to weak grids: Politechnical University of Madrid.
- Review of flicker measurement procedure IEC 61000-4-15. Influence in the Power quality characterization of wind turbines: Basque country University.
- Optimized hybrid wind-biomass system for hydrogen production: Polytechnic University of Valencia.
- Development and validation of optimized tools for wind blades manufacturing process based in resin infusion and prepare materials: CENER-Ciemat Foundation.
- CENER-GRC gearbox reliability collaborative: CENER-Ciemat Foundation.
- Control tuning base in wind turbine models in closed loop: CENER-Ciemat Foundation.
- Characterization of turbulence and dust accumulation in the surface of wind blades: CENER-Ciemat Foundation.
- Simulation and forecast of extreme wind in the Iberian Peninsula: Complutense University of Madrid.
- Development of a local wind forecasting model for offshore wind energy applications: Ciemat.
- Application of matrix converter in wind energy: University of Malaga.
- Modeling and control of wind turbines with matrix converter: University of Jaen.
- Diagnostic of wind turbines based on analytic redundancy: CARTIF Foundation

The CENIT program carried out by the Center for Industrial Technological Development (CDTI) from the Ministry of Science and Innovation is another effort to increase R&D activities. 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 GPD. The program started in 2006 and so far two projects have been approved: Windlider 2015 (completed) and Eolia (in progress).

The R&D project called Eolia is a consortium of 16 companies led by Acciona Energia. The project has been approved by the CDTI for a grant of 16.7 million €, not quite half the overall 33.9 million € 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.

Another instrument is the called "PSE Projects" are Strategic National Consortiums for Technological Research led by the industrial sector in collaboration with the public and private research centers. In the field of wind energy, a project called Minieolica is developing to promote the Spanish small wind energy sector (new developments 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 supporting manufacturers to develop new products. New designs will cover the needs of the market in the power range between 1 and 5 kW for urban and residential applications (innovative horizontal- and vertical-axis wind turbines) and from 20-kW and 100-kW very reliable, robust, and efficient newly designed small wind turbines for residential, industrial, and agricultural applications.
- Technical development breaking technological barriers and advancing technological development in key areas for small wind turbines.
- Infrastructure development activating and supporting the small wind turbine sector. The objectives of this area are promotion, dissemination, sensitization, and information collection 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 has been approved in 2009 for four years. The main objective of this project is the development of useful technology to extend the capacity to build offshore wind farms in deep waters. The partnership is composed by 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 by 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 developments of windturbine-support structure coupling solutions.

The total budget of the EMERGE project reach 9.2 million € (2009-2012)

Finally, The Spanish Wind Power Technological Platform 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 the 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.

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.

5.0 The Next Term

Expectations for the Spanish wind energy industry for 2010 are not very promising. The wind industry slowdown has been caused by funding problems related to the financial crisis and by the Register of Pre-Assignment, created by the central government in order to control more precisely the RES capacity growth. Wind was included mainly because of the high fed-in tariff cost, and also because of some local grid integration constraints.

In spite of these factors, the target defined in the PER 2005-2010 of 20,155 MW by the end of 2010 will be accomplished. Once the target is reached, a revision of the tariff scheme will be in order. The new PER 2011-2020 with new objectives and tariffs will be delivered by the end of 2010.

Electricity prices seem likely to be flat in 2010 and may not exceed 80 €/MWh (especially if the contribution of hydropower to the system continues increasing and oil prices do not increase too much). During 2010, technology and installation costs are expected to be lower than 2009. 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.

A new Renewable Energy Plan is being studied by the authorities to include the objectives of the European Union for 2020. A realistic estimate for wind energy in Spain is that 40,000 MW of onshore and 5,000 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.

(2) Wind Power Observatory. 2009, Asociación Empresarial Eólica (AEE; Spanish Wind Energy Association). January 2008. www.aeeolica.org.

(3) The Spanish Electricity System. Preliminary Report 2009, Red Eléctrica de España. REE. December 2009. www.ree.es.

(4) REOLTEC. Spanish Wind Power Technological Platform IV General Assembly. www.reoltec.net

Authors: Ignacio Cruz and Enrique Soria Lascorz, CIEMAT, Spanish Ministry of Science and Innovation, and Asociación Empresarial Eólica (AEE, the Spanish Wind Energy Association), Spain.

Sweden

1.0 Overview

The new wind energy installations in 2009 had a capacity of 512 MW, which is more than twice as much as the capacity of 216 MW installed in 2008. In 2009, an update of the quotas in the electricity certificate system for renewable production was suggested. The goal is to increase renewable generation with 25 TWh/year 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 €). 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 €). New pilot and demonstration projects have started during the year. A new research center, the Swedish Wind Power Technology Center (SWPTC) at Chalmers institute of technology was launched at the end of the year. The center will focus on complete design of an optimal wind turbine which takes the interaction among all components into account. Another new project starting in 2010 focuses on the electricity system (hvdc) for offshore wind power.

2.0 National Objectives and Progress

2.1 National targets

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 TWh in 2008 to 2.5 TWh in 2009 (Figure 1).

2.2 Progress

The Swedish electricity end use in 2009 was 138.3 TWh, a decrease of about 4% compared to 2008. 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 2009. In spite of the decreased electricity demand in 2009 Sweden turned from a net exporter of electricity in 2008 to a net importer in 2009. This was due to lower production in nuclear electricity generation and also in hydro generation. The wind power electricity generation had the largest increase of all production alternatives; in 2009 wind-generated electricity increased by 24.5% and the share is now 1.9% (Table 2).

2.3 National incentive programs

There are two main incentive programs for the promotion of wind power: electricity certificates and support for technical development in coordination with market introduction for large-scale plants offshore and in arctic areas. The work

Table 1 Key Statistics 2009: Sweden	
Total installed wind generation	1,448 MW
New wind generation installed	363 MW
Total electrical output from wind	2.519 TWh
Wind generation as % of national electric demand	1.8 %
Target:	N/A

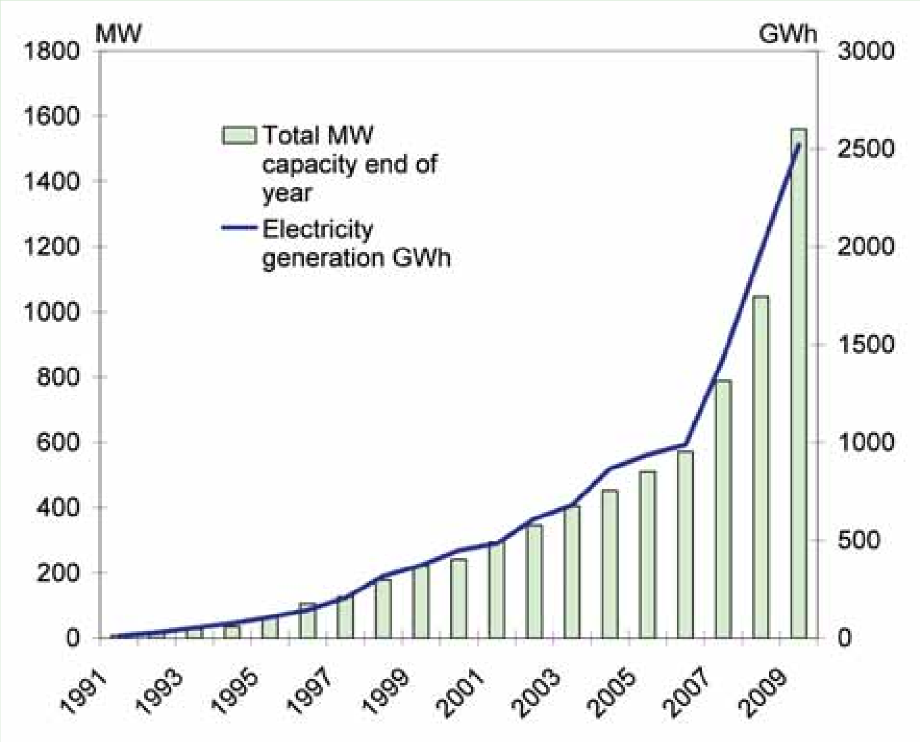

Figure 1 Installed wind power capacity in Sweden 2003 to 2009

done in assessing areas of national interest for wind power can also be considered a sort of "soft incentive."

2.3 1 Electricity Certificates

The electricity certificate system came into force on 1 May 2003, and it is intended to increase the production of renewable electricity in a cost-efficient way. The increased deployment of renewable electricity generation will be driven by stipulated quotas that are increased annually, as well as by a quota obligation fee. The principle is that there should be sellers and purchasers of certificates, and a market to bring them together. There are no specific quotas for wind power. Electricity producers receive a certificate from the state for each megawatt hour of renewable electricity that they produce. This certificate can be sold to provide additional revenue above the sale of the electricity, improving the economics of electricity production from renewable energy sources and encouraging the construction of new plants for the purpose. The demand for certificates is created by a requirement under the Act that all electricity suppliers and certain electricity users purchase certificates equivalent to a certain proportion of their electricity sales or use, known as their quota obligation. The size of this obligation is increased from year to year, increasing the demand for renewable electricity (Figure 2). The price of certificates is determined by supply and demand, and it can vary from one transaction to another.

In order to increase the electricity certificate price, and thereby the renewable generation, a new suggestion for quotas was proposed by the Swedish Energy Agency in 2009. With current quotas in the electricity certificate system it is estimated that wind energy will contribute approximately 7 to 8 TWh by 2015. The new suggestion forwarded by the Swedish government to the European Union will increase wind power generation from today's level up to 12 TWh by 2020. No difference is made between land and offshore wind power in the electricity certificate system. Further use of the space within the Swedish planning goal for wind power can be realised with other incentives and initiatives.

A new production unit can receive certificates for a period of 15 years. Old units therefore leave the system after 15 years. Around 2010 there is a "notch" in the quotas due to the fact that a number of older production units are phased out of the system after 2012. Figure 2 shows the quotas and expected production.

2.3.2 Support for technical development

In 2003, the Swedish Energy Agency launched a program to support technical development in coordination with market introduction, for large-scale plants offshore and plants in arctic areas. The aim is to stimulate the market, achieve cost reduction, and gain knowledge about environmental effects. For the years 2003 to 2007, the budget was 350 million SEK (38 million €). The market introduction program has been prolonged another five years with an additional 350 million SEK for the period 2008 to 2012. The projects funded up to date are shown in Table 3.

2.3.3 Areas of national interest

According to the environmental code, land and water areas shall be used for the purposes for which the areas are best suited in view of their nature, the situation, and the existing needs. Priority shall be given to the use that promotes good management from the point of view of public interest. These are areas of national interest for fishery, mining, nature preservation, outdoor recreation, wind power, etc.

2.3.4 Network for wind utilization (1)

The Swedish Energy Agency is the expert authority appointed by the government to promote the development of wind power, taking a holistic approach to encouraging the rapid expansion of wind power. Therefore, the Swedish Energy Agency has started a national network for wind utilization. A national network 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.

The Swedish Energy Agency has also developed a web-based information portal "Vindlov" (2) which collects and presents information related to the planning process. The Swedish Energy Agency offers a chart service (3) for the whole of Sweden, which shows:

- national interest areas for wind power

Table 2 Electricity supply and demand in Sweden, 2008 to 2009

Electricity Supply	2008	2009	%
Domestic production	146.0	133.7	-8.5
Hydro power	68.4	65.2	-4.6
Wind power	2.0	2.5	24.5
Nuclear	61.3	50.0	-18.4
Thermal	14.3	15.9	11.0
Import	12.8	13.8	8.0
Sum supply	158.8	147.4	-7.1
Electricity Demand	2008	2009	%
Domestic demand	144.1	138.3	-4.0
Industry	56.4	49.7	-11.8
Electricity, gas, heat and water supply	4.4	4.3	-1.2
Transports	2.9	2.8	-3.3
Household and service etc.	69.4	71.3	2.7
Losses	11.0	10.2	-6.9
Export	14.7	9.1	-38.3
Sum demand	158.8	147.4	-7.1

- wind speed charts at different heights (based on wind surveys),
- existing wind turbines (based on voluntary operating statistics), and
- operation follow-up.

2.4 Issues affecting growth

A need to change the quotas in the electricity certificate system has been identified and new suggestions concerning the electricity certificate system have been forwarded. The permit process for wind power projects and the process for grid connection have been identified as bottlenecks. During 2009, new decisions aimed at simplifying permits according to the Environmental Code and the Planning and Building Act have been taken. It may be necessary to revise the rules further to speed up the decision processes in municipalities (4).

3.0 Implementation

The expansion onshore is mostly driven by the large utilities like Vattenfall and E.ON but also by other actors. There are a number of utilities, developers, real estate companies, and private persons developing smaller and larger projects. Of the erected wind power in 2009, Vestas achieved a market share of 53%, Enercon 27%, Nordex 11%, WinWinD 8%, and Kenersys about 1% (Figure 3).

The large, international manufacturers of turbines, Vestas, Enercon, Nordex, and others, have sales offices in Sweden. In 2009, GE Wind acquired the Swedish wind power company ScanWind. Vattenfall increased its wind power ownership by buying the Dutch company, Nuon. A new industry for building vertical axis wind power turbines is being built in Falkenberg by Vertical Wind AB. 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

The wind park Vindpark Vänern built in Lake Vänern began operation in autumn 2009. The park was given 40 million SEK (3.7 million €) of financial support from the Swedish Energy Agency, which was 9.5% of the total estimated investment. The water depth on the site is 5 m to 7 m. The foundations consist of concrete foundations that are secured in the rock by 16 20-m-long pre-stressed anchors. This made it possible to have rather small foundations with a minor influence on the lake bottom and the ecosystem. The ten 3-MW wind turbines were delivered by WinWinD.

New wind power projects in mountainous and cold climate areas are supported by the Swedish Energy Agency during the year. In several of the projects investigating issues relating to icing of turbines are included but also questions such as employment, business, and logistics are studied. One of the projects is located in the northern Sweden, in an area called Markbygden, Piteå. This is a 450-km^2 area where Svevind AB has received authorization to construct 1,101 wind turbines. Through a new pilot project driven by Arise Windpower AB, valuable experiences are expected from building wind power in forests and complex terrain.

A new supplier of on-shore wind turbines, Kenersys, has installed its prototypes at two different locations in Sweden: the K100 2.5-MW machine at Vattenfall´s test site at Näsudden on the island of Gotland (opening photo) and one K82 2.0-MW machine in Gothenburg, owned by the local utility. The first deliveries of commercial turbines will be three K100 2.5-MW turbines with 100-m rotors and 100-m towers that will be erected in fall this year in southern Sweden. Further projects will follow in 2010. The Kenersys wind turbines have the following main characteristics: variable speed, pitch-regulated turbine with a distributed drive train including a gearbox. The electrical concept is based on a full conversion system with an electrically excited synchronous generator. Kenersys is a part of the Kalyani Group

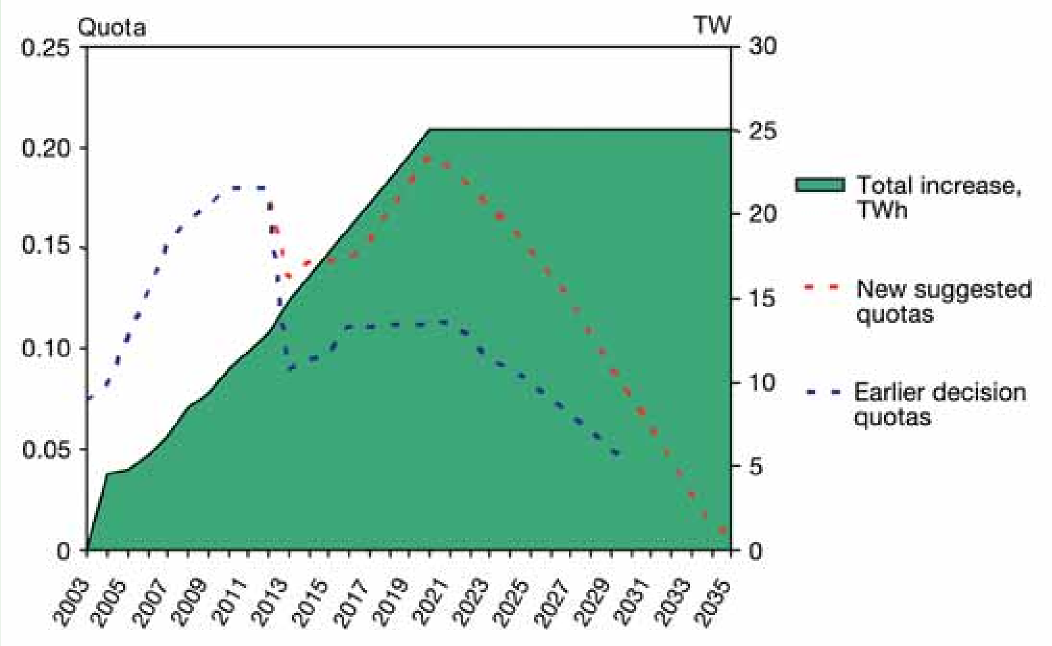

Figure 2 Quotas and production goal of the electricity certificate system

Table 3 Projects with support from the market introduction program

Project	Recipient company	Support	Location	Estimated production and estimated year of operation
Lillgrund	Örestads vindkraftpark AB (owned by Vattenfall)	213 MSEK (23 M€)	Off-shore	330 GWh; operating since late 2007
Vindpark Vänern	Vindpark Vänern Kraft AB	40 MSEK (4.3 M€)	Largest Swedish lake	89 GWh; operation in 2009
Uljabouoda	Skellefteå Kraft AB	35 MSEK (3.8 M€)	On-shore arctic	100 GWh (2008)
Kriegers Flak	Sweden Offshore Wind AB (Vattenfall AB)	9.45 MSEK (1 M€)	Off-shore	No production. Only development program, reported
Storrun	Storun AB	26.25 MSEK (2.8 M€)	On-shore	80 GWh. 2009
Large scale wind power in northern Sweden	Svevind AB	115 MSEK (12.4 M€)	On-shore	197 GWh, 2009-2011
Large scale wind power in southern Swedish forests	Arise Windpower AB	50 MSEK (5.4 M€)	On-shore	140 GWh, 2009-2010
Large scale wind power in highland areas	O2 Vindkompaniet	72.5 MSEK (7.8 M€)	On-shore	260 GWh, 2011
Havsnäs	NV nordisk Vindkraft AB	20 MSEK (2.2 M€)		256 GWh, 2009-2010
Vindval		35 MSEK (3.8 M€)		Environmental research program

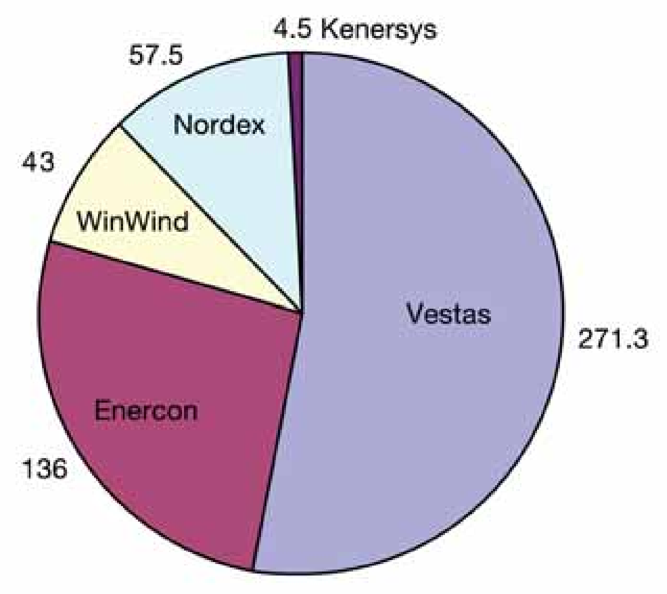

Figure 3 Installed capacity 2009 512.3 MW (5)

and has its headquarters and Center of Innovation in Münster (Germany) with a manufacturing facility in Wismar.

3.2 Wind energy costs

The average price of electricity certificates in 2009 was 293 SEK/MWh (31.6 €/MWh), which is higher than in 2008 when the average certificate price was 247 SEK/MWh (26.7 €/MWh). Experiences from Vattenfall shows that wind turbine investment costs are about 970-1,300 €/MW and total wind power project costs are 1,510 to 2,160 €/MW.

4.0 R, D&D Activities

Publicly funded wind energy research in 2009 was mainly carried out within the Vindforsk (6) and Vindval research programs (7). The present phase of Vindforsk (Vindforsk III) runs from 2009 to 2012 with a total budget of 20 million SEK/yr. The program is financed 50% by the Swedish Energy Agency and 50% by industry. Vindforsk III is organized in four project packages:

- The wind resource and establishment
- Cost effective wind power plant and design
- Optimal running and maintenance
- Wind power in the power system

In the beginning of 2009, Vindforsk III invited interested actors to an open project presentation seminar where researchers and organizations participated and presented project ideas. During the rest of 2009, intensive work has been carried out by applicants, steering groups, and the Vindforsk organization to formulate and start up new research projects. In the beginning of 2010, projects corresponding to 74% of total budget were decided and reserved.

The Vindval programme is financed by the Swedish Energy Agency and is administrated by the Swedish Environmental Protection Agency. Vindval's objective is to facilitate an increase in the expansion of wind power by compiling basic data for environmental impact assessments and permit application processes. During 2008, the program was extended through 2012 with a new budget of 35 million SEK. Within this time period, the program includes new environmental studies in important fields such as social studies; animals in the forests; and effects on economic areas like reindeer farming, nature tourism, and outdoor recreation. Other important areas will be to synthesize and spread information to important actors in the industry about the effects from wind power. Three studies have been finished during 2009:

- Environmental optimization of foundations for offshore wind power and studies of small fish at Lillgrund wind farm
- A study about how sea-based fauna is affected by noise from offshore wind power
- Experience from wind power building – support, acceptance, and resistance.

Apart from projects in these programs, other R&D projects have also been funded.

- A study on how to decrease disturbances to defense radar systems from offshore wind power have shown that the handling of wind power permitting can be simplified. Solutions for new radar applications off shore are now investigated.
- A wind power project including four 200-kW, direct-drive, vertical axis H-rotors was started during the year. The generators are built with windings with high voltage cables.
- The Swedish Energy Agency has decided to support the Swedish Wind Power Technology Center (SWPTC) at Chalmers University of technology with 33 million SEK (3.6 million €). The center starts 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.
- A Nordic consortium exists for optimisation and management of wind power parks. The focus is on wake modelling and how to optimise wind parks to maximise production and to minimise loads on the turbines. The consortium consists of researchers in Denmark, Norway, and Sweden.
- Three new projects began concerning sound from wind power. The projects aim to improve and further develop models and measurement methods for wind power sound distribution.

5.0 The Next Term

The two research programs Vindval and Vindforsk continue with new research projects in 2010. 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-fjelds." 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 start. Another project led by Chalmers University of technology, starting in 2010, focuses on high voltage direct current power systems for off shore wind power.

References and notes:

(1) www.natverketforvindbruk.se/

(2) www.vindlov.se

(3) www.energimyndigheten.se/sv/Om-oss/Var-verksamhet/Framjande-av-vindkraft1/karta/

(4) www.energimyndigheten.se/sv/Press/Nyheter/Snabbare-beslut-om-vindkraftsetablering/

(5) www.svenskvindenergi.org/files/Statistik_vindkraft2009.pdf

(6) www.vindenergi.org/

(7) www.naturvardsverket.se/sv/Verksamheter-med-miljopaverkan/Energi/Vindkraft/Vindval/

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Switzerland


Courtesy ENCO Energie-Consulting AG

1.0 Overview

By the end of 2009, 30 wind turbines were operating in Switzerland with a total rated power of 18 MW. These turbines produced 22.5 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. By 16 March 2010, six turbines with a rated power of 2.033 MW were installed under the energy policy framework of Switzerland (CRF) system. Financing was requested for 596 turbines with rated power of 1,213 MW and an estimated energy yield of 2.348 GWh/yr under this scheme. Based on the very slow development in the last years, the target for 2010 (100 GWh/yr) will likely not be achieved, yet the outlook for achieving the 2030 target (600 GWh) is very optimistic.

In Switzerland, an ancillary industry for wind turbine manufacturers and planners has developed, which acts mainly on an international level, and the total turnover is about 1,400 million €. 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

Table 1 Key Statistics 2009: Switzerland	
Total installed wind generation	18 MW
New wind generation installed	4 MW
Total electrical output from wind	0.0225 TWh
Wind generation as % of national electric demand	0.04%
Target:	100 GWh/yr in 2010 600 GWh/yr in 2025

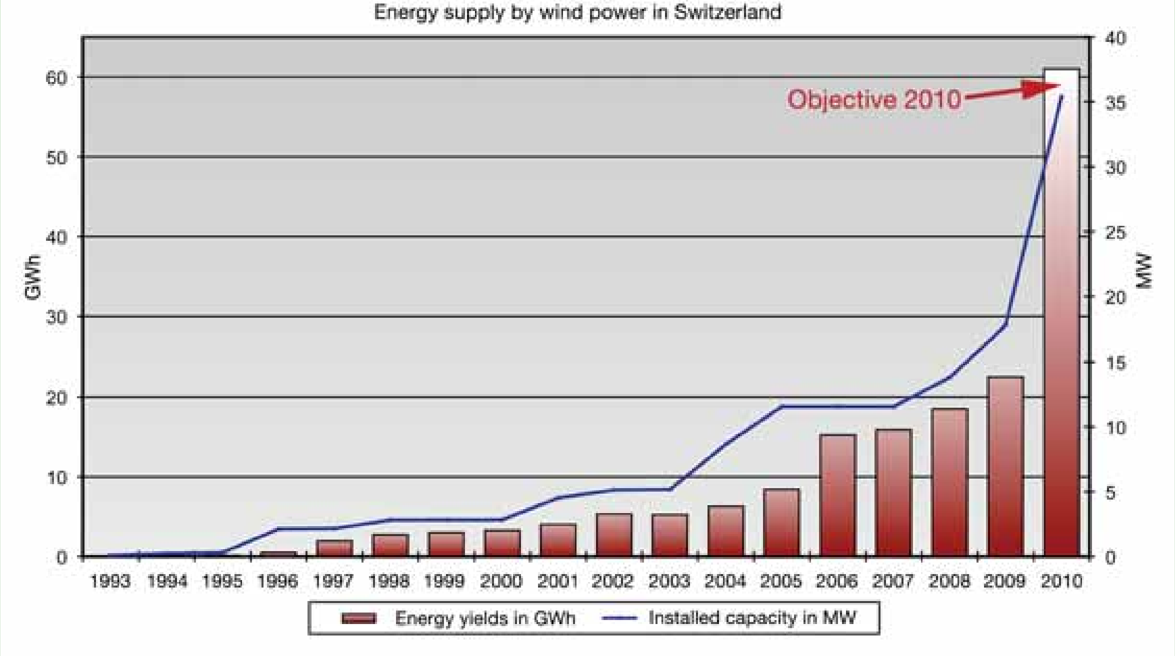

Figure 1 Installed capacity and energy yield of wind turbines in Switzerland 1993-2010

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%). There are 380 electricity supply companies that now offer certified electricity products from renewable energy, which meet 4.5% of Switzerland's electricity demand (3).

In 2009, two 2-MW turbines were put in operation. In total, 30 wind turbines are installed with a rated capacity of 18 MW. These turbines produced 22.5 GWh (Figure 1). During an average wind year, these turbines would generate 27 GWh. Eight turbines with a rated power of 2 MW each are under construction at Mt. Crosin; two more turbines will be installed on Mt. Gütsch, the famous alpine wind test site in 2010.

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 cost-covering feed-in-tariff (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 €/yr (financed by a 0.40 €/kWh fee on electricity sold in Switzerland) will be available for offsetting the difference between the cost-covering FIT and market price.

The tariffs for remuneration for electricity from renewable energy sources (green power) have been specified on the basis of reference facilities for each technology and output category. Remuneration will be applicable for a period of between 20 and 25 years, depending on the technology. A gradual downward curve is foreseen for these tariffs in view of the anticipated technological progress and the entrance of a growing number of technologies in the market. For wind energy, the same system Germany uses has been applied, whereby the higher price is 0.133 €/kWh and the lower price is 0.113 €/kWh (4). 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. Facilities put into operation prior to 1 January 2006 can benefit from this form of remuneration. Their operators can register these facilities with Swissgrid, the national grid operator.

Switzerland has pursued a consistent energy policy since 1990 through the Energy 2000 and SwissEnergy programs (5). 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 (6).

2.4 Issues affecting growth

By 16 March 2010, six wind turbines had been installed under the CRF scheme (2.03 MW). An additional 403 units with a rated power of 747 MW and a possible energy yield of 10,355 GWh had registered with the national grid operator. The high number of registrations (also for other technologies) reached the full financial cap laid down by Parliament in the Energy Act. As a result, the Swiss Federal Office of Energy (SFOE) had to declare a moratorium from 1 February 2009 for all technologies. In practical terms, this means that Swissgrid ag will put all new applications from any type of plant on a waiting list if they are postmarked 1 February 2009 or later. Wind energy projects with 193 wind turbines (466 MW) and an expected production of 993GWh/yr were on the waiting list in March 2010. Further expansion of green electricity production in Switzerland on the basis of the current CRF incentive system is only possible by increasing the finances assigned for CRF. The Swiss parliament is discussing such an increment.

Other issues affecting growth include the following:

- 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 "Social Acceptance" are 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.
- Unfortunately, the regulation for the FIT scheme provides only 0.113 to 0.133 €/kWh for wind energy. According to the Swiss Wind Energy Association, these tariffs are not cost-covering for most of the sites in Switzerland.
- Based on the important changes in the CRF, 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 by McKinsey shows significant potential of renewable energies for Swiss companies, in different scenarios (7). Figures for wind energy are shown in Table 2.

3.2 Industry status

The Swiss industry is active in the following 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 wind speeds in the range between 4.5 and 6.2 m/s, turbulent sites, and icing conditions, the average capacity factor for installations in Switzerland is below 20%. Thanks to adapted technology to the Swiss wind regime (e.g. variable speed and pitch control), the two turbines installed in an inner alpine valley show capacity factors of 28% and 29%. The only project realized in 2009 are the two 2-MW Enercon E82 turbines. These turbines were installed in St. Brais by the company ADEV, a cooperative with more than 600 shareholders (opening photo). Since these are the first turbines with variable speed installed at a typical site in the Jura mountain range (where there is big wind potential), it will be interesting to learn how these machines perform.

3.4 Wind energy costs

The specific costs of existing larger wind power plants (including installation) amounted to about 2,000 to 2,200 CHF/kW (1,220 to 1,330 €/kW). In 2009, prices for new installation rose to 2,800 CHF/kW (1,800 €/kW). These prices will result in cost-covering tariffs in the range of 0.25 CHF/kWh (0.15 €/kWh) at windy locations. Unfortunately, the regulation for the compensatory feed-in remuneration scheme provides only 0.113

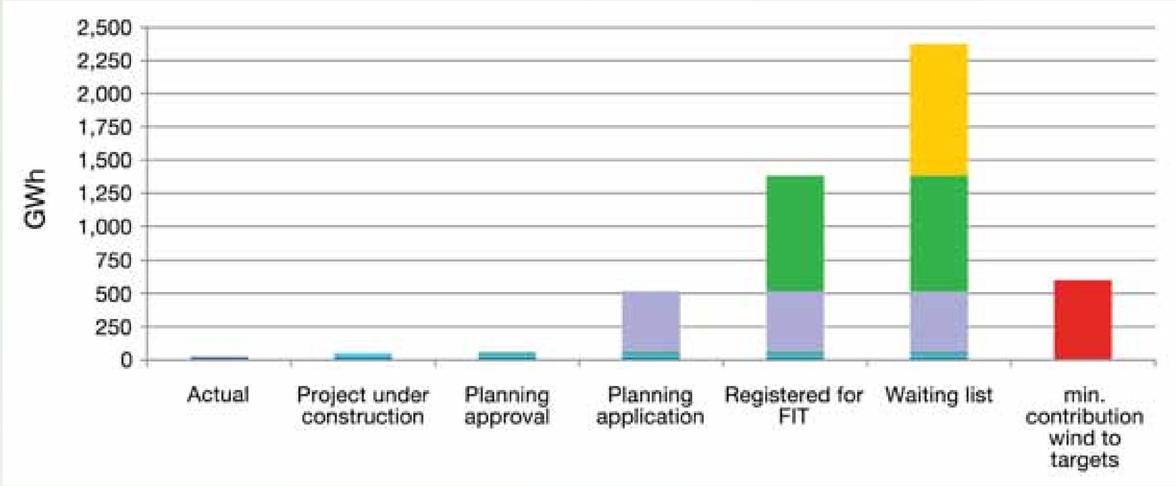

Figure 2 Estimated development of wind energy in Switzerland 2009

Table 2 Economic impact of wind energy development for Switzerland		
	2008	2020
Jobs worldwide (Swiss companies)	8,400	32,000
Jobs in Switzerland	4,200	9,600
Total turnover	1,400 million €	7,500 million €

to 0.133 €/kWh for wind energy – based on the same mechanism as the German model. In early 2010, negotiations were under way between the wind energy industry and the SFOE to raise these values. 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 (8) focuses on development of innovative turbine components for specific application in harsh climates, increase of availability and energy yield at extreme sites, increase of the "value" of the wind energy, optimization of the integration of wind energy into the grid, and an increase of 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 2009, the budget for wind energy related R&D projects was 500,000 CHF (333,000 €). This is 35% less than 2008, but still 60% more then 2007. An amount of 631,000 CHF (436,000 €) is spent on promoting activities.

4.1.1 Innovative turbine components

Antifreeze coatings for rotor blades of wind turbines: The ZHAW (Zurich University of Applied Sciences) has developed a coating that influences the freezing behavior of water. Tests showed that water droplets on the antifreeze coating take longer to freeze than droplets on the untreated glass. This effect could lead to less icing of coated rotor blades, because the droplets could be blown off the blade before they froze.

Icing map of Switzerland: 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 will be produced. Verification of this map with on-site measurements is under way. In addition, the resulting ice loads on structures will be calculated.

Development of wind turbines for safe operation in alpine environments: The influence of upstream wakes on turbine power in complex terrain, unsteady flow, and increased turbulence lead to an increased uncertainty in wind farm annual energy production, poorer reliability, shorter lifetime, and ultimately to an increased risk for investors. For these reasons, the industry needs further research in this field. A project at ETHZ focuses on quantifying these losses and understanding the responsible flow phenomena as well as proposing loss mitigation strategies.

Icing on 2-MW wind turbine in St. Brais: With this project, the icing effects on operation and energy yield of two 2-MW Enercon wind turbines in the Jura Mountains (1,300 m above sea level) are investigated. The project will look at the efficiency and reliability of different anti-icing systems. It will come up with a definition of energy losses due to icing, and calculate the energy and cost balance of the anti-icing heating system. The project will work on detection and measurement of the additional loads due to ice on the rotor blades with a rotor monitoring system. It will also define location-specific load curves of the wind turbine with and without icing by means of a Lidar measuring campaign in comparison with the load curve defined by the manufacturer.

4.1.2 Increasing availability

Forecasting electricity production of wind turbines in complex terrain: In this research project several forecast methods were developed and tested in a prototype (Figure 3). The forecasts were analyzed for two temporal horizons: short term forecasts for the next day and forecasts for intra-day trade. Hourly values of wind speed and power output were forecast.

4.1.3 Increase of the acceptance of wind energy

Code of Conduct: The Federal Office of Energy has launched a participatory process for the better implementation of wind energy projects. A Code of Conduct to assure a better social acceptance of wind projects will be jointly defined and developed by the relevant actors in the market. A feasibility study has traced a high demand among the energy suppliers, project developers, investors, and NGOs.

The effects of wind parks in the mountainous regions of Switzerland through avifauna studies at the future sites for wind parks on the Mount Schwyberg, the Gotthard pass, and in the Jura mountains will clarify to what extent the breeding birds and the bird migration are affected by wind turbines. These studies collect information pertaining to the bird migration before and after the construction of the turbines by means of radar, intensive impact counting, and observations of bat and bird breeding. Suggestions for the minimization of the negative influences are to be made for further wind energy developments in mountainous regions.

IEA Wind Task 28 Social Acceptance of Wind Energy Projects: Switzerland holds the office of Operating Agent of IEA Wind Task 28 which aims at assisting countries to 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.

4.2 Collaborative research

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

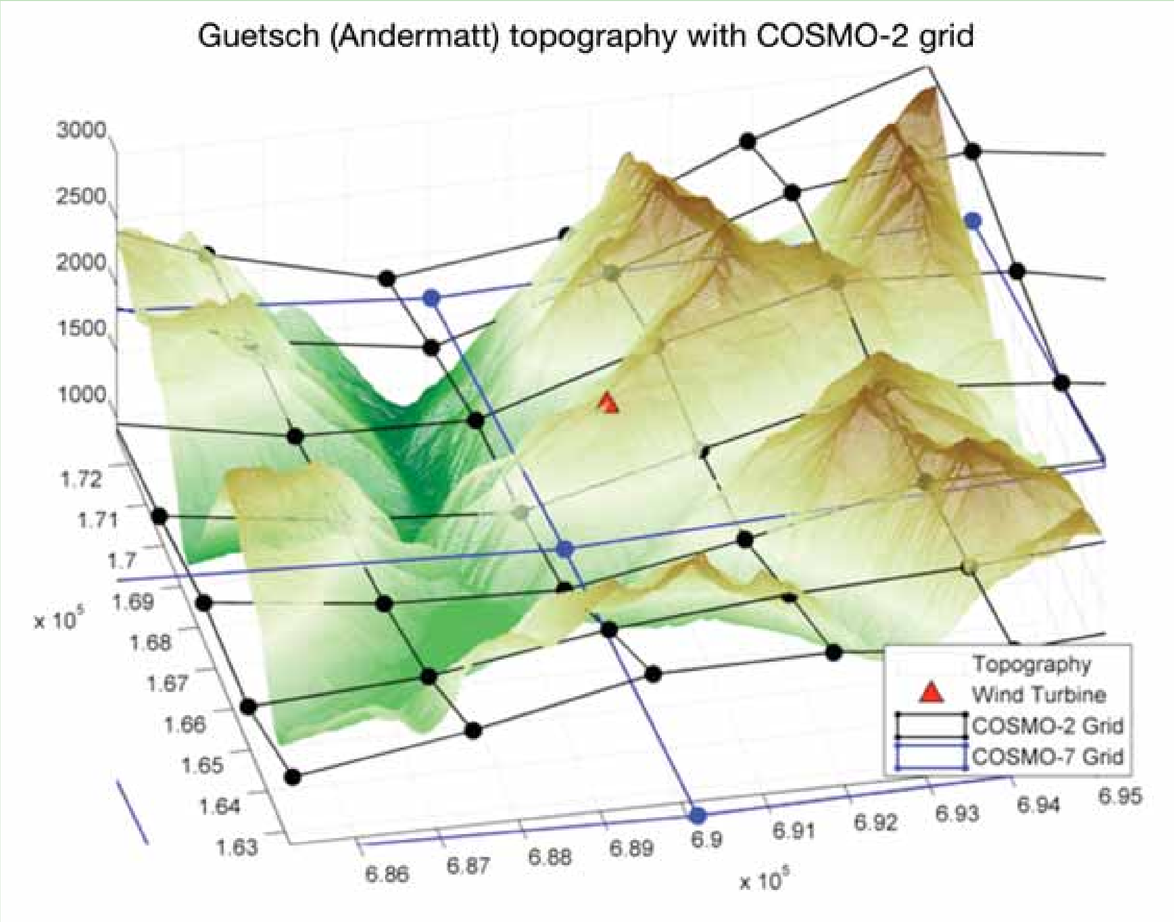

Figure 3 Comparison of the real topography with the topography used by COSMO-2 model (black dots) on Mt. Gütsch as an example

energy. Since 2008, the IEA Wind Task 28, Social Acceptance of Wind Energy Projects: Winning Hearts and Minds has been managed by Switzerland.

5.0 The Next Term

Thanks to the FIT, the registrations for new project developments are astonishing. Yet these figures must be analyzed rather critically, since to register only a contract with the land owner and the proposed installed capacity have to be presented. Various projects might therefore be abandoned during future developments due to insufficient economics, spatial planning issues, landscape protection, etc.

Promotion strategies and future research activities have to concentrate on issues which lead to the realization of a substantial amount of these planned projects.

Based on actual budget restriction, the possibilities for activities are rather limited. If the big economic effects of the wind energy for the Swiss industry (Table 2) are to be realized, a substantial rise in research and promotional activities is crucial. Today the emphasis of the research activities should concentrate on the following key issues:

- Quantifying the production losses and the downtimes due to icing; implementation and evaluation of relevant measures
- Reducing the production cost by increasing the full-load hours and the reliability of turbines in harsh conditions
- Increasing the accuracy of energy yield estimates
- 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.

The experiences in cold climates will be continuously shared in international seminars and in the project group of the IEA Wind Task 19, Wind Energy in Cold Climates. Having more experiences in difficult site development and sophisticated planning procedures than in large-scale wind energy development, Switzerland continues to manage the IEA Wind Task on Social Acceptance of Wind Energy Projects.

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) Electricity Statistics
http://www.bfe.admin.ch/themen/00526/00541/00542/00630/index.html?lang=en

(4) 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

(5) The SwissEnergy program http://www.bfe.admin.ch/energie/00458/index.html?lang=en&dossier_id=00720

(6) The Swiss Wind Energy Association "Suisse Eole"
http://www.suisse-eole.ch/de.html

(7) McKinsey, Rolf Bättig: Wettbewerbsfaktor Energie, Chancen für die Schweizer Wirtschaft, 2010
http://www.mckinsey.com/locations/swiss/news_publications/pdf/Wettbewerbsfaktor_Energie.pdf

(8) Energie Forschungs-Programm Windenergie für die Jahre 2008-2011
http://www.bfe.admin.ch/forschungwindenergie/02331/index.html?lang=en&dossier_id=02802

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United States

Courtesy Roger Wendell

1.0 Overview

Despite difficult economic conditions, more wind generation capacity (10 GW) was installed in the United States in 2009 than in any previous year, bringing total generating capacity to 35 GW. Through the activities of the U.S. Department of Energy (DOE), funds from the American Recovery and Reinvestment Act of 2009 (Recovery Act), state and local initiatives, and the efforts of the private sector, the nation is working toward achieving an even greater contribution of wind energy to the U.S. electricity supply. Wind energy is now poised to make a major contribution to the goal of doubling the nation's renewable energy generation capacity by 2012.

In 2009, as part of its ongoing efforts to improve wind technology reliability and performance, DOE expanded existing wind technology test centers and began work on additional facilities around the country. Construction began on a new blade test facility and plans are underway for a large drivetrain testing facility. DOE also began funding several university-led research consortia that will focus on critical wind energy challenges. Finally, DOE is supporting an effort to establish regional test centers for small wind technologies, and in 2010 DOE will launch a project to develop midsize (100-kW to 1,000-kW) turbines.

Investments from 2009 Recovery Act funds in wind projects and transmission infrastructure will aid future growth in wind energy development. To analyze transmission system needs, the DOE Wind Energy Program this year completed several studies on high penetrations of wind generation (between 20% and 30%) on the synchronous electricity grids covering the contiguous 48 states. The U.S. Department of the Interior developed an approval process for offshore

Table 1 Key Statistics 2009: United States	
Total installed wind generation	35,086 MW
New wind generation installed	10,010 MW (1)
Total electrical output from wind	70.76 TWh
Wind generation as % of national electric demand	1.9%
Target:	No official target for wind

wind energy development, and DOE expanded its offshore wind energy research efforts. Also in 2009, DOE announced the funding of 8 million USD to 53 new wind energy research projects to address market and deployment challenges, as well as 14 million USD to 28 new projects including wind turbine research and testing and transmission research and analysis

2.0 National Objectives and Progress

2.1 National targets

Wind energy will make a critical contribution toward doubling the nation's electricity generation capacity from renewable sources by 2012. DOE's 2008 report *20% Wind Energy by 2030* examined the feasibility, costs, and benefits of supplying 20% of the nation's electricity from wind by the year 2030. The 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 (2). Property tax revenues would increase to more than 1.5 billion USD by 2030 and payments to rural landowners would increase to more than 600 million USD in 2030.

The United States faces several major challenges along the path to 20% wind energy by 2030. There is a need for investment in the electric transmission system to deliver wind-generated electricity to urban centers, as well as for larger electric load balancing areas and improved regional planning to increase the regional diversity of generation sources. The manufacturing supply chain must grow to provide the wind turbine components, and a skilled workforce must develop 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 of Recovery Act and congressionally appropriated funds to address these barriers to achieving 20% wind energy.

2.2 Progress

In 2009, the U.S. wind industry installed 10,010 MW of generating capacity, increasing the country's installed wind capacity by 39%; wind power represented 40% of all new U.S. electric generation capacity for the year. According to the American Wind Energy Association (AWEA), the wind turbines added in 2009 generate enough electricity to power the equivalent of 2.4 million homes—the generation capacity of three large nuclear power plants. The entire wind turbine fleet's generation capacity—more than 35,000 MW—is enough to power nearly 10 million homes. Each year, this wind power capacity will avoid an estimated 62 million metric tons of carbon dioxide, equivalent to taking 10.5 million cars off the road, and will conserve about 20 billion gallons of water that would otherwise be withdrawn for steam or cooling in conventional power plants. Wind power now contributes nearly 2% of the total U.S. electricity supply, and wind contributes up to 14% of some individual states' electrical generation.

Renewable energy standards are credited with the rapid growth of wind power in Texas, including the world's largest land-based wind farm, which was constructed in just over two years (Figure 1). The Roscoe Wind Farm's 627 wind turbines, totaling 781.5 MW, can generate electricity for more than 230,000 U.S. homes.

The small wind market increased by 20 MW in 2009, a 15% increase over

Figure 1 The 781.5-MW Roscoe Wind Farm, in Texas provides 70 full-time jobs for plant operations

Table 2 Top ten states for wind generation

State	Existing generating capacity (MW)
Texas	9,405
Iowa	3,670
California	2,723
Washington	1,908
Oregon	1,821
Minnesota	1,796
Illinois	1,548
New York	1,274
Colorado	1,246
North Dakota	1,203

2008, bringing the total capacity for this sector to more than 100 MW. AWEA estimates that 10,000 units with rated capacities of 100 kW or less were installed in 2009.

More than 2,700 MW of utility-scale wind projects were under construction at the close of 2009. Nearly 270,000 MW of wind projects were in line for interconnection agreements, an early stage of project development.

2.3 National incentive programs

Federal tax and grant incentives and state renewable portfolio standards (RPS) played important roles in the record wind capacity growth of the past three years. In February 2009, federal tax credits were expanded and extended to 2012, providing a predictable, transparent incentive framework to attract investment.

2.3.1 Federal incentive programs

Because of its national importance, the energy sector receives research and development 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 0.021USD/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. The Recovery Act also allows project owners to elect to receive the investment tax credit in the form of an upfront cash grant equivalent to 30% of total project value. So far, more than 3 billion USD has been awarded to 99 wind power ventures in 32 states under this program.

Tax credits are also available to businesses and homeowners who purchase and install qualified small wind systems. Businesses and homeowners can claim the full 30% investment tax credit with no cap for qualified small wind systems (under 100 KW) through 2017. This tax credit was formerly capped at 4,000 USD. Finally, the Recovery Act also includes a 30% credit for investment in new or reequipped facilities manufacturing wind energy equipment, and extends the eligibility of DOE–issued loan guarantees to include commercial wind power technologies.

2.3.2 State and local incentive programs

State-mandated RPS programs require utilities to provide a percentage of their overall electrical generation or electrical generation from renewable resources. In 2008, state RPS policies collectively called for utilities to procure about 23 billion kWh of their generating capacity from new renewable energy generation (3). By 2010, this requirement will rise to 60 billion kWh of generating capacity and to just under 100 billion kWh by 2012. By the end of 2009, RPS programs had been adopted in 45 states at the state, local, or utility level. 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.

2.4 Issues affecting growth

Government policies addressed several issues affecting the growth of wind power in 2009. Recovery Act investments, including grants and loans from the U.S. Departments of Energy, Agriculture, Commerce, Defense and Interior, began flowing to wind power projects, thus responding to the shortage of capital and sluggish economic activity that had slowed investment in projects. The Recovery Act also supported the construction of new transmission capacity, the lack of which has posed a major obstacle to accelerated deployment of wind power projects. For example, Recovery Act funds supported the construction of new transmission lines capable of shipping more than 6,000 MW of wind-generated electricity from Montana and Wyoming to power markets in Arizona, California, and Nevada. About 32,000 MW of new transmission capacity for wind-generated electricity has been proposed for the next four years. However, more than 270,000 MW of wind projects have applied for interconnection to the electric grid. As a result, even the proposed 32,000 MW of transmission capacity will not be enough to transmit the output of the proposed queue of projects. In addition, transmission inadequacies may cause many grid-connected wind projects to face curtailment of their output or negative electric prices.

To address jurisdictional conflicts that have stalled U.S. offshore wind development, the Energy Policy Act of 2005 granted the U.S. Department of the Interior (DOI) the authority to regulate renewable energy development in federal waters on the Outer Continental Shelf. In 2009, DOI established a framework to grant leases, easements, and rights-of-way for offshore wind farms. The framework established methods for sharing revenues generated from offshore wind projects with federal, state, and local agencies and with tribal governments.

3.0 Implementation

3.1 Economic impact

In 2009, the U.S. wind industry employed about 85,000 workers throughout all 50 states. DOE's Wind Powering America team has calculated the economic benefits of wind power to rural areas and found that lease payments to landowners can total 2% to 3% of gross project revenue, or 2,500 USD to 4,000 USD/MW/year. Local property tax revenues range between

3,000 USD and 17,000 USD/MW/year. A 100-MW project supports between 100 and 200 jobs during construction and 6 to 10 permanent operations and maintenance jobs for the duration of the project's lifetime.

Sales in the small wind turbine sector were valued at 82 million USD in 2009. One-third of the small wind turbines made in the United States are exported.

3.2 Workforce Development

To address the need for a skilled wind industry workforce—a major challenge facing the U.S. wind industry—DOE's Wind for Schools project supports educational programs at the K-12 and university levels. These programs enable students to learn about wind energy through hands-on experiences with wind technology (Figure 2). In 2009, the Wind for Schools project started Wind Application Centers at universities in six states, installed 20 turbines at K-12 schools, and held training workshops at schools in five states. Early in 2010, DOE selected five additional states to receive approximately 60,000 USD each per year for three years for wind-related educational activities.

According to AWEA, 205 educational programs now offer certificates, degrees, or coursework related to wind energy. Of these programs, 45% are offered by four-year universities and colleges and 43% are offered by community colleges and technical schools.

3.3 Industry status

3.3.1 Ownership

According to statistics gathered by AWEA, NextEra Energy Resources owns the most U.S. wind plant capacity (7,458 MW), followed by Iberdrola Renewables (3,225 MW), Horizon-EDPR (2,642 MW), and MidAmerican Energy (2,205 MW). Sixteen other companies each own 400 MW or more, indicating a diversified wind energy market.

Independent power producers, many of which are unregulated utility subsidiaries, developed and owned 84% of new capacity added in 2009. Ownership by utilities stayed at about 15% for a fourth year. Among utility owners of wind capacity, MidAmerican Energy (including PacifiCorp) owns the most with 2,205 MW installed. The utility Xcel Energy is the largest wind energy user; it owns 127 MW of generating capacity and delivers 3,049 MW of additional wind-generated electricity supplied through Power Purchase Agreement contracts with other wind plant owners.

Community wind projects tend to be less than 20 MW in capacity and locally owned, providing a variety of benefits to the local communities. These types of projects provide a large number of interconnection locations and often face fewer permitting barriers than larger projects, providing an opportunity to optimize the nation's electric transmission grid. According to AWEA, community wind projects represented less than 1% of new wind generation capacity installed in 2009.

3.3.2 Manufacturing

Wind energy manufacturing continued to grow in 2009. The largest expansion was in the manufacture of utility-scale wind turbine subcomponents, such as bearings, electrical components, and hydraulic systems. According to AWEA, 39 new manufacturing facilities were opened, announced or expanded in 2009 (4). The United States now has more than 200 facilities manufacturing wind energy equipment, including facilities from nine different turbine manufacturers, 20 operating tower manufacturing facilities, and 13 blade manufacturing facilities. U.S. manufacturers provided more than half of the new turbines installed in 2009 and approximately 46% of the new wind generation capacity installed.

Companies selling utility-scale turbines in the United States, in order of market share, include: GE Energy, Vestas, Siemens, Mitsubishi, Suzlon, Clipper Windpower, Gamesa ,Repower, Acciona Windpower, Nordex, AAER Inc., DeWind, Goldwind, Northern Power Systems, and Fuhrländer.

The number of U.S. manufacturers offering small wind turbines rose from 66 in 2008 to 90 in 2009; however, only 14 reported commercial sales in 2009. 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.

3.3.3 Applications

Offshore wind

The United States could potentially generate an estimated 900,000 MW of electricity from its offshore wind resources. Although no offshore wind plants had been built in the United States by the close of 2009, more than a dozen offshore projects between 10-MW and 500-MW are planned in the states of Delaware,

Figure 2 Pocatello Community Charter School in Idaho installed a wind turbine in September 2009 as part of the Wind for Schools project. Credit: Billie Johnson

Maryland, Massachusetts, New Jersey, New York, North Carolina, Ohio, Rhode Island, Texas, and Virginia.

A collaborative effort by government and industry partners, combined with laboratory-based research, has identified a favorable market for a U.S. offshore wind industry. Accordingly, the DOE Wind Energy Program will invest in offshore wind turbine technology research and development to promote and accelerate responsible development of U.S. commercial offshore wind projects. If approved by Congress, a budget request of $49 million for fiscal year 2011 will fund research to address common barriers to offshore projects, including financial, regulatory, technical, and environmental risks.

Community wind

According to community wind advocacy group Windustry, of the 35,000 MW of wind capacity installed in the United States today, more than 1,000 MW are community wind projects. Rural landowners, public and customer-owned utilities, school districts, colleges, and Native American tribes are all benefiting from these projects. In 2009, DOE selected five community renewable energy deployment projects to receive more than $20.5 million in Recovery Act funding. One of these awards will support the development of a 30-MW wind project in Northeastern Colorado.

The United States is home to 2.4 million Native Americans living on 96 million acres of tribal lands. Wind projects on tribal lands can help reduce energy costs and support overall economic development. DOE researchers estimate that tribal lands could provide for 14% of the nation's annual electricity demand while supplying electricity and revenue to the reservations. Through DOE's Wind Powering America outreach and stakeholder engagement initiative, DOE experts have worked with multiple tribal entities to move wind projects forward.

3.4 Operational details

According to AWEA, the average capacity of new turbines installed in 2009 was 1.75 MW, compared with 1.67 MW for 2008. More than 5,600 turbines were installed in 2009, bringing the U.S. total to more than 33,000 turbines. Average project size for projects installed in 2009 is about 75 MW; however, if projects with turbines smaller than 1 MW are excluded, the average project size rises to 85 MW.

Operators report that the percentage of time that wind turbines are available to generate electricity is above 98%. According to AWEA, capacity factors in the best wind resource areas are about 40% annually.

3.5 Wind energy costs

Capacity-weighted average installed turbine cost for a sample consisting of 90% of new capacity added in 2009 was around 2,080 USD/kW (1,444 €/kW). The capacity-weighted average wind price among 30 projects built in 2009 and totaling 2,629 MW was 61.20 USD/MWh (42.47 €/MWh). This price reflects the receipt of incentives such as the production tax credit or cash grants under the 1603 program; it would be higher without these incentives.

4.0 R, D&D Activities

4.1 National R&D efforts

Beginning in FY 2009, the U.S. Department of Energy Wind Power Program substantially increased its R&D activities through competitively-awarded funding to the wind industry and 12 U.S. national laboratories. DOE-funded R&D activities work to improve wind technologies, increase turbine reliability, and reduce the costs of utility-scale and small wind systems. DOE also works to reduce nontechnical barriers to the increased deployment of wind energy.

4.1.1 Budget

DOE's budget for the Wind Power Program was 55 million USD in 2009, up from 49 million USD the previous year. An infusion of 118 million USD in Recovery Act funds for wind R&D supplemented the congressionally-appropriated budget. Congress has appropriated 80 million USD for 2010, and DOE has requested 122 million USD for 2011 (5).

4.1.2 Test facilities

In 2009, DOE expanded the testing capabilities at existing centers and began work on additional facilities around the country:

- Invested 45 million USD in Recovery Act funds to build a new drivetrain test facility, capable of testing up to 15-MW drivetrains, in Charleston, South Carolina.
- Began construction on a new 90-m blade test facility in Boston, Massachusetts, with the help of 25 million USD in Recovery Act funds.
- Invested 10 million USD in Recovery Act funds to upgrade the 2.5-MW dynamometer at the National Wind Technology Center (NWTC) to 5.5 MW.
- Installed a 1.5-MW turbine at the NWTC to conduct aerodynamics, load, and performance research.
- Launched three university-led wind energy research consortia with 24 million USD in Recovery Act funds:

Illinois Institute of Technology – Will conduct research on a utility-scale, land-based wind turbine to develop control algorithms for increasing wind turbine reliability and to develop operation and planning tools for utility power systems

University of Maine – will design, develop, and deploy prototype floating platforms for offshore turbines

University of Minnesota – will install a utility-scale, land-based turbine to investigate aerodynamics and acoustics, novel systems for mechanical power transmission and electric power generation, wind farm siting, and interactions between wind turbines and radar.

4.1.3 Results

A wind resource assessment completed by the Wind Power Program in 2009 found more than three times the wind power potential previously calculated for the United States. According to the new numbers, land-based wind resources could generate nearly 37 TWh annually—more than nine times the total U.S. electrical generation capacity in 2009. Previous government assessments, published in 1991, estimated the total wind power potential at approximately 10 TWh. The new estimates are based on high-resolution wind resource datasets for tower heights between 80 m to 100 m and capacity factors accepted by developers. In addition to the wind potential estimates, as part of its collaborative effort with AWS Truepower, DOE's National Renewable Energy Laboratory produced maps of the annual average wind speed at 80-m height for the contiguous United States and for each individual state.

In 2009, DOE's National Renewable Energy Laboratory published the *Eastern Wind Integration and Transmission Study* (6). This study evaluates the future operational and integration impacts of integrating up to 30% wind-generated electricity into the Eastern Interconnection power system by the study year 2024. Results from the study show that there are no fundamental technical barriers to the integration of 20% wind energy into the electrical system; however, transmission planning, system operation policy, and market development need to continue to evolve for these integration levels to be achieved.

The Western Wind and Solar Integration Study, published in May 2010, examines the operational impact of up to 30% wind and 5% solar energy integration into the WestConnect grid in Arizona, Colorado, Nevada, New Mexico, and Wyoming (7). This study concluded that integration of these wind and solar energy levels into the WestConnect system is feasible, provided that there is sub-hourly scheduling and substantial cooperation between utility balancing areas.

DOE's Argonne National Laboratory completed the *Wind Power Forecasting: State-of-the-Art 2009* report, which includes an in-depth description of physical and statistical forecasting approaches, an overview of available forecasting models and typical application areas, and a discussion of the strengths and limitations of current tools.

DOE's Small Wind Turbine Independent test project tested four small turbines to International Electrotechnical Commission standards as well as to draft AWEA standards for small wind turbine systems.

4.1.4 Research projects underway

The DOE Wind Power Program is working with Siemens under a cooperative research agreement to test a late stage prototype that features a novel blade design. Instrumentation of the 2.3-MW turbine installed at the NWTC in 2009 will provide data on aerodynamics, power characteristics, vibrations, system fatigue, and acoustics. Tests conducted on the Siemens turbine will provide knowledge 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.

The Wind Power Program partnered with RES Americas through a cooperative research agreement to help reduce costs of foundations and electrical power infrastructure for utility-scale wind turbines. For this project, foundations for the two multi-megawatt turbines installed at the NWTC in 2009 were custom-designed and heavily instrumented to provide data on loads. The Wind Power Program and RES Americas are also using the turbines to optimize thermal performance of underground electrical cables by installing cabling in various types of soil conditions and measuring heat dissipation.

More than 30 companies and organizations worldwide now participate in the wind turbine Gearbox Reliability Collaborative launched by the Wind Power Program in 2006. The goal of the Gearbox Reliability Collaborative is to validate the typical gearbox design process through a comprehensive dynamometer and field-test program. In 2009, the first 750-kW gearbox was instrumented and tested at DOE's NWTC dynamometer to establish baseline characteristics. The gearbox was then installed at the Xcel Energy Ponnequin wind farm in Colorado for field testing. Evaluation of the data will be shared among all participants in the collaborative and used to improve gearbox design codes.

The Wind Power Program is working with several industry and academic partners to develop innovative wind turbine load-reducing control systems. Industry partners include Catch the Wind, Garrad Hassan and Partners, Ltd., Risø National Laboratory in Denmark, the Colorado School of Mines, and the University of Colorado. One project aims to develop advanced feed-back and feed-forward controls that can be implemented on commercial turbines to mitigate loads, improve turbine performance, and reduce costs.

A 2008 renewable energy market report by ICF International Consulting identified a market potential of 220 GW for midsize turbines between 100 kW and 1,000 kW (8). In response, DOE will begin a project in 2010 to support the development and commercialization in the United States of midsize wind turbines for the global market.

Wind-radar interactions drew the attention of researchers and developers in 2006 when the U.S. Department of Defense discovered that wind turbine structures and rotors can reflect radar signals and thus interfere with accurate readings. 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.

The Wind Power 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 better understand and mitigate the effects of wind projects on wildlife. In 2009, the Wind Power Program funded 12 new projects to study wind-wildlife interactions.

4.2 Collaborative research

Collaborative research with international partners contributes to the Wind Power Program's R&D efforts. Through the Wind Power Program's work with the IEA Wind Implementing Agreement, U.S. researchers participated in all IEA Wind research tasks. U.S. researchers participated in topical expert meetings of Task 11, Base Technology Information Exchange. Active participation in Task 19, Wind Energy in Cold Climates, informs U.S. strategy for wind development in the northern states. The Wind Power Program supported U.S. researchers who acted as managers (operating agents) for Task 23, Offshore Wind Energy Technology and Deployment; Task 24, Integration of Wind and Hydropower Systems; and Task 26, Cost of Wind Energy. U.S. experts participate in Task 25, Power Systems with Large Amounts of Wind Power, which issued key reports in 2009 addressing issues of grid connection that are relevant in all countries. The United States is working with Task 27, Consumer Labeling of Small Wind Turbines, to develop a labeling protocol for small wind turbines. The Wind Power Program hosted a meeting of Task 28, Social Acceptance of Wind Energy Projects, in 2009 and data from wind tunnel tests at NASA contributes to the cooperation in aerodynamic research in Task 29, Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models.

The Wind Power Program also makes important contributions to the IEC and standards groups and has several productive bilateral agreements.

5.0 The Next Term

In fiscal year 2011, DOE will invest in activities that promote responsible offshore wind project development. Public investments will address common barriers to offshore projects, including financial, regulatory, technical, environmental, and social issues. DOE will also expand its efforts to analyze and facilitate technology supply chains and to improve manufacturing processes, and will continue its ongoing land-based wind R&D activities.

References:

U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, http://www.eere.energy.gov/

(1) American Wind Energy Association, www.awea.org/

(2) 20% Wind Energy by 2030, www.20percentwind.org/20p.aspx?page=Overview

(3) Green Power Marketing in the United States: A Status Report (2008 Data), www.nrel.gov/docs/fy09osti/46581.pdf

(4) U.S. Wind Industry Annual Market Report Year Ending 2009 (April 2010). American Wind Energy Association, www.awea.org

(5) FY 2010 Congressional Budget, EERE/Wind Energy, pp 183-206, http://www.cfo.doe.gov/budget/10budget/Content/Volumes/Volume3.pdf, accessed February 18, 2010

(6) Eastern Wind Integration and Transmission Study, www.nrel.gov/docs/fy09osti/46505.pdf

(7) Western Wind and Solar Integration Study, www.nrel.gov/docs/fy09osti/46517.pdf

(8) ICF International U.S. Renewable Power Market Study, Webinar Presentation, May 2008

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Currency conversion rates IEA Wind Annual Report 2009			
Country	Currency	1 €	1 USD
Australia	AUD	0.625	0.900
Austria	Euro	1.000	1.441
Canada	CAD	0.661	0.952
Denmark	DKK	0.134	0.194
Finland	Euro	1.000	1.441
Germany	Euro	1.000	1.441
Greece	Euro	1.000	1.441
Ireland	Euro	1.000	1.441
Italy	Euro	1.000	1.441
Japan	JPY	0.00751	0.01082
Republic of Korea	KRW	0.00060	0.00086
Mexico	MXP	0.053	0.076
Netherlands	Euro	1.000	1.441
Norway	NOK	0.120	0.174
Portugal	Euro	1.000	1.441
Spain	Euro	1.000	1.441
Sweden	SEK	0.098	0.141
Switzerland	CHF	0.674	0.971
United Kingdom	GBP	1.126	1.622
United States	USD	0.694	1.000
Source: Federal Reserve Bank of New York (www.x-rates.com) 31 December 2009			

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_2e: 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)

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 Electro-Technical Commission
IEEE: Institute of Electrical and Electronics Engineers
IPP: independent power producer
ISO: international standards organization
IT: Information technology

kW: kilowatt (one thousand watts)
kWh: kilowatt hour

£ : 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 an 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 Anonyma

tCO_2-e per capita: tonne of carbon dioxide emissions per person
TNO: transmission network operator
Toe: tonne of oil equivalent
TSO: transmission system operators
TWh: terawatt hour (one trillion watt hours)

UN: United Nations
UNDP: United Nations Development Programme

VAT: value added tax
VAWT: vertical axis wind turbine

Wind Index: the energy in the wind for the year, compared to a normal year.
WT: wind turbine

Yr: year

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Cover photo: Laventa II is located in the very windy Isthmus of Tehuantepec in the state of Oaxaca, Mexico. Average annual wind speeds in this region range from 7 m/s to 10 m/s, measured 30 m above the ground. It is estimated that more than 3,000 MW of wind power could be commercially tapped there. (Photo credit: Rick Hinrichs)

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Bremerhaven, Germany, New offshore foundation

IEA Wind

Wind power capacity worldwide increased more than 32% in 2009 to nearly 160 GW (160,000,000,000 watts). Seventy percent of the world's wind capacity was operating in the member countries of the International Energy Agency Wind Implementing Agreement (IEA Wind), in which production from wind met 2.5% of total electrical demand. Member countries in Europe, North America, Asia, and the Pacific region are sharing information and research efforts to increase the contribution of wind energy to their electrical generation mix. In 2009, these countries added more than 20 GW of wind generation for more than 111 GW of total wind capacity. Fourteen countries added more than 100 MW of new capacity, and five countries added more than a gigawatt of new capacity: the United States (10.010 GW), Spain (2.459 GW), Germany (1.880 GW), Italy (1.114 GW), and the United Kingdom (1.077 GW). Australia, Canada, Denmark, Mexico, Portugal, and Sweden added 300 MW or more. Record increases in capacity were reported in Canada, Italy, Korea, Mexico, Portugal, Sweden, and the United States for the year despite difficult economic times.

Sharing information and cooperating in research tasks has contributed significantly to the progress in wind development in IEA Wind member countries. Potential member countries are welcome to attend meetings and begin the process of joining.

This 2009 IEA Wind 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, and development of analysis tools. This report also presents information for 2009 supplied by the 20 member countries, the European Commission, 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.

iea wind